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Screening of rice germplasm against yellow stem borer, *Scirpophaga incertulas* (Walker) (Crambidae: Lepidoptera)

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Abstract
A total of 215 rice germplasm lines were screened for their relative resistance or susceptibility against rice yellow stem borer, *S. incertulas* for two successive *kharif* seasons (*kharif* 2016 & 2017). The screening trial was executed in augmented block design with 215 rice entries along with local check (BPT 5204) and susceptible check (TN1). The stem borer incidence in terms of per cent dead hearts and per cent white ears at peak infestation were recorded and based of SES scale the status of the rice germplasm screened were determined. The pooled mean of two seasons' data in terms of per cent DH infestation by YSB inferred that out of 215 germplasm lines screened, none of them registered resistance scale, whereas 87 were moderately resistant, 116 were categorized as moderately susceptible and 22 lines exhibited the status of susceptibility with damage rating of 11-20, 21-30 and 31-40 per cent DH. Similarly, the pooled mean with respect to per cent WE revealed that among 215 germplasm lines, only 14 were found to be resistant, whereas 101, 82, 17 and 1 entries were rated as moderately resistance, moderately susceptible, susceptible and highly susceptible entries, with per cent white ears damage ranged from 6-10, 11-15, 16-20 and 30 percent respectively. The rice entries which had expressed moderate resistance against dead hearts were found susceptible to white ear damage and vice versa confirming both the parameters as independent factors in conferring resistance. Keeping in view the parameters (DH & WE) influence on rice yield, seven germplasm lines (IC No. 381538, 450535, 463380, 464140, 464186, 574807 and 578388) with resistance/ moderately resistant reaction at both vegetative (DH) and reproductive (WE) stages of the rice crop were selected as promising rice genotypes for further breeding programmes.

Keywords: Rice germplasm, yellow stem borer, screening, augmented block design

Introduction
Rice cultivation constitutes about 52 per cent of the total food grain production in our country [1]. Among the rice growing countries of the world, India occupies largest acreage being second in production after China. In India, rice was cultivated in 43.39 M ha with an annual production of 104.32 M t of rice with an average productivity of 2.40 t ha^{-1} for the year 2016-17. In Andhra Pradesh for the year 2015-16, rice crop was cultivated in an area of 2.16 M ha with a production of 7.49 M t and productivity of 3466 Kg ha^{-1} [2]. Rice stem borers alone contribute yield loss of 5-10 per cent in Asian countries [3]. The yellow stem borer (YSB), *Scirphophaga incertulas* (Crambidae: Lepidoptera) is considered to be the focal and destructive pest of rice resulting in an annual yield loss of 27-34 per cent [4]. The larval feeding of stem borer and their subsequent inter nodal penetration during vegetative and reproductive stages of rice results in characteristic symptom of dead hearts and white ears, respectively [5]. The dead hearts and white ears symptoms equally attribute to yield losses in rice cultivation. The investigations to identify the new sources of resistant genotypes is an important component in rice integrated pest management (IPM) as the host plant resistance mechanism is compatible with all the methods of pest control [6]. It was quite ambiguous to judge the resistance or susceptibility of rice germplasm lines depending on a single parameter of dead heart or white ear symptoms as the varieties exhibiting resistance at dead heart stage were found susceptible at white ear stage indicating that the resistance at both the stages are independent [7]. Hence, a field experiment was executed and screened 215 entries of rice for relative resistance or susceptible reaction against yellow stem borer, *S. incertuals.*

Material and methods

A set of 215 entries of rice germplasm with indigenous collection number (I C No.) supplied by Indian Institute of Rice Research (IIRR), Rajendranagar, Hyderabad were screened against rice yellow stem borer, *S. incertulas* at Agricultural Research Station, Garikapadu for two successive seasons *i.e*., *kharif*, 2016 and *kharif*, 2017 to determine the relative susceptibility or resistance against the rice yellow stem borer, *S. incertulas*. The Augmented Block Design ABD [8]. was used for the experiment to screen 215 rice germplasm accessions along with susceptible check and local check. The susceptible check (TN1) and local check (BPT 5204) were transplanted after every fifteen entries. Each entry with two seedlings per hill in two rows of 20 hills with 5.0 m length was transplanted.

The incidence of per cent dead hearts (% DH) and per cent white ears (%WE) were recorded at the peak infestation during the vegetative stage and reproductive stage of the rice crop, respectively on the germplasm entries and check varieties.

The observations were recorded from ten randomly selected hills per entry and the per cent dead heart and white ear were calculated as follows.

$$\text{DH per cent} = \frac{\text{Total number of dead hearts in 10 hills}}{\text{Total number of tillers (dead hearts + healthy tillers) in 10 hills}} \times 100$$

$$\text{WE per cent} = \frac{\text{Total number of white ears in 10 hills}}{\text{Total number of tillers (white ears + healthy tillers) in 10 hills}} \times 100$$

Based on the damage rating and scale the status of rice germplasm towards resistance or susceptibility was determined by following the IRRI Standard Evaluation System (SES) for rice (IRRI, 2002) (Table 1 & 2). The phenotypic variations in the entries screened may be attributable to the effect of the environment on the expression and function of genes influencing the trait. Hence, the genotypical, phenotypical and environmental correlation matrix for both the seasons regarding per cent dead hearts and white ears were also assessed.

Table 1: SES for screening rice yellow stem borer in terms of per cent dead hearts

Per cent dead hearts (%DH)		
Damage (%)	**Scale**	**Status**
0	0	Highly Resistant (HR)
1-10	1	Resistant (R)
11-20	3	Moderately Resistant (MR)
21-30	5	Moderately Susceptible (MS)
31-60	7	Susceptible(S)
61 & above	9	Highly Susceptible (HS)

Table 2: SES for screening rice yellow stem borer in terms of per cent white ears

Per cent white ears (% WE)		
Damage (%)	**Scale**	**Status**
0	0	Highly Resistant (HR)
1-5	1	Resistant (R)
6-10	3	Moderately Resistant (MR)
11-15	5	Moderately Susceptible (MS)
16-25	7	Susceptible(S)
26 & above	9	Highly Susceptible (HS)

Results and discussions

The peak infestation of yellow stem borer (YSB) in terms of per cent dead hearts (% DH) was noticed at 45 days after transplantation (DAT) during *kharif*, 2016 and at 55 DAT during *kharif*, 2017. Whereas, the maximum per cent white ear (%WE) damage by YSB during reproductive stage of the crop was recorded at 125 and 130 DAT, during *kharif* 2016 and *kharif* 2017, respectively.

Field screening of rice germplasm lines against yellow stem borer in terms of per cent dead hearts

During *kharif*, 2016 among the 215 rice entries screened for susceptibility reaction against rice yellow stem borer, 81 entries exhibited the scale '3' with status of moderate resistance (MR) and the per cent DH in MR entries ranged from 10.5 (C-858) to 20.4 (C-27). A total of 107 germplasm lines exhibited moderately susceptible (MS) reaction with per cent DH damage ranged between 20.5 (C-692) and 30.1 (C-1180) and rated with scale '5'. Whereas, 27 rice entries found susceptible (scale 7) to YSB damage with per cent DH ranged from 30.5 to 39.8. In check varieties the per cent DH were recorded as 42.2 and 32.8 in TN1 and BPT 5204, respectively with susceptible status (scale 7). The frequency distribution of per cent dead hearts damage in various rice germplasm lines during *kharif*, 2016 was depicted in Fig.1.

During *kharif*, 2017 out of 215 rice accessions evaluated, only one entry (C-599) witnessed resistance (R) status with 10.3 per cent DH damage. A sum of 93 and 99 germplasm entries were moderately resistant (10.6-20.4% DH) and moderately susceptible (20.5-30.4% DH) against rice YSB. While, 22 germplasm lines were categorized as susceptible (S) entries with damage more than 31 per cent DH (scale 7). In check varieties the damage scale was '7' in TN1 (35.1% DH) and '5' in BPT 5204 (26.9% DH) with susceptible (S) and moderately susceptible (MS) pest reaction, respectively. The various rice germplasm lines screened during *kharif*, 2017 against YSB and their frequency distributions were depicted in Fig. 2.

The pooled mean of two season's data with respect to per cent DH inferred that among 215 germplasm lines evaluated for relative resistance or susceptibility against rice YSB, 87 entries found moderately resistant (11-20% DH), 106 were categorized as moderately susceptible (21-30% DH) and 22 lines exhibited susceptible scale '7' with damage rated between 31-40 per cent DH. The lowest per cent dead hearts (11.0) were recorded in C-858 and C-1372 rice entries as against highest in C-358 and C-391 with 40.0 per cent DH, respectively.

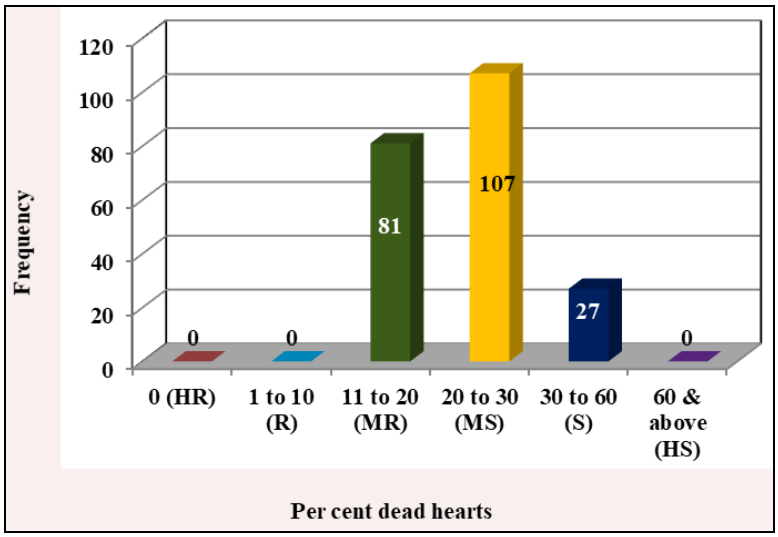

Fig 1: The frequency distribution of rice germplasm lines against yellow stem borer, *S. incertulas* in terms of per cent dead hearts during *kharif*, 2016

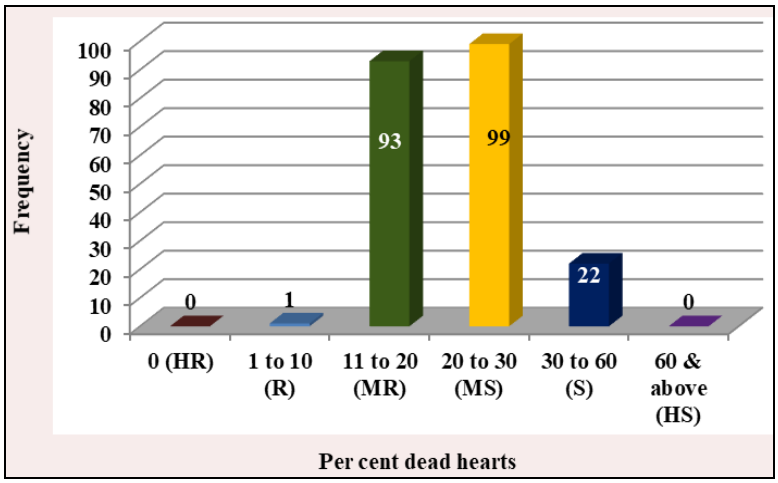

Fig 2: The frequency distribution of rice germplasm lines against yellow stem borer, *S. incertulas* in terms of per cent dead hearts during *kharif*, 2017

From the ABD ANOVA summary for per cent dead hearts (Table 3), it was evident that all the entries differed significantly between themselves during both *kharif*, 2016 and *kharif*, 2017 seasons. For *kharif*, 2016 the mean sum of squares (MSS) for per cent DH was higher in checks (662.69) compared to germplasm (37.95) as both the checks expressed DH damage more than 30 per cent and found susceptible (scale 7). The MSS (5591.66) was found significantly highest in checks vs. germplasm lines and revealed significant differences among the test entries. Similarly, for *kharif*, 2017 also there was a significant difference among 215 entries and checks varieties with 495.32, 39.89 (positive but non-significant) and 2097.23 MSS in checks, germplasm lines and checks vs. germplasm lines variances, respectively.

Table 3: ANOVA summary for augmented block design against per cent dead heart infestation by yellow stem borer infesting rice

Source of variance	df	MSS	
		***Kharif* 2016**	***Kharif* 2017**
Block (ignoring treatments)	14	68.05**	56.04
Treatment (eliminating blocks)	216	66.78**	55.28
Checks	1	662.69***	495.32*
Checks+ germplasm lines vs. germplasm lines	215	64.01**	53.23
Error	14	16.83	65.17
Block (eliminating check + germplasm line)	14	71.50**	113.98
Entries (ignoring blocks)	216	66.55**	51.52
Germplasm lines	214	37.95*	39.89
Checks vs. germplasm lines	1	5591.66***	2097.23***
Error	14	68.05	56.04

Significance Levels * = <0.05, ** = <0.01 & *** = <0.001

Field screening of rice germplasm lines against yellow stem borer in terms of per cent White ears

It was quite remarkable to note that during the period of study, the rice entries which expressed moderate resistance (MR) against dead hearts during vegetative stage were found susceptible (S) to white ears damage at reproductive stage and vice versa.

The white ears damage due to YSB incidence had ranged from 2.4 to 31.5 per cent during *kharif*, 2016 and the frequency distribution was depicted in Fig. 3. Among the 215 germplasm lines assessed, 12 lines expressed resistance status (scale 1) with less than 5 per cent WE damage. The lowest per cent WE damage was noticed in C-1433 (2.4) followed by C-1464 (3.6) rice entries as against highest incidence recorded in C-490 (31.5% WE) attaining the status of highly susceptible (HS) with scale 9. A total of 12, 95, 73, 34 and one germplasm line registered the pest status of resistance (scale 1), moderately resistance (scale 3), moderately susceptible (scale 5), susceptible (scale 7) and highly susceptible (scale 9), respectively during *kharif*, 2016.

The consequent resistance reactions of various rice germplasm lines screened against YSB in terms of per cent WE during *kharif*, 2017 revealed that 29 entries were resistant (R), 105 entries were moderately resistant (MR), 58 were moderately susceptible (MS) and 22 were susceptible (S) and only one was highly susceptible (HS) with a damage range of 2.3-5.3, 5.6-10.4, 10.5-14.8, 15.6-21.8 & 29.3 per cent WE, respectively. The frequency distribution of per cent WE during *kharif*, 2017 was depicted in Fig. 4. The lowest and highest per cent WE were recorded in C-1398 & C-490 with 2.3 and 29.3 per cent, respectively. The per cent WE damage recorded in check varieties TN1 (susceptible) and BPT 5204 (susceptible/ moderately susceptible) were 22.7, 17.6 and 17.0 & 14.6 during *kharif*, 2016 and *kharif*, 2017 respectively (Table 4.3).

The summative mean of per cent white ear damage for two *kharif* seasons revealed that out of 215 rice germplasm lines assessed, 14 entries registered stem borer incidence less than 5.0 per cent and categorized as resistant entries (R). A total of 101, 82 and 17 entries were rated as moderately resistant (MR), moderately susceptible (MS) and susceptible (S) with per cent white ears damage ranged from 6-10, 11-15 and 16-20 per cent, respectively. One entry (C-490) had exhibited highly susceptible (HS) status with 30 per cent WE as against the lowest in C-1433 and C-1464 entries with only 3.0 per cent WE damage. The average per cent WE recorded in susceptible check (TN1) and local check (BPT 5204) were 20.14 and 15.77 per cent WE, respectively with susceptible reaction to the pest (scale7).

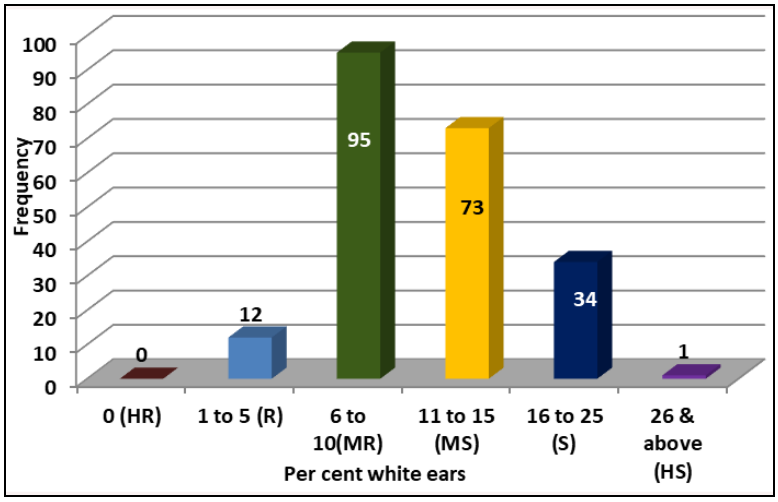

Fig 3: The frequency distribution of rice germplasm lines against yellow stem borer, *S. incertulas* in terms of per cent white ears during *kharif*, 2016

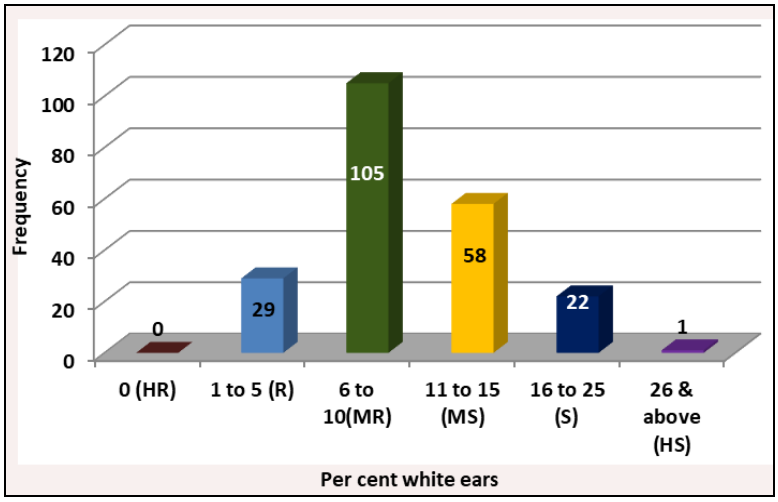

Fig 4: The frequency distribution of rice germplasm lines against yellow stem borer, *S. incertulas* in terms of per cent white ears during *kharif*, 2017

The ANOVA summary of ABD in relation to per cent white ears clearly witnessed significant difference among the germplasm lines and check entries (Table 4). During *kharif*, 2016 and *kharif*, 2017 the magnitude of mean sum of squares (MSS) in relation to per cent WE was higher for checks (245.39 & 68.40) compared to germplasm lines (17.66 & 16.85). The MSS for variance of checks vs. germplasm lines was high with 1928.62 & 1021.10 per cent respectively for *kharif* 2016 and *kharif* 2017, respectively.

Table 4: ANOVA summary for augmented block design against per cent white ears infestation by yellow stem borer infesting rice

Source of variance	df	MSS	
		***Kharif* 2016**	***Kharif* 2017**
Block (ignoring treatments)	14	34.6	32.16
Treatment (eliminating blocks)	216	29.58	24.44*
Checks	1	245.39**	68.40*
Checks+ germplasm lines vs. germplasm lines	215	28.57	24.24
Error	14	14.49	8.14
Block (eliminating check + germplasm line)	14	65.52**	73.95***
Entries (ignoring blocks)	216	27.56	21.73*
Germplasm lines	214	17.66	16.85
Checks vs. germplasm lines	1	1928.62***	1021.10***
Error	14	14.49	8.14

Significance Levels * = <0.05, ** = <0.01 & *** = <0.001

The characteristic symptoms of rice yellow stem borer *i.e.*, dead hearts and white ears equally attribute to yield losses in rice crop. It was quite ambiguous to judge the resistance or susceptibility of rice germplasm lines depending on a single parameter (DH/ WE). From the present studies, it was inferred that only few rice entries registered resistance scale with regards to both DH and WE parameters. Hence, keeping in view of both the parameters (DH & WE) influence on rice yield, seven germplasm lines were selected out of 215 entries screened, which had exhibited resistance/ moderately resistant reaction against YSB damage at both vegetative (DH) and reproductive (WE) stages of the rice crop.

The selected seven promising germplasm lines were C-497, C-685, C-858, C-901, C-903, C-1247 and C-1372 with indigenous collection number (IC no) 381538, 450535, 463380, 464140, 464186, 574807 and 578388, respectively (Table 5).

Table 5: The promising rice germplasm lines against yellow stem borer, *S. incertulas*

S. No.	IC No.	Dead hearts						White ears					
		***kharif* 2016**		***kharif* 2017**		**Mean**		***kharif* 2016**		***kharif* 2017**		**Mean**	
		% DH	**Status**	**% DH**	**Status**	**% DH**	**Status**	**% WE**	**Status**	**%WE**	**Status**	**% WE**	**Status**
1	381538	11.6	MR	14.3	MR	13	MR	10.8	MS	10.1	MR	10	MR
2	450535	16.9	MR	11.4	MR	14	MR	6.5	MR	3.5	R	5	R
3	463380	10.5	MR	10.8	MR	11	MR	4.3	R	2.9	R	4	R
4	464140	16.9	MR	13.4	MR	15	MR	5.6	MR	5.0	R	5	R
5	464186	16.8	MR	13.4	MR	15	MR	4.3	R	4.0	R	4	R
6	574807	16.3	MR	13.2	MR	15	MR	6.1	MR	4.1	R	5	R
7	578388	11.9	MR	10.8	MR	11	MR	4.0	R	3.2	R	4	R

MR: Moderately Resistant

R: Resistant

Similar investigations were made by many researchers to identify the source of resistance for yellow stemborer infesting rice. Screening of rice cultures against YSB [9] also confirmed that the genotype CB 08504 recorded lowest per cent DH (1.48) with the resistance rating of '1' followed by TM 08610 (4.65% DH) and CB 06651 (5.10% DH). The genotype AD 08142 had recorded lowest % WE (1.25) and significantly differed from all other cultures, followed by ADT (R) 46 and TNRH 206 with 5.40 and 5.62 per cent WE, respectively. Prasad and co workers [10] evaluated 55 promising rice genotypes against YSB along with susceptible check variety (TN1) and resistant check (variety Suraksha) and inferred that genotypes RP-Bio-Patho-02, BPT-5204 and R-DRR-02 were promising and highly resistant with 0.67, 0.78 and 1.22 per cent mean YSB infestation in comparison to susceptible check and resistant check with 20.69 and 5.22 per cent mean YSB infestation, respectively. Rishikesh and his associates [11] also screened 73 rice genotypes under field conditions during *kharif* 2016 and 2017 against YSB and inferred that lowest WE (pooled mean) were recorded in IR 36, R 1700-302-1-156-1, Shyamla and IR 64 with 0.0, 0.17, 0.17 & 0.17 per cent WE per plant on each genotypes, respectively.

Conclusions

Among 215 rice accessions screened, seven entries (IC No. 381538, 450535, 463380, 464140, 464186, 574807 and 578388) were promising with moderate resistance/ resistance to yellow stem borer both in terms of per cent dead hearts and white ears. The selected promising rice germplasm against yellow stem borer from the present investigations can be further studied at genomic level. The molecular characterisation and identification of QTLs for resistance against YSB through molecular markers may be utilised for introgression of resistant genes in the breeding programmes of rice cultures.

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