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Screening of paddy genotypes to *Sitotroga cerealella* (Oliver) by free choice method

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Abstract
A laboratory experiment on screening of paddy genotypes was conducted at Department of Entomology, Agricultural College, Bapatla during, 2021-2022 to find out the resistant genotypes against Angoumois grain moth, *Sitotroga cerealella.* A total of 38 released and pre released paddy genotypes were screened for their susceptibility to *S. cerealella*. Screening was done in free choice test. In free choice test the paddy genotypes *viz.*, MTU-1290, NLR-30491, NLR-28600 when screened against *S. cerealella* recorded a prolonged mean developmental period, lower susceptibility index (6.57-7.04) with lesser adult emergence, were categorized as “Susceptible” varieties. Remaining all the varieties were found to be falling under the category of moderately resistant and highly susceptible to *S. cerealella* infestation. The per cent weight loss of paddy genotypes due to infestation by *S. cerealella* were ranged from 0.88 to 14.28% in free choice test. Similarly, the per cent grain damage of paddy genotypes due to infestation by *S. cerealella* were ranged from 1.33 to 11.33% in free choice test.

Keywords: Angoumois grain moth, resistant, susceptible, free choice test

1. Introduction
Rice (*Oryza sativa* L.) is the most important grain with regard to human nutrition and calorific intake, providing the source for more than one fifth of the calories consumed by the human beings. India ranks second world-wide in the production of rice, with a share of 22% of the total world rice production.

Storage pests can cause serious losses up to twenty per cent or more in developing countries (Pimentel, 1991) [9]. During storage, paddy is highly vulnerable to infestation by a variety of insect pests and diseases. Among these, Angoumois grain moth, *Sitotroga cerealella* (Oliver) is the most destructive pest of stored paddy, also known to damage the grains of other stored cereals such as wheat, maize, sorghum, oat and barley. The harm caused by the pest's larvae, which bore into the grains and consume between 30 and 50 percent of their contents, is what causes the loss of germination, foul odour, and ugly appearance. Several researchers have examined the relative resistance of a few well-known paddy types to *S. cerealella* in a lab setting (Abraham *et al.*, 1972; Sardar, 1975) [1, 13]. Therefore, it is necessary to screen novel varieties of paddy to determine their degrees of resistance to *S. cerealella*.

2. Materials and Methods
The experimental procedures adopted to carry out research work entitled “Studies on management of Angoumois grain moth, *Sitotroga cerealella* (Oliver) (Lepidoptera: Gelechiidae) in stored paddy” are elaborated in this chapter. Experiments were carried at the Department of Entomology, Agricultural College, Bapatla, Guntur District, Andhra Pradesh during 2021-2022.

Screening of paddy genotypes to *S. cerealella* was studied by collecting paddy genotypes were collected from three important Rice research stations located in Andhra Pradesh *viz.*, Agricultural Research Station (ARS) Bapatla, Agricultural Regional Station (ARS) Nellore, Regional Agricultural Research Station (RARS) Maruteru. A total of 38 paddy genotypes (15 from RARS Maruteru, 8 from ARS Bapatla, 15 from ARS Nellore) were collected and kept separately for screening experiments (Table 1).

The screening experiment was done by free choice method. In free-choice test, the relative preference of *S. cerealella* to different genotypes of paddy were observed, where the insects were allowed to choose their preferred one of grains. Fifty grams of each rice genotype were taken in individual plastic cups and all were arranged equidistantly in a circle in a plastic tray.

Table 1: Paddy genotypes used for screening against *S. cerealella*

Location	No. of Genotypes	Paddy Genotypes
RARS, Maruteru	15	MTU-1190, MTU-3626, MTU-1184, MTU-1290, MTU-7029, MTU-1217, MTU-1075, MTU-1010, MTU-1001, MTU-1071, MTU-1187, MTU-1156, MTU-1166
ARS, Bapatla	8	BPT-1235, BPT-2824, BPT-2776, BPT-2846, BPT-2595, BPT-5204, BPT-2766, BPT-2295
ARS, Nellore	15	NLR-20104, NLR-20084, NLR-3041, NLR-34449, NLR-3083, NLR-145, NLR-40024, NLR-30491, NLR-33892, NLR-33358, NLR-9674, NLR-28600, NLR-28523, NLR-40058, NLR-33671

80 newly emerged adults were released in the middle to choose the grains of their choice and were closed immediately with another tray and both the trays were secured tightly with binder clips. The adults were removed after their death and the grains were transferred into individual jars. The jars were kept undisturbed till the emergence of adults under laboratory conditions. Day wise adult emergence were recorded from the first day of adult emergence onwards till cessation. The date and no. of adults emerged were noted daily to work out the Mean Development Period (MDP), Susceptibility Index (SI), Per cent grain damage and Per cent weight loss.

2.1 Data Collection and Statistical Analysis
2.1.1 Median Development Period (MDP)
Mean developmental period is the time taken for 50 percent emergence of the adults from the medium. It was measured by taking the daily counts of the adult emergence after introduction. Emerging adults were collected daily and the number of F1 adults emerging from each sample was counted till the emergence ceased. From this, the mean developmental period (days) in different genotypes was calculated.

$$\text{MDP} = \frac{\text{d1a1+d2a2+d3a3......+dnan}}{\text{Total no.of adults emerged}} \times 100$$

d1=day on which the moths started to emerge (day1)
a1=Number of moths emerged on d1th day (1st day)

2.1.2 Per cent grain content loss
The final weight of the treatments was recorded to calculate the weight loss in individual treatment due to the development of *S. cerealella.* The percent grain loss was calculated as mentioned below

$$\text{Weight Loss (\%)} = \frac{\text{W1}-\text{W2}}{\text{W1}}\times 100$$

W1 = Initial weight of grains W2=Final weight of grains

2.1.3 Per cent damaged grain
After recording weight loss, a sample of 5g was taken from each treatment in which total number of grains and number of damaged grains were counted. Per cent damaged grain was calculated as follows.

$$\text{Per cent damaged grain} = \frac{\text{Number of damaged grains found}}{\text{Total number of grains observed}}\times 100$$

2.1.4 Susceptibility Index
It is an important characteristic that indirectly determines the development of moth. It involves the F_1 progeny number and length of median developmental time.

$$\text{SI} = \frac{\text{LogF}}{\text{D}}\times 100$$

F_1-Total number of F_1adults; D-Median Development Period

2.2 Statistical Analysis
The data on per cent adult emergence, total number of adults emerged, mean development period and per cent grain damage, per cent weight loss were subjected to suitable transformations, and then subjected to ANOVA (CRD) (Snedecor and Cochran, 1967) [14].

3. Results
3.1 Screening of different paddy genotypes against *S. cerealella*
A total of 38 released and pre released paddy genotypes were screened under laboratory conditions for their reaction to Angoumois grain moth, *S. cerealella* by following free choice test. During the screening process, number of adults emerged, mean developmental period, susceptibility index of grains, per cent damage, per cent weight loss were recorded for all the genotypes.

3.1.1 Free Choice Test
3.1.1.1 Adult Emergence
The number of *S. cerealella* adults varied from 6.33 to 25.67 per 50 g of the each paddy genotype. The minimum number of adult emergence was noticed in MTU-1290 (6.33), NLR-28600 (6.67), NLR-30491 (7.00), MTU-1184 (7.33), BPT-2776 (7.33), NLR-33671 (7.67) which were significantly different from other paddy genotypes. These were followed by NLR-40058 (8.00), NLR-3041 (9.33), BPT-2824 (9.67). Maximum adult emergence was noticed in MTU-1166 (25.67), BPT-5204 (22.33), BPT-2295 (20.00) which were significantly different from other genotypes, followed by MTU-1187 (18.33), MTU-1262 (17.67), NLR-40024 (17.67), MTU-1010 (17.33). In the remaining genotypes, adult emergence varied from 10.00 to 16.33. (Table 2. and Fig 1).
The observations of the present study are in conformity with earlier findings of Mishu (2015) [16] who reported that highest number of adult emergence in BRRI dhan 50 (77.67) and lowest number of adult emergence in BR 11 (27.67). Ahamed and Raza (2010a) recorded the maximum number of moth emergence 34N43 and Golden (10.33) and minimum moth emergence in China-1 (3.66). The higher adult emergence was noticed in most susceptible genotypes than the least susceptible genotypes.

Table 2: Screening of paddy genotypes against *S. cerealella* infestation through free choice test

S. No.	Genotypes	No. of adults emerged	Mean Development Period (days)*	Susceptibility Index	Group
1	MTU-1190	11.33 (3.44)	25.06	9.69	S
2	MTU-3626	13.00 (3.67)	24.18	10.61	HS
3	MTU-1184	7.33 (2.79)	27.52	7.24	S
4	MTU-1290	6.33 (2.61)	28.08	6.57	MR
5	MTU-7029	11.67 (3.47)	25.92	9.48	S
6	MTU-1217	13.00 (3.67)	24.74	10.37	HS
7	MTU-1075	14.67 (3.89)	25.05	10.72	HS
8	MTU-1010	17.33 (4.22)	23.24	12.27	HS
9	MTU-1001	15.00 (3.92)	24.01	11.28	HS
10	MTU-1071	16.33 (4.10)	23.52	11.88	HS
11	MTU-1187	18.33 (4.34)	23.81	12.22	HS
12	MTU-1156	10.00 (3.24)	24.63	9.35	S
13	MTU-1166	25.67 (5.11)	20.88	15.54	HS
14	MTU-1262	17.67 (4.26)	22.95	12.51	HS
15	MTU-2077	12.00 (3.52)	25.16	9.88	S
16	NLR-20104	16.33 (4.10)	23.37	11.95	HS
17	NLR-20084	14.67 (3.89)	22.88	11.74	HS
18	NLR-3041	9.33 (3.13)	26.09	8.56	S
19	NLR-34449	13.33 (3.71)	23.99	10.80	HS
20	NLR-3083	11.67 (3.47)	24.46	10.05	S
21	NLR-145	13.33 (3.72)	24.06	10.76	HS
22	NLR-40024	17.67 (4.26)	22.82	12.58	HS
23	NLR-30491	7.00 (2.73)	27.65	7.04	MR
24	NLR-33892	13.67 (3.75)	22.89	11.43	HS
25	NLR-33358	14.00 (3.80)	23.84	11.07	HS
26	NLR-9674	16.00 (4.05)	22.64	12.25	HS
27	NLR-28600	6.67 (2.67)	27.84	6.82	MR
28	NLR-28523	12.33 (3.57)	23.21	10.82	HS
29	NLR-40058	8.00 (2.90)	26.54	7.84	S
30	NLR-33671	7.67 (2.85)	26.95	7.56	S
31	BPT-1235	11.33 (3.44)	24.83	9.78	S
32	BPT-2824	9.67 (3.18)	25.14	9.03	S
33	BPT-2776	7.33 (2.79)	27.10	7.35	S
34	BPT-2846	11.67 (3.48)	23.85	10.30	HS
35	BPT-2595	13.33 (3.70)	25.01	10.36	HS
36	BPT-5204	22.33 (4.78)	21.56	14.41	HS
37	BPT-2766	10.00 (3.24)	24.26	9.49	S
38	BPT-2295	20.00 (4.52)	22.03	13.60	HS
Mean		13.079 (3.631)			
S.Em		0.157			
CD (0.05)		0.443			
CV %		7.501			

*Values are means of three replications
Figures in parenthesis of square transformed values
MR-Moderately Resistant (6.57-7.04)
S-Susceptible (7.51-9.74)
HS-Highly Susceptible (10.18-16.38)
(MTU-Maruteru; BPT-Bapatla; NLR-Nellore

3.1.1.2 Mean developmental period (days)

The average mean developmental period of *S. cerealella* was 24.52 days and it ranged from 20.88 to 28.08 days. Longer mean developmental period of 28.08 days was recorded in MTU-1290 followed by NLR-28600 (27.84), NLR-30491 (27.65), MTU-1184 (27.52), BPT-2776 (27.10), NLR-33671 (26.95), NLR-40058 (26.54). Shorter mean developmental period of 20.88 days was recorded in MTU-1166 followed by BPT-5204 (21.56), BPT-2295 (22.03), NLR-9674 (22.64), NLR-40024 (22.82), NLR-20084 (22.88). In the remaining genotypes mean developmental period was varied from 22.89 to 26.09 days. (Table 2.) (Fig. 2)

The present results are in agreement with those of Kumar *et al.* (2020) [6] who reported that mean development period of *S. cerealella* ranged from 25.00 to 39.40 days on different paddy genotypes. The mean development period was found minimum in Tarori Basmati (25.00 days) and maximum in Manipuri black (39.50 days). The prolonged mean developmental period was observed in the least susceptible genotypes than the susceptible genotypes.

3.1.1.3 Susceptibility index

The susceptibility indices of different paddy genotypes against *S. cerealella* ranged from 6.57 to 15.54. The susceptibility index of MTU-1290 (6.57) was the lowest and followed by NLR-28600 (6.82), NLR-30491 (7.04), MTU-1184 (7.24), BPT-2776 (7.35). Highest susceptibility index was noticed in MTU-1166 (15.54) followed by BPT-5204 (14.41), BPT-2295 (13.60), NLR-40024 (12.58), MTU-1262 (12.51), MTU-1010 (12.27), NLR-9674 (12.25). In other genotypes, susceptibility index ranged from 7.56 to 12.22. (Table 2, Fig 3). The present results conform to the earlier findings of Kumar *et al.* (2020) [6] who documented the susceptibility index ranging from 3.95 in variety Manipuri black to 9.29 in Tarori Basmati against *S. cerealella* on different paddy genotypes. Muthukumar (2014) [8] also reported that susceptibility index ranged from 9.80 to 19.19. The lowest susceptibility index was noticed in BPT-2689 (PR) (9.80) and highest was noticed in BPT-2295 (19.19). The different paddy genotypes screened against *S. cerealella* in the present study with the lower and higher values of susceptible index can be considered as the least and highly susceptible genotypes to *S. cerealella*, respectively.

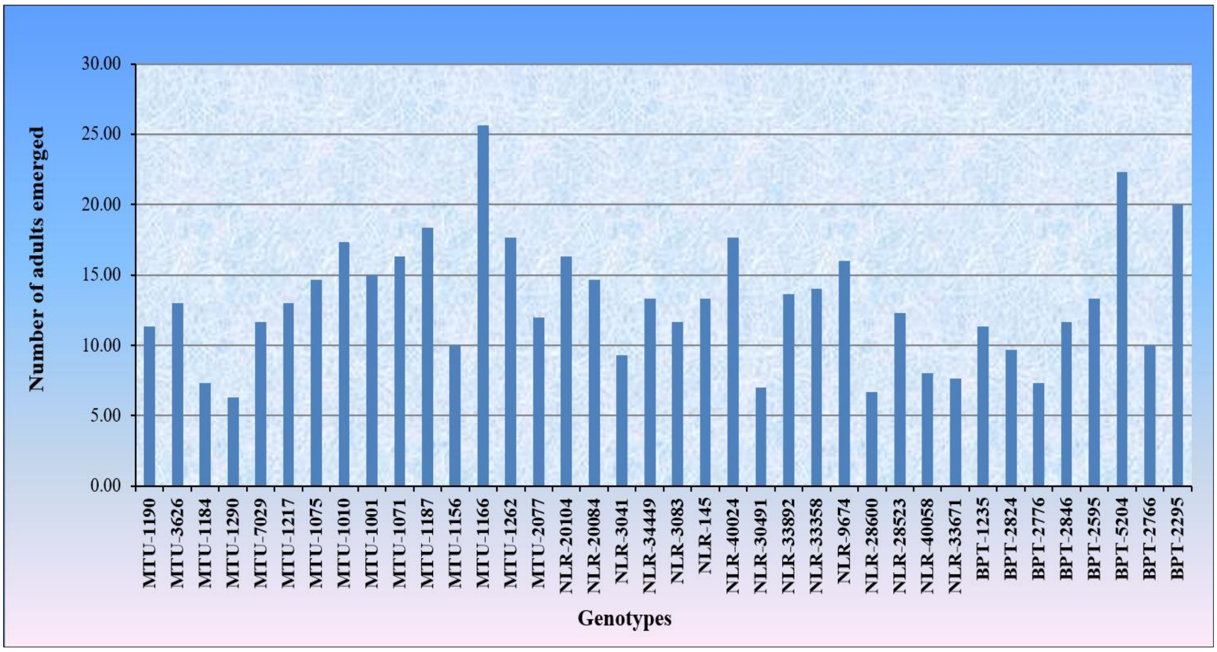

Fig 1: Adult emergence of *S. cerealella* in different paddy genotypes in free choice test

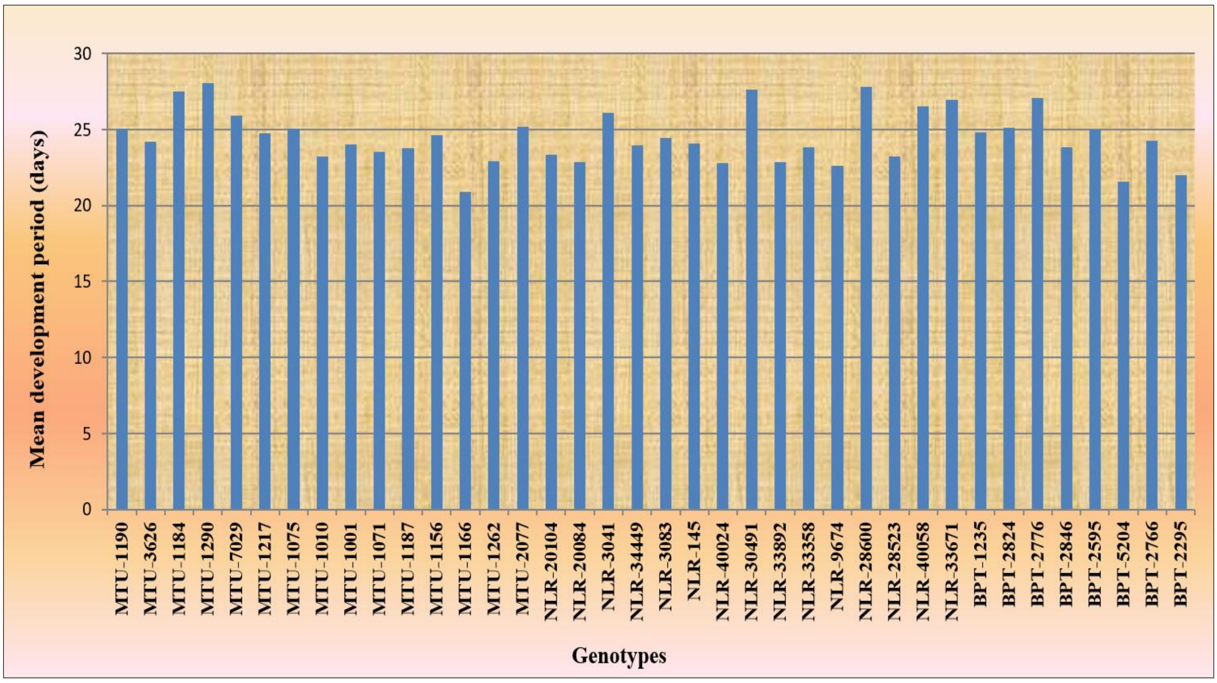

Fig 2: Mean developmental period of *S. cerealella* in different paddy genotypes in free choice test

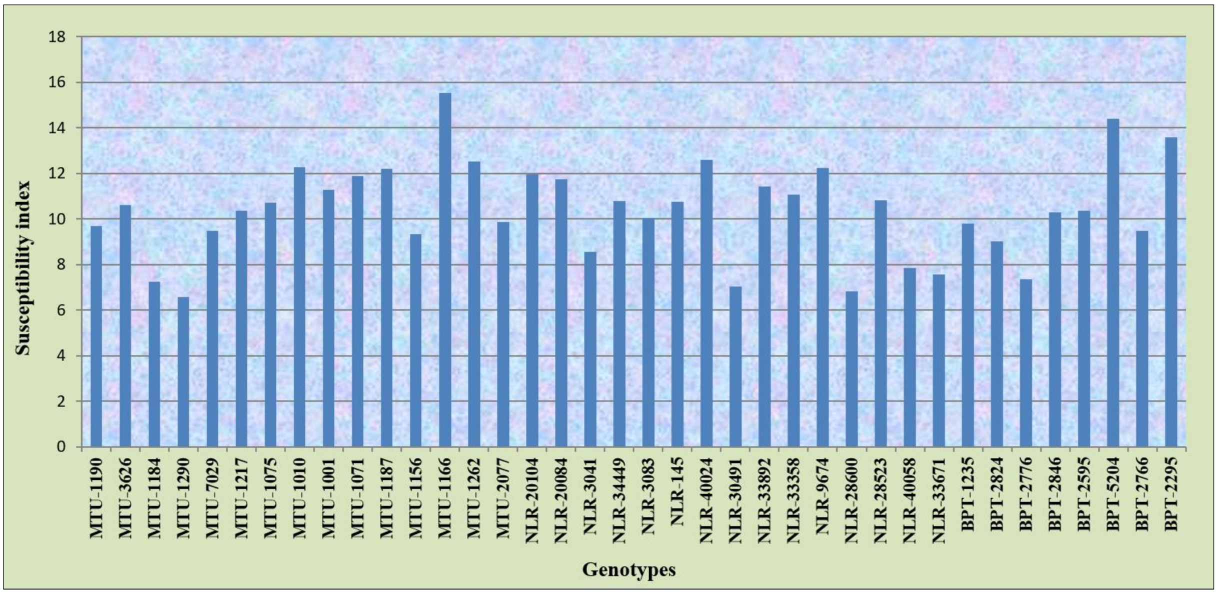

Fig 3: Susceptibility Index of paddy genotypes for *S. cerealella* in free choice test

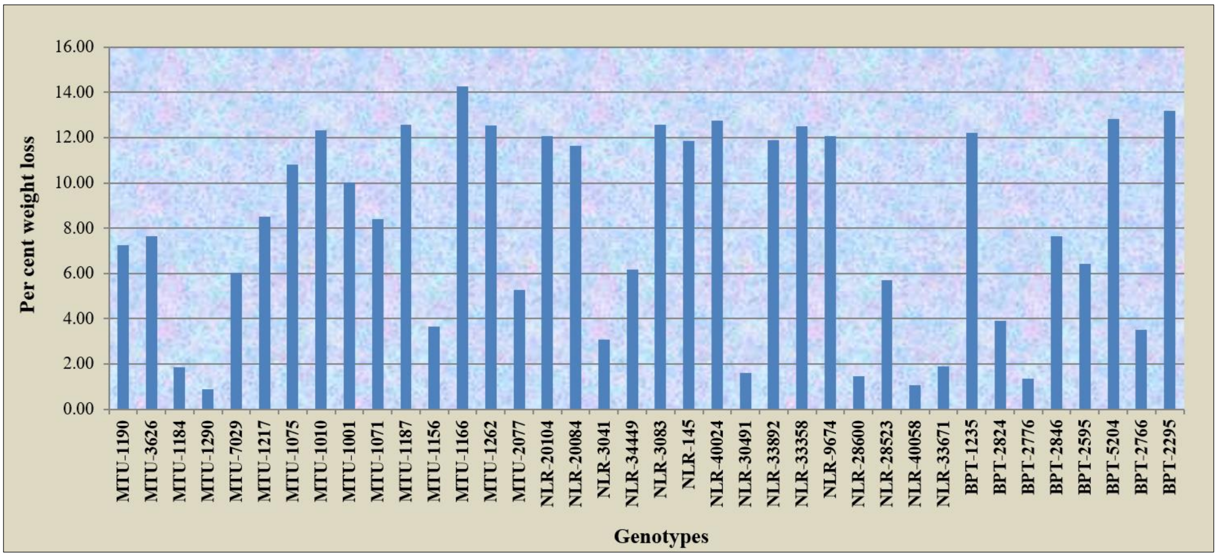

Fig 4: Per cent weight loss in different paddy genotypes due to *S. cerealella* in free choice test

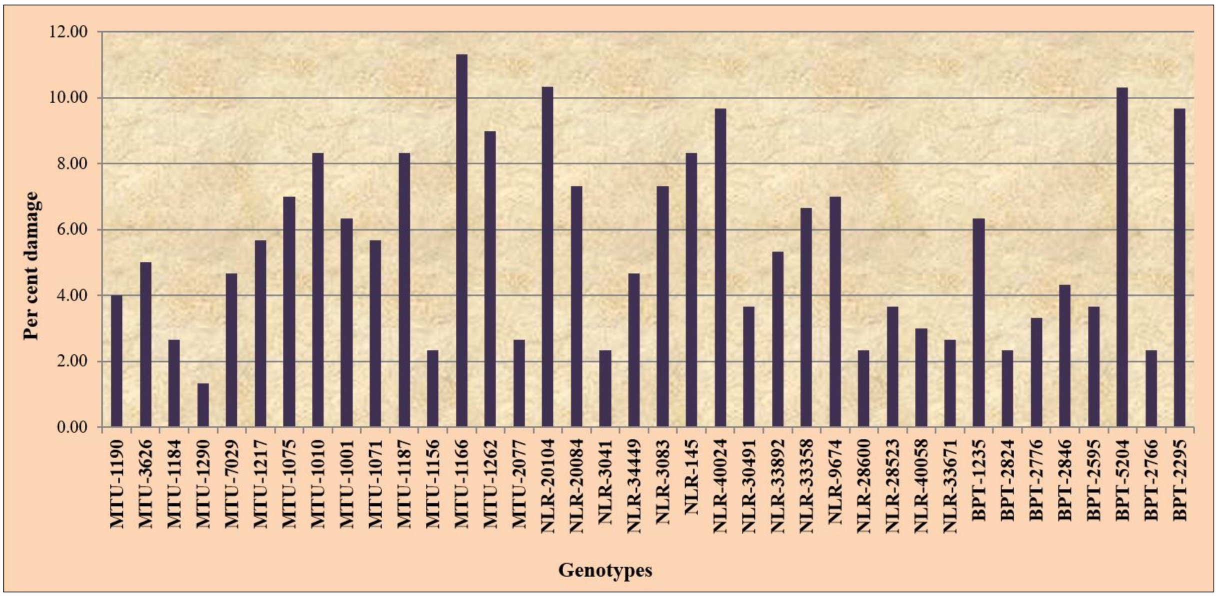

Fig 5: Per cent damage in different paddy genotypes due to *S. cerealella* in free choice test

3.1.1.4 Per cent weight loss
There was significant difference for per cent weight loss among the 38 genotypes was observed under studies. Per cent weight loss was ranged from 0.88 to 14.28 per cent. The maximum per cent weight loss was observed in MTU-1166 (14.28 %), which was on par with BPT-2295 (13.18%) and BPT-5204 (12.82%) and were significantly different from other paddy genotypes. The minimum weight loss was found in MTU-1290 (0.88%), which was on par with NLR-40058 (1.08%) and BPT-2776 (1.36%) and were significantly different from other paddy genotypes. The per cent weight loss of remaining genotypes was in the range of 1.46-12.74%. (Table 3, Fig 4). The present results are in agreement with Mathew *et al.* (2019) [7] who reported per cent grain content loss maximum in RMLT-104 (15.67%) and minimum in RMLT-505 (1.29%). Maximum per weight loss was observed in highly susceptible genotypes and minimum per cent weight loss was observed in least susceptible genotypes.

Table 3: Per cent weight loss and Per cent damage of paddy genotypes due to infestation by *S. cerealella* through free choice test.

S. No.	Genotypes	Per cent weight loss	Per cent damage
1	MTU-1190	7.24 (15.61)	4.00 (11.53)
2	MTU-3626	7.64 (16.05)	5.00 (12.92)
3	MTU-1184	1.84 (7.80)	2.67 (9.40)
4	MTU-1290	0.88 (5.38)	1.33 (6.62)
5	MTU-7029	6.04 (14.23)	4.67 (12.48)
6	MTU-1217	8.52 (16.97)	5.67 (13.77)
7	MTU-1075	10.82 (19.20)	7.00 (15.34)
8	MTU-1010	12.32 (20.55)	8.33 (16.78)
9	MTU-1001	10.04 (18.47)	6.33 (14.57)
10	MTU-1071	8.42 (16.87)	5.67 (13.77)
11	MTU-1187	12.56 (20.76)	8.33 (16.78)
12	MTU-1156	3.64 (10.99)	2.33 (8.79)
13	MTU-1166	14.28 (22.20)	11.33 (19.67)
14	MTU-1262	12.56 (20.75)	9.00 (17.45)
15	MTU-2077	5.28 (13.28)	2.67 (9.40)
16	NLR-20104	12.08 (20.34)	10.33 (18.75)
17	NLR-20084	11.64 (19.95)	7.33 (15.71)
18	NLR-3041	3.06 (10.08)	2.33 (8.79)
19	NLR-34449	6.16 (14.37)	4.67 (12.48)
20	NLR-3083	12.58 (20.77)	7.33 (15.71)
21	NLR-145	11.84 (20.13)	8.33 (16.78)
22	NLR-40024	12.74 (20.91)	9.67 (18.11)
23	NLR-30491	1.62 (7.31)	3.67 (11.04)
24	NLR-33892	11.88 (20.16)	5.33 (13.35)
25	NLR-33358	12.52 (20.72)	6.67 (14.96)
26	NLR-9674	12.08 (20.34)	7.00 (15.34)
27	NLR-28600	1.46 (6.95)	2.33 (8.79)
28	NLR-28523	5.72 (13.84)	3.67 (11.04)
29	NLR-40058	1.08 (5.96)	3.00 (9.97)
30	NLR-33671	1.88 (7.87)	2.67 (9.40)
31	BPT-1235	12.2 (20.45)	6.33 (14.58)
32	BPT-2824	3.9 (11.39)	2.33 (8.79)
33	BPT-2776	1.36 (6.70)	3.33 (10.52)
34	BPT-2846	7.66 (16.07)	4.33 (12.01)
35	BPT-2595	6.44 (14.70)	3.67 (11.04)
36	BPT-5204	12.82 (20.98)	10.33 (18.74)
37	BPT-2766	3.52 (10.82)	2.33 (8.79)
38	BPT-2295	13.18 (21.29)	9.67 (18.11)
	Mean	7.935 (15.599)	5.552 (13.213)
	S.Em	0.037	0.044
	CD (0.05)	0.104	0.125
	CV (%)	0.411	0.582

*Values are the means of three replications
Figures in parenthesis are Arcsine transformed value

3.1.1.5 Per cent grain damage
Maximum grain damage was reported in MTU-1166 (11.33%) and the lowest grain damage was observed in MTU-1290 (1.33%) due to *S. cerealella* infestation, which was significantly different from other paddy genotypes. The remaining paddy genotypes had grain damage ranging from 2.33 to 10.33 per cent. (Table 3.) (Fig. 5.)
The observations of the present study are in conformity with earlier findings of Rizwana *et al.* (2011) [12] who found the maximum insect damage in Bamati-Pak (33.3%) and minimum in Basmati-370 (7.8%).

4. Conclusion
According to the Dobie's susceptibility index the different genotypes were classified as resistant, moderately resistant, susceptible and highly susceptible. None of the genotype of

the present study shows resistant to *S. cerealella*. All the genotypes were either in moderately resistant, susceptible or highly susceptible group. The paddy genotypes *viz.,* MTU-1290, NLR-30491, NLR-28600, when screened against *S. cerealella* recorded a prolonged mean developmental period, lower susceptibility index (6.57-7.04) with lesser adult emergence, were categorized as "Moderately Resistant" genotypes. The paddy genotypes *viz.*, MTU-1190, MTU-1184, MTU-7029, MTU-1156, MTU-2077, NLR-3041, NLR-3083, NLR-40058, NLR-33671, BPT-1235, BPT-2824, BPT-2776, BPT-2776 were categorized as "Susceptible" genotypes (7.24-10.05). The paddy genotypes *viz.*, MTU-3626, MTU-1217, MTU-1075, MTU-1010, MTU-1001, MTU-1071, MTU-1187, MTU-1166, MTU-1262, NLR-20104, NLR-20084, NLR-34449, NLR-145, NLR-40024, NLR-33892, NLR-33358, NLR-9674, NLR-28523, BPT-2846,BPT-2595, BPT-5204, BPT-229 when screened against *S. cerealella* recorded a less mean developmental period, higher susceptibility index (10.30-15.54) with more adult emergence, were categorized as "Highly Susceptible" genotypes Table 4.1.

The similar results were reported earlier (Raghavaiah *et al.*, 1983; Ratnasudhakar, 1987; Bamaiyi *et al.*, 2007) [10, 11, 3]. Resistant genotypes of paddy allowed minimum adult emergence, prolonged mean developmental period of *S. cerealella* than the susceptible genotypes. Similar results were also documented by Irshad *et al.* (1988a) [5], Sundararaj and Sundararajan (1990) [15], Rizwana *et al.* (2011) [12], Akter *et al.* (2013) [2], Muthukumar (2014) [8], Mathew *et al.* (2019) [7].

5. Authors' Contribution

Procurement of paddy genotypes (ARM, TM), Data analysis (ARM, TM) Contributed to literature search (ARM, RBMN), Contributed to conceptualizing and refining research ideas (ARM, CVR).

6. Declaration

The authors declare that they have no conflict of interests.

7. Acknowledgements

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