Field Resistance of Crosses of Sesame (*Sesamum indicum* L.) to Charcoal Root Rot Caused by *Macrophomina phaseolina* (Tassi.) Goid.

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Abstract

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Two segregating generations (F_3 and F_4) from 6 × 6 half-diallel crosses, excluding reciprocals, of a sesame breeding program were exposed to natural infection by the root rot pathogen (*Macrophomina phaseolina)* in two successive seasons (2004 and 2005). There was highly significant variability in the progeny of all investigated crosses which might be a valuable tool for further breeding programs for root rot disease management. The level of infection in 2004 ranged from 2.63% (cross $P_2 \times P_5$) to 52.42% ($P_4 \times P_5$) in the F_3, and from 1.28 % ($P_1 \times P_5$) to 51.78% ($P_4 \times P_5$) in the F_4. During 2005, infection varied from 1.01% ($P_2 \times P_5$) to 50.91% ($P_4 \times P_5$) in the F_3, and from 1.00% ($P_3 \times P_4$) to 48.00% ($P_4 \times P_5$) in the F_4. These crosses were ranked resistant or highly susceptible and gave seed yields per feddan (= 4200 m) of 536.67, 361.67, 641.67, and 408.33, respectively. The F_3's and F_4's of five crosses, i.e. $P_1 \times P_2$, $P_1 \times P_4$, $P_1 \times P_5$, $P_2 \times P_6$, and $P_3 \times P_4$, were resistant in both segregating generations and both seasons. Such crosses might be helpful for breeding programs due to their stable resistance. Lines from the crosses $P_1 \times P_6$, $P_2 \times P_4$ and $P_4 \times P_5$ could also be used for improving resistance due to an increase of inherited resistance from one generation to another. The estimated heritability showed high values in all cases and indicated that selection for these traits could be useful for breeding programs for resistance to root rot with seed yield potential. Correlation coefficients showed that there were some positive correlations such as percentage of infection by *M. phaseolina* between both generations (F_3's and F_4's) as well as within each generation during a season's evaluation, i.e. 0.742 , 0.976, 0.846, 0.732, and 0.987. The highest significant and positive correlations assisted in the selection of some crosses to be used in breeding programs and will aid breeders to achieve sesame cultivars with charcoal root rot resistance.

Keywords: sesame; root rot; *Macrophomina phaseolina*; disease resistance; seed yield; field conditions

Sesame (*Sesamum indicum* L.) is one of the ancient oilseed crops, with early origins in East Africa and India (Bedigian 1985). It is perhaps one of the oldest crops cultivated by man, having been grown in the Near East and Africa for more than 5000 years for cooking and medicinal needs (Dudley *et al.* 2000). In Egypt, sesame is grown in many Governorates, and ranks first among the cultivated oil crops in Ismailia Gov. (Anonymous 2005a). Although it has been cultivated for a long time, no significant increase in productivity has been achieved yet. This low productivity (1145.71 kg/ha, Anonymous 2005b) has been attributed to pests and diseases. The crop suffers from various fungal, bacterial, viral and phytoplasma diseases. Charcoal root rot, caused by *Macrophomina phaseolina* (Tassi.) Goid., is one of the main disease of this crop in Egypt and the world (Rajput *et al.* 1998; El-Barougy 1990; El-Shakhess 1998; Dinakaran & Mohammed 2001). It is very serious and destructive in all sesame growing areas and causes about 5–100% yield loss as estimated by Vyas (1981), while Maiti *et al.* (1988) reported an estimated yield loss of 57% at about 40% of disease incidence.

The most common symptom of the disease is the sudden wilting of growing plants when, mainly after the flowering stage, the stem and roots become black due to severe infection. The pathogen survives as sclerotia in the soil and crop residues and has also been reported to be seed-borne, characteristics that make it difficult to control (Maiti *et al.* 1988).

Breeding programs in sesame especially aimed at disease resistance are relatively limited. They could, however, be effective once basis and degree of inheritance of disease resistance and of economic characters become known, and efficient breeding methods have been devised. In this particular case, great fluctuation in seed yield of high-yielding genotypes is expected to occur due to susceptibility to root-rot disease (El-Shakhess 1998). In our region (Ismailia Governorate), there is considerable variability in the reaction of genotypes toward *M. phaseolina*, which could be used in breeding program aimed at producing a resistant cultivar that can be used for large-scale cultivation. The main target of the present study was, therefore, to screen the available sesame germplasm for its reaction to the root rot pathogen, *M. phaseolina*, under natural infection in the field. Since there is little information about the genetics and heritability estimates of resistance to root rot disease in the offspring of crosses, such estimates will provide information on transmission of traits from parents to progeny and facilitate the evaluation of genetic and environmental effects, and help in the selection, in advanced generations, of sesame lines from which the breeder can anticipate improvement in various traits. Also, the association/correlation of root rot disease resistance with seed yield may greatly help in an accurate selection.

MATERIAL AND METHODS

The F_3's and F_4's as segregating sesame generations had been produced in a breeding program at the Agronomy Department, Faculty of Agriculture, Suez Canal University, Ismailia, Egypt, concerning, among other characters, the resistance to Fusarium wilt (El-Bramawy 1997, 2003; El-Shazly *et al.* 1999; El-Bramawy *et al.* 2001; Ammar *et al.* 2004). The characteristics of parental plants and their combinations are listed in Table 1. Both generations (F_3's and F_4's) were planted in field trials during May 2004 and May 2005 on

Table 1. Name and source of sesame parents and their combinations used in the study

No.	Parents of sesame	Sources
1	Hybrid 38	Agriculture Research Centre, Giza, Egypt
2	Local line 14	U.C.R. × Giza 25, Egypt
3	Local line 1	El Tal Kabir district, Ismailia Governorate, Egypt
4	Local line 2	Mina El Kamih district, El Sharkia Governorate, Egypt
5	Local line 3	Abou Hammad district, El Sharkia Governorate, Egypt
6	Local line 4	Abou Hammad district, El Sharkia Governorate, Egypt

No.	♂ × ♀	No.	♂ × ♀	No.	♂ × ♀
1	Hybrid 38 × Local line 14	6	Local line 14 × Local line 1	11	Local line 1 × Local line 3
2	Hybrid 38 × Local line 1	7	Local line 14 × Local line 2	12	Local line 1 × Local line 4
3	Hybrid 38 × Local line 2	8	Local line 14 × Local line 3	13	Local line 2 × Local line 3
4	Hybrid 38 × Local line 3	9	Local line 14 × Local line 4	14	Local line 2 × Local line 4
5	Hybrid 38 × Local line 4	10	Local line 1 × Local line 2	15	Local line 3 × Local line 4

Table 2. The scale of evaluation used in the study

Percent infection	Disease scale	Category
1–10	1	resistant (R)
11–20	3	moderately resistant (MR)
21–30	5	moderately susceptible (MS)
31–50	7	susceptible (S)
51–100	9	highly susceptible (HS)

a commercial field (Abo Soltan Village, Ismailia Gov.) with a history of natural infection by the disease. The field experiment was laid out in a randomised complete block design (RCBD) with four replications. Each accession was raised on a plot of 7.2 m^2 in four-row plots with 4 m row length and a spacing of 45 × 15 cm. The recommended agricultural practises for sesame production, i.e. fertiliser dose, irrigation times and plant protection measures against insects pests, were performed at the proper times during the two seasons.

The disease level of each replication was determined weekly after sowing, with the final reading 75 days after sowing (ten plants per each grad). The reactions of these accessions (F_3's and F_4's) to the root-rot pathogen were classified as indicated in Table 2 on the scale of Dinakaran and Mohammed (2001). Seed yield per plot was determined and the yield in kg per feddan was calculated according to these data (1 Feddan = 4200 m^2).

The obtained data were converted into arcsin transformation and subjected to statistical analysis using the method outlined by Cochran and Cox (1957). The differences between mean values of crosses were estimated by Duncan's Multiple Range (L.S.R) test at 0.05 level of probability (Duncan 1955).

The estimates of genetic variability such as phenotypic and genotypic coefficients of variation (PCV and GCV) were also calculated using the formula outlined by Burton (1952). Heritability in a broad sense (Tb) as well as in narrow sense (Tn) were estimated according to Lush (1940) and the genetic advance was calculated following Burton (1952) and Johnson *et al.* (1955). Moreover, the correlation coefficients for the resistance to root rot disease with seed yield based on mean values were worked out on sesame production by using the formula suggested by Singh and Chaudhary (1985).

RESULTS AND DISCUSSION

The results (Table 3) show significant differences with great variation in the level of infection by root rot disease as well as seed yield/feddan. This indicates the presence of sufficient variability for all investigated crosses, which could thus be valuable in a further breeding program for root rot disease management with high seed yield. These findings are similar to those of other investigators (El-Barougy 1990; El-Shakhess 1998; Chattopadhyay & Kalpana Sastry 1998; Dinakaran & Mohammed 2001) who worked with different sesame populations under natural and artificial infection by *M. phaseolina.*

The infection percentages ranged from 2.63% ($P_2 \times P_5$) to 52.42% ($P_4 \times P_5$) in the F_3, and from 1.28 % ($P_1 \times P_5$) to 51.78% ($P_4 \times P_5$) in the F_4 during 2004. These crosses were ranked as resistant (R), highly susceptible (HS), resistant (R) and highly susceptible (HS), respectively, and gave a seed yield of 536.67, 361.67, 641.67 and 408.33 kg/feddan. On the other hand, in 2005 the F_3' s varied from 1.01 ($P_2 \times P_5$) to 50.91 ($P_4 \times P_5$) and the F_4' s from 1.00 ($P_3 \times P_4$) to 48.00 ($P_4 \times P_5$) as shown in Table 3. These crosses behaved as resistant (R) with 355.83 kg/feddan, highly susceptible (HS) with 408.33 kg/feddan, resistant (R) with 641.67 kg/feddan and susceptible (S) with 425.00 kg/feddan seed yield, respectively. These results indicated that the resistance to *M. phaseolina* in cross $P_2 \times P_5$ could be stable, as well as susceptibility in cross $P_4 \times P_5$. This can be attributed to the possibility that the resistant characters are qualitative characters and can be affected by environment. Our data are supported by similar results reported by El-Marzoky (1982) and El-Shakhess (1998) on different sesame materials.

Progeny from the five crosses $P_1 \times P_2$, $P_1 \times P_4$, $P_1 \times P_5$, $P_2 \times P_6$ and $P_3 \times P_4$, kept their resistance classes in both segregating generations (F_3 and F_4) and in both years (Table 3). Such crosses might be helpful for breeding programs due to their stable resistance. Similar findings were reported for the same disease by El-Marzoky (1982) and for other diseases by El-Bramawy (2003) and Ammar *et al.* (2004). In regard to seed yield/feddan, there was little change from F_3 to F_4 as well as from 2004 to 2005. This could be expected from quantative characters that are sensitive to environmental conditions.

The results also showed some interesting points. The F_3's of some crosses ($P_1 \times P_6$, $P_2 \times P_4$ and $P_4 \times P_5$) that had been ranked as moderately susceptible

Table 3. Percentage of infection by the root rot pathogen (*Macrophomina phaseolina)* and seed yield (in kg/feddan) of sesame parents and of the F_3 and F_4 populations grown in 2004 and 2005

2005						2004						Crosses	No.
F_4			F_3			F_4			F_3				
Seed yield	category	means	seed yield	category	means	seed yield	category	means	seed yield	category	means		
560.00 e	R	3.33 (10.47) g	711.67 a	R	3.28 (10.47) i	770.00 a	R	2.70 (9.46) cd	705.83 a	R	3.07 (10.14) g	$P_1 \times P_2$	1
530.83 f	MS	21.08 (27.35) c	542.50 g	MR	16.29 (23.81) d	542.50 c	MR	22.12 (28.04) bc	542.50 f	MR	12.64 (20.79) def	$P_1 \times P_3$	2
641.67 b	R	2.08 (8.33) h	583.33 d	R	8.17 (16.64) g	583.33 de	R	2.83 (9.63) de	641.67 c	R	9.88 (18.34) efg	$P_1 \times P_4$	3
700.00 a	R	1.22 (6.29) i j	583.33 d	R	2.25 (10.47) ij	641.67 c	R	1.28 (6.55) e	676.67 b	R	4.74 (12.52) g	$P_1 \times P_5$	4
437.50 g	MR	15.96 (23.50) d	641.67 c	MS	24.13 (29.40) c	466.67 g	MS	24.25 (29.53) bc	350.00 h	MS	25.78 (30.35) c	$P_1 \times P_6$	5
589.17 c	R	1.73 (7.49) hi	501.67 i	S	10.05 (18.53) f	589.17 e	R	2.17 (8.53) de	583.33 de	MR	14.21 (22.14) de	$P_2 \times P_3$	6
408.33 i	MS	26.31 (30.85) b	577.50 e	S	34.55 (36.03) b	420.00 h	S	35.99 (36.87) ab	291.67 i	S	33.87 (35.61) b	$P_2 \times P_4$	7
583.33 d	MR	12.25 (20.53) c	355.83 l	R	1.01 (5.74) j	641.67 c	MR	13.13 (21.30) cde	536.6 f	R	2.63 (10.94) g	$P_2 \times P_5$	8
700.00 a	R	3.01 (9.98) g	571.67 f	R	3.40 (10.63) i	641.67 c	R	3.75 (11.24) de	589.17 d	R	4.66 (12.52) fg	$P_2 \times P_6$	9
641.67 b	R	1.00 (5.74) j	641.67 c	R	1.72 (9.46) i j	700.00 b	R	2.22 (8.53) de	641.67 c	R	5.90 (14.06) g	$P_3 \times P_4$	10
583.33 d	R	1.61 (7.27) hij	653.33 b	MR	11.85 (20.18) e	589.17 d	R	1.95 (8.13) de	565.83 e	MR	15.26 (23.03) d	$P_3 \times P_5$	11
589.17 c	R	1.25 (6.55) ij	641.67 c	R	5.58 (13.69) h	583.33 de	R	1.47 (7.04) c	583.33 de	MR	10.44 (18.81) d	$P_3 \times P_6$	12
425.00 h	S	48.00 (43.85) a	408.33 k	HS	50.91 (45.52) a	408.33 i	HS	51.78 (46.03) a	361.67 h	HS	52.42 (46.38) a	$P_4 \times P_5$	13
700.00 a	R	1.06 (6.02) j	484.17 j	MS	23.12 (28.97) c	641.67 c	R	1.00 (5.74) cd	466.67 g	S	33.98 (35.67) b	$P_4 \times P_6$	14
560.00 e	R	9.68 (18.15) f	530.83 h	R	2.66 (9.46) ij	542.50 f	MR	13.03 (21.13) cde	560.00 de	R	5.80 (13.94) b	$P_5 \times P_6$	15
*	–	*	*	–	*	*	–	*	*	–	*	Mean square of crosses	

R = Resistant, MR = Moderately Resistant, MS = Moderately Susceptible, S = Susceptible and HS = Highly Susceptible

*significant at 0.05 level of probability, respectively

Table 4. Variability, heritability and genetic advance of charcoal root rot disease resistance and seed yield in F_3 and F_4 of crosses of sesame during 2004 and 2005

Parameters	Percentage of charcoal root rot				Seed yield (kg/feddan)			
	F_3		F_4		F_3		F_4	
	2004	2005	2004	2005	2004	2005	2004	2005
Mean ± SE	16.30 ± 16.81	541.62 ± 177.02	12.60 ± 87.86	583.60 ± 20.89	1.48 ± 0.17	562.08 ± 9.09	9.98 ± 0.16	576.68 ± 1.79
P.C.V.%	1.76	0.46	2.22	0.34	2.21	0.34	2.68	0.33
G.C.V.%	1.76	0.46	2.19	0.33	2.21	0.34	2.86	0.33
Tb	99.51	99.99	97.18	99.99	99.96	99.99	99.99	99.99
Tn	78.29%		77.28%		68.48%		6.86%	
G.A.% of mean	58.97	507.70	55.91	406.76	61.10	394.28	55.07	393.91

SE = Standard deviation, P.C.V.% = Phenotypic coefficients of variation, G.C.V.% = Genotypic coefficients of variation, Tb = Heritability in a broad sense, Tn = Heritability in a narrow sense, G.A.% = Genetic advance

and highly susceptible during the first season (2004), behaved differently in the second season (2005) where they were ranked as moderately resistant, moderately susceptible and susceptible (Table 3), with seed yield (kg/feddan) of 437.50, 408.33 and 425.00, respectively. These crosses can also be used for improving resistance to root rot disease in future breeding programs due to the enhancement of resistance characterstics from season to another season. In contrast, some other crosses (e.g. $P_1 \times P_4$) ranked lower in the second season than in the first one. This cross scored as moderately resistant in both F_3's and F_4's in 2004, while only in the F_3's 2005 it was moderately susceptible with a 530.83 seed yield/feddan. These findings appear to show that complete resistance to root rot disease, caused by *M. phaseolina*, will be difficult to achieve. This agrees with the results reported by El-Marzoky (1982), El-Deeb *et al.* (1987) and El-Deeb (1989).

Estimates of the phenotypic (P.C.V) and genotypic (G.C.V) coefficients of variation, heritability and genetic advance as percent of means are presented in Table 4. Stability of characters is confirmed by the low difference between P.C.V and G.C.V as well as the value of each one alone (Table 4). This could be noticed from the values for the two growing seasons between the two generations. Moreover, the heritability of the resistant character was very high in both generations during 2004 and 2005 as determined by the high heritability in a broad sense (Tb) and heritability in a narrow sense (Tn). High genetic advance coupled with high heritability indicated the additive nature of the resistance genes and consequently a high gain from selection. The same trend was observed for the seed yield/feddan. All this supported the selection of some offspring for future breeding programs.

The correlation coefficients for the percentage of infection of *M. phaseolina* with seed yield/feddan for both F_3 and F_4 generations during 2004 and 2005 are presented in Table 5. Highly significant correlations were found between the investigated traits. Among them, there were some positive correlations such as resistance to infection by *M. phaseolina* in both generations (F_3's and F_4's) during the two seasons of evaluation (Table 5). While highly significant positive correlations were detected between resistance and seed yield/feddan of the F_4's in both seasons, the correlations did not reach the significant level in the F_3's. On the other hand, there was a highly significant cor-

Table 5. Correlation coefficient of the percentage of infection by *Macrophomina phaseolina* with seed yield (in kg/feddan) for different crosses (F_3's and F_4's) during 2004 and 2005

2005				2004					Characteristic of generations and seasons
Seed yield/feddan		% of infection		seed yield/feddan		% of infection			
F_4	F_3	F_4	F_3	F_4	F_3	F_4	F_3		
							–	F_3	% of infection (2004)
						–	0.742**	F_4	
					–	–0.801**	–0.825**	F_3	seed yield/feddan (2004)
				–	0.820**	–0.805**	–0.587*	F_4	
			–	–0.651**	–0.844**	0.846**	0.976**	F_3	% of infection (2005)
		–	–0.836**	–0.765**	–0.729**	0.987**	0.732**	F_4	
	–	–0.459	–0.309	0.562	0.341	–0.400	–0.330	F_3	seed yield/feddan (2005)
–	0.678**	–0.793**	–0.688**	0.719**	0.737**	–0.846**	–0.574 *	F_4	

*, ** significant at 0.05 and 0.01 levels of probability, respectively

relation between percentage of infection by *M. phaseolina* and seed yield/feddan in both seasons for both generations. Similar results were previously recorded with F_3's and F_4's by El-Bramawy (2003) and some other investigators (El Deeb *et al.* 1987; El-Shakhess-Sammar 1998).

The low and insignificant values of correlation (r) illustrated that dominant and recessive genes could be of equal proportion in the parents. This, in addition to the positive and highly significant correlation of the traits, supported the selection of lines from some crosses to be used in breeding programs. These findings provide a major incentive for breeders to plan a significant breeding program for resistance to charcoal root rot disease.

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