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INHERITANCE OF RESISTANCE TO GREENBUG (*Schizaphis graminum*) AND BIRD CHERRY-OAT APHID (*Rhopalosiphum padi*) IN WHEAT CROSSES.

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ABSTRACT

Diallel crosses (except reciprocals) were made in 2001/2002 season between 8 parents of wheat (Triticum aestivum) that varied in resistance to aphids. In 2002/2003 season parents and F_1s were evaluated for resistance to bird cherry-oat aphid (BCOA) and greenbug (GB) under field and greenhouse conditions. The main objective was to study type of gene action, combining ability and probable number of genes controlling resistance to these aphids. Results of artificial infestation indicated that general (GCA) was more important than specific (SCA) combining ability variances in determining the plant reaction against both aphid species. The best general combines were Bush and Gz-170 for resistance to BCOA and Gem-9 and Sd-1 for resistance to GB. The best F_1 crosses in SCA effects were identified. Overdominance was controlling resistance to both aphids. Heritability in narrow sense was 41.0 and 22.4% for resistance to BCOA and GB, respectively. Results indicated that one gene (one group of genes) controlled the inheritance of wheat resistance to each of the studied aphids.

Key words: ***Bread wheat, Triticum aestivum, Bird cherry, Oat aphid, Greenbug, Resistance, Inheritance, Gene action, Combining ability, Heritability.***

INTRODUCTION

In Egypt wheat (*Triticum aestivum*) suffers from infestation with different cereal aphid species, which represent a major biotic stress for wheat production.

Cereal aphids belong to the order: *Homoptera* and include different genera. The major cereal aphids in wheat fields in Egypt include: bird cherry- oat aphid (*Rhopalosiphum padi* L.), greenbug (*Shizaphis graminum* Rondani.), corn leaf aphid (*Rhopalosiphum maidis*.), English grain aphid

(*Macrosiphum avenae*) and Russian wheat aphid (*Diuraphis noxia* Mordvilko.)

The losses in wheat yield in Egypt due to aphid infestation are estimated to be about 25% (National Bulletin of Wheat Research Program, 2004).

The aphid infestation in wheat fields starts from January and reaches its peak in March. Aphids cause a great direct damage to the host plants, because they feed on wheat plant sap, cause honeydew, which encourages many fungi to grow on it, and if the infestation occurs before heading, the spike may not go for heading (Pike and Scahaffer 1985, Burton *et al* 1985, Kieckhefer and Kantack 1988 and Ismail *et al* 2003). Severe infestations cause dwarfing of the straw and curling of the leaf. Moreover, aphid infestation is playing a role as a vector of virus diseases like Barley Yellow Dwarf Virus (BYDV) in wheat (Waziery 1996 and Hoffman and Kolb 1998).

Host-plant resistance restricts or eliminates damage caused by the insect. It does not increase cost, does not require special equipment and does not cause environmental pollution. In addition, the efficiency of this method is compatible with other chemical and biological control methods (Scott *et al* 1977).

Breeding methods used to develop cultivars resistant to the insect are determined by the mode of gene action that conditions resistance in the host plant to insect (Russell 1972). Type of gene action for host-plant resistance to aphids was studied in maize and sorghum. General (GCA) was more important than specific (SCA) combining ability effects, suggesting that additive predominated over non-additive genetic variance in controlling the inheritance of resistance to aphids in these crops (Hsieh and Pi 1988, Dixon *et al* 1990, Bing *et al* 1992 and Tuinestra *et al* 2001).

However, in wheat, researches were conducted to study the type of gene action conditioning resistance to aphids are very scarce.

Contrasting results are reported in the literature regarding number of genes controlling resistance. Some investigators suggested that wheat resistance to greenbug (GB) is controlled by a single dominant gene (Joppa *et al* 1980, Tyler *et al* 1986, Porter *et al* 1994 and Tolmay *et al* 1999) or a single recessive gene (Daniels and Porter 1958). Others indicated that resistance is controlled by two pairs of recessive genes (Wood and Curtis 1967, Youssef *et al* 1985 and 1991). Moreover, Miller *et al* (1992) and Castro *et al* (1999) reported that numerous genetic factors contribute to plant's resistance to aphid populations.

Therefore, the objectives of the present study were to: (1) Identify the type of gene action controlling the inheritance of greenbug (GB) (*Schizaphis graminum*) and bird cherry-oat aphid (BCOA) (*Rhopalosiphum padi*) resistance in bread wheat, (2) Estimate combining ability in some parental wheat genotypes and their F_1 diallel crosses the components of genetic variations and heritability for plant resistance to these two aphids and (3) Determine the probable number of genes (or gene groups) controlling the resistance to these two aphids in bread wheat.

MATERIALS AND METHODS

Materials

Eight bread wheat genotypes (*Triticum aestivum* L.) were chosen for this study on the basis of their diversity of origin, earliness, and agronomic traits. Besides, they differed in their tolerance to aphid infestation, based on previous field and laboratory screening to recognizing the expected reaction to infestation for each cultivar (Table 1).

Table 1. Wheat parents used in this study, their pedigree, origin and reaction to aphid.

Parents	Pedigree	Origin	Expected reaction to aphid
Giza 168 (Gz-168)	MRL/BUC//SEREI C.CM93046-8M-0y-0y-2y-0B	Egypt	R
Giza 170 (Gz-170)	KAUZ/Altr .84 //ASO 2001	Egypt	R
Sakha 69(Sk-69)	INI/RL-4220//7C/yr "S"–CM15430-2S-6S-0S-0S	Egypt	S
Gemmieza9 (Gem-9)	ALD "S" / HUAC"S" //CMH74- A630/S CG.M4583-5GM-1GM-0GM.	Egypt	R
Sids 1 (Sd-1)	HD2/ 72 / PAVON"S"// 1158.57	Egypt	R
IRENA	CM91575-28Y-0M-0Y-IM-0Y	Mexico	S
Bush/Amig (Bush)	Bush land T X F79518-2x77A /5/ AMIGO//T 10	ICARDA	R
Sakha 93 (Sk-93)	Sakha 92/ TR810328. S8871-1S-2S	Egypt	S

Methods

Field experiments

Two-field experiments were carried out in 2001/2002 and in 2002/2003 seasons. In the first season, 2001/2002, half diallel crosses involving the eight parents, without reciprocals, were made at Giza Agric. Res. Stat., Agric. Res. Center, Ministry of Agric., Egypt. Thirty female spikes, per cross, were hand emasculated and crossed with pollen grains of the desired parent.

In the second season, 2002/2003, the field of Sids. Agric. Res. Station was chosen as a hot spot for aphid infestation to evaluate the reaction of 36 genotypes (8 parents and 28 F_1 hybrids) under the natural infestation conditions and under protected conditions (as a control) by using a randomized complete block (RCB) design with four replications. The first experiment (unprotected) was left to the natural infestation. The second experiment (protected) was kept free from aphid infestation by spraying Malathion (150 cm^3 /100 liter water) three times during the season.

Each parent or F_1 was represented by one row, two meters long. Spaces were 30 cm between rows and 10 cm within rows between plants. In the unprotected experiment the border was sown with the local cultivar Beni suief 3, which proved to be susceptible to aphid infestation, to help as a spreader. The cultural practices were applied as recommended and weeds were controlled by hand. Plants were tested every two weeks to record aphid infestation from the first of January to the end of March. Plant resistance to infestation with aphids was assessed by determining the amount of damage to the plant caused by the aphids according to the method used by the Egyptian Entomologists of A.R.C.

Greenhouse experiments

To secure enough F_1 seed for this experiment, diallel crosses among the eight parents were again produced in the field in 2002/2003 season. To estimate the mode of gene action and the other genetic parameters of the parents and their F_1 crosses under artificial infestation, two greenhouse experiments under controlled conditions were carried out in summer 2003 at the greenhouse of Wheat Section, FCRI, ARC at Giza, one with GB and other with BCOA.

The eight parents and their 28 F_1's were tested under the conditions of artificial infestation. The infestation was done with (GB) and (BCOA) in the greenhouse, because they are the most abundant species of aphid in Egypt (Salem and Mogahed 1990). The greenhouse was divided into two laboratories, one for rearing the bird cherry- oat aphid, and the other for rearing greenbug. In these laboratories, the temperature regime was adjusted to 22±2 ^{0}C, 60±5% RH and 16/8 hr-light/ dark photoperiod, according to El-Hariry *et al* (2001).

Wheat genotypes were grown in three experiments one as control, the second was for the evaluation of infestation with greenbug and the third was for infestation with bird cherry- oat aphid. Each genotype was grown separately in 15 cm diameter plastic pots, filled with a mixture (1: 1: 1) of (clay: peat moss: sand) according to El-Hariry *et a*l (2001), each pot contained 10 grains planted in circules. A glass cage was fitted on each pot to keep parasitoids away, a fine gauzed material was adhered on its tops. The genotypes were arranged in a randomized complete block design with three replications in each experiment.

Techniques of the greenbug (GB) infestation

The seedlings were infested with adults of greenbug according to Kieckhefer and Gellner (1992), by placing two adults on each seedling after one week of seed germination. After two days from the onset of the 1st infestation, infestation was repeated for each seedling with one or two insects. Two weeks later, data were recorded on five seedlings per replication. The evaluation procedure depended on the reaction of seedlings tissues to the toxic aphid saliva.

The scale (from 1 to 5) used herein to evaluate plant reaction to artificial infestation with greenbug was the same used by the National Entomology Program as described by El- Hariry *et al* (2001) as follows:-

1 = Aphids are present on the seedlings with no apparent damage on leaves, 2 = Small red spots with black centers denoting to styled tips, 3 = Appearance of yellow patches around the red spots, 4 = Expansion of yellow color, besides, one leaf is died and 5 = Dead seedlings.

The intensity of damage (ID) value was calculated as follows:

$$ID = (ID1 + ID2 + \ldots\ldots + IDn) / N$$

Where ID1, ID2,...........IDn denote intensity of damage of the tested infested seedling No. 1, No, 2......No n. and N = Number of tested infested seedlings. Genotypes were classified according to their ID into: resistant (R) (less than 1.7), moderately resistant (MR) (from 1.7 to less than 2.7), and susceptible (S) (2.7 or above). This is our own classification. The classes were determined according to data of the present study.

Techniques of bird cherry-oat aphid (BCCA) infestation

After four days from seed germination, the seedlings were infested with 2 adult insects of bird cherry-oat aphid on each seedling. In addition, the infestation was repeated after two days for each tested seedling with one or two insects. The data were recorded on five seedlings from each replication, after two weeks from infestation.

Evaluation scale used herein was based on the number of insects exist on each seedling after 2 weeks of infestation as an average of readings on the five seedlings as follows: 1 to < 16 insects /plant (Resistant), 16 to < 30 insects /plant (Moderately resistance) and $\geq$30 insects/seedling (susceptible). This scale is currently used by the Egyptian Entomologist of ARC for screening wheat germplasm for susceptibility to the bird cherry-oat aphid.

The data were used to calculate the percentage of susceptible seedlings (after 14 days) as follows: Percentage of susceptible seedlings =[(No. of susceptible seedlings / pot) / (Total No. of seedlings / pot)] x 100

Genotypes were classified according to the percentage of susceptible seedlings into: resistant (R, less than 30%), moderately resistant (MR, from 30 to less than 50%) and susceptible, more than 50%). This also is our own classification.

General (GCA) and specific (SCA) combining ability variances and effects were estimated according to Griffing (1956) Model I (i.e, the fixed model I Method II). The components of genetic variance were estimated according to Hayman (1954a&b,).

RESULTS AND DISCUSSION

Field experiments

No differences between protected and non-protected field experiments were found regarding nature of aphid infestation symptoms. Absence of natural infestation symptoms in the field could be attributed to the following reasons: 1) The temperature and the relative humidity prevailing from planting dates until ripening in 2002/2003 season in the location of the present field experiment were not satisfactory for natural infestation, 2) The presence of natural enemies in the experiment and 3) The presence of a more preferable crop other than wheat or a preferable wheat cultivar grown on a large scale near the field experiment. The absence of natural infestation with aphids in the field could not therefore help for studying the inheritance of wheat resistance to aphids. This is why, hereafter we will discuss the results taken from the greenhouse experiments which were based on artificial infestation with the aphids BCOA and GB.

Greenhouse Experiments

a) Seedling reaction to artificial infestation

Means of percentage of susceptible plants to BCOA and intensity of damage to (GB) recorded for seedlings of 8 parental cultivars and their 28 F_1 diallel crosses after the artificial infestation with BCOA and GB are presented in Table (2).

Table 2. Mean percentage of susceptible plants to BCOA and intensity of damage with GB of eight parents and their 28 F_1 's under artificial infestation.

Parents/crosses	% Susceptible plants to BCOA	Reaction*	Intensity of damage with GB (scale)	Reaction*
Gz-168	47.60	MR	2.37	MR
Gz-170	40.27	MR	2.10	MR
Sk-69	55.57	S	2.80	S
Gem-9	35.67	MR	1.37	R
Sd-1	17.87	R	1.70	R
IRENA	34.77	MR	3.00	S
Bush	17.80	R	2.20	MR
Sk-93	57.33	S	2.60	MR
Average	38.50		2.27	
Range	17.80-57.33		1.37 – 3.00	
Gz-168 x Gz-170	15.60	R	2.73	MR
Gz-168 x Sk-69	48.87	MR	2.63	MR
Gz-168 x Gem-9	41.07	MR	2.17	MR
Gz-168 x Sd-1	32.50	MR	2.63	MR
Gz-168 x IRENA	10.40	R	3.00	S
Gz-168 x Bush	9.10	R	2.67	MR
Gz-168 x Sk-93	27.50	R	2.90	S
Gz-170 x sk-69	24.53	R	2.98	S
Gz-170 x Gem-9	11.00	R	2.33	MR
Gz-170 x Sd-1	15.87	R	2.43	MR
Gz-170 x IRENA	10.97	R	2.48	MR
Gz-170 x Bush	9.67	R	2.87	S
Gz-170x Sk-93	9.73	R	2.43	MR
Sk-69x Gem-9	10.17	R	2.50	MR
Sk-69x Sd-1	38.37	MR	2.67	MR
Sk-69x IRENA	52.80	S	2.67	MR
Sk-69x Bush	11.33	R	3.10	S
Sk-69 x Sk-93	74.40	S	2.57	MR
Gem-9 x Sd-1	31.73	MR	2.40	MR
Gem-9 x IRENA	38.57	MR	2.60	MR
Gem-9 x Bush	31.33	MR	2.00	MR
Gem-9 x Sk-93	38.23	MR	3.00	S
Sd-1xIRENA	9.67	R	2.53	MR
Sd-1 x Bush	13.73	R	3.30	S
Sd-1 x Sk-93	14.87	R	2.00	MR
IRENAxBush	5.80	R	2.93	S
IRENAx Sk-93	34.67	MR	3.40	S
Bush x Sk-93	27.30	R	1.70	R
Average	24.99		2.63	
Range	5.80-74.40		1.70-3.40	
LSD $_{0.05}$	4.99		0.54	

* R = resistance MR = moderately resistance S = susceptible

Parental variety means ranged from 17.80 to 57.33% for percentage of susceptible plants with BCOA and from 1.36 to 3.00 for artificial infestation with GB. Sd-1 and Bush behaved as resistant, while Gz-168, Gz-170, Gem-9 and IRENA were moderately resistant but Sk-69 and Sk-93 showed a high level of susceptibility for BCOA. On the contrary, Mannaa (2000) tested twelve Egyptian wheat cultivars, and observed that Sk-69 was the least infested cultivar (tolerant) with *R. padi.* His experiment was done under natural field conditions in the New Valley and data were recorded on adult plants while the present data were collected at seedling stage and under artificial infestation in the greenhouse.

For GB, Gem-9 and Sd-1 behaved as resistant cultivars, Gz-168, Gz-170, Bush and Sk-93 were moderately resistant and Sk-69 and IRENA showed the highest rate of infestation (susceptibility). Mannaa (2000) found also that Sk-69 was the least infested cultivar with GB among the twelve cultivars he tested in the Nile Valley under natural infestation.

For BCOA, the cross between the two susceptible cultivars (Sk-69 x Sk-93) showed susceptibility. Moreover, progeny of the resistant x resistant cross (Sd-1 x Bush) exhibited resistance for BCOA. In addition, the cross between resistant x susceptible (Bush x Sk-93) showed resistant reaction to BCOA infestation. Thus, genes controlling resistance to BCOA would be dominant. But, for greenbug, the cross between the two susceptible cultivars (Sk-69 x IRENA) showed a moderately resistant reaction. Such behavior was anticipated by Abdalla (1971) to be due to non-specific resistance genes. Moreover, the cross between resistant x resistant (Gem-9 x Sd-1) was moderately resistant. This indicated that the parent with less degree of resistance to GB dominated the other parent in the F_1 of their cross.

The crosses between resistant and susceptible parents were moderately resistant with an intensity of damage very close to the susceptible parent, indicating that genes responsible for resistance to GB would be recessive in nature. Thus the mode of gene action for resistance to the two aphid species may be different.

b) Combining ability

Analysis of variance

Analysis of variance of 8 parents and their diallel crosses (Table 3) showed highly significant differences among all genotypes for the two studied traits under artificial infestation with the two aphid species in the greenhouse. Besides, the diallel analysis revealed highly significant differences among either parents or crosses for reaction to both aphid

Table 3. Analysis of variance of percentage of susceptible plants to BCOA and the intensity of damage with GB for parents and their diallel crosses in the greenhouse.

Source of variation	D.F.	Mean squares	
		Oat aphid	Greenbug
Genotypes	35	799.63**	0.60**
Parents (P)	7	513.41**	0.90**
(P vs. C).	1	3145.66**	2.46**
Crosses(C)	27	780.55**	0.45**
GCA	7	1593.47**	1.01**
SCA	28	601.16**	0.49**
Error	70	9.73	0.11
GCA/SCA		2.65	2.05

** Significant at the 0.01 probability level.

species. The results also show that parents *vs.* crosses exhibited highly significant mean squares for reaction to infestation with both aphid species. The significance of the orthogonal comparison of parents *vs.* crosses indicated the presence of non-additive genetic effects (heterosis) in crosses. Therefore, this is justifying that separation of parents and crosses before the diallel analysis was done.

General (GCA) and Specific (SCA) combining ability variances

Table (3) showed that GCA and SCA mean squares revealed highly significant values for reaction to both aphid species. This indicates that all types of intraallelic interactions (i.e., additive and dominance) and interallelic interactions (additive x additive, additive x dominance and dominance x dominance) effects may be involved in the inheritance of resistance to both aphid species in bread wheat.

Comparing the magnitude of mean squares for GCA with that of SCA reveals that GCA mean squares was 2-2.6 times larger than SCA mean squares (GCA / SCA ratio = 2.6 and 2.05 for BCOA and GB, respectively). This demonstrated that additive gene effects are more important than the non-additive in determining the expression of seedling genotypes against BCOA, GB infestation in bread wheat. Results of the present study regarding GCA and SCA variances for wheat reaction to greenbug and bird cherry-oat aphid are in complete agreement with those reported by other investigators on resistance to aphids in sorghum (Dixon *et al* 1990 and Tuinestra *et al* 2001) and maize (Bing *et al* 1992). They also found that GCA was more important than SCA effects in determining plant tolerance to aphids.

GCA and SCA effects for reaction to BCOA

The estimates of GCA effects of each parental cultivar and SCA effects of their crosses in their reaction with respect to BCOA infestation are presented in (Table 4).

Table 4. Estimates of general combining ability (g_i) effects (in parentheses) and specific combining ability (S_{ij}) effects (above diagonal) for reaction of wheat genotypes to artificial infestation with BCOA.

Parents	GZ-168	GZ-170	SK-69	Gem-9	Sd-1	IRENA	Bush/ Amigo	SK-93
GZ-168	(2.99)*	-6.93*	6.45*	7.42*	8.43*	-19.04*	-12.67*	-8.99*
GZ-170		(-6.98)*	-3.96	-13.35*	1.09	-8.16*	-1.83	-20.43*
SK-69			(10.1) *	-31.82	6.14*	14.33*	-16.40*	17.70*
Gem-9				(3.13)*	7.55*	10.77*	13.91*	0.28
Sd-1					(-4.69)*	-12.50*	1.90	-15.19*
IRENA						(-2.14)*	-13.70*	2.61
Bush/Amigo							(-10.50)*	4.34*
SK-93								(8.06)*

Standard errors

SE (g_i) = 1.04 **SE ($g_i - g_j$) = 1.50**

SE (S_{ij}) = 3.20 **SE ($S_{ij} - S_{ik}$) = 4.74**

SE ($S_{ij} - S_{kl}$) = 4.47

Four parents showed negative GCA effects (i.e., Gz-170, Sd-1, IRENA and Bush), and four parents showed positive GCA effects (i.e., Gz-168, Sk-69, Gem-9 and Sk-93). It should be noted that negative effects indicated a contribution towards resistance, while positive values represented the opposite. The highest negative GCA effect was noticed for the resistant parent Bush/ Amigo. Moreover, four out of seven crosses that involved this variety as a common parent showed also significant negative SCA effects. Besides two of the highly resistant F_1 progenies (i.e., F_1 of the crosses Sk-69 x Bush/Amigo and IRENA x Bush/Amigo) had this parent as a common parent. It seems that this parent has the ability to transmit the resistance to artificial infestation with BCOA in the seedling stage to their offspring even in crosses with susceptible parents. Similar trend was also observed for the cultivar Gz-170. This cultivar was able to transmit the favorable reaction against the artificial infestation with BCOA to six out of its seven F_1 progenies. It should be noted that higher negative Sij effects were recorded for crosses between cultivars that were classified as moderately resistant, according to the scale used herein, and those that were classified as susceptible cultivars. Examples are Gz-168 x Sk-93 (Sij = -8.99), Gz-170 x Sk-93 (Sij = -20.43) and the cross between resistant cultivar x susceptible cultivar Bush/Amigo x Sk-69 (Sij = -16.40). The highest Sij value (-31.82) was shown by the cross moderately resistant x susceptible (Sk-69 x Gem-9).

GCA and SCA effects for reaction to GB

The estimates of GCA effects of each parental cultivar and SCA effects of their crosses in their reaction with respect to GB infestation are presented in Table (5). Three parents (i.e., Gz-170, Gem-9 and Sd-1) showed negative GCA effects. It should be noted that negative effects indicate additive gene contributions towards resistance. The highest negative GCA effects were noticed for the commercial parental cultivar Gem-9. Moreover, two out of the seven crosses that involved this cultivar (viz. Gz-168 x Gem-9 and Gem-9 x Bush/ Amigo) as a common parent showed also negative Sij effect. It seems that this parent has the ability to transmit the favorable additive genes to F_1 wheat plants in the seedling stage, only when the second parent has some minor genes that offer a mild resistance level. In the context, Sk-93 and Bush / Amigo although were classified, in the present scale, as MR (Table 2), they revealed positive GCA effects. But, crosses between them showed the highest negative Sij effect, which might be due to the presence of minor modifier genes, with additive gene effects. The accumulation of these additive genes resulted in the highest negative SCA effect. The previous argument could be supported by the number of F_1 progenies with high negative Sij effects, which included Sk-93 as a common parent.

Table 5. Estimates of general combining ability (g_i) effects (in parentheses) and specific combining ability (S_{ij}) effects (above diagonal) for reaction of wheat genotypes to artificial infestation with GB.

Parents	GZ-168	GZ-170	SK-69	Gem-9	Sd-1	IRENA	Bush/ Amigo	SK-93
GZ-168	(0.05)	0.18	-0.15	-0.11	0.19	0.13	0.63*	0.27
GZ-170		(-0.05)	0.30	0.15	0.09	-0.29	0.36*	-0.09
SK-69			(0.18)*	0.09	0.10	-0.33	0.37*	-0.19
Gem-9				(-0.32)*	0.33	0.10	-0.23	0.75*
Sd-1					(-0.16)*	-0.13	0.91*	-0.42*
IRENA						(0.27)*	0.11	0.56*
Bush/Amigo							(0.00)	-0.88*
SK-93								(0.26)*

Standard errors

SE (g_i) = 0.114   SE ($g_i - g_j$) = 0.172

SE (S_{ij}) = 0.348   SE ($S_{ij} - S_{ik}$) = 0.516

SE ($S_{ij} - S_{kl}$) = 0.486

c) Genetic nature of resistance to BCOA and GB

Components of genetic variation

Genetic components for resistance to BCOA and GB according to the scale used for each insect were estimated according to Hayman (1954 a and b) for parents and F_1's (Table 5).

The diallel analysis indicated that estimates of additive genetic component of variation (D) were highly significant for wheat reaction to both aphid species. However, the magnitude was different in the two cases (168.06 for BCOA and 0.26 for GB) due to the difference in the scale of measurements used in each case.

Dominance component of variation (H_1) was also highly significant for BCOA (786.01) and GB (0.53). However, the dominance component was higher in the magnitude than the additive component for both aphid species.

Table 6. Genetic and environmental components of variation, ratios of genetic components and heritability estimates for percentage of susceptible plants to BCOA and intensity of damage with GB under laboratory conditions.

Parameters	BCOA	GB
D	168.06** ± 43.55	0.26** ± 0.083
F	27.02 ± 102.67	0.20 ± 0.20
H_1	786.01** ± 99.94	0.53** ± 0.19
H_2	684.56** ± 86.91	0.50** ± 0.17
H^2	265.06** ± 58.23	0.39** ± 0.11
E	3.16 ± 115.88	0.04 ± 0.03
$(H_1 / D)^{½}$	2.16	1.43
$(H_2 / 4H_1)$	0.22	0.23
(K_D / K_R)	1.00	1.72
K	0.40	0.78
h^2_b	98.9	80.05
h^2_n	41.00	22.36

The ratio $(H_1 /D)^{1/2}$ indicates the presence of overdominance in both cases (the ratio was 2.16 for BCOA and 1.43 for GB). Consequently, selection for resistance in the segregating generations is not a suggested strategy. Crude estimates of frequencies at non-additive loci controlling this trait obtained from (H_2 / $4H_1$), which measure the proportion of the genes with positive and negative effects in the parents, were a little bit less than 0.25 for BCOA (0.22) and for GB (0.23). However, due to the insignificance of difference between H_2 and H_1, it may be assumed that with the ratio of 0.22 and 0.23 for BCOA and GB, respectively, which is close to 0.25, the negative and positive alleles are symmetrically distributed in the parents.

The proportion of dominant and recessive genes (K_D / K_R ratios) was equal one for BCOA, revealing that dominant and recessive alleles controlling this trait are equal. By contrast, the ratio K_D / K_R was more than one for GB, suggesting that dominant alleles exceeded recessive alleles in the parents. The number of genes (or gene groups) exhibiting dominance (K) were found to be one for both BCOA and GB resistance.

Narrow sense heritability (h^2n) estimates (Table 5) were 41.00 % for BCOA and 22.3 % for GB resistance. In contrast to the low h^2_n, the broad sense heritability (h^2_b) was near 100 (98.9%) for resistance to BCOA. It was also very high (80.05%) with respect to intensity of damage with GB. Thus, most of the genetic variance for wheat reaction to both aphid species is mainly a non-additive genetic variance. Consequently, besides the efficiency of selection strategy, heterosis breeding would be of greater efficiency in improving wheat resistance against both aphid species at the seedling stage.

d) Graphical analysis for BCOA and GB resistance

For reaction to BCOA and GB the regression line passes below the origin, cutting Vr axis (Figures 1, 2). Thus, it denotes the presence of over dominance in both cases.

With respect to graphical analysis of reaction to BCOA (Fig. 1), it is clear that the parents Gz-170 (P_2), Gem-9 (P_4), Sd-1 (P_5) and Bush/Amigo (P_7) have more dominant resistance genes, while, Sk-69 (P_3), IRENA (P_6), and Sk-93 (P_8) have more recessive susceptibility genes and Gz-168 (P_1) has equal frequencies of dominant and recessive genes.

With respect to graphical analysis of GB (Fig. 2), the parents Gz-168 (P_1), Gz-170 (P_2), Sk-69 (P_3) and IRENA (P_6) have more dominant susceptible genes, the parents Gem-9 (P_4), Sd-1 (P_5) and Sk-93 (P_8) have more recessive resistance genes and the parent Bush (P_7) has equal frequencies of dominant and recessive genes.

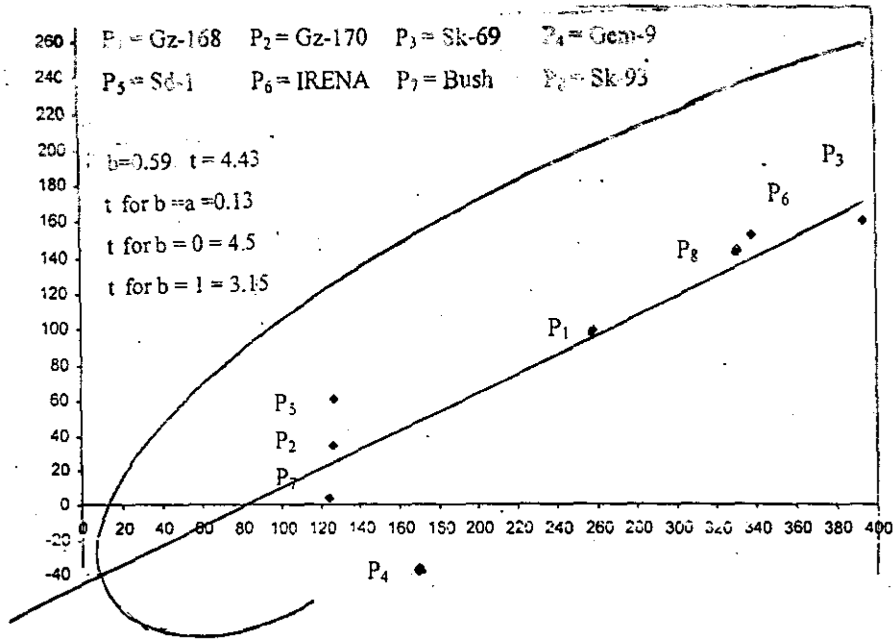

Fig (1) : Wr/Vr graph for percentage of susceptible wheat seedlings to BCOA under artificial infestation in the greenhouse.

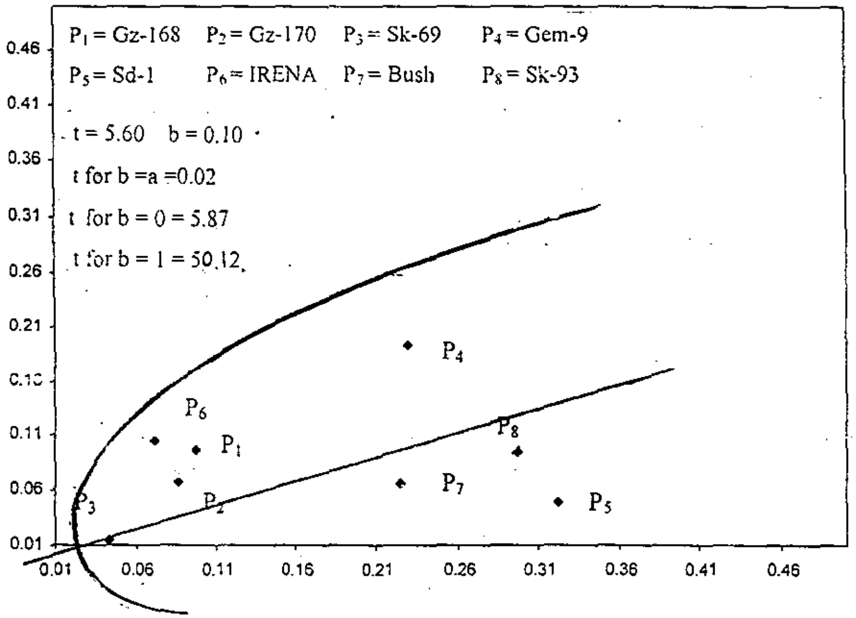

Fig (2) :- Wr/Vr graph for intensity of damage to GB under artificial infestation in the greenhouse.

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وراثة المقاومة لحشرتي المن الأخضر و من الشوفان في هجن القمح.

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تم إجراء الهجن الدائرية (ما عدا العكسية) خلال موسم ٢٠٠١/٢٠٠٢ بين ثمانية آباء من قمح الخبز تختلف فى مقاومتها للمن. و تم تقييم الآباء وال ٢٨ هجين F_1 في موسم ٢٠٠٢/٢٠٠٣ من حيث مقاومة حشرتى "من الشوفان" و"المن الأخضر" تحت ظروف العدوى الطبيعية فى الحقل والعدوى الصناعية فى الصوبة. و كانت أهداف الدراسة معرفة طبيعة الفعل الجينى و القدرة على الإئتلاف و عدد الجينات التى تتحكم في صفة المقاومة لكلا النوعين من المن. أشارت النتائج إلي أن القدرة العامة على الإئتلاف كانت أكثر أهمية من القدرة الخاصة على الإئتلاف و ذلك بالنسبة للمقاومة لكلا من نوعى المن مما يدل على أن التباين الوراثى المضيف أكثر أهمية من التباين غير المضيف فى مقاومة هاتين الحشرتين. وكانت أعلى قيمة سالبة (مرغوبة) للقدرة العامة على الائتلاف بالنسبة للمقاومة لحشرة "من الشوفان" قد سجلت بواسطة الصنف بوش وجيزة ١٧٠ و بالنسبة للمقاومة لحشرة "المن الأخضر" بواسطة الصنف المحلى جميزة ٩وسدس ١. كما أعطت هجن هذه الآباء قيم سالبة عالية للقدرة الخاصة على الائتلاف. وكانت السيادة الفائقة هى التى تتحكم فى المقاومة لكلا النوعين من المن. أظهرت التحليلات الوراثية أن صفة المقاومة أو الإصابة محكومة بجين واحد (أو مجموعة جينية واحدة) لكلا النوعين من المن. كانت قيم كفاءة التوريث في المفهوم الضيق ٤١,٠% للمقاومة لمن الشوفان و ٢٢,٤% للمقاومة للمن الأخضر.

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