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INHERITANCE OF STRIPE RUST RESISTANCE IN SOME EGYPTIAN WHEAT CULTIVARS

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ABSTRACT

Increased range of virulence of stripe rust caused by *Puccinia striiformis* Westend f. sp. *tritici* Eriks. & E. Henn. on wheat (*Triticum aestivum*, L.) of Egyptian commercial wheat cultivars has required assemblage of a broad genetic basis of resistance. Plant reactions of some wheat Egyptian cultivars were evaluated in 16 crosses included parents, F_1's and F_2's plant population from resistant by susceptible and susceptible by susceptible parents crosses suggested that digenic control plant reaction to the fungus. Of course, digenic expression is more common in field; also, no segregation was recorded neither with susceptible/susceptible cross nor the resulting susceptibility. Some cultivars exhibited resistance *i.e.,* Giza 168, Sids1 and Giza 144 which were crossed with other susceptible wheat cultivars *i.e.,* Gemmeiza 1, Giza 162, Giza 163, Sakha 8 and Sakha 69 probably had combined gene(s) that work against fungus. Some cultivars had different gene(s) for the adult plants. The F_2 progeny that was derived from susceptible parents expressed digenic control of resistance or susceptibility. Genetic diversity was modest among the various cultivars except for susceptible / susceptible cultivar cross expressed epistasis of progeny than parents.

INTRODUCTION

Yellow (stripe) rust of wheat caused by *Puccinia striiformis* Westend f. sp. *tritici* Eriks. & E. Henn. (*Triticum aestivum*, L.) is an important disease worldwide and Egypt.

Breeding for disease and pest resistance is a method of crop protection from damage due to biotic factors. Inherited resistance is a valuable attribute because it is easy for the grower to use and reduce the need for other type of resistance has predominant in wheat improvement (Robbelen & Sharp, 1978, CIMMYT, 1988, Knott, 1989, and Denissen, 1993.

Shaw (1963) reported that, the infected plant usually produces fewer tiller, set fewer seeds per head and the kernels are small in size and weight. Furthermore, the milling quality and the food value of the grain were reported to be poor. However, certain stripe rust resistance genes are only effective in adult-plant stage and hence, seedling studies may not identify the complete resistance genotype of the host (Zwer and Qualset, 1994)

In Egypt, breeding resistant wheat cultivars especially for rust disease is the major means used for controlling these diseases. On the other hand, rust fungi are able to form (within a very short time) new isolates that are capable of breaking the resistance of new resistant wheat cultivars. Most of the Egyptain wheat cultivars showing good looking for resistance under natural conditions but if the viable and fresh inoculum is present as well as the favorable environmental conditions, severe infection will occur (Enayat *et al*., 1983 and El-Daoudi *et al*., 1990).

The purpose of this study was to differentiate genetically among some Egyptian commercial wheat cultivars, which contained stripe rust resistance genes from different sources, using test that measured adult plant reaction to inoculate and naturally occurring races mixture in the field.

MATERIALS AND METHODS

This work was carried out at Sakha Agricultural Research Station, Kafr El-Shekh during 2005/2006 season.

The main objective of this work is to assign the proper cross (es) of the prospective of stripe rust resistance. Used Egyptian, resistant and susceptible, wheat cultivars were: Giza 168, Sids 1 and Giza 144 and Giza 162, Giza 163, Sakha 8, Sakha 69 and Gemmeiza 1, respectively. Each resistant cultivar was crossed with one or more of the susceptible cultivars, and also, cross susceptible by susceptible cultivar with exception some crosses were lost during cultural practices. These parents were crossed and resulted 16 crosses were tested under field conditions. The commercial cultivars were selected according to their susceptibility or resistance on their reaction basis in the field during elapsed growing seasons. The crosses within the wheat cultivars aimed to searching for complementary or additive genes governing the resistance.

The cultivars were sown during 2003/2004 growing season in 1.5 m long and 30 cm apart. Each row was sown by 15 seeds with sown distance of 10 cm. the experimental unite included 4 rows of each parental cultivar. The parents were sown at 3 sowing dates to obtain the pollen grains may at the proper time. All possible crosses among commercial wheat cultivars were performed to produce the hybrid seeds of 16 crosses.

In 2005/2006 growing season, part of 16 F_1's cross as were sown to produce F_2 seeds and other part was left for the final experiment in the next season.

An experiment contains: seeds of the F_1 and F_2 from the 16 cross and parents were planted in the field in 20 November 2005 at Sakha Agricultural Research Station Farm at Kafr El-Shekh. The seeds were hand – spaced at 10 cm intervals in 2 m rows which were spaced 30 cm apart. Thirteen rows of each F_2 population were planted with single rows of the parents between crosses. Also, single rows of F_1 plants were planted next to the parents. Mixture of susceptible cultivars *i.e*., *Triticum spelta* saharensis, Morocco and Little club were planted every seventeenth row as a rust spreader.

The whole experiment was inoculated on 25 January 2006 with more virulent races mixture of stripe rust *P. striiformis* using a hand- sprayer containing a talcum powder plus urediniospore mixtures in the approximate ratio of 100 : 1 (W:W).

Individual plants were rated at the post - heading stage beginning 20 March 2006. Resistant plants were marked with blue tape and susceptible ones by red tape. The number of plants rated ranged from 190 – 260 per cross F_2 population. The adult plant reaction was recorded according to Zwer and Qualset (1994) pointed to the infection types which were rated on the 1 to 9 scale as used in the seedling stage (McNeal *et al*, 1971) where 1 to 3 were classified as resistant, 4 to 6 were intermediate and 7 to 9 were susceptible. These infection type were grouped into two classes in the adult study, scores of 0-6 were normally considered a low infection type (resistance) and 7 – 9 as high infection type (susceptible) Sharma *et al*. (1995) and disease severity, was determined according to the modified Cobb Scale, (Peterson, 1948).

Statistical and genetic analysis:

Frequency distribution values were computed for parental, F_1 and F_2 plant populations for stripe rust severity percentage under field conditions

In respect to mode of inheritance, goodness of fit of the observed to the expected ratios of the phenotypic classes concerning the stripe rust severity and infection types, 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) and heritability in its broad-sense was estimated according to Lush (1949).

RESULTS

Evaluation of parents, F_1 and F_2 plant populations against races mixture of *Puccinia striiformis* f. sp. *tritici* at adult plant stage under field conditions was carried out during 2005/2006 growing season at Sakha Agricultural Research Station.

The disease reaction was studied with 16 Egyptian wheat cultivar crosses and classified into two categories. The first group was represented by eleven crosses among resistant cultivars *i.e*., Giza 168, Sids 1 and Giza 144 and susceptible ones were Gemmeiza 1, Giza 162, Giza 163, Sakha 8 and Sakha 69. The second group was represented by the five crosses among the previously mentioned susceptible wheat cultivars only. Obtained data are qualitatively and quantitatively analyzed as follows:

I. Qualitative analysis:

The frequency distribution of stripe rust disease severity for F_1, F_2 and their two respective parents of sixteen crosses are classified into two categories are presented in Table (1).

The first category:

Data presented in Table (1) indicate that the wheat cultivars Gemmeiza 1, Giza 162, Giza 163, Sakha 8 and Sakha 69 consistently expressed high infection type (susceptibility) to stripe rust with rust severity ranged from 10Ms to 60s. However, the three parents *i.e.* Giza 168, Sids 1 and Giza 144 exhibited low degree of rust severity (resistance) ranged from 0 – 10R.

The disease severity of F_1 plants showed resistance with all crosses except for one cross *i.*e., Giza 144/Sakha 8 was found to be susceptible.

The F_2 plant population showed that all 11 crosses were segregated in ratios ranging between resistant and susceptible types.The resistance dominance was recorded with nine crosses. While, the susceptible dominance was recorded with the two crosses *i.e.* Giza168/Giza163 and Giza144/Sakha 8.

Table (1): Stripe rust severity (%) frequency distribution of the two parents, F_1, F_2, phenotypic classes F_2, expected, X^2 and P. value of sixteen crosses inoculated with stripe rust (*Puccinia striiformis* f. sp. tritici) at adult plant stage under field conditions in 2005/2006 growing season.

No.	Cross name		No. of tested plants	Disease severity 0	10R	10MR	20MR	10Ms	10s	20s	30s	40s	50s	60s	Phenotypic classes R : S	Expected ratio	X^2	P. values
	Resistant X Susceptible																	
1	Giza168/ Gemmeiza1	P_1	20	18	2													
		P_2	20							19	1							
		F_1	20	19	1													
		F_2	218	40	52	73	36	6	5	3	2	1			201:17	15:1	0.848	0.5-0.25
2	Giza168/ Giza162	P_1	20	18	2													
		P_2	20					18	2									
		F_1	20	19	1													
		F_2	199	38	59	51	36	10	5						184:15	15:1	0.53	0.5-0.25
3	Giza168/ Giza163	P_1	20	18	2													
		P_2	20						17	3								
		F_1	20			19	1											
		F_2	197	47	20	12		95	23						79:118	7:9	1.07	0.5-0.25
4	Giza168/ Sakha8	P_1	20	18	2													
		P_2	20									18	2					
		F_1	20	19	1													
		F_2	215	11	63	59	35	15	12	11	5	4			168:47	13:3	1.33	0.25-0.1
5	Giza168/ Sakha69	P_1	20	18	2													
		P_2	20										19	1				
		F_1	20	19	1													
		F_2	203	19	27	38	77			18	12	10	2		161:42	13:3	0.48	0.5-0.25
6	Sids1/ Gemmeiza1	P_1	20	19	1													
		P_2	20							19	1							
		F_1	20	19	1													
		F_2	203	85	51	28	24	7	5	2	1				188:15	15:1	0.45	0.5-0.25
7	Sids1/ Giza162	P_1	20	19	1													
		P_2	20					18	2									
		F_1	20	19	1													
		F_2	211	61	67	51	16	8	4	3	1				195:16	15:1	0.63	0.5-0.25
8	Sids1/ Sakha8	P_1	20	19	1													
		P_2	20									18	2					
		F_1	20	19	1													
		F_2	201	15	20	31	49	31	19	17	9	7	3		115:86	9:7	0.07	0.9-0.75
9	Sids1/ Sakha69	P_1	20	19	1													
		P_2	20										19	1				
		F_1	20	19	1													
		F_2	205	31	38	40	79				8	7	2		188:17	15:1	1.39	0.25-0.1
10	Giza144/ Giza163	P_1	20	17	3													
		P_2	20						17	3								
		F_1	20	19	1													
		F_2	217	64	30	35		58	30						129:88	9:7	0.89	0.5-0.25
11	Giza144/ Sakha 8	P_1	20	17	3													
		P_2	20									18	2					
		F_1	20					17	3									
		F_2	217	2	16			119	45	35					18:199	1:15	1.51	0.25-0.1
	Susceptible X Susceptible																	
12	Giza163 / Giza162	P_1	20						17	3								
		P_2	20					18	2									
		F_1	20			18	2											
		F_2	210	35	39	42	51	21	17	5					167:43	13:3	0.41	0.75-0.5
13	Giza163/ Sakha69	P_1	20						17	3								
		P_2	20										19	1				
		F_1	20			2	18											
		F_2	201	40	70	60	15	11	3	2					185:16	15:1	0.98	0.5-0.25
14	Gemmeiza1/ Giza162	P_1	20							19	1							
		P_2	20					18	2									
		F_1	20			2	18											
		F_2	207		83	97	11	9	7						191:16	15:1	0.75	0.5-0.25
15	Gemmeiza1/ Sakha8	P_1	20							19	1							
		P_2	20									18	2					
		F_1	20							2	18							
		F_2	212	1	15			3	120	45					16:196	1:15	0.59	0.5-0.25
16	Sakha8/ Sakha 69	P_1	20									18	2					
		P_2	20										19	1				
		F_1	20								17	3						
		F_2	204							37	90	70	7		0:204	0:1	0	>0.99

Concerning the first group in Table (1), the present data indicated that their eleven crosses were segregated in direction of resistant or susceptible dominance, in the direction of susceptibility dominance were recorded with two crosses *i.e.* Giza 168 X Giza 163 and Giza 144 X Sakha 8 with ratios 7:9 and 1:15 and exhibited probable values of 0.50-0.25 and 0.25-0.10. The rest crosses were segregated in direction of resistance.

The second category; susceptible/susceptible

Data presented in Table (1) demonstrate that all parents used in this group appeared susceptible reactions. However, the F_1 plants showing dominant resistance were recorded with three crosses in this group, while the other two crosses exhibited dominant susceptibility.

The F_2 plant populations showed that three crosses out of five exhibited dominant resistance on susceptibility, but the cross; Gemmeiza1/Sakha8 appeared to have susceptible dominant on resistance. On the other hand, the cross Sakha 8/Sakha 69 showed no segregation and tends to exhibit susceptibility. The second group that included five crosses were segregated in direction of resistance or susceptibility dominance except one cross *i.e*. Sakha 8 X Sakha 69 which did not show segregation and appeared susceptible.

II. Quantitative analysis:

To study the genetic behavior of adult plant resistance to stripe rust quantitatively, the two parents, F_1 and F_2 populations for each of the sixteen crosses were tested in the adult stage under field conditions. Population means 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 the number of functioning genes for each cross (Table,2) were also studied.

The average means for the three resistant cultivars *i.e.* Giza 168, Sids 1 and Giza 144 and five other susceptible cultivars *i.e.* Gemmeiza 1, Giza 162, Giza 163, Sakha 8 and Sakha 69 were 0.209, 0.1095 and 0.3085 and 20.50, 8.2, 11.5, 41.0 and 50.5, respectively (Table, 2).

Data presented in Table (2) show the 11 crosses of resistant / susceptible that belong to the first group and also, the 5 crosses of susceptible / susceptible that belong to the second group. The F_1 values of the two groups crosses were 0.109, 0.109, 4.2, 0.109, 0.109, 0.109, 0.109, 0.109, 0.109, 0.109, 8.3, 4.4, 7.6, 7.6, 29.0 and 31.5, respectively. These means values were lower than their respective mid-parent values, indicating the presence of dominant resistance for low disease severity (adult plant resistance).

The F_2 means values for these were 4.437, 3.72, 5.47, 6.567, 10.060, 2.871, 3.1308, 10.12, 7.26, 4.45, 9.83, 5.202, 3.276, 3.787, 11.232 and 31.5, in sequence. These means showed values lower than those calculated for their respective mid-parents. These results predicted the presence of partial dominance for low disease severity as confirmed by the results obtained from the F_1's (Table, 2).

Table (2): Means of P_1, P_2, F_1 and F_2; degree of dominance of F_1 and F_2 as well as broad-sense heritability and number of genes for disease severity (%) of Egyptian commercial wheat cultivars crosses inoculated with races mixture of *Puccinia striiformis* f. sp. tritici West. at the adult stage under field conditions in 2005/2006 growing season.

No.	Cross name	Mean of					Degree of dominance		Heritability	No. of genes
		P_1	P_2	F_1	F_2	MP	h_1	h_2		
	Resistant/Susceptible									
1	Giza168/Gemmeiza1	0.209	20.5	0.109	4.437	10.354	-1.009	-1.17	93.30	2.057
2	Giza168/Giza162	0.209	8.2	0.109	3.72	4.204	-0.853	-0.131	96.56	0.932
3	Giza168/Giza163	0.209	11.5	4.2	5.47	5.85	-0.293	-0.14	66.86	1.21
4	Giza168/Sakha8	0.209	41.0	0.109	6.567	20.604	-1.005	-1.376	94.119	3.858
5	Giza168/Sakha69	0.209	50.5	0.109	10.06	25.354	-1.003	-0.608	98.513	2.67
6	Sids1/ Gemmeiza1	0.1095	20.5	0.109	2.871	10.305	-1.00	-1.46	89.03	3.376
7	Sids1/Giza162	0.1095	8.2	0.109	3.131	4.155	-0.999	-0.506	98.30	0.573
8	Sids1/Sakha8	0.1095	41.0	0.109	10.12	20.55	-1.00	-1.203	96.95	2.087
9	Sids1/Sakha69	0.1095	50.5	0.109	7.26	25.304	-1.0	-1.432	94.30	3.53
10	Giza144/Giza163	0.309	11.5	0.109	4.45	5.904	-1.035	-0.259	68.671	1.109
11	Giza144/Sakha8	0.309	41.0	8.3	9.83	20.654	-0.607	-1.1	86.05	8.84
	Susceptible/Susceptible									
12	Giza163/Giza162	11.5	8.2	4.4	5.202	9.85	-3.303	-5.633	70.516	0.91
13	Giza163/Sakha69	11.5	50.5	7.6	3.28	31.0	-1.2	-2.843	31.28	0.935
14	Gemmeiza1/Giza162	20.5	8.2	7.6	3.787	14.85	-1.097	-3.435	49.79	6.472
15	Gemmeiza1/Sakha8	20.5	41.0	29.0	11.23	30.75	-0.171	-3.81	70.14	3.203
16	Sakha8/Sakha69	41.0	50.5	31.5	32.3	45.75	-3.0	-5.66	85.5	0.234

Expression of gene action measured as the degree of dominance h_1 and h_2 has been shown in Table (2). The values of $F_1(h_1)$ of sixteen crosses were -1.009, -0.853, -0.293, -1.005, -1.003, -1.00, -0.999, -1.00, -1.00, -1.035, -0.607, -3.303, -1.2, -1.097, 0.171 and -3.0 in sequence. The significant negative values of h1 revealed the presence of partial dominance for low disease severity.

Meanwhile, the estimated values for degrees of dominance of F_2 (h_2) were highly significant in all crosses. These values were -1.17, -0.131, -0.14, -1.376, -0.608, -1.46, 0.506, -1.203, -1.432, -0.259, -1.1, -5.633, -2.843, -3.435, -3.81 and -5.66, respectively. The negative values estimated in these crosses, also, suggested the manifestation of partial dominance for stripe rust resistance and supported the F_1 result.

The heritability values for most of the tested crosses are considered to be high tending resistance except two crosses exhibited low heritability. These values were 93.30%, 96.56%, 94.119%, 98.513%, 89.03%, 98.30%, 96.95%, 94.30%, 68.671% 86.05%, 70.516%, 31.28% 49.79% 70.14% and 85.5% for the above mentioned sixteen crosses, respectively, where the dominant alleles were not in equal distribution for the parents, because the effect of environmental conditions.

The minimum number of effective genes controlling the partial resistance or susceptibility was digenic for each of the all crosses except the cross number 16 which did not show any segregation. The estimated numbers were tabulated in Table (2).

DISCUSSION

Inheritance of stripe rust resistance of eight wheat cultivars, their F_1 and F_2 progenies at the adult plant stage under field condition was qualitatively and quantitatively studied.

Resistance to stripe rust in cultivated wheat is based mainly on major genes. In addition to major gene of resistance, Lewellen *et al*. (1967) found another type of resistance based on what they called "minor gene", Sharp and Volin (1970) pointed out to accumulation of minor effect genes should result in longer – lasting resistance.

The F_2 plant populations showed inhibitory, complementary and additive gene actions (major and minor genes) for stripe rust resistance in commercial wheat cultivars. That is exactly what was established in our study by the occurrence of transgressive segregation towards higher resistance in most of crosses out of 6 crosses demonstrate an additive effect of these genes.

The occurrence of additive resistance genes in F_2 population *i.e*., Giza 163/Giza 162, Giza 163/ Sakha 69 and Gemmeiza 1/ Giza 162 show that the two parents in each of the three crosses posses different genes (Grama, *et al*., 1984). On the other hand, the occurrence of susceptible segregates in F_2 *i.e*., Giza 168/Giza 163, Giza 144/ Sakha 8 and Gemmeiza 1/ Sakha 8 appeared that different genes are involved. The absence of resistant plants only in one out of 16 crosses *i.e.,* (Sakha 8/ Sakha 69) may indicate that major or minor effective genes are involved in this way. The rest crosses showed resistance segregant (digenic control).

The F_2 plant populations showed more resistance than one or two of their respective parents and this suggests great deal with dominance genes, in this respect, the major or minor effect genes in these crosses appear to be different from their respective cultivated parents. Since the additive resistance was detected in F_2 and was expressed in F_3 (Grama *et al.*, 1984). Segregation pattern from resistance by susceptible or susceptible by susceptible parents cross suggested digenic dominance or recessive control. The obtained results are in accordance with those adapted with by Griffy and Allan (1988) who pointed to digenic expression more common in field. Singh *et al*. (1988), willing *et al*. (1988) and Van Silfhout *et al*. (1989) mentioned that F_2 segregation ratios observed indicated that in 67% of the selection, resistance was based on one or more dominant gene(s), in 18% it was conferred by 10r more recessive genes, and in 15% by a combination of dominant and recessive genes. A further 26 selections yielded F_2 segregation ratios indicating the presence of modifier, suppressor or minor effect genes. These results was in accordance with our results which pointed that the digenic control expression more common in field.

The quantitative analysis of the obtained data revealed that F_1 and F_2 stripe rust severity means in the sixteen crosses were, in general, lower than the estimated means for their respective mid-parents. These results pronounced the existence of partial dominance for low disease severity in most crosses.

The estimated values of degrees of dominance (h_1 and h_2) were significant and negative in all crosses under study. These results supported the manifestation of partial dominance for low disease severity and confirmed the previous conclusion.

This result was confirmed by those obtained by Millus and Line (1985), Line and Chen (1989), Shehab El-Din *et al*. (1991 a&b) and Shehab El-Din and Abdel-Latif (1996). The heritability in its broad-sense estimated from parents, F_1's and F_2's for partial stripe rust resistance are considered to be high in magnitude, since the values ranged from 31.309% to 98.513%. However, high heritability values are indicative for high rates of success in recovering the desired genes in future generations. The heritability in broad-sense was low for the two crosses due to the effect of environmental conditions was the highest for those crosses and the dominant alleles were not equally distributed for parents, and the vice versa in the case of high heritability. Also, these high estimates 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 Kuhn *et al.* (1980), Lee and Shaner (1985), Bjarko and Line (1988), Shehab El-Din *et al*. (1991b), Das *et al*. (1993), Abd-El-latif *et al*. (1995), Shehab El-Din and Abdel-Latif (1996), Najeeb *et al*. (2004), Negm (2004) and Shahin (2005).

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وراثة مقاومة الصدأ المخطط في بعض أصناف القمح المصري

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تم دراسة مدي زيادة الإصابة في الصدأ المخطط المتسبب عن بكسينيا سترايفورمس تراتيساي علي القمح في أصناف القمح التجارية المصرية بغية تجميع أساس وراثي واسع للمقاومة. حيث تم تقييم تفاعل النباتات في بعض أصناف القمح التجارية في ١٦ هجيناً اشتملت علي الآباء والجيل الأول وعشيرة نباتات الجيل الثاني وذلك من تهجين أصناف مقاومة في الأصناف القابلة للإصابة وأيضا من تهجين الأصناف القابلة للإصابة في القابلة للإصابة.

وقد افترضت طبيعة الانعزال المتحصل عليه من تهجين آباء مقاومة في قابلة للإصابة وقابلة للإصابة في قابلة للإصابة أن المقاومة ممثلة بزوجين من الجينات في تفاعل النبات مع الفطر. حيث كان التعبير بزوجين من الجينات أكثر شيوعا في الحقل وقد لوحظ أيضا عدم وجود انعزالات والتي تم تسجيلها من تهجين أصناف قابلة للإصابة × قابل للإصابة وقد أعطت قابلية للإصابة. وقد بينت بعض الأصناف التي تملك مقاومة عالية مثل جيزة ١٦٨ وسدس ١ وجيزة ١٤٤ والتي تم تهجينها مع أصناف قمح أخري قابلة للإصابة مثل جميزة ١ و جيزة ١٦٢ و جيزة ١٦٣ و سخا ٨ وسخا ٦٩ احتمال تواجد جينات مشاركة بها في التفاعل ضد الفطر. وحيث أن بعض الأصناف بها جينات مختلفة فقد تم التعبير عن المقاومة أو القابلية للإصابة في أفراد الجيل الثاني في صورة زوجين من الجينات.

وقد كانت الاختلافات الوراثية متوسطة بين الأصناف المختلفة باستثناء تهجين أصناف قابلة للإصابة × أصناف قابلة للإصابة التي تعبر عن تفوق النسل عن الآباء.