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Research Article

Evaluation of wild rice MAGIC population for biophysical parameters and yellow stem borer resistance

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Abstract

Field evaluation of 50 wild rice MAGIC population along with susceptible check, TN 1, stem borer resistant donor *O. glaberrima* (Acc.No. CG 14) and local checks TRY 2 and TRY 3 was done at Anbil Dharmalingam Agricultural College and Research Institute, Trichy. Five MAGIC genotypes, WRM-6, WRM-12, WRM-57, WRM-111 and WRM-126 showed resistance at the vegetative stage while 12 genotypes viz., WRM-3, WRM-6, WRM-30, WRM-56, WRM-57, WRM-58, WRM-72, WRM-74, WRM-111, WRM-112, WRM-115, WRM-126 along with *O. glaberrima* showed resistance to yellow stem borer during the reproductive stage. Correlation studies were carried out with biophysical parameters and yellow stem borer damage. Results revealed that the trichome density was significantly negatively correlated whereas, stem girth was significantly positively correlated at the vegetative stage and significantly negatively correlated at the reproductive stage. While, plant height, top internodal length and leaf length were significantly negatively correlated and leaf breadth is significantly positively correlated.

Key words: Yellow stem borer, resistance, wild rice MAGIC population, biophysical characters

INTRODUCTION

Rice (*Oryza sativa* L.) is the major staple food crop belonging to Poaceae family. In India, more than two third of the population depends on rice for their food (Singh *et al.*, 2014 and Lal *et al.*, 2014). India is the second largest producer of rice next to China with a production of about 118.43 million tonnes with an area of about 43.78 million hectares which accounts for the share of 22 per cent among major crops in India (Anonymous, 2020). Several biotic and abiotic factors act as yield constraints in rice, among these biotic factors, insect-pests causes a substantial yield loss in rice production and productivity (Chatterjee and Mondal, 2014). Due to the existence of trait-specific genes, landraces and wild rice species have enormous potential to withstand or resist various biotic and abiotic stressors (Keerthivarman *et al.*, 2019). Rice

is attacked by more than 100 insect species in India, with 20 of them recorded as severe pests that cause up to 30 per cent yield loss (Salim *et al.*, 2001). Among them Yellow stem borer, *Scirpophaga incertulas* Walker, is the most common and devastating insect pest, causing yield losses of 10-60 per cent across the country (Chatterjee and Mondal, 2014). The yellow stem borer *S. incertulas* is a monophagous pest of rice. It causes damage by drying the central stalk, which is known as 'dead heart' at the vegetative stage and also causes 'white earhead' at maturity, which results in chaffy grains, lowering rice yield. Farmers depends on various chemicals to control the pest but the indiscriminate use of pesticides resulted in insecticide resistance, resurgence, secondary pest outbreaks, disruption of the natural enemy complex,

biodiversity loss, and environmental degradation (Dhaliwal and Arora, 2000). Host plant resistance an important component of IPM has proven to be effective for yellow stem borer management by developing a variety that is showing resistance against stem borer. For developing stem borer resistant cultivars, there are limited resistance sources available. Breeding for yellow stem borer resistance has been difficult due to the complexity of genetic characteristics and inherent challenges in screening (Selvi *et al.*, 2002). Wild rice germplasm acts as a source of resistant genes for developing a resistant variety which helps the farmers to reduce the overdependence on chemicals for controlling the pests to large extent and moreover it is environment friendly. Hence, the present study was carried out to assess resistance in the wild introgressed lines. To characterize the resistance, biophysical parameters were analyzed to evaluate the basis for resistance.

MATERIALS AND METHODS

The present study was carried out in open field conditions at Anbil Dharmalingam Agricultural College, Tiruchirapalli during 2020-21. Wild Rice MAGIC (WRM) population used in the study are descendants of crosses from eight *Oryza* species, including *Oryza rufipogon*, *O. nivara*, *O. meridionalis*, *O. glumaepatula*, *O. barthi*, *O. glaberrima*, *O. longistaminata*, and *O. sativa*. A total of 50 WRM accessions along with two local checks TRY 2, TRY3 (*O. sativa*) and one susceptible check TN-1 and resistant check *O. glaberrima* (accession number CG 14) were used for screening and evaluation of resistance against yellow stem borer. The entries were raised in the nursery and 25 day old seedlings were transplanted in the experimental field in randomized block design with two replications. All the necessary agronomic practices were followed except plant protection measures and the field was maintained without any chemical pesticides throughout the season.

Observations in the screening plots were recorded at the vegetative stage *ie.* 30, 45 and 60 days after transplanting (DAT) for dead heart symptoms and at reproductive stage *ie.* at 75 and 90 DAT for white ear damage symptoms. Five hills were selected randomly from each row and observed for damage by a yellow stem borer. The damage percentage was worked out and converted into D-factor.

Standard protocol was used to arrive at resistant grade (Heinrichs *et al.*, 1985)

$$\text{Percent dead hearts} = \frac{\text{Number of damaged tillers (dead hearts)}}{\text{Total number of tillers}} \times 100$$

Percentage of dead heart will be converted to D

$$D = \frac{\% \text{ dead hearts in test entry}}{\% \text{ dead hearts in susceptible check}} \times 100$$

Per cent infestation of white ear =

$$\frac{\text{Number of damaged productive tillers (White ears)}}{\text{Total number of tillers}} \times 100$$

Percentage of white ears will be converted to D

$$D = \frac{\% \text{ white ears in test entry}}{\% \text{ white ears in the susceptible check}} \times 100$$

Based on the damage rating scale of 0-9 the entries were categorized as highly resistant, resistant, moderately resistant, susceptible, moderately susceptible and highly susceptible by following IRR Standard Evaluation System (SES) (Heinrichs, 1985).

Seven biophysical parameters like the number of trichomes (per cm² of leaf), plant height (cm), top internodal length (cm), leaf length (cm), leaf breadth (cm), leaf area and stem girth (cm) are responsible for resistance were analyzed in 50 WRM introgressed lines from randomly selected three plants as replications. Leaf area was measured by following the standard procedure described by Yoshida *et al.* (1976).

RESULTS AND DISCUSSION

The results from field screening of 50 wild rice magic population revealed that 26 accessions showed nil dead heart symptoms at 30 DAT and at 45 DAT three accessions *viz.*, WRM-3, WRM-12, WRM-25 showed no dead heart symptoms. At 60 DAT all plants showed dead heart symptoms with the highest damage in WRM-91 (9.54%) and least dead heart symptoms observed in WRM-111 (1.66%). The mean dead heart damage was recorded high in TN-1 (10.81%) and low in WRM-126 (1.43%). The entries *viz.*, WRM-6, WRM-12, WRM-57, WRM-111, WRM-126 were found to be resistant and the local checks TRY-2 and TRY-3 were found to be moderately susceptible. The parent check CG 14 was found to be moderately resistant in the mean of three observations (Table 1). It was noticed that the entries which were showing resistance or moderate resistance during initial counts were found to show moderate resistance or moderate susceptibility in the subsequent counts during 75 and 90 DAT. It indicates that during the maturity stage, these lines loss the resistant characters and become relatively susceptible to yellow stem borer infestation. In general, the production of biochemical or secondary plant compounds is higher in the younger stage of the crop where it shows a greater level of resistance to insect attack. The production of secondary compound can be gradually decreased to certain level during maturity stage that leads to susceptibility. Norris and Kogan *et al.* (1980) revealed that secondary chemicals like DIMBOA and similar products are most prevalent in young corn plants, deterring *Ostrinia nubilalis* larvae from feeding and growing, but older tissues do not contain as many

Table 1. Field screening of wild rice MAGIC population at vegetative stage

Genotypes	Dead heart damage (%)			Mean	Score	Category of Resistance
	30DAT	45 DAT	60 DAT			
WRM-2	0 (4.05)	4.0 (12.24)	3.33 (11.28)	2.44	3	MR
WRM-3	0 (4.05)	5.71 (14.42)	5.9 (14.65)	3.87	5	MS
WRM-6	0 (4.05)	0 (4.05)	4.67 (13.14)	1.55	1	R
WRM-10	4.0 (12.24)	3.33 (11.28)	4.16 (12.46)	3.83	3	MR
WRM-12	0 (4.05)	0 (4.05)	4.9 (13.43)	1.63	1	R
WRM-17	0 (4.05)	6.19 (14.98)	3.92 (12.13)	3.37	3	MR
WRM-18	0 (4.05)	5.83 (14.57)	4.72 (13.2)	3.51	3	MR
WRM-21	7.33 (16.24)	5.55 (14.23)	6.69 (15.55)	5.73	5	MS
WRM-22	5.71 (14.42)	4.72 (13.23)	3.09 (10.91)	4.50	3	MR
WRM-23	0 (4.05)	7.33 (16.24)	5.35 (13.99)	4.22	5	MS
WRM-25	5.0 (13.56)	5.71 (14.42)	5.59 (14.28)	5.43	5	MS
WRM-27	0 (4.05)	6.5 (15.33)	6.38 (15.20)	4.29	5	MS
WRM-29	4.0 (16.24)	5.83 (14.56)	4.16 (12.46)	5.77	5	MS
WRM-30	0 (4.05)	6.66 (15.51)	5.15 (13.74)	3.93	5	MS
WRM-52	10.66 (19.51)	8.41 (17.36)	6.72 (15.58)	8.59	7	S
WRM-54	0 (4.05)	6.85 (15.72)	4.22 (12.54)	4.29	5	MS
WRM-56	0 (4.05)	3.33 (11.28)	4.72 (13.2)	5.77	3	MR
WRM-57	0 (4.05)	0 (4.05)	2.5 (9.97)	3.93	1	R
WRM-58	0 (4.05)	2.85 (10.54)	3 (10.78)	3.69	3	MR
WRM-60	0 (4.05)	5.83 (14.56)	5.7 (14.41)	2.68	3	MR
WRM-61	2.85 (12.84)	5.35 (13.99)	4.5 (12.91)	0.83	5	MS
WRM-63	0 (4.05)	6.5 (15.33)	3.36 (11.32)	1.95	3	MR
WRM-64	6.66 (15.51)	7.59 (16.52)	5.37 (14.01)	3.84	5	MS
WRM-65	6.85 (15.72)	6.19 (14.95)	6.38 (15.20)	5.34	5	MS
WRM-66	8.33 (17.28)	7.17 (16.87)	8.05 (17)	3.28	7	S
WRM-70	6.19 (14.98)	6.54 (15.38)	4.91 (13.44)	6.54	5	MS
WRM-72	0 (4.05)	4.16 (12.46)	3.09 (10.84)	6.47	3	MR

WRM-74	0 (4.05)	5.71 (14.42)	5.33 (13.97)	7.85	3	MR
WRM-75	6.85 (15.72)	6.94 (15.82)	5.71 (14.42)	5.88	5	MS
WRM-79	3.33 (11.28)	5 (13.56)	5.24 (13.85)	2.41	5	MS
WRM-80	0 (4.05)	5.35 (13.99)	3.09 (10.91)	3.68	3	MR
WRM-82	10.66 (19.51)	8.57 (17.52)	6.81 (15.67)	6.5	7	S
WRM-86	6.85 (15.72)	5.71 (14.42)	5.48 (14.15)	4.52	5	MS
WRM-88	9.04 (17.98)	8.33 (17.28)	6.72 (15.58)	2.81	5	MS
WRM-89	6.85 (15.72)	5.07 (13.65)	5.98 (14.73)	8.68	5	MS
WRM-90	0 (4.05)	6.19 (14.98)	5.42 (14.08)	6.01	3	MR
WRM-91	10.19 (19.08)	8.05 (17)	9.54 (18.48)	5.01	9	HS
WRM-92	0 (4.05)	6.19 (14.98)	5.83 (14.57)	5.96	5	MS
WRM-97	8.33 (17.28)	7.57 (16.49)	6.89 (15.77)	3.87	7	S
WRM-98	0 (4.05)	6.66 (15.51)	5.31 (13.94)	9.26	5	MS
WRM-107	6.66 (15.51)	5.83 (14.57)	3.68 (11.79)	4.00	5	MS
WRM-109	7.85 (16.79)	6.42 (15.25)	5.76 (14.48)	7.59	7	S
WRM-111	0 (4.05)	2.85 (10.54)	1.66 (8.44)	3.99	1	R
WRM-112	5.35 (13.99)	4.72 (13.42)	3.24 (11.14)	5.39	3	MR
WRM-114	0 (4.05)	7.57 (16.49)	6.74 (15.6)	6.67	5	MS
WRM-115	5.71 (14.42)	4.31 (12.66)	3.2 (11.09)	1.50	3	MR
WRM-119	0 (4.05)	5.93 (14.68)	5.17 (13.77)	4.43	3	MR
WRM-121	7.33 (16.24)	6.5 (15.33)	5.85 (14.59)	4.77	5	MS
WRM-125	6.85 (15.72)	5.07 (13.65)	6.54 (15.38)	4.40	5	MS
WRM-126	0 (4.05)	2.5 (9.97)	1.81 (8.73)	3.7	1	R
TN-1	14.0 (22.35)	9.61 (18.53)	8.82 (17.77)	10.81	9	HS
TRY-2	7.33 (16.24)	5.55 (14.23)	3.59 (11.66)	5.49	5	MS
TRY -3	7.5 (16.42)	5.42 (14.07)	4.63 (13.08)	5.85	5	MS
<i>O.glaberriema</i> (CG 14)	0 (4.05)	5.83 (14.57)	4.52 (12.94)	3.45	3	MR
SEd	0.41	0.10	0.13			
CD (p=0.05)	0.83	0.21	0.26			

Figures in the parenthesis are the arc sin transformed values

DH - Dead heart

deterrents. Allomonics development of young, quickly proliferating cells vs older differentiated cells appears to be evolutionarily essential in most annual plants. Based on the duration of rice varieties also the damage on dead heart and white ears may vary. Bandong and Litsinger, (2005) recorded in early maturing rice variety IR-72, resistance occurred from panicle initiation to pre booting, while resistance was extended from late vegetative to booting in the medium maturing rice variety IR-70. The observations taken during 75 DAT in the present study revealed that genotypes viz., WRM-6, WRM-12, WRM-22, WRM-57, WRM-111, WRM-126 showed no white ear symptoms but data collected at 90 DAT revealed that all the plants shown white ear symptoms with the highest percentage recorded in WRM-70 (8.96%) and the lowest recorded in WRM-126 (0.68%). The overall mean white ear damage at 70 and 90 DAT was found to be the highest in WRM-70 (9.67%) and the lowest in WRM-126 (0.43%). The per cent white ear damage in TN-1, local checks TRY-2, TRY-3 and parent check *O. glaberrima* was recorded as 5.09, 3.17, 3.13 and 0.90, respectively (Table 2). Elanchezhyan *et al.* (2015) reported that the infestation by stem borer varied from 2.48 to 23.58 per cent dead heart during the vegetative stage and 1.94 to 12.25 per cent white ear during the reproductive stage in rice. Reuolin *et al.* (2019) revealed that from field screening that the wild rice introgressed nine lines among 38 entries tested were moderately resistant to yellow stem borer. Padmakumari and Ram (2012) discovered donors for rice yellow stem borer resistance in *O. rufipogon* and *O. glaberrima* accessions. Sarao *et al.* (2013) examined 62 wild rice germplasm accessions and found that CR100316 (*O. nivara*) had the least stem borer damage. Chen *et al.* (2006) reported that the larval survival rate was 25 per cent higher in cultivated accessions than wild rice accessions of *Oryza nivara* and *O. rufipogon*. The wild introgression lines used in the present study were derived from eight parents viz., *O. rufipogon*, *O. nivara*, *O. meridionalis*, *O. barthii*, *O. glumaepatula*, *O. longistaminata*, *O. glaberrima* and *O. sativa*.

The biophysical parameters were recorded for 50 WRM accessions along with local checks. Observation at 45 DAT and 75 DAT count the number of trichomes was maximum in WRM-74 (101/cm² and 123.6/cm²) and minimum in WRM-91 (23.4/cm² and 23.5/cm²) (Table 3 & 4). WRM-91 has less trichomes showing its susceptible reaction to stem borer in the field screening. Ananthakrishnan *et al.* (2001) indicated that trichomes act as a physical barrier to stem borer, leaf folder and plant hoppers. The plant height was maximum in WRM-72 (98.4 cm) and minimum in WRM-60 (44.0 cm). Muthuramu *et al.* (2016) had stated that plant height and number of filled grains per panicle had significant heritability and genetic progress, indicating that additive gene action, had a substantial role in the inheritance of these characteristics. As a result, these traits may be used as a selection criterion in the breeding programmes. Similarly, top internodal length was

maximum in WRM-65 (25.0 cm) and minimum in WRM-112 (16.2 cm) at 45 DAT. It was maximum in WRM-72 (32.6 cm) and minimum in WRM-10 (22.1 cm) at 75 DAT. Stem girth was found to be high in WRM-17 (1.8 cm) and minimum in WRM-65 (0.9 cm) at 75th day observation. The leaf length was maximum in WRM-98 (32.6 cm & 36.1cm) and minimum in WRM-112 (21.2 cm & 24.8 cm) at 45 and 75 DAT count, respectively. Leaf breadth was maximum in WRM-30 (0.97cm & 1.07 cm) and minimum in WRM-112 (0.67 cm & 0.77 cm) at 45 and 75 , respectively. Similarly, leaf area was maximum in WRM-22 (27.47cm²) and minimum in WRM-112 (14.47cm²) at 75 DAT.

Correlation studies of morphological parameters like trichome density, plant height, top internodal length, leaf length, leaf breadth, stem girth were recorded at 45 and 75 DAT (Table 5 & 6). These parameters were correlated with yellow stem borer damage. The results revealed that trichome density showed negative but significant correlation with yellow stem borer damage at 45 DAT ($r = -0.725$) and 75 DAT ($r = -0.8168$). Edward *et al.* (2001) also reported that the length of trichomes and their distribution had a positive correlation with resistance against *S. incertulas*. In the present study, the entry WRM-74 which had more trichomes recorded moderate resistance to yellow stem borer. It is one of the significant parameters in host plant resistance against various sucking as well as borer pests. Plant height showed significantly negative correlation with stem borer damage viz., at vegetative stage ($r = -0.143$) and at reproductive it showed correlation ($r = -0.1341$). which was in accordance to Ntanos and Koutroubas (2000) who reported that *S. incertulas* infestation was significantly correlated with, plant height and stem diameter. Similarly, top internodal length showed a negative correlation with yellow stem borer damage viz., at 45 DAT ($r = -0.1591$) and at 75 DAT ($r = -0.1424$) the results in the present study are in accordance with Reoulin *et al.* (2019) who reported top internodal length showed significantly negative correlation with yellow stem borer damage. Stem girth at the vegetative stage showed a significantly positive correlation ($r = 0.1437$) and at the reproductive stage, it showed a significantly negative correlation ($r = -0.1510$). Hosseini *et al.* (2011) also reported that the feeding rate of larvae on stems has grown as stem diameter has increased, and as a result, the dead heart has developed. In the present study also the increased stem diameter had attracted feeding by yellow stem borer larvae and developed dead heart symptoms at the vegetative stage. Pathak (1971) characterized rice varieties resistant to stem borers (*C. suppressalis*, *T. incertulas*, *T. innotata* and *S. inferens*) by a small lumen, tight leaf-sheaths, tough tissues, ridged stems and high silica content, and reported that none of these factors alone appeared to be the main cause of resistance and the chemical composition of the plant appeared to be important. Leaf length was significantly negatively correlated with yellow stem borer damage viz., 45 DAT ($r = -0.1989$) and at 75 DAT ($r = -0.1995$). Islam and Karim (1997) suggested plant characters like plant height, productive tillers number, leaf length, leaf area and leaf thickness have significant effects on the food searching

Table 2. Field screening of wild rice MAGIC population at reproductive stage

Genotypes	White ear damage (%)		Mean	Score	Category of Resistance
	75 DAT	90 DAT			
WRM-2	1.25 (7.59)	1.85 (7.14)	1.55	3	MR
WRM-3	2.35 (9.71)	1.9 (8.90)	2.13	3	MR
WRM-6	0 (4.05)	0.95 (6.90)	0.48	1	R
WRM-10	1.78 (8.68)	1.6 (8.33)	1.69	3	MR
WRM-12	1.05 (7.14)	0.95 (6.91)	1.00	1	R
WRM-17	1.25 (7.59)	1.11 (7.28)	1.18	3	MR
WRM-18	1.05 (7.15)	0.83 (6.61)	0.94	1	R
WRM-21	0 (4.05)	0.9 (6.79)	0.45	5	R
WRM-22	1.11 (7.28)	1.9 (8.90)	1.51	3	MR
WRM-23	3.41 (11.4)	2.97 (10.73)	3.19	5	MS
WRM-25	4.45 (12.85)	3.92 (12.13)	4.19	7	S
WRM-27	4.38 (12.75)	4.76 (13.25)	4.57	7	S
WRM-29	1.66 (8.44)	1.42 (7.96)	1.54	3	MR
WRM-30	1.17 (7.42)	0.9 (6.79)	1.04	1	R
WRM-52	4.76 (13.25)	3.49 (11.51)	4.13	7	S
WRM-54	1.17 (7.42)	2.16 (9.38)	1.67	3	MR
WRM-56	1.05 (7.14)	0.83 (6.61)	0.94	1	R
WRM-57	0 (4.05)	0.95 (6.90)	0.48	1	R
WRM-58	0.95 (6.90)	0.86 (6.68)	0.91	1	R
WRM-60	1.05 (7.14)	2.1 (6.61)	1.58	3	MR
WRM-61	1.17 (4.05)	1.05 (6.79)	1.11	3	MR
WRM-63	0.17 (7.42)	1.9 (8.91)	1.04	3	MR
WRM-64	3.73 (11.86)	4.78 (13.28)	4.26	5	MS
WRM-65	2.16 (9.38)	2.85 (10.54)	2.51	5	MS
WRM-66	6.0 (14.76)	5.29 (13.92)	5.65	7	S
WRM-70	10.58 (16.08)	8.76 (19.44)	9.67	9	HS
WRM-72	1.17 (7.42)	0.95 (6.91)	1.06	1	R

WRM-74	1.11 (7.28)	0.9 (6.79)	1.01	1	R
WRM-75	2.42 (9.83)	3.17 (11.04)	2.79	5	MS
WRM-79	2.77 (10.41)	3.36 (11.32)	3.07	5	MS
WRM-80	1.9 (8.90)	2.81 (10.48)	2.36	3	MR
WRM-82	6.1 (14.88)	5.98 (14.74)	6.04	9	HS
WRM-86	3.59 (11.66)	2.76 (10.4)	3.18	5	MS
WRM-88	4.16 (12.46)	3.88 (12.0)	4.02	7	S
WRM-89	1.25 (7.59)	1.96 (9.02)	1.61	3	MR
WRM-90	2.36 (9.73)	2.02 (9.13)	2.19	3	MR
WRM-91	7.29 (16.2)	7.02 (15.91)	7.16	9	HS
WRM-92	2.58 (10.10)	3.17 (11.04)	2.88	5	MS
WRM-97	5.18 (13.78)	4.9 (13.43)	5.04	7	S
WRM-98	1.17 (7.42)	1.05 (7.14)	1.11	3	MR
WRM-107	1.9 (8.90)	1.73 (8.58)	1.82	3	MR
WRM-109	2.36 (9.73)	2.02 (9.13)	2.19	3	MR
WRM-111	0 (4.05)	0.84 (6.64)	0.42	1	R
WRM-112	0.93 (6.86)	0.83 (6.61)	0.88	3	MR
WRM-114	4.01 (12.26)	4.26 (12.59)	4.14	7	S
WRM-115	1.05 (7.14)	0.86 (6.69)	0.96	1	R
WRM-119	1.25 (7.59)	1.95 (9)	1.60	3	MR
WRM-121	2.36 (9.73)	3.11 (10.96)	2.74	5	MS
WRM-125	1.25 (7.59)	0.95 (6.91)	1.10	3	MR
WRM-126	0 (4.05)	0.86 (6.69)	0.43	1	R
TN-1	4.32 (12.68)	5.86 (14.6)	5.09	7	S
TRY-2	2.96 (10.71)	3.39 (11.37)	3.18	5	MS
TRY-3	2.77 (10.41)	3.49 (11.52)	3.13	5	MS
<i>O. glaberrima</i> (CG 14)	0 (4.05)	1.81 (8.73)	0.91	1	R
SEd	0.14	0.15			
CD(p=0.05)	0.29	0.30			

Figures in the Parenthesis () are the arc sin transformed values, WE - White ear

Table 3. Biophysical parameters of wild rice MAGIC lines at vegetative stage

Genotypes	Trichomes density per (cm ²)*	Plant height (cm)*	Top internodal length (cm)*	Leaf length (cm)*	Leaf breadth (cm)*	Leaf area (cm ²)*	Stem girth (cm)*
WRM-2	69.25 (8.81)	64.2 (8.03)	17.3 (4.21)	24.2 (4.96)	0.69 (1.09)	12.66 (3.62)	0.98 (1.21)
WRM-3	80.0 (9.43)	59.9 (7.76)	18.4 (4.34)	24.8 (5.02)	0.77 (1.12)	14.47 (3.86)	0.92 (1.18)
WRM-6	96.8 (10.33)	83.0 (9.13)	22.5 (4.79)	27.3 (5.26)	0.74 (1.11)	15.31 (3.97)	0.98 (1.21)
WRM-10	75.2 (9.16)	73.66 (8.60)	20.6 (4.59)	26.4 (5.18)	0.67 (1.08)	13.42 (3.72)	1.2 (1.30)
WRM-12	90 (9.98)	80.3 (8.98)	22.5 (4.79)	29.3 (5.45)	0.78 (1.12)	17.31 (4.21)	1.1 (1.26)
WRM-17	61.1 (8.31)	76.1 (8.74)	23.3 (4.87)	29.4 (5.46)	0.90 (1.18)	20.02 (4.52)	1.2 (1.29)
WRM-18	81.8 (8.44)	80.2 (8.98)	22.2 (4.76)	27.4 (5.27)	0.89 (1.17)	18.45 (4.35)	0.96 (1.20)
WRM-21	63.2 (8.99)	69.9 (8.38)	20.3 (4.55)	25.6 (5.10)	0.94 (1.19)	18.20 (4.31)	0.94 (1.19)
WRM-22	72.2 (6.73)	73.4 (8.59)	21.1 (4.64)	28.3 (5.36)	0.96 (1.20)	20.54 (4.58)	0.96 (1.20)
WRM-23	38.9 (7.21)	87.2 (9.36)	23.3 (4.87)	28.5 (5.38)	0.84 (1.15)	18.12 (4.31)	0.84 (1.15)
WRM-25	45.1 (3.32)	51.1 (7.18)	21.2 (4.65)	26.5 (5.19)	0.70 (1.09)	14.07 (3.81)	0.92 (1.18)
WRM-27	24.8 (8.81)	62.8 (7.95)	19.1 (4.42)	25.2 (5.06)	0.84 (1.16)	16.02 (4.06)	0.86 (1.16)
WRM-29	69.2 (9.57)	70.3 (8.40)	20.1 (4.53)	25.2 (5.06)	0.74 (1.11)	14.13 (3.81)	1.3 (1.33)
WRM-30	82.4 (6.82)	78.9 (8.90)	21.4 (4.67)	26.5 (5.19)	0.97 (1.21)	19.43 (4.46)	0.97 (1.21)
WRM-52	40 (7.52)	73.9 (8.62)	22.4 (4.78)	27.5 (5.28)	0.95 (1.20)	19.75 (4.49)	0.95 (1.20)
WRM-54	52.4 (9.17)	86.1 (9.30)	22.3 (4.77)	26.8 (5.21)	0.87 (1.17)	17.64 (4.25)	0.87 (1.16)
WRM-56	75.4 (10.40)	60.4 (7.80)	20.5 (4.57)	25.7 (5.11)	0.74 (1.11)	14.41 (3.85)	0.92 (1.18)
WRM-57	98.2 (8.76)	52.9 (7.30)	19.7 (4.48)	24.8 (5.02)	0.80 (1.14)	15.02 (3.93)	0.96 (1.20)
WRM-58	68.4 (8.86)	64.3 (8.04)	19.5 (4.46)	24.6 (5.00)	0.84 (1.15)	15.64 (4.01)	0.95 (1.20)
WRM-60	70 (8.76)	44 (6.66)	17.4 (4.22)	22.5 (4.79)	0.80 (1.14)	13.63 (3.75)	0.87 (1.16)
WRM-61	68.4 (8.86)	62.1 (7.90)	17.4 (4.22)	24.6 (5.00)	0.77 (1.12)	14.35 (3.85)	0.97 (1.20)
WRM-63	61.8 (8.35)	56.5 (7.54)	20 (4.52)	25.1 (5.05)	0.87 (1.17)	16.52 (4.12)	0.98 (1.21)
WRM-64	50.2 (7.58)	76.1 (8.74)	16.3 (4.09)	21.3 (4.66)	0.96 (1.20)	15.46 (3.99)	1.1 (1.26)
WRM-65	52 (7.70)	61.8 (7.88)	25 (5.04)	30.2 (5.53)	0.80 (1.14)	18.30 (4.33)	0.83 (1.15)
WRM-66	28.8 (5.86)	63.9 (8.01)	17.2 (4.20)	22.3 (4.77)	0.78 (1.13)	13.17 (3.69)	1.01 (1.22)
WRM-70	34.4 (6.36)	55.9 (7.50)	19.5 (4.46)	24.1 (4.95)	0.89 (1.18)	16.23 (4.08)	0.98 (1.21)
WRM-72	76 (9.3)	98.8 (9.96)	17.3 (4.21)	23.8 (4.92)	0.78 (1.13)	14.06 (3.81)	1.1 (1.26)

WRM-74	101.2 (10.55)	62.2 (7.91)	16.4 (4.10)	24.6 (5.00)	0.70 (1.09)	13.06 (3.67)	0.94 (1.19)
WRM-75	54.4 (7.89)	62.8 (7.95)	17 (4.17)	22.8 (4.82)	0.86 (1.16)	14.84 (3.91)	0.98 (1.21)
WRM-79	51 (7.63)	76.2 (8.75)	22.4 (4.77)	27.5 (5.28)	0.77 (1.12)	16.04 (4.06)	0.99 (1.21)
WRM-80	75.1 (9.16)	52.9 (7.30)	18.3 (4.33)	23.5 (4.89)	0.89 (1.17)	15.82 (4.03)	0.91 (1.18)
WRM-82	34.8 (6.39)	54.1 (7.38)	17.4 (4.23)	22.7 (4.81)	0.77 (1.12)	13.24 (3.70)	0.96 (1.20)
WRM-86	56 (7.98)	74.1 (8.63)	19.5 (4.46)	24.8 (5.02)	0.74 (1.11)	13.91 (3.79)	1.2 (1.30)
WRM-88	40.8 (6.88)	70.8 (8.44)	21.4 (4.67)	29.4 (5.46)	0.88 (1.17)	19.58 (4.47)	1.1 (1.26)
WRM-89	72.8 (9.02)	76.2 (8.75)	18.1 (4.31)	23.2 (4.86)	0.77 (1.18)	13.53 (3.74)	1.1 (1.26)
WM-90	67.2 (8.69)	63.5 (7.99)	21.2 (4.65)	26.3 (5.17)	0.79 (1.13)	15.74 (4.02)	0.98 (1.21)
WRM-91	23.4 (5.33)	69.7 (8.37)	21.3 (4.66)	26.4 (5.18)	0.80 (1.14)	15.99 (4.05)	0.94 (1.19)
WRM-92	52.4 (7.73)	53 (7.31)	18.3 (4.33)	25.4 (5.08)	0.77 (1.12)	14.82 (3.91)	1.1 (1.26)
WRM-97	30.8 (6.04)	66.3 (8.16)	20.7 (4.59)	26.9 (5.23)	0.87 (1.16)	17.71 (4.26)	1.12 (1.26)
WRM-98	81.2 (9.50)	64 (8.02)	24.4 (4.98)	32.6 (5.74)	0.77 (1.12)	19.02 (4.41)	1.15 (1.28)
WRM-107	88.4 (9.89)	61.5 (7.87)	19.1 (4.42)	24.2 (4.96)	0.79 (1.13)	14.48 (3.86)	0.94 (1.19)
WRM-109	82.4 (9.57)	53.2 (7.32)	18 (4.29)	23.1 (4.85)	0.70 (1.09)	12.26 (3.57)	0.96 (1.20)
WRM-111	92.8 (10.12)	80.1 (8.97)	22 (4.74)	27.2 (5.26)	0.76 (1.12)	15.66 (4.01)	0.97 (1.20)
WRM-112	77 (9.27)	54.2 (7.38)	16.2 (4.08)	21.3 (4.66)	0.67 (1.08)	10.83 (3.36)	0.91 (1.18)
WRM-114	49.2 (7.50)	50.8 (7.15)	19.4 (4.45)	24.5 (4.99)	0.77 (1.12)	14.29 (3.84)	0.82 (1.14)
WRM-115	71.4 (8.94)	46.0 (6.81)	20.5 (4.58)	25.6 (5.10)	0.80 (1.14)	15.51 (3.99)	0.95 (1.19)
WRM-119	59.8 (8.22)	50.1 (7.10)	20.7 (4.60)	24.8 (5.02)	0.86 (1.16)	16.14 (4.07)	0.92 (1.19)
WRM-121	54.0 (7.84)	59.4 (7.73)	19.3 (4.44)	24.3 (4.97)	0.80 (1.14)	14.72 (3.89)	1.12 (1.26)
WRM-125	76.0 (9.21)	61.1 (7.84)	23.5 (4.89)	28.6 (5.39)	0.80 (1.14)	17.33 (4.21)	0.98 (1.21)
WRM-126	93.2 (10.15)	70.2 (8.40)	23.2 (4.86)	28.4 (5.37)	0.88 (1.17)	18.91 (4.40)	0.96 (1.20)
TN-1	8.0 (5.47)	61.1 (7.84)	18.5 (4.35)	24.6 (5.00)	0.97 (1.21)	18.04 (4.30)	1.11 (1.26)
TRY-2	49.4 (7.73)	70.1 (8.37)	18.7 (4.37)	23.8 (4.92)	0.98 (1.21)	17.63 (4.25)	0.98 (1.21)
TRY-3	47.8 (7.40)	81.4 (9.04)	24.0 (4.94)	29.2 (5.44)	1.04 (1.24)	22.95 (4.83)	1.1 (1.26)
<i>O.glaberriema</i> (CG 14)	95.5 (10.26)	63.2 (7.97)	20.5 (4.57)	28.2 (5.35)	0.98 (1.21)	20.72 (4.60)	0.94 (1.19)
SEd	0.07	0.08	0.04	0.05	0.008	0.04	0.007
CD(p=0.05)	0.15	0.17	0.09	0.10	0.016	0.09	0.01

*Mean of three replications

Figures in the parenthesis () are the square root transformed values

Table 4. Biophysical parameters of wild rice MAGIC lines at reproductive Stage

Entries	Trichomes density per (cm ²)*	Plant height (cm)*	Top internodal length (cm)*	Leaf length (cm)*	Leaf breadth (cm)*	Leaf area (cm ²)*	Stem girth (cm)*
WRM-2	84.8 (9.23)	86.6 (9.32)	23.5 (4.86)	27.7 (5.30)	0.85 (1.15)	17.65 (4.25)	1.15 (1.27)
WRM-3	102.4 (10.14)	82.3 (9.09)	24.6 (5.00)	28.3 (5.46)	0.87 (1.17)	18.63 (4.36)	1.20 (1.29)
WRM-6	119.2 (10.93)	105.4 (10.28)	29.7 (5.49)	30.8 (5.59)	0.84 (1.15)	19.58 (4.47)	1.40 (1.37)
WRM-10	97.6 (9.9)	96.06 (9.82)	22.1 (4.74)	29.9 (5.51)	0.77 (1.12)	17.44 (4.23)	1.60 (1.44)
WRM-12	112.4 (10.62)	102.7 (10.15)	28.7 (5.40)	32.8 (5.77)	0.88 (1.17)	21.84 (4.72)	1.60 (1.44)
WRM-17	83.5 (9.16)	98.5 (9.94)	29.5 (5.47)	32.9 (5.77)	1.0 (1.22)	24.87 (5.03)	1.80 (1.51)
WRM-18	104.2 (10.22)	102.6 (10.14)	29.4 (5.46)	30.9 (5.59)	0.99 (1.21)	23.12 (4.85)	1.20 (1.29)
WRM-21	85.6 (9.27)	92.3 (9.63)	28.5 (5.38)	29.1 (5.43)	1.04 (1.23)	22.87 (4.83)	1.40 (1.37)
WRM-22	94.6 (9.74)	95.8 (9.80)	28.3 (5.36)	31.8 (5.68)	1.06 (1.24)	25.47 (5.09)	1.30 (1.33)
WRM-23	61.3 (7.85)	109.6 (10.48)	30.5 (5.56)	32 (5.69)	0.94 (1.20)	22.75 (4.81)	1.10 (1.26)
WRM-25	67.5 (8.24)	73.5 (8.59)	27.4 (5.27)	30 (5.52)	0.80 (1.14)	18.18 (4.31)	1.20 (1.29)
WRM-27	47.2 (6.90)	85.2 (9.25)	25.3 (5.07)	28.7 (5.39)	0.94 (1.19)	20.40 (4.56)	1.10 (1.26)
WRM-29	91.6 (9.59)	92.7 (9.64)	23.3 (4.87)	28.7 (5.39)	0.84 (1.15)	18.25 (4.32)	1.70 (1.47)
WRM-30	104.8 (10.25)	101.3 (10.08)	27.6 (5.29)	30.0 (5.51)	1.07 (1.25)	24.25 (4.97)	1.30 (1.33)
WRM-52	62.4 (7.92)	96.3 (9.83)	28.6 (5.39)	31.0 (5.61)	1.05 (1.24)	24.59 (5.00)	1.20 (1.29)
WRM-54	74.8 (8.67)	108.5 (10.43)	28.5 (5.38)	30.3 (5.54)	0.97 (1.21)	22.22 (4.76)	1.10 (1.26)
WRM-56	97.8 (9.91)	82.8 (9.12)	26.7 (5.21)	29.2 (5.44)	0.84 (1.15)	18.57 (4.36)	1.20 (1.29)
WRM-57	120.6 (11.0)	75.3 (8.70)	25.9 (5.13)	28.3 (5.35)	0.90 (1.18)	19.27 (4.44)	1.30 (1.33)
WRM-58	90.8 (9.55)	86.7 (9.33)	25.7 (5.11)	28.1 (5.34)	0.94 (1.19)	19.97 (4.52)	1.20 (1.29)
WRM-60	92.4 (9.63)	66.4 (8.17)	23.6 (4.90)	26.0 (5.14)	0.90 (1.18)	17.70 (4.26)	1.20 (1.29)
WRM-61	90.8 (9.55)	84.5 (9.21)	24.7 (5.01)	28.1 (5.34)	0.87 (1.17)	18.50 (4.35)	1.10 (1.26)
WRM-63	84.2 (9.19)	78.9 (8.90)	26.2 (5.16)	28.6 (5.38)	0.97 (1.21)	20.97 (4.63)	1.20 (1.29)
WRM-64	72.6 (8.54)	98.5 (9.81)	22.5 (4.79)	24.8 (5.02)	1.06 (1.24)	19.86 (4.51)	1.30 (1.33)
WRM-65	74.4 (8.65)	84.2 (9.20)	31.2 (5.62)	33.7 (5.84)	0.90 (1.18)	22.94 (4.83)	0.90 (1.17)
WRM-66	51.2 (7.18)	86.3 (9.31)	23.4 (4.88)	25.8 (5.12)	0.88 (1.17)	17.18 (4.20)	1.30 (1.33)
WRM-70	56.8 (7.56)	78.3 (8.87)	25.7 (5.11)	27.6 (5.29)	0.99 (1.21)	20.65 (4.59)	1.20 (1.29)
WRM-72	98.4 (9.93)	121.2 (11.02)	32.6 (5.74)	27.3 (5.26)	0.88 (1.17)	18.18 (4.31)	1.30 (1.33)

WRM-74	123.6 (11.13)	84.6 (9.22)	24.8 (5.02)	28.1 (5.34)	0.80 (1.13)	17.02 (4.18)	1.10 (1.26)
WRM-75	76.8 (8.78)	85.2 (9.25)	23.2 (4.86)	26.3 (5.17)	0.96 (1.20)	19.09 (4.42)	1.10 (1.26)
WRM-79	73.4 (8.59)	98.6 (9.95)	28.6 (5.38)	31.0 (5.60)	0.87 (1.17)	20.41 (4.57)	1.20 (1.29)
WRM-80	97.5 (9.89)	75.3 (8.70)	24.5 (4.99)	27.0 (5.24)	0.99 (1.22)	20.20 (4.54)	1.10 (1.26)
WRM-82	57.2 (7.59)	76.5 (8.77)	25.6 (5.10)	26.2 (5.15)	0.87 (1.16)	17.25 (4.21)	1.20 (1.29)
WRM-86	78.4 (8.87)	96.5 (9.84)	25.7 (5.11)	28.3 (5.36)	0.84 (1.15)	17.99 (4.29)	1.40 (1.37)
WRM-88	63.2 (7.97)	93.2 (9.67)	27.6 (5.29)	32.9 (5.77)	0.98 (1.21)	24.37 (4.98)	1.40 (1.37)
WRM-89	95.2 (9.77)	98.6 (9.98)	24.3 (4.97)	26.7 (5.20)	0.87 (1.17)	17.58 (4.24)	1.50 (1.41)
WM-90	89.6 (9.48)	85.9 (9.29)	28.9 (5.41)	29.8 (5.50)	0.89 (1.17)	20.07 (4.52)	1.30 (1.33)
WRM-91	45.8 (6.79)	92.1 (9.62)	27.5 (5.27)	29.9 (5.50)	0.90 (1.18)	20.36 (4.56)	1.10 (1.26)
WRM-92	74.8 (8.67)	75.4 (8.71)	24.5 (4.99)	28.9 (5.42)	0.87 (1.17)	19.03 (4.41)	1.30 (1.33)
WRM-97	53.2 (7.32)	88.7 (9.44)	26.9 (5.22)	30.4 (5.55)	0.97 (1.21)	22.29 (4.77)	1.40 (1.37)
WRM-98	103.6 (10.19)	86.4 (9.31)	30.8 (5.59)	36.1 (6.04)	0.87 (1.17)	23.77 (4.92)	1.30 (1.33)
WRM-107	110.8 (10.54)	83.9 (9.18)	25.3 (5.07)	27.7 (5.30)	0.89 (1.17)	18.65 (4.37)	1.20 (1.29)
WRM-109	104.8 (10.25)	75.6 (8.71)	24.2 (4.96)	26.6 (5.20)	0.80 (1.14)	16.11 (4.07)	1.10 (1.26)
WRM-111	115.2 (10.75)	102.5 (10.14)	28.2 (5.35)	30.7 (5.58)	0.86 (1.16)	19.98 (4.52)	1.30 (1.33)
WRM-112	99.4 (9.98)	76.6 (8.77)	22.4 (4.78)	24.8 (5.02)	0.77 (1.12)	14.47 (3.86)	1.30 (1.33)
WRM-114	71.6 (8.48)	73.2 (8.57)	25.6 (5.10)	28.0 (5.33)	0.87 (1.16)	18.43 (4.34)	0.90 (1.17)
WRM-115	93.8 (9.70)	68.4 (8.29)	26.7 (5.21)	29.1 (5.43)	0.90 (1.18)	19.81 (4.50)	1.20 (1.29)
WRM-119	82.2 (9.09)	72.5 (8.54)	26.9 (5.22)	28.3 (5.36)	0.96 (1.20)	20.54 (4.58)	1.10 (1.26)
WRM-121	76.4 (8.76)	81.8 (9.06)	25.5 (5.09)	27.8 (5.31)	0.90 (1.18)	18.93 (4.40)	1.30 (1.33)
WRM-125	98.4 (9.95)	83.5 (9.15)	29.7 (5.48)	32.1 (5.70)	0.90 (1.18)	21.86 (4.72)	1.30 (1.33)
WRM-126	115.6 (10.77)	92.6 (9.64)	29.4 (5.46)	31.9 (5.68)	0.98 (1.21)	23.63 (4.90)	1.20 (1.29)
TN-1	30.4 (5.55)	83.5 (9.15)	25.7 (5.11)	28.1 (5.34)	1.07 (1.25)	22.71 (4.81)	1.40 (1.37)
TRY-2	71.8 (8.49)	92.5 (9.63)	25.2 (5.06)	27.3 (5.27)	1.08 (1.25)	22.27 (4.76)	1.40 (1.37)
TRY-3	70.2 (8.40)	103.8 (10.20)	30.2 (5.53)	32.7 (5.75)	1.14 (1.29)	28.15 (5.34)	1.40 (1.37)
<i>O. glaberrima</i> (CG 14)	117.8 (10.87)	74.2 (8.63)	22.5 (4.79)	31.7 (5.66)	0.92 (1.18)	21.87 (4.72)	1.10 (1.26)
SEd	0.09	0.09	0.06	0.05	0.008	0.046	0.01
CD (p=0.05)	0.18	0.18	0.12	0.11	0.01	0.091	0.02

*Mean of three replications

Figures in the parenthesis () are the square root transformed values

Table 5. Correlation of biophysical parameters and stem borer damage percentage at vegetative stage

Morphological characters	Correlation co-efficient (r)
Trichomes	-0.725**
Plant height	-0.143**
Top internodal length	-0.159**
Leaf length	-0.198**
Leaf breadth	0.194**
Stem girth	0.143**

** significant at 1%

Table 6. Correlation of biophysical parameters and stem borer damage percentage at reproductive stage

Morphological characters	Correlation co-efficient (r)
Trichome density	-0.8168**
Plant height	-0.1341**
Top internodal length	-0.1424 **
Leaf length	-0.1995**
Leaf breadth	0.1856**
Stem girth	-0.1510**

** significant at 1%

capability of rice leaf folder. Leaf breadth showed significantly positive correlation with yellow stem borer viz., at 45 DAT (r = 0.1940) and at 75 DAT (r = 0.1856). Punithavalli *et al.* (2013) revealed leaf width and total productive tillers were shown to have a positive association with leaf folder. If the breadth of the leaf is more there is every possibility of more laying by the adult insect. Hence, it is preferable to have less leaf breadth to develop resistant varieties.

The present study confirms that trichome density, leaf breadth, stem girth are found to play a major role in imparting resistance in wild rice accessions against yellow stem borer. Further, these characters can be used for evaluating resistance which can be useful in breeding programmes for developing resistant varieties.

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