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BIOCHEMICAL AND GENETIC BASES OF RESISTANCE TO STEM BORER IN RICE GENOTYPES

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ABSTRACT

This study was conducted at Rice Research & Training Center, Sakha, Kafr El-Sheikh, Egypt during 2007, 2008 and 2009 growing seasons. Seventeen genotypes were used including three CMS lines, three restorers, nine hybrids and two Egyptian checks (Egyptian yasmine as a highly susceptible and Sakha 101 as a resistant genotype) and grown in a randomized complete block design with three replications. The main objective of this study is to identify the genetical and biochemical bases of rice resistance against rice stem borer. The results revealed that the high values of infestation were detected in rice genotypes having low phosphorus, dry matter and silica contents. In contrast, the genotypes that showed low infestation had the highest contents of phosphorus, dry matter and silica. On the other hand, potassium, pH values and plant moisture contents were positively correlated with the infested stems. The estimate of variance due GCA was higher than that due to SCA for all traits suggesting greater importance of additive genetic variance. However, breeders and entomologists should select rice entries with high silica, phosphorus and dry matter contents to reduce feeding capacity of stem borer larva.

INTRODUCTION

Rice is a major crop in the world and provides food for over half of the world's population (Ma *et al*., 2007). The rice stem borer, *Chilo agamemnon* Bles. is a serious pest of rice causing considerable damage to the plant from seedling to maturity, thus accounts for a large share of crop losses (Assas, 2005). The use of insecticides is not an easy way for its control because of high expenses and it requires repeated applications. Hence, other avenues of control measures should be explored where genotypic resistance is one important approach. Resistance may be due to physical, chemical or both combined factors which are genetically controlled. Silica might play an active role in enhancing host resistance to plant pests by stimulating defense reaction mechanisms (Ma and Yamaji 2006). To ascertain some of the biochemical factors responsible for resistance or susceptibility to rice stem borer, some rice entries were studied to understand the nature of resistance to stem borer in rice.

MATERIALS AND METHODS

The present study was carried out at the experimental farm, Rice Research & Training Center, Sakha, Kafr El-Sheikh during 2007, 2008 and 2009 growing seasons. Three cytoplasmic male sterile lines viz., IR 69625A, IR 70368A and IR 58025A, as well as, three restorers, Giza 178 R, Giza 181

R and Giza 182 R, moreover, two rice checks, one resistance (Sakha 101) and one susceptible (Egyptian yasmine) were used. In 2008, line x tester model was used to produce seeds from nine crosses. In 2009, the nine F_1 hybrids beside their parents and the two checks were grown in a Randomized Complete Blocks Design with three replications. Each plot consisted of five rows. Each row was 5m long to insure 25 individual plants within plot at spacing of 20cm between hills. Cultural practices were performed as recommended (RRTC 2006). To ascertain some of the chemical factors responsible for resistance in rice genotypes to rice stem borer, a few known resistant an susceptible rice genotypes were grown in the field in the summer season of 2009 with three replications. One hill was selected from each plot after 60 days from transplanting for chemicals analyses. Chemical analysis to rice plants were conducted at laboratory of Rice Research and Training Center, Sakha. Plant samples were wet digested according to Richard, 1954. The total phosphorus content (%) was assessed colorimetrically (Snell and Snell, 1967). The total potassium (%) was assessed by the flame photometer (Jackson, 1958). Total water content (%) was estimated as difference between fresh weight and dry weight of plants. Dry weight was taken by drying the plants to a constant weight in a force-air oven maintained at 90^0C. The pH of the plant samples was recorded with the help of pH meter. Total contents of silica in rice stems were estimated according to Jeffery and Wilson (1960).

Ten guarded plants from the middle row of each plot were randomly chosen to measure the dead hearts (40 days after transplanting) and white heads (three weeks before harvest). Statistical analysis were carried out using SAS statistic package and SPSS software according to Griffing. (1956).

RESULTS AND DISCUSSION

The average of genotypes as parents and hybrids for the eight studied traits are presented in Table 1. Rice genotypes differed from each other in their performance regarding to all studied traits. For infestation%, the IR 69625A and Giza 181 R were highly resistance parents, they gave the lowest infestation values 3.29% and 2.20% for dead heart, and 2.56% and 1.35% for white head, respectively. Sakha 101 showed the lowest values (0.59%) for dead heart and 2.03% for white head. Also, the hybrid plants derived from the lines: IR 69625A and Giza 181 R or Giza 182 R were highly resistant to rice stem borer, because these genotypes gave the lowest values of dead hearts and white heads% comparing to the susceptible rice variety Egyptian yasmine (15.05% and 12.10%) for dead heart and white head, respectively.

The lines: IR 70368A, IR 58025A, Giza 178 R and their hybrids were highly susceptible to rice stem borer, whereas, the highest values of dead hearts and white heads were obtained as seen in Table 1.

Rice genotypes significantly varied in their phosphorus, dry matter and silica contents, whereas, the IR 69625 A, Giza 181 R and Giza 182 R had the highest values of phosphorus, dry matter and silica% (0.24, 23.05 and 8.80% for IR 69625A); (0.25, 25.70 and 9.28% for Giza 181 R) and (0.23, 22.80 and 8.64% for Giza 182 R), respectively.

Table 1: Mean performance for some chemical traits of parental lines, F_1 hybrids and the two checks varieties.

Genotypes	D. H. (%)	W. H. (%)	K (%)	P (%)	pH values	Moisture (%)	Dry matter (%)	Si (%)	Genotype reaction for stem borer
Lines									
IR 69625A	3.29	2.56	2.25	0.24	6.20	76.95	23.05	8.80	R
IR 70368A	11.39	9.45	2.55	0.21	6.25	78.80	21.20	7.89	MS
IR 58025A	18	13.28	3	0.20	6.33	80.35	19.65	7.36	S
Mean	10.89	8.43	2.6	0.21	6.27	78.70	21.30	8	
Testers									
Giza 178 R	16	11.08	2.90	0.20	6.28	80.15	19.85	7.58	S
Giza 181 R	2.20	1.35	2.20	0.25	6.18	74.30	25.70	9.28	R
Giza 182 R	6.84	6.48	2.46	0.23	6.21	77.20	22.80	8.64	MR
Mean	8.15	6.13	2.52	0.23	6.22	77.22	22.78	8.50	
Over all mean	9.52	7.28	2.56	0.22	6.25	75.46	22.04	8.25	
Hybrids									
IR 69625A X Giza 178 R	8.95	6.35	2.60	0.22	6.24	79.20	20.80	8	MR
IR 69625A X Giza 181 R	4.35	2.18	2.45	0.25	6.20	75.44	24.56	9.01	R
IR 69625A X Giza 182 R	4.50	4.29	2.50	0.23	6.22	78.05	21.95	8.75	R
IR 70368A X Giza 178 R	10.55	9.63	3.01	0.19	6.29	80	20	7.62	MS
IR 70368A X Giza 181 R	6.56	5.08	2.70	0.22	6.23	77.50	22.50	9.07	MR
IR 70368A X Giza 182 R	8.30	7.55	2.80	0.20	6.25	79.10	20.90	7.90	MS
IR 58025A X Giza 178 R	21.78	17.65	3.30	0.18	6.40	80.60	19.40	7.18	HS
IR 58025A X Giza 181 R	9.48	8	2.86	0.20	6.27	78.80	21.20	8.34	MR
IR 58025A X Giza 182 R	11.66	9.92	3	0.19	6.29	79.85	20.15	7.80	MS
$\bar{X}$	9.57	7.85	2.80	0.21	6.27	78.73	21.27	8.19	
Checks									
Sakha 101	0.59	2.03	2.02	0.26	6.10	73.14	26.86	10.02	R
Egyptian yasmine	15.05	12.10	3.31	0.19	6.35	80.30	19.70	7.14	S
Mean	7.82	7.07	2.57	0.22	6.25	78.22	21.78	8.26	
L. S. D at 5%	0.40	4.25	0.02	0.02	0.02	0.05	0.05	1.16	
at 1%	0.54	5.72	0.02	0.02	0.02	0.07	0.07	1.56	

R = Resistant
S = Susceptible
MR = Moderately Resistant
MS = Moderately Susceptible
HS = Highly Susceptibility
D.H. = Dead heart
W.H.= White head
K = Potassium
P = Phosphorus
Si = Silica

On the other hand, the highly susceptible rice genotypes, such as, IR 70368A, IR 58025A and Giza 178 R with their hybrids had the lowest values of phosphorus, dry matter and silica contents as seen in Table 1, indicating that the high level of phosphorus and silica could play an important role in controlling the rice stem borer. The results agree with those obtained by Chandramani *et al*. (2006) who mentioned that, silica might play an active role in enhancing host resistance to plant pests by stimulating defense reaction mechanisms. Moreover, in Egypt Awadallah and Maximos (1978) reported that the borer infestation was reduced at enhanced doses of phosphorus.

With respect to, potassium, pH values and plant moisture contents, the highly susceptible rice genotypes had the highest values of these traits, (2.55, 6.25 and 78.80% of IR 70368A); (3.00, 6.33 and 80.35% of IR 58025A) and (2.90, 6.28 and 80.15% of Giza 178 R), respectively. The same trend were obtained from the hybrids, IR 70368A x Giza 178 R, IR 58025A x Giza 178 R and IR 58025A x Giza 182 R indicating that these hybrids were highly susceptible to rice stem borer. In contrast, the highly resistant rice genotypes were IR 69625A, Giza 181 R and Giza 182 R with their hybrids recoded the lowest values of these traits. These results suggest that these traits play an important role to increase the damage by rice stem borer.

The general mean values of parental lines were, 9.52, 7.28, 2.56, 0.22, 6.25, 75.46, 22.04 and 8.25% for dead heart, white head, potassium, phosphorus, pH values, moisture content, dry matter and silica content, respectively, while the hybrid general mean values were, 9.57, 7.85, 2.80, 0.21, 6.27, 78.73, 21.27 and 8.19 for the same traits, respectively. These results indicate into positive heterosis for dead heart, white head, potassium, pH values and plant moisture content. In contrast, negative heterosis for phosphorus, dry matter and silica content were obtained. Thus, the data towards the high levels of phosphorus, dry matter and silica content would explain the increase in resistance of stem borer.

These results reveal that the mechanism of resistance is genetically controlled. Also, the results are in line with those obtained by Abo Youssef (2001), who mentioned that the selection of the tested parental genotypes could be practiced either on the basis of mean performance or GCA effects. Furthermore, the correlation estimates among either dead heart or white head percentage and various chemical traits are presented in Table 2.

Table 2: Correlation matrix between rice stem chemical constituents and rice stem borer infestation rates.

Variable	Potassium%	Phosphorus%	pH values	Moisture%	Dry matter%	Silica%
Dead heart	0.882**	-0.868**	0.936**	0.860**	-0.860**	-0.909**
White head	0.894**	-0.904**	0.932**	0.861**	-0.861**	-0.900**

****: Significant at 1% level of probability.**

The correlation among the dead heart or white head with each of potassium, pH values and moisture content were positive and highly significant. These values were (0.882 and 0.894 for potassium, 0.936 and 0.932 for pH values and 0.860 and 0.861 for moisture content), respectively. Moreover, the highly significant and negative correlation values were obtained among the dead heart or white head with each of, phosphorus (-0.868 and -0.904), dry matter (-0.860 and -0.861) and silica contents (-0.909 and -0.900), respectively.

Analysis of variance for all tested genotypes for chemical traits are presented in Table 3. The results revealed significant and highly significant differences among the tested genotypes for all studied traits, except potassium, phosphorus and pH value. The hybrids, CMS lines and testers showed significant and highly significant differences for all traits, except potassium, phosphorus and pH values. Parents vs. hybrids mean square showed insignificant values indicated that average heterosis was also insignificant in all hybrids for all studied traits under investigation.

Table 3: Analysis of variance of some rice genotypes for chemical studied traits.

Source of variance	d.f	D. H.%	W. H.%	K%	P%	pH	Moisture %	Dry matter %	Si %
Reps(R)	2	$0.07^{n.s}$	$0.02^{n.s}$	$0.01^{n.s}$	$0.000^{n.s}$	$0.000^{n.s}$	$0.00^{n.s}$	$0.00^{n.s}$	$0.57^{n.s}$
Genotypes(G)	14	95.49^{**}	60.57^{**}	$0.37^{n.s}$	$0.002^{n.s}$	$0.010^{n.s}$	10.26^{**}	10.26^{**}	2.21^{*}
Parents	5	132.90**	64.89^{**}	$0.45^{n.s}$	$0.001^{n.s}$	$0.010^{n.s}$	15.72^{**}	15.72^{**}	$1.75^{n.s}$
Hybrids	8	84^{**}	64.83^{**}	$0.26^{n.s}$	$0.002^{n.s}$	$0.010^{n.s}$	7.32^{**}	7.32^{**}	2.68^{*}
Parents vs. hybrids	1	$0.30^{n.s}$	$4.80^{n.s}$	$0.75^{n.s}$	$0.001^{n.s}$	$0.006^{n.s}$	$6.38^{n.s}$	$6.38^{n.s}$	$0.69^{n.s}$
Lines	2	163^{**}	144.33^{**}	$0.16^{n.s}$	$0.002^{n.s}$	$0.014^{n.s}$	16.75^{**}	16.75^{**}	4.39*
Testers	2	133^{**}	92.33^{**}	$0.80^{n.s}$	$0.005^{n.s}$	$0.023^{n.s}$	10.89^{**}	10.89^{**}	4.48^{*}
Lines x testers	4	20^{**}	11.33^{**}	$0.05^{n.s}$	$0.000^{n.s}$	$0.002^{n.s}$	$0.83^{n.s}$	$0.83^{n.s}$	$0.93^{n.s}$
Error	28	0.07	0.02	0.00	0.000	0.000	0.00	0.00	0.55
C. V.%		2.69	1.96	0.51	5.12	0.000	0.01	0.04	9.17
GCA/SCA		4.69	6.58	5.59	100	100	10.33	10.33	5.93
L. S. D at 5%		0.44	0.24	0.00	0.00	0.00	0.00	0.00	1.24
at 1%		0.60	0.32	0.00	0.00	0.00	0.00	0.00	1.67

D.H. = dead heart W.H. = white head K = potassium
P = phosphorus Si = Silica
***, **: Significant at 5% and 1% levels of probability, respectively. n.s: Not significant.**

Table 4: Estimates of genetic parameters and heritability in broad and narrow senses for some chemical traits.

Parameters	D. H.%	W. H. %	K%	P%	pH	Moisture%	Dry matter%	Si%
σ^2A	28.45	23.78	0.095	0.0007	0.003	2.89	2.89	0.77
σ^2D	6.64	3.77	0.017	0.0000	0.000	0.28	0.28	0.13
σ^2E	0.07	0.02	0.000	0.0000	0.000	0.00	0.00	0.55
σ^2G	35.09	27.55	0.112	0.0007	0.003	3.17	3.17	0.90
σ^2P	35.16	27.57	0.112	0.0007	0.003	3.17	3.17	1.45
$(h^2_b)\%$	99.72	99.93	100	100	100	100	100	62.07
$(h^2_n)\%$	80.92	86.25	84.82	100	100	91.17	91.17	53.10
gca%	81.08	86.32	84.82	100	100	91.17	91.17	85.56
sca%	18.92	13.68	15.18	0.0000	0.000	8.83	8.83	14.44

- **Relative importance of gca% = σ^2A/σ^2G**
- **Relative importance of sca% = σ^2D/σ^2G**

The analysis of variance for combining, ability given in Table 3 revealed significant and highly significant differences among the genotypes, hybrids, lines and testers for dead heart, white head, moisture, dry matter and silica contents. These results showed highly significant mean squares of lines x testers for dead heart and white head traits. The estimate of variance due GCA was higher than that due to SCA for all traits suggesting greater importance of additive genetic variance.

The estimates of genetic parameters for the eight studied traits (Table 4), indicated that the additive variance (σ^2A) and relative importance of GCA% for all studied traits were greater than non additive genetic variance including dominance variance (σ^2D) and relative importance of SCA%. The additive gene action for the inheritance of these traits is important.

The results emphasizes that, phosphorus, dry matter and silica content play important roles in increasing the resistance to stem borer in rice plants. The current results were confirmed those obtained by Soliman *et al*. (1997) who recorded a negative correlation between the silica contents in rice plants and infestation by the rice stem borer. By considering the results of this research, it could be recommend that for production of resistance genotypes against stem borer, some of traits such as increased dry matter, phosphorus and silica contents should be considered in developing new lines. There is no a rice genotypes completely resistant to stem borer. However, breeders and entomologists should select rice entries with high silica, phosphorus and dry matter contents to reduce feeding capacity of stem borer larvae.

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الأسس الكيموحيوية والوراثية لمقاومة ثاقبة الساق فى تراكيب وراثية للأرز

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أجريت هذه الدراسة فى مركز البحوث والتدريب فى الأرز, سخا – كفرالشيخ - مصر خلال مواسم النمو 2007, 2008 و2009. تم تقييم سبعة عشر تركيباً وراثياً, اشتملت على ثلاث سلالات ذات عقم ذكرى سيتوبلازمى, ثلاث سلالات معيدة للخصوبة وتسعة هجن وصنفى مقارنة سخا 101 (صنف مقاوم) وياسمين المصرى (شديد الإصابة). كان الهدف من الدراسة هو معرفة الأساس الكيميائى والوراثى لمقاومة التراكيب الوراثية لثاقبة الساق. اشارت النتائج إلى أن أعلى نسبة إصابة كانت فى الأصناف المحتوية على نسب منخفضة من الفسفور, والمادة الجافة والسيليكا بينما كانت أقل نسبة إصابة فى الأصناف المحتوية على نسب أعلى من الفسفور, والمادة الجافة والسيليكا. كانت العلاقة بين البوتاسيوم ودرجة الحموضة والرطوبة والإصابة بثاقبة ساق الأرز عالية المعنوية وموجبة. وكانت القدرة العامة على التآلف لمعظم الصفات أكبر من القدرة الخاصة مما يشير إلى أهمية الفعل الجينى المضيف فى التحكم الوراثى لهذة الصفات. لذلك يجب على مربى النبات والحشرات الانتخاب لتراكيب وراثية من الأرز ذات محتوى عالى من السيليكا والفوسفور والمادة الجافة لخفض قابلية اليرقة على التغذية.

قام بتحكيم البحث

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