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QUALITATIVE AND QUANTITATIVE STUDIES ON THE INHERITANCE OF WHEAT RESISTANCE TO THE THREE RUSTS

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ABSTRACT

Three possible wheat crosses were made among three wheat cultivars; Sakha 93, Gemmiza 9, and Sids 6 in 2001/2002 at Sakha Agricultural Research Station to study their inheritance to stripe, leaf and stem rusts on qualitative and quantitative bases and to determine their resistant genes. In next season, part of hybrid seeds were sown to give F_1 plants. These plants were sown to produce the F_2 seeds. Moreover, in 2003/2004 F_1 and F_2 for each cross were grown in order to obtain F_2 and F_3 seeds, respectively. The final experiment was conducted in 2004/2005 season. The experiment included the five populations P_1, P_2, F_1, F_2 and F_3, of each cross using the randomized complete block design (RCBD) with three replications.

Results indicated that each of Sakha 93 and Gemmiza 9 has one resistance gene pairs to stripe rust. However, the segregation observed in the F_2 population of their cross indicated that these two genes are different from each other. Moreover, Sakha 93 and Gemmiza 9 have two and one resistance gene pairs to leaf rust, respectively. Furthermore, both Sakha 93 and Gemmiza 9 have two resistant gene pairs to stem rust. Meanwhile, Sids 6 has no resistance genes for the prevalent pathotypes of the causal agents of any of the three rusts occurred at North Delta Region in 2004/2005 season. This proved the diversity of resistant genes of these cultivars which is the ultimate goal of the Wheat National Breeding Program and fulfilled the strategy of protecting wheat crop in Egypt.

In addition the quantitative analyses revealed that heritability estimates in broad sense were high, and in narrow sense were medium to high reflecting that resistance to the three rusts is a simple inherited character controlled by one, two or few gene pairs and proved the results obtained from the qualitative analyses. Therefore, selecting resistant plants could be successfully practiced in early generations.

Key words: ***Wheat, Crosses, Stem rust, Stripe rust, Leaf rust, Resistant genes, Heritability***

INTRODUCTION

Wheat (*Triticum aestivum*), the leading cereal crop in the world, is subjected to various diseases. Rusts are among those destructive diseases that significantly reduce the wheat production in Egypt (Shehab EL-Din *et al*, 1996). Stripe, leaf and stem wheat rusts caused by *Puccinia striiformis*, *P.recondita* and *P. graminis,* in sequence, are the most serious diseases.

In 1994/95 growing season, wheat plants were subjected to sever attack by *Puccinia striiformis* the causal agent of stripe rust; the most destructive wheat disease. Except for Sakha 61, all Egyptian commercial wheat cultivars were susceptible. However, the disease severity for these cultivars were different and ranged from 10 S to 100 S. Therefore, much attention was given to develop new resistant cultivars. As a result of that attention, the cultivar Sakha 93 was developed at Sakha, Gemmiza 7 and 9 at EL-Gemmiza and Giza 168 at EL-Giza (Shehab EL-Din *et al* 1991a, Abu El-Naga *et al* 1999, Abdel-Latif and Boulot 2000, Shehab EL-Din *et al* 2000).

Several investigators proved that wheat resistance to rusts is a simple character controlled by one, two, or few major gene pairs. However, resistance was dominant over susceptibility in most cases and vice verse was true in others. (Bartos *et al* 1986, Shehab EL-Din *et al* 1991a, Abd el-Latief *et al* 1995, Abdel-Latif and Boulot 2000, Shehab EL-Din *et al* 2000 and Mahgoub 2001).

On the other hand, several researchers reported that wheat stance to rusts is a quantitative character affected by many gene pairs as well as environmental conditions (Knott 1982, Singh and McIntosh 1984, Padidam and Knott 1988, Abdel-Latif and Boulot 2000 and Mahgoub 2001)

Therefore, the main target of this research was to study the inheritance of Sakha 93, Gemmiza 9 and Sids 6 resistance to stripe leaf and stem rust on qualitative and quantitative bases and to determine the resistant gene of the three wheat cultivars.

MATERIALS AND METHODS

The field experiments were carried out at Sakha Agricultural Research Station for four successive seasons from 2001/2002 to 2004/2005. Three diverse bread wheat cultivars in their reaction to the three wheat rusts were selected. However, the names and pedigrees as well as their reactions to stripe, leaf, and stem rusts are presented in Table (1).

Table 1. Cross name and pedigree as well as reactions to stripe, stem, and leaf rusts of the studied bread wheat cultivars.

parent	Name	Cross Name and Pedigree	Reaction to Rusts		
			YR*	LR	SR
1	Sakha 93	Sakha 92/TR 810328 S 8871-1S-2S-1S-0S	R**	S	R
2	Gemmiza 9	Ald "S" / Huac // Cmh 74A. 630 / Sx CGM 4583-5GM-1GM-0GM	R	R	R
3	Sids 6	Maya"S"/Mon"S"/CMH47.A.592/3/Sakha8*2. SD10002-4sd -3sd-1sd-osd.	S	S	S

*YR = Yellow rust; LR = Leaf rust, and SR = Stem rust
** R = resistant S = susceptible

In 2001/2002 season, the three cultivars (parental genotypes) were sown at three planting dates to secure enough hybrid seeds of the three possible crosses made among the parents to produce F_1 hybrid designated as follows :-

Cross 1 : Sakha 93 x Gemmiza 9

Cross 2: Sakha 93 x Sids 6

Cross 3 Gemmiza 9 x Sids 6

In the second season, F_1 plants were sown and left to produce the F_2 seeds. Moreover, in 2003/2004 season, 20 and 60 seed from F_1 and F_2 for each cross were grown in order to obtain F_2 and F_3 seeds, respectively. In addition, the three parents were planted and the same crosses were repeated to obtain additional and/or fresh hybrid seeds.

The final experiment was conducted in 2004/2005 season,. The experiment including the five populations P_1, P_2, F_1, F_2 and F_3 was planted at the third week of November, using the randomized complete block design (RCBD) with three replications as indicated by Steel and Torrie (1980). Each replicate consisted of 49 rows for each cross (one row for each of parent and F_1; 6 rows for F_2 generation and 40 rows for F_3 families). Each row was 3 meters long and 30 cm apart. Moreover, plants within rows were 20 cm apart so, each row included 15 plants. The experiment was surrounded by 2m width spreader grown with a mixed of highly susceptible wheat cultivars to stripe, leaf, and stem rusts i.e. Giza 139, Giza 144, Giza 163, Sakha 92, Sids 7, *Triticum spelta*, and Baart to help in the dissemination of the pathogen's uredeniospore. The spreader was subjected to an artificial inoculation using a mixture of fresh uredeniospore of each of the three pathogens mixed with talcum powder at rate of 1:20. The inoculation of stripe rust was carried out soon after the sun set in the last week of January using the method of Travet and Cassel (1951).

In addition, the region was subjected to sever attack from stripe rust causal agent. Furthermore, the artificial inoculation took place in the third week of February for both leaf and stem rusts. The recommended cultural practices were implemented to the final experiment. Finally the infection types were recorded for plants according to the scale of Chen and Line (1992).

For the qualitative study, 0, 0;, R, and MR infection types well be jointly considered as the resistant class, while MS, and S will be considered as the susceptible one.

The infection type frequency distributions for parental, F_1, F_2, and F_3 populations for rust reaction in all crosses were computed. In respect to mode of inheritance, goodness of fit classes, was determined by x^2 analysis. Number of genes controlling the character was also estimated on the basis of breeding behavior of F_3 families. Moreover, the x^2 tests were used to verify the expected segregation ratios indicated from F_2.

For the quantitative analysis, field reaction was converted into an average coefficient of infection (ACI) according to the method developed by of Stubbs *et al* (1986) and adjusted by Shehab EL-Din and Abdel-Latif (1996). In this method, the (ACI) could be obtained by multiplying infection severity by an assigned constant value namely, 0.025, 0.05, 0.2, 0.4, 0.6, 0.8 and 1 for 0, 0;, R, MR, M, MS, and S infection types, respectively.

Type of gene effects was estimated according to Hayman model in 1958 as described by Singh and Chaudhary (1985). Furthermore, heritability was calculated in broad sense (h^2_b) according to Mather (1949) and in narrow sense (h^2_n) in F_3-families by the formula of Lush (1949).

RESULTS AND DISCUSION

1- Stripe rust reaction

The population means and variances of the five populations (P_1, P_2, F_1, F_2, and F_3) for the three wheat crosses; Sakha 93 x Gemmiza 9, Sakha 93 x Sids 6, and Gemmiza 9 x Sids 6 inoculated with the uredeniospore of *Puccinia striiformis* at the adult stage under field conditions are shown in Table (2). Furthermore, Table (3) the estimated mean effect of F_2 (m), which reflects the contribution due to the over all mean plus the locus effect and

Table 2. Means (X) and variances (S^2) for the reactions of the five populations (P_1, P_2, F_1, F_2 and F_3 families) for the three bread wheat crosses to stripe rust

Cross name	Parameters	P_1	P_2	F_1	F_2	F_3
Sakha 93 x Gemmiza 9	$\overline{X}$	0.14	0.23	0.47	6.35	7.68
	S^2	0.01	0.001	0.216	23.10	0.53
Sakha 93 x Sids 6	$\overline{X}$	0.14	17.67	7.27	13.58	17.38
	S^2	0.01	4.33	1.88	3.43	7.98
Gemmiza 9 x Sids 6	$\overline{X}$	0.23	17.67	2.82	5.95	9.35
	S^2	0.001	4.33	2.39	3.20	19.91

Table 3. Gene action parameters for reaction of three crosses of bread wheat to stripe rust.

Cross Name	m	d	h	l	i
Sakha 93 x Gemmiza	6.35*	0.05*	- 7.48	- 8.54	- 7.67
Sakha 93 x Sids 6	13.58*	-8.77*	-14.35*	3.45	-30.24*
Gemmiza 9 x Sids 6	5.95*	-8.72*	-11.16	9.77	-22.45*

m = mean infection d= additive h = dominance
l = dominance x dominance i = additive x additive

interactions of the fixed loci, was found to be significantly represents the estimation of gene action components; additive (d), dominance (h), dominance x dominance (l), and additive x additive (i) for the three crosses.

Different types of gene effects indicated that (d) effects of the three crosses and (h) effects in the second cross were more pronounced. In addition, (i) effects in the second and third crosses were the most important in the expression of the genes controlling inheritance of resistance to wheat stripe rust.

F_1 plants were resistant in cross 1, while they were susceptible in cross 2 and 3. These data indicated that resistance was dominant over susceptibility in the first cross and vice verse in the other two crosses (Table 4).

The number of F_2 resistant : susceptible plants for the three crosses were 83:7, 25:65, and 24:66, respectively. These numbers fitted the theoretical expected ratio 15:1, 1:3, and 1:3 with P = 0.54, 0.54, and 0.51, in sequence (Table 4). These ratio proved that wheat resistance to stripe rust is governed by two gene pairs in the first cross and by one gene pair in the other two crosses.

Table 4. Infection type frequency distribution and phenotypic classes of the parents, F_1, and F_2 populations of the three bread wheat crosses to the stripe rust.

Cross name	No of plants	Infection types		Expected ratio	χ^2	probabilty
		R	S			
Sakha 93 x Gemmiza 9						
P_1	15	15				
P_2	15	15				
F_1	15	15				
F_2	90	83	7	15 : 1	0.359	0.54
Sakha 93 x Sids 6						
P_1	15	15				
P_2	15		15			
F_1	15		15			
F_2	90	25	65	1 : 3	0.37	0.54
Gemmiza 9 x Sids 6						
P_1	15	15				
P_2	15		15			
F_1	15		15			
F_2	90	24	66	1 : 3	0.13	0.51

Concerning, the F_3 data presented in Table (5) show that 28, 7 and 5 families were true breeding for resistance, segregating and true breeding for susceptibility, respectively in the first cross. This ratio fitted the theoretical dihybrid ratio 12:3:1 (with p = 0.26) and confirmed the results obtained from F_2 population. Meanwhile, in the other two crosses, F_3 families segregated to the three mentioned above categories with a ratio of 1:2:1 with P = 0.74 and 0.66, in sequence. These results confirmed the monohybrid ratio indicated from F_2 population of each cross.

The dihybrid ratio of the first cross indicate that wheat cultivars Sakha 93 and Gem. 9 have two different resistant gene pairs, that can insure long term – resistant to stripe rust when the two cultivars grown at a specific region This is a very useful for the National Wheat Program and a good strategy to protect wheat crop in Egypt. Similar results were obtained by Shehab EL-Din and Abdel-Latief (1996), Abu El-Naga *et al* (1999) and Shehab El-Din *et al* (2000).

Heritability values in broad and narrow senses, for the infection type character, are given in Table (5). The broad sense heritability estimate were 99.95, 87.36, and 97.30% while in narrow sense estimates these values were 78.57, 59.13, 57.49% in the three crosses, respectively. These values being high in broad sense and high to medium in narrow sense indicate that wheat resistance to stripe rust is a simple inherited character and that selecting

Table 5. Infection type frequency distribution and phenotype classes of the F_3 populations of the three bread wheat crosses to the Stripe -rust reactions

Cross name	No of families	Infection types			Expected ratio	X^2	P. Value	Heritability %	
		Resistant	Segregation	Susceptible				Broad sense	Narrow sense
Sakha 93 x Gemmiza 9	40	28	7	5	12: 3 :1	2.67	0.26	99.95	78.57
Sakha 93 x Sids 6	40	8	22	10	1: 2 :1	0.60	0.74	87.36	59.13
Gemmiza 9 x Sids 6	40	8	19	12	1:2:1	0.85	0.66	97.30	57.49

resistant plants could be practiced in early generation. These results are in accordance with those obtained by Shehab EL-Din *et al* 1991 , Shehab EL-Din and Abdel -Latief1996, and Abdel - latif Boulot 2000, and Mahgoub, 2001.

2- Leaf rust reaction

The population means and variances of the five populations (P_1, P_2, F_1, F_2, and F_3) for the three wheat crosses; inoculated with the uredeniospore of *Puccinia recondita* . at the adult stage under field conditions are shown in Table 6. In addition, Table 7 represents the estimation of gene action components for the three crosses.

Table 6. Means ($\bar{X}$) and variances (S^2) for the reactions of the five populations (P_1, P_2, F_1, F_2 and F_3 families) for the three bread wheat crosses to leaf rust

Cross name	Parameters	P_1	P_2	F_1	F_2	F_3
Sakha 93 x Gemmiza 9	$\bar{X}$	0.22	0.32	9.07	13.95	17.32
	S^2	0.001	0.01	0.36	10.60	0.95
Sakha 93 x Sids 6	$\bar{X}$	0.40	16.96	4.80	10.22	18.62
	S^2	0.12	1.07	1.38	4.73	5.39
Gemmiza 9 x Sids 6	$\bar{X}$	0.23	8.47	9.48	33.23	37.32
	S^2	0.001	0.22	6.30	4.00	7.31

Table 7. Gene action parameters for reaction of three crosses of bread wheat to leaf rust.

Cross Name	m	d	h	l	i
Sakha 93 x Gemmiza	13.95*	-0.05	-12.23*	4.94	-21.14*
Sakha 93 x Sids 6	10.22*	-8.28*	-26.00*	30.30	-38.67*
Gemmiza 9 x Sids 6	33.23*	-4.12*	-26.75*	-41.43*	-40.13*

m = mean infection d= additive h = dominance
l = dominance x dominance i = additive x additive

The estimated mean effect of F_2(m), which reflects the contribution due to the over all mean plus the locus effect and interactions of the fixed loci, was found to be significantly. The different types of gene effects indicated that (d) effects of the second and third crosses and (h) effects in the three crosses were more pronounced. Moreover, (l) effect in the third one and (i) effects in the three crosses were the most important in the expression resistance to wheat leaf rust.

The F_1 plants were susceptible in the three crosses. These data indicated that susceptibility was dominant over resistance (Table 8).

Table 8. Infection type frequency distribution and phenotypic classes of the parents, F_1, and F_2 populations of the three bread wheat crosses to the leaf rust.

Cross name	No of plants	Infection types		Expected ratio	χ^2	probabilty
		R	S			
Sakha 93 x Gemmiza 9						
P_1	15		15			
P_2	15	15				
F_1	15		15			
F_2	90	23	67	1 : 3	0.48	0.47
Sakha 93 x Sids 6						
P_1	15		15			
P_2	15		15			
F_1	15		15			
F_2	90	6	84	1 : 15	0.03	0.48
Gemmiza 9 x Sids 6						
P_1	15	15				
P_2	15		15			
F_1	15		15			
F_2	90	27	63	1 : 3	1.2	0.62

Number of resistant: susceptible plants in the F_2 population for the three crosses were 23:67, 6:84, and 27:63 respectively. These numbers fitted the theoretical expected ratio 1 : 3 in the first and third crosses with P = 0.47, and 0.62, respectively . Meanwhile they fitted the dihybride ratio 1: 15 in the second one,

Concerning, the F_3 data; Table 9 show that the observed ratio for true breeding for resistance: segregating: true breeding for susceptibility in first and third crosses fitted the theoretical monohybrid ratio 1:2:1. Meanwhile, this ratio fitted the dihybrid ratio 1:6:9 in the second cross and confirmed the results obtained from F_2 population.

These results indicated that Sakha 93 has two gene pairs while Gemmiza 9 has only one. This is a good achievement for the wheat program that aims to develop high yielding cultivars having different resistant genes to protect the crop in Egypt. Similar results were obtained by Abdel-Latif *et al* 1995 and Mahgoub 2001.

Table 9. Infection type frequency distribution and phenotype classes of the F_3 populations of the three bread wheat crosses to the leaf -rust reactions

Cross name	No of families	Infection types			Expected ratio	X^2	P. Value	Heritability %	
		Resistant	Segregation	Susceptible				Broad sense	Narrow sense
Sakha 93 x Gemmiza 9	40	11	20	9	1 : 2 : 1	0.20	0.90	99.68	86.17
Sakha 93 x Sids 6	40	3	14	23	1 : 6 : 9	0.18	0.91	97.7	49.28
Gemmiza 9 x Sids 6	40	8	24	8	1 : 2 : 1	1.60	0.45	98.59	47.86

Heritability values in broad and narrow senses, for the infection type character, are given in Table 9. The broad sense heritability estimate were 99.68, 97.7, and 98.59% while in narrow sense estimates these values were 86.17, 49.28, 47.86% in the three crosses, respectively. These values being high in broad sense and high to medium in narrow sense indicate that wheat resistance to leaf rust is a simple inherited character and that selecting resistant plants might be successfully practiced in early generation. These results are in accordance with those obtained by Shehab EL-Din *et al* 1991a , Shehab EL-Din and Abdel-Latief 1996, Youssef *et al* 1999, Abdel -Latif and Boulot 2000 and Mahgoub, 2001.

3- Stem rust reaction

The population means and variances of the five populations (P_1, P_2, F_1, F_2, and F_3) for the same three wheat crosses, inoculated with the uredeniospore of *Puccinia graminis* the causal agent of stem rust, at the adult stage under field conditions are shown in Table 10. Moreover, Table 11 represents the estimation of gene action components for the three crosses.

Table 10. Means (X) and variances (S^2) for the reactions of the five populations (P_1, P_2, F_1, F_2 and F_3 families) for the three bread wheat crosses to stem rust

Cross name	Parameters	P_1	P_2	F_1	F_2	F_3
Sakha 93 x Gemmiza 9	$\overline{X}$	0.12	0.27	0.90	2.84	7.49
	S^2	0.01	0.001	0.32	0.96	3.88
Sakha 93 x Sids 6	$\overline{X}$	0.23	31.67	23.33	30.62	33.55
	S^2	0.001	8.33	9.33	15.55	15.17
Gemmiza 9 x Sids 6	$\overline{X}$	0.25	32.33	14.67	25.33	33.23
	S^2	0.003	6.33	2.33	12.33	4.00

Table 11. Gene action parameters for reaction of three crosses of bread wheat to stem rust.

Cross Name	m	d	h	l	i
Sakha 93 x Gemmiza 9	2.84*	-0.08*	-13.71*	19.65*	-14.56*
Sakha 93 x Sids 6	30.62*	-15.72*	-12.69	-3.76	-51.50*
Gemmiza 9 x Sids 6	25.33*	-16.04*	-28.16*	13.64	-58.61*

m = mean infection d= additive h = dominance
l = dominance x dominance i = additive x additive

The estimated mean effect of F_2(m), which reflects the contribution due to the over all mean plus the locus effect and interactions of the fixed loci, was found to be significantly. The different types of gene effects indicated that (d) effects of the three crosses and (h) effects in the first and third ones were more pronounced. Moreover, (l) effect in the first cross and (i) effects in the three crosses were the most important in the expression of the inheritance of resistance to wheat stem rust.

The F_1 plants were resistant in all crosses. These data indicated that resistance was dominant over susceptibility (Table 12).

Table 12. Infection type frequency distribution and phenotypic classes of the parents, F_1, and F_2 populations of the three bread wheat crosses to the stem rust.

Cross name	No of plants	Infection types		Expected ratio	χ^2	probabilty
		R	S			
Sakha 93 x Gemmiza 9						
P_1	15	15				
P_2	15	15				
F_1	15	15				
F_2	90	80	10	15 : 1	3.62	0.60
Sakha 93 x Sids 6						
P_1	15	15				
P_2			15			
F_1	15	15				
F_2	90	86	4	15 : 1	0.50	0.42
Gemmiza 9 x Sids 6						
P_1	15	15				
P_2	15		15			
F_1	15	15				
F_2	90	83	7	15 : 1	0.36	0.51

Number of F_2 resistant :susceptible plants for the three crosses were 80:10, 86:4, and 83:7 respectively. These numbers fitted the theoretical hybrid ratio 15 : 1 with P = 0.60, 0.42, and 0.51, sequentially.

Concerning, the F_3 data in Table (13) show that 20, 19 and 1 families were true breeding for resistance, segregating and true breeding for susceptibility, respectively in the first cross. This ratio fitted the theoretical dihybrid ratio 9 : 6 : 1 (with P = 0.33). On the other hand, in the other two crosses; this ratio was 13true breeding to resistance:3 segregating. These results confirmed the dihybrid ratio indicated from F_2 population of each cross (Table 13).

Table 13. Infection type frequency distribution and phenotype classes of the F_3 populations of the three bread wheat crosses to the stem -rust reactions

Cross name	No of families	Infection types			Expected ratio	X^2	P. Value	Heritability %	
		Resistant	Segregation	Susceptible				Broad sense	Narrow sense
Sakha 93 x Gemmiza 9	40	20	19	1	9 : 6 : 1	2.24	0.33	98.76	60.09
Sakha 93 x Sids 6	40	31	9	--	13 : 3	0.37	0.52	97.45	48.01
Gemmiza 9 x Sids 6	40	35	6	--	13 : 3	0.46	0.37	97.30	61.40

The segregation observed in F_2 plants data for cross 1, revealed that the parental cultivars (Sakha 93 and Gemmiza 9) have different resistant gene pairs.

The results indicated that there are at least three different gene pairs function against stem rust causal agent in these parents. This proved the diversity of the cultivars which is the ultimate goal of the breeding program. Th diversity of resistance genes is very useful for the National Wheat Program and a good strategy to protect wheat crop in Egypt. Similar results were obtained by Shehab EL-Din *et al*, 1991 (a and b), and Abdel-Latif and Boulot, 2000, and Mahgoub, 2001.

Heritability values in broad and narrow senses, for the infection type character, are given in Table 13. The broad sense estimate were 98.76, 97.45, and 97.30% while in narrow sense estimates were 60.09, 48.01, 61.40% in the three crosses, respectively. These values being high in broad sense and medium in narrow sense indicate that wheat resistance to stem rust is a simple inherited character and that selecting resistant plants could be successively practiced in the early generations. These results are in line with those obtained by Shehab EL-Din *et al* 1991a, Shehab EL-Din and Abd EL-Latief1996, Youssef *et al* 1999, Abdel - latif and Boulot 2000 and Mahgoub, 2001.

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دراسات نوعية وكمية على توارث مقاومة القمح للأصداء الثلاثة

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البرنامج القومى لبحوث القمح – معهد بحوث المحاصيل الحقلية مركز البحوث الزراعية –

تم عمل الثلاثة هجن الممكنة بين ثلاثة أصناف من قمح الخبز سخا ٩٣ وجميزة ٩ وسدس ٦ فى عام ٢٠٠٢/٢٠٠١ بمزرعة محطة البحوث الزراعية بسخا لدراسة مقاومة القمح لأمراض الصدأ المخطط وصدأ الأوراق وصدأ الساق ومعرفة جينات المقاومة لكل منهم . وفى الموسم التالى تمت زراعة جزء من البذور الهجينية لإنتاج نباتات الجيل الأول وبذور الجيل الثانى. و فى موسم ٢٠٠٤/٢٠٠٣ تمت زراعة جزء من بذور الجيل الأول والثانى للحصول على بذور الجيل الثانى والثالث لكل هجين على التوالى. وقد أقيمت التجربة النهائية فى موسم ٢٠٠٥/٢٠٠٤ واشتملت على كل من الآباء والجيل الأول والجيل الثانى والجيل الثالث لكل هجين . وقد تم تنفيذ التجربة باستخدام تصميم القطاعات كاملةالعشوائية (RCBD) فى ثلاث مكررات.

وقـد أظهرت النتائج أن كل من الصنفين سخا ٩٣ وجميزة ٩ به زوج من جينات المقاومة لمـرض الصدأ المخطط . وتبين من الانعزال المشاهد فى عشيرة الجيل الثانى للهجين بينهما أن هذين الجينين مختلفان عن بعضهما. كما أظهرت النتائج أن الصنف سخا ٩٣ يحتوى على زوجين من العوامل الوراثية والصنف جميزة ٩ يحتوى على زوج واحد من العوامل الوراثية الخاصة بمقاومة صدأ الأوراق. وكذلـك أظهـرت النتائج أن كلاً من الصنفين السابقين يحتوى على زوجين من جينات المقاومة لصدأ السـاق الأسود لسلالات الفطر المنشرة فى منطقة شمال الدلتا فى هذا الموسم. كما أوضحت النتائج أن الصنف سدس ٦ لا يحتوى على أى جينات مقاومة لأى من الأصداء الثلاثة. تدل هذه النتائج على مدى التـباعد الوراثى بين الصنفين سخا ٩٣ وجميزة ٩ بالنسبة لصفة المقاومة. هذا التباعد هو فى النهاية هدف برنامج تربية القمح. كما أنها توضح مدى ملاءمة هذه الأصناف المتباعدة وراثياً لحماية محصول القمح فى مصر.

وقـد أظهـرت نتائج التحليل الكمى أن قيم المكافئ الوراثى بمعناه الواسع كانت عالية بينما بمعـناه الضـيق تراوحت مابين متوسطة إلى عالية فى الهجن الثلاثة مما يدل على أن صفة المقاومة للأصـداء الثلاثة هى صفه بسيطة يتحكم فيها زوج أو زوجان أو عدد قليل من العوامل الوراثية . كما أكـدت هـذه النتائج تلك المتحصل عليها من التحليل النوعى. لذا فإن انتخاب نباتات مقاومة لأى من الأصداء الثلاثة يمكن أن يتم بنجاح فى الأجيال الانعزالية المبكرة.