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Influence of rice grain traits on susceptibility to the lesser grain borer, *Rhyzopertha dominica* (F.) (Coleoptera, Bostrichidae)

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ABSTRACT: Rice grains of 20 varieties were tested for their physical and biochemical basis of resistance against lesser grain borer, *Rhyzopertha dominica* (F.) (Coleoptera, Bostrichidae). Physical parameters such as grain length x breadth, thousand seed weight, and grain hardness exhibited significant differences among tested varieties. Grain hardness conferred resistance significantly by resulting in delayed adult emergence (-0.519), and weight loss per cent (-0.603). Biochemical parameters such as total carbohydrates and proteins showed significant differences among the varieties. Total carbohydrate was positive and significantly correlated with adult emergence, but with median development period negatively correlated. Protein content was also found positively correlated with adult emergence and negatively correlated with the median development period.

KEY WORDS: Adult emergence, development period, susceptibility index, physical- biochemical factors

INTRODUCTION

Rice is the most commonly grown cereal with high food value worldwide. Rice grains are stored for various reasons, including food safety, seed purpose, and trading to make monetary gains. In tropical agriculture conditions, lack of suitable storage facilities and the high humidity, losses of cereal grains can exceed 30 per cent due to insect pests (Ramputh *et al*., 1999). *Rhyzopertha dominica* (F.) (Coleoptera, Bostrichidae) infestation alone can diminish the weight of brown rice by around 40 per cent (Smith,1989). Globally in cereal grains, *R. dominica* is one of the important stored pests,

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and it reduces the kernels to the pericarp by feeding (Winterbottom 1922; Cambell and Sinha 1976). Eggs are laid on the surface of the grain by female and first instar larvae enter into the kernels, choosing broken grains or germ portion. Larvae and adults of *R. dominica* spend the majority of their time inside the kernel, feeding on the endosperm and germ, which directly affects the physicochemical characteristics of the grain and results in damage (Edde, 2012). The host-plant variety selection that hinders insect growth could be a substitute for treatment with insecticides for any cereal crop that suffer from post-harvest insect pests. A study was undertaken to assess a selection of rice varieties for host-plant resistance to *R. dominica* and determine any specific physical or chemical characteristics of the grains that may contribute to this resistance.

MATERIALS AND METHODS

The experiment was carried out with 20 rice varieties (Table 1) in the Department of Entomology, MSSSoA, Parlakhemundi from 2021 to 2022. The selected varieties of rice were obtained from ICAR – National Rice Research Institute, Cuttack; while RNR-15048 was obtained from the Seed Unit at Centurion University. These varieties were kept in the oven for disinfestation at a temperature of 55°C for 4 hours to eliminate the hidden infestation if any, without affecting the viability of the seeds (Singh, 1989). The grains were kept in a desiccator with KOH solution (51g of KOH per 100 ml of water) for 21 days after disinfection to raise the moisture content near equilibrium (Solomon, 1951). This pre-conditioned seed material was used for screening.

The culture of *R. dominica* was obtained from the storage Entomology laboratory, Centurion University. Beetles were mass multiplied throughout the experimental period in the laboratory on rice variety, RNR-15048 and maintained (at 27±2°C and 65±5% RH). Five pairs of newly emerging adults of *R. dominica* were released into each plastic jar of 20g healthy seeds from each variety and replicated thrice in a Complete Randomized Design. Muslin cloth was used to cover the jar mouth. The insects were removed after seven days of oviposition, and the jars were then maintained under the same experimental conditions. Data were analysed using the SPSS software version 16.0. The following parameters were used to compare the susceptibility of different rice varieties to *R. dominica.*

Developmental parameters: The development of beetle was indirectly determined by the index of susceptibility. It was an important characteristic which was calculated using the method of Dobie (1974) where 0–3 (resistant), 4–7 (moderately resistant), 8–10 (susceptible) and>11 (highly susceptible). The growth index a key factor to determine host suitability was calculated (Tripathi *et al*., 2012; Soumia *et al*., 2015) and grain weight loss per cent was done by count and weight method (Gwinner and Harnish, 1996).

Physical parameters of rice varieties: The length and breadth of grain measured using digital vernier callipers were expressed in millimetres (mm). Likewise, thousand seed weight (TSW) was also recorded for each variety and was counted and weighed per replication with the help of electronic balance. The hardness of the grains was determined by the pressure exertion method using a texture analyser (Brookfield, Model: CT3 10K, USA). On a flat plate, a single kernel was compressed using a 12mm flat probe at a cross-head speed of 50mm per min. Hardness (N) a measurement of the force necessary to rupture (first break) a grain of rice was recorded, in three replications (Taghinezhad *et al*., 2016).

Biochemical Properties of rice varieties: Standard and widely accepted methods were used to estimate the amount of soluble protein (Lowry *et al*., 1951). Similarly, the estimation of carbohydrates (also known as sugars) was carried out as per Hedge and Hofreiter (1962).

RESULTS AND DISCUSSION

Insect development characters: In test varieties of rice, there were significant differences in adult emergence, median developmental period, susceptibility index, growth index, weight losses per

cent towards insect response (Table 1). Maximum adult emergence was found in RNR-15048 (24.67) whereas the least emergence was found in Sneha (2.33) followed by CR Dhan 206 (3.00) and CR Dhan 201(3.67). The highest developmental period was observed in CR Dhan 201(46.67days) and the minimum developmental period was observed in CR Dhan 205 (35 days) followed by RNR-15048(35.33 days). The susceptibility index ranged from 1.94 (Sneha) to 9.08 (RNR-15048). Out of twenty rice varieties, Sneha, CR Dhan 206 and CR Dhan 201 were found to be resistant whereas RNR-15048 variety is susceptible as per Dobie (1974). Resistance/ susceptibility reaction among the varieties was observed as per growth index. It ranged from 0.05 for variety Sneha and 0.70 for RNR-15048. The highest per cent of weight loss was found in variety RNR-15048 (15.75), while Sneha registered minimum weight loss (1.47).

Physical parameters of rice varieties: The thousand seed weight of the test varieties varied from 13.13 to 25.20g. The highest thousand seed weight was noticed in CR Dhan209 (25.20g)

Table 1. Development parameters of *R. dominica* in grains of rice varieties

Rice varieties	Adult emergence (No)	MD	SI	GI	Weight loss
CR Dhan 40	4.67 *(2.27)^{jkl}	43.00^{b}	3.57^{h}	0.11^{def}	2.88 *(1.84)^{j}
CR Dhan 101	6.33 (2.61)^{ghij}	40.67^{de}	4.54^{fg}	0.16^{cdef}	5.27 (2.40)^{i}
CR Dhan 200	10.00 (3.24)^{cde}	39.67^{ef}	5.81^{cd}	0.25^{bcdef}	8.24 (2.96)^{ef}
CR Dhan 201	3.67 (2.04)^{klmn}	46.67^{a}	2.76^{i}	0.08^{ef}	2.08 (1.60)^{k}
CR Dhan 202	7.33 (2.80)^{fgh}	36.00^{h}	5.53^{de}	0.2^{cdef}	8.14 (2.94)^{efg}
CR Dhan 203	4.67 (2.27)^{jklm}	38.00^{g}	4.04^{gh}	0.12^{def}	3.44 (1.99)^{j}
CR Dhan 204	6.67 (2.68)^{fghij}	37.67^{g}	5.03^{ef}	0.18^{cdef}	7.98 (2.91)^{efg}
CR Dhan 205	12.00 (3.54)^{c}	35.00^{h}	7.1^{b}	0.34^{bc}	10.85 (3.37)^{b}
CR Dhan 206	3.00 (1.87)^{lm}	40.00^{e}	2.75^{i}	0.08^{ef}	1.93 (1.56)^{k}
CR Dhan 207	8.67 (3.03)^{def}	38.67^{fg}	5.58^{de}	0.22^{cdef}	8.38 (2.98)^{de}
CR Dhan 209	11.00 (3.39)^{cd}	38.00^{g}	6.31^{c}	0.29^{bcd}	9.86 (3.22)^{bcd}
Virender	7.00 (2.74)^{fghi}	41.67^{cd}	4.67^{fg}	0.17^{cdef}	6.85 (2.71)^{fgh}
Hazari dhan	5.67 (2.48)^{hij}	41.33^{d}	4.19^{gh}	0.14^{def}	5.61 (2.47)^{hi}
Santha bhima	5.67 (2.48)^{hij}	39.67^{ef}	4.37^{fg}	0.14^{def}	6.79 (2.70)^{gh}
Sneha	2.33 (1.68)^{n}	42.67^{bc}	1.94^{j}	0.05^{f}	1.47 (1.40)^{k}
Sadabahar	16.00 (4.06)^{b}	37.67^{g}	7.36^{b}	0.42^{b}	10.38 (3.30)^{bc}
IR-64 DIRT	8.33 (2.97)^{efg}	35.67^{h}	5.94^{cd}	0.23^{cdef}	8.79 (3.05)^{cde}
Anjali	5.00 (2.35)^{ijk}	37.67^{g}	4.27^{g}	0.13^{def}	6.19 (2.59)^{hi}
Abhishek	10.33 (3.29)^{cde}	37.67^{g}	6.2^{cd}	0.27^{bcde}	9.55 (3.17)^{bcde}
RNR-15048	24.67 (5.02)^{a}	35.33^{h}	9.08^{a}	0.70^{a}	15.75 (4.03)^{a}

The values in parentheses are transformed * $\sqrt{x+0.5}$ value; DAS: Days after storage; Any two means having a common letter are not significantly different at the 5% level of significance by DMRT. MD - Median development (days); SI - Susceptibility index; G I - Growth Index; Weight loss per cent at 120DAS

followed by Hazari dhan (25.07g) and Anjali (24.37g) whereas the lowest seed weight was noticed in RNR-15048 (13.13g) followed by Sneha (16.9g) and CR Dhan 40 (18.21g) (Table 2). Thousand seed weight was found to have a non-significant and negative effect on susceptibility index (r = -0.283), growth index (r = -0.514), weight loss per cent (r = -0.264), and adult emergence (r = -0.494), but non-significant and positive response with median development period (r = 0.171) (Table 3).

The grain length x breadth ranged from 14.62 to 26.27mm. The maximum length x breadth was noticed in CR Dhan 200 (26.27mm) followed by Santha Bhima (25.99mm) and CR Dhan 207 (24.33mm). Minimum was noticed in RNR-15048 (14.62mm) followed by Abhishek (17.41mm) and CR Dhan 40 (18.20mm) (Table 2). The adult emergence (r = -0.341), susceptibility index (r = -0.162), growth index (r = -0.361), and weight loss per cent (r = -0.123) exhibited negative non-significant relation with grain length x breadth; But non-significant and positive correlation with the median development period (r = 0.089) (Table 3).

The hardness of tested varieties ranged from 128.00 (Sneha) to 83.67 N (CR Dhan204). The highest grain hardness was noticed in Sneha (128.00 N), CR Dhan 206 (126.33N) and CR Dhan 201 (125.33N), whereas the lowest grain hardness was noticed in CR Dhan 204 (83.67N) followed by RNR-15048 (101.33N) and Sadabahar (102.33N) (Table 2). Grain hardness showed significant negative correlation with susceptibility index (r = -0.577), adult emergence (r = -0.519), growth index (r = -0.522), and weight loss per cent (r = -0.603) whereas positive and non-significant relation with median development period (r = 0.499) (Table 3).

Biochemical parameters of rice varieties: The carbohydrates in different rice varieties ranged from 64.32 to 78.03 per cent with significant differences. The highest carbohydrates were noticed in RNR-15048 (78.03%) followed by Virender (76.14%), Sadabahar (74.67%), and CR Dhan209 (73.24%), whereas the lowest carbohydrates were in Sneha (64.32%) followed by CR Dhan 200 (65.30%) (Table 2). Total carbohydrates were positive and significantly correlated with susceptibility index (r = 0.691), growth index (r = 0.751), weight loss per cent (r = 0.682), and adult emergence (r = 0.765) whereas negative and non-significant relation with median development period (r = -0.274).

Protein content in test rice varieties ranged from 9.3 to 6.2 per cent. The varieties CR Dhan 206 (6.2%) and CR Dhan205 (6.5%) had the lowest protein per cent, while CR Dhan205 had the greatest protein per cent (9.3%), followed by Sadabahar (8.5%) and RNR-15048 (8.3%). All the insect developmental characters *viz*, adult emergence (r = 0.611), susceptibility index (r = 0.606), growth index (r=0.604), and weight loss per cent (r = 0.557) were positively correlated with protein content except median development period (r = -0.272) which was non-significant and negatively related (Table 3).

These findings are in line with Singh *et al*. (1984) who reported that the number of adult emergences determines the extent of their damage and subsequently grains permitting more rapid adult emergence will be more extensively damaged. Samyal *et al*. (2006) and Sayed *et al*. (2006) stated that the maximum population, per cent loss in weight was supported by the highly susceptible variety, whereas, the lowest population and minimum loss had the least susceptible variety. According to Swamy *et al*. (2022) in BPT2411 *R. dominica* emergence was the least in under-free choice (13.00 adults/100g) and non-choice (16.33 adults/100g) conditions. Singh *et al*. (2001) observed that the developmental period of *R. dominica* varied from 39.82-43.29 days on different wheat varieties. Bhargava and Hussain (2014) reported that grain damage per cent and weight loss per cent in wheat varieties varies against *R. dominica* to the extent of 17.32 to 45.79 and 6.15 to 18.50, respectively.

Prasad *et al*. (2015) reported that seed weight and *Sitophilus* emergence were negatively correlated in sorghum grains in accordance with the current results. Stejskal and Kucerova (1996) and Prasad *et al*. (2015) corroborated the current findings that the size of the grain in wheat and sorghum is negatively correlated with weevil emergence. In contrast to several of the earlier studies, Segrove (1951), Haine (1991) and Campbell (2002) reported

Table 2. Physical and biochemical characteristics of grains of rice varieties

Variety	1000 seed weight (g)	Grain length X breadth (mm)	Grain x hardness (N)	Carb (%)	Protein (%)
CR Dhan 40	18.21^{i}	18.20^{k}	117.67^{cde}	66.69^{jkl}	7.0^{ef}
CR Dhan 101	21.93^{def}	20.47^{fgh}	118.33^{cd}	68.66^{g}	7.9^{cd}
CR Dhan 200	22.97^{bcd}	26.27^{a}	116.67^{e}	66.07^{lmn}	7.4^{de}
CR Dhan 201	23.33^{bcd}	22.32^{d}	125.33^{b}	68.42^{gh}	7.6^{d}
CR Dhan 202	22.07^{cdef}	23.34^{c}	114.65^{f}	65.3^{n}	7.8^{d}
CR Dhan 203	22.00^{cdef}	19.39^{ij}	117.33^{cde}	65.75^{mn}	6.8^{f}
CR Dhan 204	20.17^{gh}	21.08^{efg}	83.67^{i}	66.89^{jk}	6.5^{fg}
CR Dhan 205	18.42^{i}	21.44^{def}	117.67^{cde}	71.29^{e}	9.3^{a}
CR Dhan 206	20.77^{fg}	19.92^{hij}	126.33^{b}	68.32^{gh}	6.2^{g}
CR Dhan 207	23.00^{bcd}	24.33^{b}	115.00^{f}	70.27^{f}	6.6^{fg}
CR Dhan 209	25.20^{a}	21.84^{de}	113.33^{g}	73.24^{d}	7.6^{d}
Virender	22.40^{cde}	20.16^{ghi}	118.67^{c}	76.14^{b}	7.6^{d}
Hazari dhan	25.07^{a}	20.46^{fgh}	118.00^{cde}	67.82^{hi}	6.5^{fg}
Santha Bhima	21.87^{def}	25.99^{a}	115.33^{f}	67.14^{ij}	7.5^{d}
Sneha	16.90^{j}	19.11^{j}	128.00^{a}	64.32^{o}	6.8^{f}
Sadabahar	19.03^{hi}	20.13^{ghi}	102.33^{h}	74.67^{c}	8.5^{b}
IR-64 DIRT	23.45^{bc}	21.13^{ef}	114.33^{fg}	69.02^{g}	6.5^{fg}
Anjali	24.37^{ab}	21.2^{ef}	117.00^{de}	66.22^{klm}	6.8^{f}
Abhishek	21.21^{efg}	17.41^{k}	115.33^{f}	72.58^{d}	7.5^{d}
RNR-15048	13.13^{k}	14.62^{l}	101.33^{h}	78.03^{a}	8.3^{bc}

Any two means having a common letter are not significantly different at 5% level of significance by DMRT.

that larger grains have more progeny and better larval survival than small grains. The current findings concur with Swamy *et al*. (2022) who reported that rice variety BPT 2411 had the highest kernel hardness (7.28 kgf) and least favoured grain for the stored insects tested, including the lesser grain borer and angoumois grain moth, in rough rice. Insect fitness was found to be inversely correlated with kernel hardness (Morallo-Rejesus *et al*., 1982). According to Astuti *et al*. (2013), in rice kernels grain hardness, amylose content, non-chalkiness, and phenol content all are associated to the variety's resistance to stored rice insects. Grain hardness is one of the characteristics that influence *R. dominica* infestation, according to Keskin and Ozkaya (2013). Mechanical structures of the rice grain varieties have been related to the resistance (Lale and Yusuf, 2001; Ashamo, 2001 and Lale and Kartay, 2006).

The results of the present experiments are in line with that of Kumar *et al*. (2020) who observed that developmental features of *R. dominica* had a significant positive correlation with ash, carbohydrate, and fat contents whereas significant negative association of surface wax, total phenol,

Table 3. Correlation between physical and biochemical characteristics of rice varieties and development of *R. dominica*

Character	AE	MDP	SI	GI	WL	GLB	TSW	GH	Carbohydrate	Protein
AE	1.000									
MDP	-0.587**	1.000								
SI	0.934**	-0.754**	1.000							
GI	0.998**	-0.616**	0.933**	1.000						
WL	0.912**	-0.754**	0.977**	0.914**	1.000					
GLB	-0.341NS	0.089NS	-0.162NS	-0.361NS	-0.123NS	1.000				
TSW	-0.494*	0.171NS	-0.283NS	-0.514*	-0.264NS	0.599**	1.000			
GH	-0.519*	0.499*	-0.577**	-0.522*	-0.603**	0.124NS	0.251NS	1.000		
Carb	0.765**	-0.274NS	0.691**	0.751**	0.682**	-0.428NS	-0.287NS	-0.289NS	1.000	
Protein	0.611**	-0.272NS	0.606**	0.604**	0.553*	-0.072NS	-0.376NS	-0.112NS	0.522*	1.000

AE = Adult emergence, MDP = Median developmental period, SI= Susceptibility index, GI= Growth index, WL =Weight loss per cent, GLB =Grain length x breadth, TSW= Thousand seed weight, GH= grain hardness; *Significant at 0.05 level, **Significant at 0.01 level

and total hull per cent in brown rice. The current findings concur with that of Rekha *et al*. (2017), who found a positive association between growth index (0.354), adult emergence (0.384), oviposition (0.394), pod damage (0.522), and weight loss (0.819) of *Caryedon serratus* with total soluble sugars of pods. The present findings corroborate with Swamy *et al*. (2022), who observed that the grain hardness and low protein content of variety BPT 2411 might be the key reasons for its least fitness for the progeny development of lesser grain borer, angoumois grain moth in rough rice, and red flour beetle in milled rice. The current results are also consistent with those of Swamy *et al*. (2022) who reported the least progeny development in stored insects such as lesser grain borer (13.0 adults/100g), and red flour beetle (23.33 adults/ 100g) were found due to grain hardness and low protein content in BPT 2411cultivar under free-choice conditions. Additionally, our results are in good agreement with Nemati *et al*. (2018) that the adult longevity and fecundity of *R. dominica* fed on barley cultivars were positively correlated to the protein content, showing that these parameters have a significant influence on the fitness of this insect. The results of the present study are in conformity with Sahoo and Sahoo (2016) who found that the protein content was positively correlated with grain damage per cent and adult emergence 0.878 and 0.827 respectively by *Sitophilus oryzae*. Additionally, our findings closely align with those of Murad and Batool (2017) who reported that high protein content varieties were highly susceptible to *Sitotroga cerealella and Sitophilus oryzae* (Soujanya *et al*., 2017).

The experimental results suggest that resistant varieties have the least adult emergence, grain damage per cent and weight loss per cent and prolonged median developmental period. Physiochemical parameters such as grain hardness contributed to resistance while carbohydrates and proteins have a positive effect on *R. dominica* development.

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