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HETEROSIS AND COMBINING ABILITY ESTIMATES FOR DEFENSE MECHANISMS OF YELLOW MAIZE AGAINST PINK STEM BORER (*Sesamia cretica* LED)

Motawei, A. A.
Maize Research Section, Field Crop Research Institute, Agriculture Research Center.

ABSTRACT

The pink stem borer (PSB) is the main and most important insect attacks maize (*Zea mays* L.) in Egypt. Little is know about combining ability for antibiosis and tolerance to this insect. Therefore, the objectives of this work were: to estimate combining ability effects; to determine mode of gene action; to measure heterotic effects for antibiosis traits [percentage of resistance to infested plants (RIP %) , dead hearts (RDH%)], to determine tolerance traits measured as [yield of infested (YI), yield of non-infested (YN) plants and estimates of percentage of yield loss (YL%)]. And finally to find out the phenotypic and genotypic correlation among tolerance and antibiotical traits.

A half-diallel crosses of 8 inbreds were evaluated for the above traits under two conditions, i.e. artificial infestation with PSB and non-infestation. Both additive and non-additive types of genetic variation were operative in the genetic control of the five studied traits. However, the non-additive genetic variance were found to represent the major part of the total genetic variance in the inheritance of RIP%, RDH%,YI and YN traits while, the additive genetic variance effect played an important role in the inheritance of YL% trait. It seems that over-dominance was prevailing than partial dominance gene action in the conditioning of all studied traits. Average heterotic effects relative to mid-parent were 68.6, 46.8, 380.8, 318.4 and -11.8% for RIP%, RDH%, YI, YN and YL% traits, respectively. Meanwhile, heterotic effects relative to better-parent gave 36.7, 15.1, 289.0, 235.9 and -36.6% for RIP%, RDH%, YI, YN and YL% traits, respectively. The inbred lines Gem-1002, L-121 and B-73 are elite and good combiners for resistance to PSB, yielding ability and decreased yield loss. The single crosses SK-7266 x SK-9203 and B-73 x SK-8118 showed positive and significant SCA effects for resistance to PCB attack and high yielding ability simultaneously. Thus, both hybrids could be used directly by farmers in areas and/or planting date which showed heavy attack with PSB or in future breeding programs as a source of a new antibiotical resistant inbred lines.

Phenotypic correlation between each of the two antibiosis traits and the tolerance traits (YI and YN) was found to be positive and highly significant. While, it was negative and significant with YL% trait. Correlation coefficients between line *per se* and their g_i effects of any of the two antibiotic traits were positive and highly significant. Furthermore, additive genetic (GCA effects of line) linkage between YI and each of the tow antibiosis traits was found to be significantly positive.

INTRODUCTION

Insect pests can cause high yield losses at different phonological stages of maize. The perfect method for controlling an insect pest is to grow insect-resistant cultivars (Wiseman and Davis,1990). The pink stem borer (*Sesamia cretica* Led.) is one of the most serious borer infesting maize cultivars in the Mid-East, N.Africa and Mediterranean regions. This insect attacks maize plants shortly after emergence, devouring the whorl leaves and sometimes killing the growing point, causing dead heart. It is, also, capable of damaging older plants and excavating tunnels into the stem, ears and cobs.

Little informations were available on the genetic behavior and mode of gene action for resistance to this insect in Egypt and other countries and mostly were taken under natural infestation because of non availability of the artificial rearing and infestation facilities of this insect. However, recently in Egypt, Motawei (1996) was the first maize breeder who studied the genetic basis of resistance to *S. cretica* in Egypt and found that the deviation between inbreds (I) and single crosses (C) was significant under artificial infestation for infested plants% and No. of larvae/100 plants. He also reported that over-dominance was more important than partial dominance gene action in the conditioning of susceptibility to this insect. AL-Naggar *et al*., (2000a) found that hybrids were superior than inbreds in their resistance to *S. cretica* under artificial infestation. They also found that both additive and non-additive gene effects have equal importance in controlling dead heart (DH%), but additive genetic portion played a much greater role than non-additive gene effects in the genetic control of maize resistance to infested plants trait (IP%). Over-dominance gene action controls DH% while, partial dominance was apparent for IP%. Meanwhile, AL-Naggar *et al*., (2000b) reported that additive gene action played the greatest role in the genetic control of DH%, while non-additive gene effects represented the greater part in the genetic control of the IP% when experiments were conducted under natural infestation. Heterosis estimates relative to better parent ranged from -0.40 to 251% and from -43.8 to 129.1% for IP% and DH%, respectively. Moreover, Galal *et al*., (2002) found that dominance and additive x dominance (non-additive) gene effects composed the major portion and conditioning the resistance to pink stem borer (PSB) under natural and artificial infestation. Over- and partial-dominance gene actions controlled both resistance and susceptibility to PSB.

In other countries, Lynch (1980) indicated that the knowledge about combining ability effects for yield loss and yield under infestation conditions and their relationship would help in determining the best strategy to improve resistance to PSB. Butron *et al*., (1999) found that additive gene action played the most important role in the inheritance of all stem damage traits caused by PSB. GCA and SCA mean squares were significant for yield under infestation and non-infestation conditions with PSB and yield loss traits. On the other hand, Pablo *et al*., (2002) found that the genetic control of resistance for ear damage trait under PSB infestation was due to additive effects. The objectives of this work were :----

(i) to estimate genetic variances for resistance to PSB and its effect on yield and yield loss under infestation and non infestation conditions with PSB.

(ii) to determine heterotic effect relative to mid and better parent, and

(iii) to examine the phenotypic and genotypic correlations among tolerance and antibiotical traits, to choose the most useful traits for evaluating the defense mechanism against pink stem borer in maize.

MATERIALS AND METHODS

Eight yellow inbred lines of maize [L-121, B-73, Gm-1002, SK-7266, SK-8118, SK-9121, SK-9203 and S.T.N-8] were used as parents to obtain 28 hybrids in a half diallel crosses mating system (i.e., without reciprocals) in 2002 season at Sakha Agriculture Research Station. The eight parental lines and their 28 F_1s were evaluated under normal field condition in two different experiments. The first was evaluated under artificial infestation condition by larvae of pink stem borer (*Sesamia cretica* led) and the second under non-infestation condition. Sowing date was on June 25 to coincide with the time of minimum natural infestation of PSB and also to coincide with the time of laying eggs in the laboratory with the ideal growth stage for artificial infestation by PSB. Each experiment included 36 entries (the eight inbred lines and their 28 F_1s). The Randomized Complete Blocks Design (RCBD) with two replications was used at each experiment. Plot size was one row 2m long. Each row consisted of 10 hills. Two kernels were seeded per hill. The distance between rows was 0.80 m and the hills were spaced at 0.20 m apart. Hills were thinned to one healthy plant after emergence (at age 21 days from plating) obtaining a final plant density of 26250 plants/faddan. Each trial received 15Kg P_2O_5 per faddan before seeding. Nitrogen fertilizer was given with the rate of 120 Kg N. per faddan in two equal doses before the first and second irrigation. In the first experiment, under infestation condition with pink stem borer, all insecticide treatments were avoided and 10 plants were infested artificially by adding 10 new hatching larvae/plant by the staff of the laboratory of breeding for pink stem borer in the maize section. The following data were recorded :---

1- Percentage of resistance to infested plants (RIP%) at 15 to 20 days after artificial infestation was computed as:

$$RIP\% = \left(1 - \frac{\text{no.of plants showing symptoms of infestation / plot}}{\text{no. of artificially infested plants / plot}}\right) x100$$

2- Percentage of resistance to dead hearts (RDH%) at 20 to 25 days after artificial infestation was completed as :-

$$RDH\% = \left(1 - \frac{\text{no. of plants with dead hearts / plot}}{\text{no. of artificially infested plants / plot}}\right) x100$$

3- At harvest, grain yield per plot (Kg), adjusted to 15.5% moisture content and presented as ardab / faddan was recorded for each experiment. On the basis of the yield of infested and non-infested trials, the percentage of yield loss (YL%) was computed as:-

$$YL\% = \left(1 - \frac{\text{yield of infested plants / plot}}{\text{yield of non infested plants / plot}}\right) x100$$

The collected data were subjected to a normal analysis of variance of RCBD according to Snedecor and Cochran (1989) separately for each experiment. Estimates of general (GCA) and specific (SCA) combining ability variances, effects and standard error were calculated according to Griffing (1956) method-Π, model-1(fixed effects).

Heterosis percentages and standard errors relative to mid-parents ($\overline{M.P}$) and better parent ($\overline{B.P}$) were computed as:--

$$H.M.P\% = \frac{\bar{F}1 - \overline{M.P}}{\overline{M.P}} x100$$

$$H.B.P\% = \frac{\bar{F}1 - \overline{B.P}}{\overline{B.P}} x100$$

Where :F_1 = Mean of F_1 cross, $\overline{M.P} = \frac{\bar{P}1 + \bar{P}2}{2}$ and (B.P) = mean of better parent.

To detect the significance of heterotic effects, the least significant difference value from zero (L.S.D) was calculates as:--

L.S.D = t x S.E

Where: S.E for H.M.P% = $\sqrt{\frac{3Mse}{2r}}$

And S.E for H.B.P%= $\sqrt{\frac{2Mse}{r}}$

Mse = mean squares for error

r = number of replications

t = tabulated value at degrees of freedom of error and at certain probability level.

Potance ratio (P) was estimated as outlined by Smith (1952) as a criteria for explaining nature and degree of dominance as shown in the following equation:

$$P = \frac{\bar{F}1 - \overline{M.P}}{1/2(\bar{P}1 - \bar{P}2)}$$

Where: $\bar{P}1$ = mean of higher parent.

$\bar{P}2$ = mean of smaller parent.

RESULTS AND DISCUSSION

Highly significant differences were detected among genotypes for all studied traits as appeared in Table 1 , indicating the presence of large amount of variability among the studied genotypes for the characters of resistance to pink stem borer and grain yield. The Inbred lines and their F_1 crosses exhibited significant difference for all traits, except for yield under infestation (IY) and non-infestation (NY) with pink stem borer of parents.

Considerable and high significant heterotic effects (I.vs.C) were also detected for all traits expect for yield loss% (YL%).

Table 1: Mean squares from the analysis of variance for the percentage of resistance to infested plants (RIP%), percentage of resistance to dead hearts (RDH%),yield under infestation (YI) and non infestation (YN) with pink stem borer, and percentage of yield loss (YL%) for eight inbreds and their F1 crosses.

S.O.V	d.f	RIP%	RDH%	Yield (ard/fad)		YL%
				I	N	
Replications	1	11.984	8.988	1.334	0.026	27.949
Genotypes	35	966.893**	975.643**	187.464**	231.402**	389.462*
Crosses (C)	27	709.669**	770.282**	61.999**	47.135**	360.439*
Inbreds (I)	7	732.769*	1114.623**	9.338	21.517	466.777*
I. vs. C	1	9550.818**	5547.546**	4821.895**	6675.813**	631.867
G.C.A	7	722.705*	903.91*	49.961*	99.148**	528.463*
S.C.A	28	1027.94**	993.575**	221.839**	264.466**	354.711*
Error	35	286.506	298.251	18.040	15.525	198.121
GCA/SCA		0.7	0.91	0.230	0.38	1.49
$\overline{x}$		67.897	73.179	20.797	25.774	19.881
C.V%		24.93	23.60	20.42	15.29	70.80

*,** significant at the 0.05 and 0.01 percent level of probability, respectively.
* Ard = Ardab = 140 kg one faddan = 4200 m^2

The mean squares due to both general (GCA) and specific (SCA) combing abilities were significant for all traits under study, indicating that both additive and non-additive genetic variances are important in the inheritance of these traits. However, the variances due to specific combining ability were more important than the variances due to general combining ability in the inheritance of all traits, except YL%. This was seen from the ratio of GCA/SCA mean squares, where it was less than the unity for the first four traits, while for YL% trait, this ratio exceeded the unity as presented in Table 1. This indicated that non-additive genetic effects (dominance and epistatic effects) were predominant and played the major role in the inheritance of RIP%, RDH%, YI and YN traits. Meanwhile, the additive genetic effects played an important role than non-additive genetic variance in the expression of YL% trait. These results are in agreement with those obtained by EL-Naggar *et al.*, (2000b) and Galal *et al.*, (2002) who reported that non-additive gene effects represent the greatest portion in the genetic control of maize resistance to pink stem borer. While, EL-Naggar *et al.* (2000a) reported that each of the additive and non-additive gene effects have equal importance in controlling DH%, but additive gene effects played a much greater role than non-additive gene effects for IP%. On the other side, additive and non-additive genetic variation were involved in the genetic variability of grain yield, but non-additive effects appeared to be more important in the expression of this trait as indicated by Dehghanpour *et al.*, (1996) and Geetha and Jayaraman (2000). Furthermore, Butron *et al.*, (1999) found that GCA and

SCA exhibited significant values for yield under infestation and non-infestation conditions with pink stem borer and percentage of yield loss traits.

Percentages of resistance to pink stem borer for parental lines as presented in Table 2, ranged from 12.5 to 73.33 with an average of 46.35 and from 20.84 to 77.78 with an average of 56.76 for RIP% and RDH% traits, respectively. Mean of grain yield under infestation and non-infestation conditions for parental lines ranged from 1.24 to 7.87 with an average of 5.49 and from 1.55 to 13.12 with an average of 7.76 ard/fad, respectively. Yield loss% trait ranged from 6.37 (SK-9121) to 46.37 (S.T.M-8) with an average of 25.37. It was interesting to notice that the inbred lines Gm-1002 and SK-9121 which had the highest value of resistance to pink stem borer were the lowest inbred lines of yield loss%. Meanwhile, the inbred line SK-7266 which was the highest in susceptibility to pink stem borer had the lowest value of grain yield under infested and non-infested plants.

The mean performances of the single crosses ranged from 15.46 to 95.46, from 15.48 to 100%, from 8.06 to 33.58 ard/fad, from 17.77 to 38.33 ard/fad and from 1.39 to 60.46 for RIP%, RDH%, YI, YN and YL% traits, respectively. As postulated in the aforesaid data, S.C.L-121x SK-7266 which was the lowest single crosses for resistance to pink stem borer had worst grain yield under infestation condition and had the highest percentage of yield loss (60.46%). Generally, F_1 crosses were superior than parental lines in their resistance to pink stem borer, yield under infestation and non-infestation and had low yield loss traits.

Percentage of heterosis relative to mid and better parent for resistance to IP and DH%, yield under infested and non-infested plants and yield loss traits are given in Table 3. Heterosis estimates relative to mid parent ranged from -71.37 to 241.48 with an average of 62.6, from -53.76 to 209.2 with an average of 380.8, from 177.84 to 568.65 with an average of 318.4 and from -84.36 to 250.77 with an average of -11.8 for RIP%, RDH%, YI, YN and YL%, respectively. The results exhibited that 22 and 13 single crosses had significantly positive heterotic effects (desirable) relative to mid and better parent for RIP% trait, respectively. Moreover, the best heterotic effects are found in 18 and 7 single crosses for RDH% relative to mid and better parent, respectively. Meanwhile, the all F_1 crosses showed desirable significant positive heterobeltiosis for grain yield under infestation and non-infestation conditions with pink stem borer relative to mid or better parent. Regarding yield loss% trait, 17 and 19 F_1 crosses had desirable heterotic estimates relative to mid and better parent, respectively. The best 10 single crosses which had the highest values of heterotic effect for the two traits of resistance to PSB relative to mid or better parent gave the best heterotic estimate for grain yield production under infestation and non-infestation condition. This result indicated that the selection for single crosses with high yield potential combined with high level of resistance to PSB attack could be effective in the future production maize programs. In this respect, EL-Naggar *et al.*, (2000b) found that heterosis estimates relative to better parent ranged from -0.40 to 251% for IP% and from -43.8 to 129% for DH% traits. Meanwhile, Dehghanpour *et al.* (1996) found that the average of mid parent heterosis was 152% for grain yield and Geetha and Jayaraman (2000) showed that the highest value of heterosis over better parent was 97.45% for the same trait.

Table 2: Mean performance for the percentage of resistance to (RIP%), percentage of resistance to (RDH%), yield under infestation (YI) and non infestation (YN) with pink stem borer, and percentage of yield loss (YL%) for eight parental lines and their 28 single crosses.

Genotypes	RIP%	RDH%	Yield (ard/fad)		YL%
			I	N	
L-121	41.56	46.10	4.72	7.08	35.019
B-73	55.11	65.91	7.32	8.95	12.52
Gem-1002	73.33	83.89	5.55	6.53	11.56
SK-7266	12.50	20.84	1.24	1.55	16.60
SK-8118	28.579	28.57	4.60	7.08	34.97
SK-9121	62.50	77.50	7.51	8.01	6.37
SK-9203	47.22	53.47	7.87	13.12	39.99
S.T.N-8	50.00	77.78	5.09	9.77	46.37
Average Lines	46.35	56.76	5.49	7.76	25.42
L-121 X B-73	90.00	100.00	22.03	30.16	27.15
X Gm-1002	80.56	88.89	29.44	38.33	23.20
X SK-7266	15.48	15.48	8.06	23.81	60.46
X SK-8118	73.02	73.02	30.93	36.99	16.01
X SK-9121	95.46	95.46	22.96	31.49	27.09
X SK-9203	70.24	74.41	23.20	36.63	36.67
X S.T.N-8	86.36	90.91	30.25	37.50	19.18
B-73 XGm-1002	90.91	95.46	28.39	28.77	1.39
X SK-7266	62.50	68.75	22.97	25.34	10.32
X SK-8118	90.91	100.00	29.05	34.18	12.50
X SK-9121	56.25	62.50	30.42	31.15	2.50
X SK-9203	80.81	80.81	21.17	30.66	30.96
X S.T.N-8	55.56	61.11	25.65	27.53	7.04
Gm1002 X SK-7266	75.00	75.00	25.84	26.98	4.55
X SK-8118	56.25	62.50	20.21	34.04	40.39
X SK-9121	56.43	66.43	21.43	30.80	31.43
X SK-9203	88.89	88.89	33.07	37.95	12.87
X S.T.N-8	95.00	100.00	29.91	31.44	4.54
SK-7266 X SK-8118	70.14	76.39	25.60	28.37	9.76
X SK-9121	66.07	66.07	22.93	28.83	21.72
X SK-9203	84.44	89.44	33.58	36.31	7.91
X S.T.N-8	83.33	94.44	15.93	17.77	10.12
SK-8118 X SK-9121	82.96	82.96	20.25	24.98	16.97
X SK-9203	81.25	81.25	30.52	33.91	9.49
X S.T.N-8	88.89	88.89	25.51	31.38	18.10
SK-9121 X SK-9203	89.90	94.44	21.17	29.64	28.94
X S.T.N-8	73.57	73.57	24.70	26.92	9.08
SK-9203 X S.T.N-8	33.33	33.33	29.65	33.99	12.00
Average Crosses	74.05	77.87	25.17	30.92	18.30
L.S.D at 0.05	34.39	35.06	8.622	7.99	28.57
0.01	46.21	47.15	11.59	10.76	38.43

Table 3: Heterosis percentage relative to mid parent (M.P) and better parent (B.P) for 28 single crosses of the five traits under study.

Crosses	RIP%		RDH%		Yield (ard/fad)				YL%	
					I		N			
	M.P	B.P	M.P	B.P	M.P	B.P	M.P	B.P	M.P	B.P
L-121 x B-73	86.20**	63.33**	78.55**	51.72**	266.08**	200.82**	276.41**	236.98**	14.29	-22.43
x Gm-1002	40.23**	9.85	36.76*	5.96	474.24**	431.23**	464.09**	441.38**	-0.34	-33.71*
x SK-7266	-71.37**	-62.76**	-53.76**	-66.42**	170.92**	71.13**	451.80**	236.3**	134.43**	72.74**
x SK-8118	10.824**	75.70**	95.57**	58.39**	564.23**	556.48**	422.46**	422.46**	-82.82**	-54.26**
x SK-9121	83.46**	52.73**	54.46**	23.17**	276.09**	206.13**	317.77**	293.75**	30.82**	-22.63
x SK-9203	58.23**	48.75**	49.46**	39.16*	268.68**	194.66**	262.67**	179.19**	-2.21	-8.3
xS.T.N-8	88.65**	72.73**	46.77**	16.88	517.98**	495.47**	345.10**	283.83**	-52.89**	-58.63**
B-73 x Gm 1002	42.56**	23.97	27.45	13.79	341.37**	287.7**	272.00**	221.34**	88.45**	-88.81**
x SK-7266	84.86**	13.41	58.5**	4.31	436.45**	213.66**	382.67**	183.46**	-29.07**	-37.83*
x SK-8118	117.28**	64.96**	11.69**	51.72**	387.25**	296.72**	326.18**	281.79**	-47.35**	-64.25**
x SK-9121	-4.35	-10.0	-12.84	-19.35	310.53**	305.60**	267.43**	247.93**	-73.52**	-80.01**
xSK-9203	57.92**	46.63**	35.38*	22.61	178.74**	168.87	177.84**	133.69**	17.94*	-22.58*
xS.T.N-8	5.7	0.82	-14.94	-21.43	313.55**	250.27**	194.12**	181.78**	-76.12**	-84.81**
Gm1002 xSK-7266	74.74**	2.28	43.23**	-10.6	662.24**	366.43**	568.65**	313.8**	-67.74**	-72.65**
xSK-8118	10.4	-23.29	11.15	-25.5	298.62**	264.62*	400.59**	380.65**	73.61**	15.52
x SK-9121	-16.92	-23.05	.17.68	-20.46	219.61**	185.6**	324.24**	285.00**	250.77**	172.03**
xSK-9203	47.46**	21.22	29.43	5.96	393.21**	320.08**	286.46**	189.25**	-50.06**	-67.82**
xS.T.N-8	54.05**	29.55	23.71	19.20	463.28**	439.89**	286.0**	221.8**	-84.36**	-90.23**
SK-7266 xSK-8118	241.48**	145.5**	209.21**	167.38**	776.71**	456.52**	457.37**	300.71**	-62.18**	-72.11**
x SK-9121	76.19**	5.71	34.37*	-14.75	424.03**	205.73**	503.56**	260.25**	89.03**	30.78*
xSK-9203	182.79**	78.82**	140.72**	67.27**	637.21**	326.63**	394.89**	176.68**	-72.08**	-80.25**
xS.T.N-8	166.66**	66.66**	91.52**	21.42	404.11**	213.58**	213.96**	81.88**	-67.89**	-78.99**
SK-8118 xSK-9121	82.16**	32.74	56.43**	7.04	234.71**	170.0**	231.30**	212.25**	-17.90*	-51.47**
xSK-9203	114.38**	72.07**	118.68**	51.95**	389.49**	287.8**	235.34**	158.38**	-74.65**	-76.30**
xS.T.N-8	126.24**	77.78**	67.17**	14.28	426.86**	401.97**	272.34**	221.08**	-55.52**	60.98**
SK-9121 xSK-9203	63.87**	43.84*	44.22**	21.6	175.34**	168.87**	180.59**	125.84**	24.82**	-27.65
xS.T.N-8	30.79*	17.71	-5.24	-5.41	292.69**	229.33**	202.87**	175.44**	-65.57**	-80.41**
SK-9203 xS.T.N-8	-31.43*	-33.34	-49.21**	-57.15**	357.76**	276.62**	196.90**	158.99**	-72.24**	-84.30**
Average	68.6	36.7	46.8	15.1	380.8	289.0	318.4	235.9	-11.8	-36.6
L.S.D at 0.05	29.76	34.36	30.36	35.06	7.47	8.62	6.93	7.99	16.49	28.57
0.01	40.02	46.21	40.83	47.15	10.04	11.60	9.32	10.7	22.19	38.43

***,** significant at the 0.05 and 0.01 percent level of probability, respectively.**

As presented in Table 4, the values of potence ratio for RIP% trait revealed that 23 S.C. exhibited over-dominance gene action toward resistance to PSB attack and only one S.C. gave partial dominance. On contrarily, partial and over-dominance gene effect existed in 3 and 1 S.C. for PSB sensitive, respectively. For resistance to DH% trait, the over-dominance existed in 19 S.C for PSB resistance and 3 S.C exhibited partial dominance gene action. While, six S.C gave over-dominance towards susceptibility of maize plants to PSB attack. In relation to potence ratio of grain yield under infestation and non-infestation conditions with PSB, all the F_1 crosses exhibited over-dominance gene action. Regarding yield loss% trait, both partial and over-dominance gene action are noticed in 5 and 15 single crosses toward decreased yield loss. Meanwhile, the partial and over-dominance existed in 4 S.C. per each type of gene action towards increased yield loss trait. These results indicated that the resistance of PSB attack was predominating on the susceptibility and the over-dominance gene action played the major role in the inheritance of resistance to this insect. Moreover, grain yield under infested and non-infested conditions and yield loss are controlled mainly by over-dominance gene effects. These results are in agreement with those obtained by EL-Naggar *et al.*, (2000a) who found that over-dominance gene action controlled DH%. Also, Motawei (1996) pointed out that the over-dominance was more important than partial dominance gene action in conditioning susceptibility to PSB. While, Galal *et al.*, (2002) revealed that the over- and partial-dominance gene action controlled both resistance and susceptibility to PSB under artificial infestation conditions.

Table 4: Potance ratio of 28 single crosses for the percentage of resistance relative to infested plants (RIP%) and dead hearts (RDH%) plants, yield infested (YI) and non-infested (YN) plants with PBS and yield loss (YL%) traits.

Crosses	RIP%	RDH%	Yield (ard/Fad)		YL%
			I	N	
L-121 x B-73	6.15	4.44	12.3	23.69	0.302
x Gm-1002	1.46	1.26	58.64	114.65	-0.006
x SK-7266	-2.66	-1.42	2.93	7.05	3.76
x SK-8118	5.84	4.07	469.11	59.81	-1224.52
x SK-9121	4.16	2.14	12.08	25.75	0.445
x SK-9203	8.64	6.68	8.8	4.39	-0.33
x S.T.N-8	9.62	1.83	137.0	21.57	-21.52
B-73 x Gm 1002	2.93	2.29	24.7	17.34	-22.14
x SK-7266	1.35	1.13	6.14	5.43	-2.06
x SK-8118	3.69	2.83	16.97	27.98	-54.96
x SK-9121	-0.69	-1.59	245.38	48.87	-6.94
x SK-9203	7.51	3.4	48.6	9.41	0.34
x S.T.N-8	1.17	-1.81	17.37	44.31	-1.32
Gm1002 x SK-7266	1.05	0.72	10.44	9.22	-3.78
x SK-8118	0.24	0.23	31.85	98.14	1.46
x SK-9121	-2.12	-2.23	15.01	31.81	8.67
x SK-9203	2.19	1.33	22.62	8.53	-0.907
x S.T.N-8	2.85	6.27	106.9	14.35	-1.40
SK-7266 x SK-8118	6.17	6.39	13.5	8.42	-1.74
x SK-9121	1.14	0.60	5.92	7.45	1.99
x SK-9203	3.14	3.20	8.75	9.28	-1.74
x S.T.N-8	2.78	1.59	6.65	2.9	-1.43
SK-8118 x SK-9121	·2.21	1.22	9.79	37.7	-0.25
x SK-9203	4.65	3.23	14.85	7.88	-11.83
x S.T.N-8	4.63	1.45	86.0	17.06	-3.96
SK-9121 x SK-9203	4.59	2.41	84.18	7.45	0.34
x S.T.N-8	2.77	-29.07	15.21	20.42	-0.86
SK-9203 x S.T.N-8	-10.99	-2.66	16.60	13.45	-9.78

General combining ability effects for eight inbred lines of five studied traits as seen in Table 5 revealed that the inbred line Gm-1002 had positive and significant GCA effect towards the two criteria of resistance to PSB attack. While, the opposite was found by the inbred line SK-7266 which had negative significant value towards sensitivity. On the other hand, inbred line SK-9203 had significant positive GCA effects for yield under infestation and non-infestation conditions. Also, inbred line L-121 exhibited positive and highly significant GCA estimates for grain yield of non-infested plants. Moreover, only inbred line B-73 gave negative and significant estimates of GCA effects towards decreased yield loss. While, the opposite trend was found by inbred line L-121 which had positive and significant estimates of GCA effect towards increase yield loss. These results concluded that the inbred lines L-121, SK-9203 and Gm-1002 are elite and good combiners for yielding ability and resistance to PSB attack in future breeding maize programme.

Table 5 : General combining ability effects (GCA) for RIP% and RDH%, yield of infested (YI) and non infested (YN) plants with pink stem borer and percentage of yield loss (YL%) from a diallel set of 8 inbred lines.

Inbreds	RIP%	RDH%	Yield (ard/Fad)		YL%
			I	N	
L-121	-1.685	-2.825	-1.088	1.709*	10.085**
B-73	2.609	4.183	0.713	-0.629	-6.202*
Gem-1002	7.863*	8.633*	1.219	0.939	-3.745
SK-7266	-12.911**	-13.647**	-2.977**	-4.147**	-2.091
SK-8118	-1.052	-3.647	0.410	0.602	1.424
SK-9121	3.456	3.781	-0.830	-1.217	-2.846
SK-9203	1.223	-0.909	2.093*	3.334**	3.989
S.T.N-8	0.497	3.920	0.460	-0.591	-0.614
L.S.D 0.05	7.118	7.33	1.805	1.672	5.977
0.01	9.665	9.85	2.425	2.249	8.037

*,** significant at the 0.05 and 0.01 percent level of probability, respectively.

Specific combining ability effects of the two resistance traits, yield under infested and non-infested conditions and yield loss% are presented in Table 6. The results indicated that the positive and significant SCA effects were detected for SK-7266 x SK-9203 and SK-7266 x S.T.N-8 for resistance to IP% and DH% simultaneously. Moreover, S.C.L-121 x Sk-9121 for RIP%, S.C. L-121 x B-73 and B-73 x SK-8118 had positive and significant (desirable) SCA effects for RDH%. On the other hand, 14 and 16 single crosses exhibited positive and significant SCA effects for grain yield under infested and non-infested conditions, respectively. While, yield loss% trait did not give any desirable SCA effects.

In the light of these results, the two single crosses Sk-7266 x Sk-9203 and B-73 x SK-8118 which had positive and significant SCA effects for resistance to PCB attack and yielding ability could be used directly by farmers in areas and planting dates which are showing heavy attack of PSB. Also, it could be used by maize breeders as a source of a new antibiotic resistant inbred lines.

Estimation of correlation coefficient (r) between resistance to PSB and each of YI and YN were positive and highly significant as presented in Table 7. This was meaning that the high yield potential of these genotypes might have a high value of resistance to this insect. While, the relationship between YL% and each of the two resistance traits to PSB was negative and significant, indicating that the genotypes which scored low level of resistance to PSB gave high values of yield loss%. These results suggested that breeding for maize genotypes which could carry both resistance to PSB and high grain yield simultaneously is possible.

Correlation coefficient estimates between line *per se* and g_i effects and each of the two traits of resistance to PSB are positive, highly significant and greater in magnitude (Table 7). These indicated that primary selection of parents for hybrid combinations may be largely based on the insect reaction of the inbred lines. These results are in agreement with those obtained by (Butron, *et al.*, 1998) who reported that the performance of hybrids for PSB attack could be predicted from the performance of the inbred lines.

Table 6: Specific combining ability effects (SCA) of 28 F_1 crosses among 8 inbred lines for RIP%, RDH%, yield under infestation (YI) and non infestation (YN) conditions and for percentage of yield loss(YL%).

Crosses	RIP%	RDH%	Yield (ard/Fad)		YL%
			I	N	
L-121 x B-73	21.18	25.463*	1.603	3.306	3.390
x Gm-1002	6.481	9.902	8.507**	9.909**	-3.016
x SK-7266	-37.825**	-41.741**	-8.668**	0.474	32.587**
x SK-8118	7.856	6.309	10.808**	8.901**	-15.379
x SK-9121	25.787*	21.319	4.081	5.224*	-0.032
x SK-9203	2.803	4.96	1.397	5.813*	2.714
x S.T.N-8	19.654	16.635	10.081**	10.608**	-10.174
B-73 x Gm 1002	12.541	9.46	5.657*	2.682	-8.54
x SK-7266	4.905	4.524	4.433	4.342	-1.267
x SK-8118	21.456	26.285*	7.126*	8.429**	-2.600
x SK-9121	-17.711	-18.644	9.741**	7.217	-8.331
x SK-9203	9.079	4.355	-2.434	2.181	13.292
x S.T.N-8	-15.447	-20.171	3.677	2.976	-6.026
Gm1002 x SK-7266	12.151	6.325	6.801*	4.414	-9.500
x SK-8118	-18.457	-15.665	-2.218	6.721*	22.832*
x SK-9121	-22.787*	-19.165	0.241	5.305*	18.136
x SK-9203	11.906	7.986	8.957**	7.903**	-7.254
x S.T.N-8	18.743	14.268	7.435**	5.319*	-10.987
SK-7266 x SK-8118	16.205	19.993	7.373*	6.141*	-9.455
x SK-9121	7.63	2.248	5.941*	8.415**	6.771
x SK-9203	28.235*	30.311**	13.671**	11.343**	-13.871
x S.T.N-8	27.850	30.482**	-2.349	-3.266	-7.060
SK-8118 x SK-9121	12.654	9.641	-0.127	-0.183	-1.49
x SK-9203	13.182	12.627	7.222*	4.195	-15.805
x S.T.N-8	21.547	15.437	3.842	5.591*	-2.594
SK-9121 x SK-9203	17.323	18.393	-0.894	1.744	7.917
x S.T.N-8	1.721	-7.309	4.278	2.949	-7.338
SK-9203 x S.T.N-8	-36.284**	-42.857**	6.298*	5.468*	-11.260
L.S.D at 0.05	22.031	22.478	5.528	5.128	18.321
0.01	29.628	30.229	7.435	6.897	24.638

*,** significant at the 0.05 and 0.01 percent level of probability, respectively.

Table 7: Correlation coefficients among mean performance (above diagonal), mean performance of inbreds and their GCA effects (diagonal) and among GCA effects of inbreds (below diagonal) for the five traits under study.

Traits	RIP%	RDH%	IY	NY	YL%
RIP%	(0.941**)	0.966**	0.639**	0.570**	-0.425*
RDH%	0.958**	(0.937**)	0.527**	0.453**	-0.397*
IY	0.770*	0.685*	(0.737*)	0.929**	-0.483**
NY	0.591	0.410	0.777*	(0.756*)	-0.155
YL%	-0.196	-0.336	-0.048	0.553	(0.655)

*,** significant at the 0.05 and 0.01 percent level of probability, respectively.

Regarding to correlation coefficients among GCA effects of lines (additive effects) for yield under infestation (YI) and each of GCA effects of RIP% and RDH% traits were detected positive and significant. Furthermore, the additive genetic linkage was found positive and highly significant between the two antibiosis traits whereas, the RIP% confirmed RDH%.

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قياس قوة الهجين والقدرة على التآلف لميكانيكيات دفاع الذرة الشامية ضد ثاقبة الساق القرنفلية

عاصم عبده مطاوع
مركز البحوث الزراعية- معهد المحاصيل الحقلية- قسم بحوث الذرة الشامية

تعتبر ثاقبة الساق القرنفلية واحدة من أهم وأكثر الحشرات التي تصيب الذرة الشامية في مصر. وبالرغم من ذلك فان القليل معروف عن القدرة على التآلف لصفات التحمل والتضاد الحيوي لهذه الحشرة. ومن هذا المنطلق تم وضع ثلاثة أهداف لهذا العمل هي قياس تأثيرات القدرة على التآلف وتحديد نوع الفعل الجينى وقياس قوة الهجين لصفات التضاد الحيوي للحشرة (نسبة المقاومة للنباتات المصابة ، نسبة المقاومة للقلب الميت) وكذلك صفات التحمل (المحصول تحت العدوى الصناعية - المحصول تحت المقارنة – وتقديرات نسبة النقص المحصولى) وذلك بالإضافة إلى قياس معامل الارتباط المظهري و الوراثى بين صفات التحمل وصفات المقاومة الحيوية النباتية. وقد قيمت ثمانية سلالات في نظام التهجين نصف الدائري لهذه الصفات تحت ظروف العدوى الصناعية بالثاقبة القرنفلية وكذلك تجربة المقارنة التي تم فيها منع حدوث إصابة.

وكانت أهم النتائج المتحصل عليها ما يلي :-

كان لكل من القدرة العامة والخاصة على التآلف للفعل الجينى دور في التحكم الوراثى للصفات الخمس تحت الدراسة. وقد لعبت القدرة الخاصة على التآلف أهمية أكثر في التحكم الوراثى في صفات المقاومة للنباتات المصابة وكذلك القلب الميت بالإضافة إلى صفة المحصول تحت ظروف العدوى الصناعية وكذلك محصول المقارنة بينما كانت القدرة العامة على التآلف أكثر أهمية لصفة الفقد في المحصول.

كان الفعل الجينى الفوق سيادي أكثر أهمية عن السيادة الجزئية للصفات الخمس تحت الدراسة. ومن ناحية أخرى كان متوسط قوه الهجين بالنسبة لمتوسط الأبوين لصفتى المقاومة، والمحصول تحت العدوى، والمقارنة، وفقد المحصول هي ٦٨,٦ ، ٤٦,٨ ، ٣٨٠,٨ ، ٣١٨,٤ ، -١١,٨ على التوالي بينما كان متوسط قوة الهجين لنفس الصفات على التوالي بالنسبة للأب الأفضل هي ٣٦,٧ ، ١٥,١ ، ٢٨٩,٠ ، ٢٣٥,٩ ، -٣٦,٦.

أظهرت السلالات جميزة ١٠٠٢ ، السلالة ١٢١، ب-٧٣ قدرة تآلف جيدة و مرغوبة لصفات المقاومة للحشرة، والقدرة المحصوليه، ونقص الفقد المحصولى على التوالي. بينما أظهر الهجينان سخا ٧٢٦٦ × سخا ٩٢٠٣ و سخا ٨١١٨ × ب- ٧٣ قدرة تآلف خاصة موجبة و معنوية لصفات القدرة المحصوليه والمقاومة الحيوية معا لذلك فمن الممكن الاستخدام المباشر لهذين الهجينين إما للإنتاج المحصولى في المناطق أو مواعيد الزراعة التي تتعرض للإصابة الشديدة بحشرة ثاقبة الساق القرنفلية أو تستخدم كمصدر لسلالات جديدة تحمل صفات المقاومة الحيوية لهذة الحشرة في برنامج تربية الذرة الشامية.

كان معامل الارتباط المظهري بين صفتي المقاومة الحيوية وصفتي التحمل (المحصول تحت العدوى الصناعية - المحصول تحت المقارنة) موجبا وعالي المعنوية بينما كان سالبا ومعنويا مع صفة الفقد في المحصول. كان الارتباط المظهري بين متوسطات السلالات وقدرتها على الائتلاف موجبا ومعنويا لصفتي المقاومة الحيوية النباتية. علاوة على ذلك كان الارتباط الوراثى بين صفة المحصول تحت العدوى الصناعية وصفتي المقاومة الحيوية النباتية موجبا ومعنويا.