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Resistance to the Pink Stem Borer in Twenty Exotic Maize Populations Under Natural and Artificial Infestation Conditions

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Abstract

Twenty exotic maize populations with different genetic background representing different geographical zones were obtained from Maize Gene Bank of Maize Res. Dept., Field Crops Res. Inst. (FCRI), Agric. Res. Center (ARC), Egypt. They were evaluated in 2011 to determine their level of resistance to the pink stem borer *Sesamia cretica* under natural infestation at Nubaria, Gemmeiza and Sakha Agric. Res. Stn. and under artificial infestation at Giza Agric. Res. Stn. A Randomized Complete Block Design was used. Evaluation trials under natural infestation were planted in the early summer (April) while under artificial infestation planting took place in the normal growing season (May). Three resistance expressing traits, i.e. percentage of infested plants (IP), percentage of plants with dead hearts (DH) and intensity of damage (ID) were used to evaluate the level of resistance in the twenty populations. Five-classes rating scale was developed to evaluate the intensity of damage caused by larvae of *S. cretica*. Results showed that, populations Tamps. 23 and Antigua have relatively good level of resistance to infestation by larvae of *S. cretica*. The two populations could be integrated into maize breeding programs which aim at developing hybrids resistant to *S. cretica*. Highly significant correlation coefficients were found among pairs of the three resistance expressing traits under artificial infestation. Correlation between results under natural and artificial infestation for the three studied traits showed low to moderate correlation which indicated that, for precise results on the level of resistance to *S. cretica*, evaluation should be made under artificial infestation conditions. In addition, exotic germplasm should be considered as a source for resistance genes in breeding programs for insect-pest resistance.

Keywords: pink stem borer, Sesamia cretica, natural and artificial infestation, correlation coefficients, exotic germplasm

1. Introduction

Maize is considered as one of the most important cereal crops in Egypt. It can play a major role in narrowing the present food gap via expansion in cultivation of maize hybrids with high yield potentiality and resistant to major diseases and insect pests affecting maize production.

In Egypt, maize plants are usually attacked by several injurious insect pests. The pink stem borer, *Sesamia cretica* Led. and the European corn borer, *Ostrinia nubilalis* (Hub.) are considered the major insects affecting maize productivity since they can cause great yield losses. James (2003) stated that 9% of the world maize crop is lost annually due to damage caused by insect pests. Oloyede et al. (2011) found that grain yield losses due to *S. calamistis* infestation ranged from 25-30%.

The pink stem borer *S. cretica* is considered the most damaging corn borer in Egypt since it attacks young maize plants shortly after emergence, devours the whorl leaves and may kill the growing point causing complete death of small maize plants and consequently reducing number of plants at harvest causing drastic yield losses (Semeada, 1985; EL-Naggar, 1991; Soliman, 1994). This insect is also capable of damaging older plants through excavating tunnels into the stems, ears and/ or cobs. Yield reduction due to *S. cretica* depends on many factors including the stage at which the plant is infested, the insect population available for infestation in addition to the environmental conditions during the growing season.

Several investigations were carried out to evaluate maize cultivars for their resistance to the pink stem borer, most of them were conducted in Egypt either under natural infestation (Simeada, 1985; EL-Sherif et al., 1986; Tantawy et al., 1989; Al-Naggar et al., 2000b; Soliman et al., 2001, Malver et al., 2007; Hemida et al., 2008) or under artificial infestation (EL-Sherif & Mostafa, 1987; Al-Naggar et al., 2000b; Soliman et al., 2001; Sekhara et al., 2008; Oloyede, 2011; El-Rawy & Abdalla, 2011; Santosh et al., 2012; Ismail, 2012) or under both natural and artificial infestation (Soliman, 1997; Soliman et al., 2001; Galal et al., 2002; Mosa & Amer, 2004; Mourad & El-Rawy, 2012). However, most researchers working on host plant resistance to corn borers other than *S. cretica* are convinced that artificial infestation is superior and more efficient than natural infestation for accurate differentiation among maize genotypes for their resistance to corn borers (Guthrie, 1982; Mihm, 1983a). However, in case where there is a need to screen a large number of maize genotypes and the environmental conditions allow for uniform and heavy infestation with larvae of *S.cretica*, evaluation under natural infestation would allow for obtaining primary evaluation of these genotypes especially if evaluation can be achieved over a wide range of environments. Later, artificial infestation can be performed but will be, in this case, with a smaller number of genotypes for results confirmation.

The objectives of the present investigation were to: 1- determine the level of resistance to *S. cretica* in 20 exotic maize populations under natural and artificial infestation conditions, 2-assess the consistency of resistance results obtained from both methods of evaluation and 3- to decide if any of these populations can be integrated into the national breeding program that aims at developing maize hybrids resistant to the pink stem borer.

2. Materials and Methods

Twenty exotic maize populations were chosen for the purpose of this investigation. They were obtained from the Gene Bank of Maize Research Department, Field Crops Research Institute (FCRI) Agriculture Research Center (ARC), Egypt. These populations have different genetic backgrounds representing different geographical zones (Table 4).

Planting of these populations under natural infestation of *S. cretica* was carried out at Nubaria (29°30' longitude, and 30°54' latitude), Gemmeiza (31°00' longitude and 30°83' latitude) and Sakha (30°98' longitude and 31°11' latitude), Agric. Res. Stn. of ARC on April 6th, 19th and 21st, 2011, respectively. Day temperatures during summer growing season are from 27-33°C at Nubaria and Sakha and from 29-35°C at Gemmeiza location. High humidity is normally prevailing during July-August. These planting dates were chosen so that the plants reach the growth stage most preferred by this insect and the moth emergence from hibernating larvae reached its maximum to assure maximum natural infestation (Ahmed & Kira, 1960). These populations were also evaluated under artificial infestation of at Giza Agric. Res. Stn. of ARC. Sowing date for artificial infestation was on May 30th, 2011. This planting date was chosen to coincide with the time of minimum natural infestation and so, minimizing intervening of natural and artificial infestation which can affect obtained results. Artificial infestation was performed by newly hatched larvae artificially reared in the Corn Borers Lab of Maize Res. Dept., FCRI, ARC using the Bazoka equipment as a mechanical dispenser according to Mihm (1983 a). Infestation was applied two times to ten plants in each row at 20-25 days after planting at the early whorl stage. Splitting of infestation was to assure occurrence of infestation. Each plant received 8-10 larvae in each application.

Randomized Complete Block Design with four replicates was used in all testing locations. Plot size under natural infestation was 4 rows of 6 m length, 60 cm width, with hills spaced at 25 cm, while for artificial infestation, the experimental plot was one row 4 m length, 70 cm width and 25 cm hill spacing. Technical recommendations for maize growing were applied except pest control which was entirely avoided. Required field data were recorded at all testing locations 35 days after planting in case of evaluation under natural infestation and after 15 days from infestation of plants when evaluation was carried out under artificial infestation.

Data were recorded under natural artificial infestation on the following traits using five-classes rating scale which can accurately differentiate among tested genotypes.

2.1 Percentage of Infested Plants

$$\frac{No.of\ infested\ plants\ plot^{-1} \times 100}{Total\ no.of\ plants\ plot^{-1}}$$

Genotypes were classified according to their mean percentage of infested plants into: Resistant, R (less than 30%). Moderately Resistant, MR (from 30% to less than 40%), Intermediate, I (from 40% to less than 50%), Susceptible, S (from 50% to less than 60%), and Highly Susceptible, HS (more than 60%).

2.2 Percentage of Plants with Dead Hearts

$$\frac{No. of\ \ plants\ with\ dead\ hearts\ \ plot^{-1} \times 100}{Total\ no. of\ \ plants\ plot^{-1}}$$

Genotypes were classified according to their mean percentage of plants with dead hearts into: Resistant, R (less than 8%). Moderately Resistant, MR (from 8% to less than 12%), Intermediate, I (from 12% to less than 16%), Susceptible, S (from 16% to less than 20%), and Highly Susceptible, HS (more than 20%).

2.3 Intensity of Damage

Five-classes rating scale was developed to evaluate the intensity of damage caused by attack of *S. cretica* larvae. The description of this scale is as follows:

Class 1: No visible injury on plants (no symptoms).

Class 2: Less than 25% of plants plot^{-1} is with holes less than 1 mm in diameter across partially or fully unfolded whorl leaves.

Class 3: Several folded and unfolded whorl leaves with relatively larger round and/or elongated holes accompanied with small yellowish green pillets of frass aggregated in the whorl.

Class 4: Plants with relatively larger round and/or elongated irregular holes, evident distortion of the leaves (most leaves have long holes), withering of whorl and accumulation of comparatively large sized pellets of frass in the whorl or on the ground around the stem.

Class 5: Plants with dead hearts.

The intensity of damage (ID) value for each plot was calculated as follows**:**

$$\mathrm{ID} = \frac{\mathrm{ID1} + \mathrm{ID2} + \ldots\ldots\ldots\ldots.. + \mathrm{IDn}}{\mathrm{N}}$$

Where, N is the number of inspected plants.

Genotypes were classified according to their ID into: Resistant, R (less than 1.5), Moderately Resistant, MR (from 1.5 to less than 1.9), Intermediate, I (from 1.9 to less than 2.3), Susceptible, S (from 2.3 to less than 2.7), and Highly Susceptible, HS (more than 2.7).

Data that were collected in percentage were subjected to arcsine transformation for the purpose of statistical analysis. However, such data were presented hereafter in original percentages. Due to heterogeneity of error variances at the three testing locations, combined analysis was performed. Correlation coefficients among the three resistance expressing traits were also computed. All statistical analyses were performed according to Steel and Torrie (1980).

3. Results and Discussion

3.1 Analysis of Variance

Combined analyses of variance of the twenty maize populations for the three characters expressing maize plant resistance to *Sesamia cretica* (percentage of infested plants, percentage of plants with dead hearts, and intensity of plant damage) under natural infestation are presented in Table 1, while analysis of variance for the same characters under artificial infestation is presented in Table 2. Locations mean squares were highly significant for all studied traits (Table 1) indicating differences in the climatic conditions among the three testing locations at time of infestation which resulted in performance differences among the tested populations. Either significant or highly significant differences were detected among the 20 populations for the three resistance expressing traits under natural and artificial infestation (Tables 1 and 2). This indicated the presence of real differences in the genetic constitution of these populations concerning their level of resistance to infestation by the pink stem borer. Location×entry mean squares (Table 1) were highly significant for percentage of infested plants and plants with dead hearts which showed that the 20 populations behaved differently from one location to another and also indicated the importance of multilocation testing.

Table 1. ANOVA analysis to evaluate significant differences among the twenty maize populations evaluated under natural infestation across three locations in 2011

S.O.V.	d.f.	Infested Plants	Dead Hearts	Intensity of Damage
Locations (Loc.)	2	6491.9**	6685.2**	46.63**
Rep's (Loc)	9	52.5**	19.4*	0.42**
Populations (Pop)	19	110.8**	29.3**	0.28*
Loc × Pop	38	39.9**	32.1**	0.21
Error	171	16.8	9.9	0.14

Table 2. ANOVA analysis to evaluate significant differences among the twenty maize populations evaluated under artificial infestation in 2011

S.O.V.	d.f.	Infested Plants	Dead Hearts	Intensity of Damage
Replications	2	232.53**	1.94	0.116*
Populations	19	470.36**	83.48**	2.240**
Error	38	15.81	1.63	0.027

3.2 Mean Performance of Populations

Mean performances and insect reaction scores of the twenty populations under natural (combined) and artificial infestation are presented in Tables 3 and 4, respectively. Results for level of resistance under natural infestation, at separate locations, are presented in Table 5. Results varied considerably from one location to another where Sakha location had severe infestation while Nubaria location had the lowest and could not discriminate precisely among tested populations.

Table 3. Mean performance for percentage of infested plants, percentage of plants with dead hearts and intensity of damage under natural and artificial infestations of S. cretica, in 2011

Entry No.	Population	Infested plants (%)		Plant with dead hearts (%)		Intensity of damage	
		Natural	Artificial	Natural	Artificial	Natural	Artificial
1	V.55	30.8	43.9	19.8	26.4	2.03	2.62
2	Yellow Kenya	31.9	42.2	17.9	23.4	2.18	2.48
3	Iowatigua- Tep 953	29.4	50.2	17.6	27.7	2.05	3.27
4	Carotigua-Tep 955	33.2	49.1	20.7	26.0	2.17	2.93
5	Tamps-8	29.5	45.0	15.9	21.7	2.05	2.39
6	Tamps-23	28.6	37.2	15.0	15.0	1.89	2.10
7	Thick Rind	35.7	48.3	18.1	24.2	2.31	3.05
8	Antigua	28.7	38.9	17.3	15.0	2.05	2.24
9	Westigua	34.8	61.5	17.4	24.0	2.20	3.74
10	Pool-29	35.3	64.5	18.6	27.9	2.37	4.07
11	Pool-30	40.9	78.0	20.6	31.1	2.44	4.82
12	Pool-33	33.9	54.2	18.3	26.0	2.37	3.49
13	Pool-34	33.7	57.6	18.7	27.1	2.30	3.74
14	Mexico-207	31.9	55.9	16.9	24.8	2.04	3.57
15	Sonora GP.03	33.2	61.9	19.4	26.1	2.27	3.44
16	Guat-104	30.2	70.0	16.5	29.0	2.07	4.38
17	Managua-7432	33.9	64.2	18.4	27.3	2.18	3.81
18	Tep.5	33.4	78.0	20.3	38.4	2.20	4.77
19	Tuxpeno	31.3	70.3	16.2	32.8	2.11	4.65
20	Lancaster	28.4	69.3	16.6	30.0	1.91	4.50
Mean		32.4	57.0	18.0	26.2	2.2	3.5
C.V.		12.6	7.0	17.4	4.9	17.6	4.7
LSD(0.05)		3.29	6.57	2.53	2.11	0.31	0.27

Table 4. *Pink stem borer* resistances scores of the tested populations under natural (Nat.) and artificial (Art.) infestation across locations, in 2011

Entry No.	Pedigree	Origin	I.P.*		D.H.		I.D.	
			Nat	Art	Nat	Art	Nat	Art
1	V.55	CIMMY**	MR	I	S	HS	I	HS
2	Yellow Kenya	Kenya	MR	I	S	HS	I	HS
3	Iowatigua- Tep 953	CIMMYT	R	S	S	HS	I	HS
4	Carotigua-Tep 955	CIMMYT	MR	I	HS	HS	I	HS
5	Tamps-8	CIMMYT	R	I	I	HS	I	HS
6	Tamps-23	CIMMYT	R	MR	I	I	MR	I
7	Thick Rind	USA	MR	I	S	HS	I	HS
8	Antigua	CIMMYT	R	MR	S	I	I	I
9	Westigua	CIMMYT	MR	S	S	HS	S	HS
10	Pool-29	CIMMYT	MR	S	S	HS	S	HS
11	Pool-30	CIMMYT	I	HS	HS	HS	S	HS
12	Pool-33	CIMMYT	MR	S	S	HS	S	HS
13	Pool-34	CIMMYT	MR	S	S	HS	I	HS
14	Mexico-207	CIMMYT	MR	S	S	HS	I	HS
15	Sonora GP.03	CIMMYT	MR	HS	S	HS	I	HS
16	Guat-104	CIMMYT	MR	HS	S	HS	I	HS
17	Managua-7432	CIMMYT	MR	HS	S	HS	I	HS
18	Tep.5	CIMMYT	MR	HS	HS	HS	I	HS
19	Tuxpeno	CIMMYT	MR	HS	S	HS	I	HS
20	Lancaster	USA	R	HS	S	HS	I	HS

*. I.P., D.H., and I.D: Infested plants (%), Dead hearts (%) and intensity of damage, respectively.

**. CIMMYT: International Center for Maize and Wheat Improvement, located in El-Batan, Mixico. Genetic stocks introduced from CIMMYT represent mainly Latin American germplasm.

Table 5. Mean performance for resistance expressing traits at Nubaria, Gemmeza and Sakha research stations under natural infestation of *S. cretica* in 2011

Ent no.	population	Nubaria						Gemmeiza						Sakha					
		I.P.%		D.H.%		I.D.		I.P.%		D.H.%		I.D.		I.P.%		D.H.%		I.D.	
		score	scale	score	scale	score	scale	score	scale	score	scale	score	scale	score	scale	score	scale	score	Scale
1	V.55	27.1	R	14.4	I	1.6	MR	26.9	R	17.0	S	1.8	MR	38.4	MR	28.1	HS	2.8	HS
2	Yellow Kenya	27.6	R	12.3	I	1.5	MR	26.0	R	14.4	I	1.8	MR	42.2	MR	26.8	HS	3.2	HS
3	Iowatigua Tep 953	20.0	R	8.5	MR	1.5	MR	28.7	R	15.7	I	1.9	I	39.7	I	28.5	HS	2.8	HS
4	Carotigua Tep 955	27.3	R	17.6	I	1.8	MR	29.2	R	16.6	S	1.8	MR	43.1	MR	27.8	HS	2.9	HS
5	Tamps-8	25.3	R	9.8	MR	1.5	MR	26.4	R	14.9	I	1.7	MR	36.9	MR	23.7	HS	2.8	HS
6	Tamps-23	26.9	R	9.1	MR	1.4	MR	25.3	R	16.0	I	1.7	MR	33.6	MR	20.8	HS	2.4	HS
7	Thick Rind	28.6	R	9.7	MR	1.6	MR	34.1	MR	20.2	S	2.3	S	44.4	S	24.5	HS	3.0	HS
8	Antigua	19.5	R	9.8	MR	1.4	MR	30.9	MR	20.3	S	2.1	I	35.7	I	22.7	HS	2.6	S
9	Westigua	25.4	R	6.6	R	1.4	MR	34.6	MR	16.9	S	2.1	I	44.5	I	28.6	HS	3.0	HS
10	Pool-29	25.2	R	10.0	MR	1.5	MR	32.9	MR	16.0	I	2.4	S	47.8	S	29.5	HS	3.2	HS
11	Pool 30	28.0	R	9.2	MR	1.6	MR	37.9	MR	16.7	S	2.2	I	56.8	I	36.1	HS	3.5	HS
12	Pool 33	26.0	R	7.2	R	1.5	MR	30.8	MR	19.1	S	2.0	I	45.0	I	28.7	HS	3.7	HS
13	Pool 34	24.4	R	9.8	MR	1.5	MR	32.5	MR	18.9	S	2.3	S	44.0	S	27.5	HS	3.0	HS
14	Mexico-207	23.5	R	7.5	R	1.5	MR	30.1	MR	15.1	I	1.8	MR	42.0	MR	28.2	HS	2.9	HS
15	Sonora GP 03	28.4	R	10.6	MR	1.7	MR	28.0	R	18.5	S	1.8	MR	43.2	MR	29.0	HS	3.3	HS
16	Guate-104	20.1	R	7.1	R	1.4	MR	28.3	R	12.0	I	1.6	MR	41.5	MR	30.4	HS	3.1	HS
17	Managua-7432	23.1	R	7.0	R	1.4	MR	31.8	MR	16.7	S	1.8	MR	46.8	MR	31.4	HS	3.4	HS
18	Tep-5	24.8	R	11.2	MR	1.6	MR	33.1	MR	19.6	S	2.0	I	42.3	I	30.2	HS	3.0	HS
19	Tuxpeno	25.1	R	8.3	MR	1.6	MR	23.1	R	14.5	I	1.6	MR	45.6	MR	25.7	HS	3.1	HS
20	Lancaster	23.4	R	6.6	R	1.5	MR	26.0	R	17.5	S	1.8	MR	35.3	MR	25.6	HS	2.4	S
	Mean	25.0		9.5		1.6		30.0		16.8		1.9		42.8		27.7		1.9	
	Scale	R		MR		MR		MR		S		I		I		HS		I	
	C.V.	14.2		22.4		14.9		11.3		17.2		15.7		12.0		15.0		18.0	

3.2.1 Infested Plants (%)

Results in Tables 3 and 4 showed that, under natural infestation, only five populations, i.e. Iowatigua, Tamps.8, Tamps.23, Antigua and Lancaster were significantly resistant, while all the other populations were moderately resistant except Pool 30 which was intermediate. However, under artificial infestation only two populations, i.e.Tamps.23 and Antigua were moderately resistant and five entries, i.e. V. 55, Yellow Kenya, Carotigua, Tamps.8, and Thick Rind were intermediate. No strong consistency was found for results of resistance under natural and artificial for this trait, indicating that selection of resistant genotypes should mainly depends on artificial infestation.

3.2.2 Plants with Dead Hearts (%)

Results for resistance under natural infestation showed that populations Tamps.8 and Tamps.23 were intermediate while the other 18 populations were either susceptible or highly susceptible. Under artificial infestation, populations Tamps. 23 and Antigua were intermediate while the other populations were highly susceptible (Tables 3 and 4). Results of this trait under artificial infestation were, to some extent, similar to those under natural infestation.

3.2.3 Intensity of Damage

Results on intensity of damage (Tables 3 and 4) revealed that, under natural infestation only one population (Tamps. 23) was moderately resistant, 14 populations were of intermediate resistance , and five populations were susceptible. Results under artificial infestation showed that only two populations (Tamps. 23 and Antigua) were of intermediate resistance while the remaining populations were highly susceptible. Results showed also that, scores for the three resistance traits were much higher under artificial infestation as compared to those under natural infestation. This indicated that natural infestation in 2011, in general, was not severe enough to accurately assess the intensity of damage caused by larvae of S. cretica except at Sakha location, while artificial infestation had enforced good infestation pressure on the tested populations and was successful in discovering differences among them concerning resistance to infestation by larvae of *S. cretica*.

The top performing populations that behaved as resistant, moderately resistant or intermediate under both natural and artificial infestation were considered. Based on this criterion, populations Tamps. 23 and Antigua were considered of usefulness and could be integrated in the national maize breeding program for developing maize hybrids with resistance to infestation by larvae of *S. cretica* as well as high yield potentiality. Results revealed also that, out of the twenty exotic populations only two populations (10%) had relatively good level of resistance to *S.cretica*.The role of exotic germplasm as a source for resistance to *Sesamia spp*.was investigated by many researchers. Burton et al. (1999) screened 121 exotic maize inbred lines representing seven germplasm groups and they found that only 7 inbred lines (6%) were considered resistant to *S. nonagrioidis*. Santosh et al. (2012) evaluated 48 exotic inbred lines for resistance to *S. inferences* and found that only 8 inbred lines (16%) were resistant. Mourad and El-Rawy (2012) evaluated 13 exotic sorghum lines for resistance to *S. cretica* and only one line (8%) was found resistant. Results of this investigation indicated that natural infestation with *S. cretica* was not able to discriminate precisely between resistant and susceptible populations for the three resistance expressing traits. This conclusion was reached also by Soliman (1997) and Soliman et al. (2001). They indicated that maize breeders should depend only on artificial infestation in order to get precise results about the level of resistance to *S. cretica* in the genotypes under study. However, contradictory results were obtained by Tantawi et al. (1989) where they found that artificial infestation was successful in differentiating between resistant and susceptible hybrids. Also, Galal et al. (2002) indicated that natural infestation was suitable for studying the genetic behavior of resistance to the pink stem borer. Investigations of the last two researchers may be conducted in some years where environmental conditions allowed for high and uniform infestation levels.

Table 6. Correlation coefficients among pairs of the three resistance expressing traits under artificial and natural infestation, in 2011

Traits	I.P.		D.H.		I.D.	
	Nat	Art	Nat	Art	Nat	Art
Infested plants (%), IP	--	--	0.938**	0.768**	0.730**	0.919**
Dead heart plants (%), DH	--	--	--	--	0.572**	0.827**
Intensity of damage, ID	--	--	--	--	--	--

Table 7. Correlation coefficients between results under natural and artificial infestation for the three resistance expressing traits, in 2011

TRAIT	I.P. (natural)	D.H. (natural)	I.D. (natural)
I.P.+ (artificial)	0.475**	….	….
D.H.+ (artificial)	….	0.331**	….
I.D.+ (artificial)	….	….	0.262*

+ I.P., D.H., and I.D.: refer to infested plants (%), plants with dead hearts (%) and Intensity of damage, respectively.

3.3 Correlation among Resistance Traits

Simple correlation coefficients among pairs of the three resistance expressing traits, i.e. percentage of infested plants (IP), percentage of plants with dead hearts (DH) and intensity of damage (ID) are presented in Table 6. Results showed that, under natural infestation, correlation coefficients between IP and DH, IP and ID, DH and ID were 0.94, 0.73 and 0.57, respectively, while under artificial infestation, the correlation coefficients were (0.77, 0.92 and 0.83), respectively. Results confirmed the presence of highly significant positive correlation among the three traits and that; these positive correlations were higher, except for percentage of infested plants, under artificial infestation as compared to those under natural infestation conditions. These results indicated also that, only one or two of the three resistance expressing traits can be used in S. cretica resistance investigations. Using percentage of plants with dead hearts and intensity of plant damage should be enough in evaluation experiments for resistance to *S. cretica.* This is due to their effect on plant growth and number of plants at harvest and consequently obtained yield. Similar results were obtained by Odiyi (2007) who studied the effect of infestation by *S. calamistis* on grain yield and found moderate to high correlations among most pairs of resistance expressing traits.

Correlation coefficients between results under natural and artificial infestation for each of the three resistance expressing traits are presented in Table 7. Significant or highly significant positive correlation coefficients were obtained, but the correlation was not strong enough since the correlation values were low to moderate. This emphasizes the need for artificial infestation in order to get precise results for the level of resistance in any tested genotypes. Similar results were reported by Soliman (1997) who found low correlation between results under natural and artificial infestation by *S. cretica.*

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