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Studies on biology at different temperature regimes and screening of indigenous stored rice cultivars against rice weevil, *Sitophilus oryzae* (L.) in Meghalaya

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ABSTRACT

Rice is one of the most widely grown cereals with high global recognition and food value. In stored conditions, the most notorious pest of rice is Rice weevil (*Sitophilus oryzae*) causing approx. 10% harvest loss annually in India. Therefore, the present experiments were conducted on "Studies on Biology at Different Temperature Regimes and Screening of Indigenous Stored Rice Cultivars against Rice weevil, *Sitophilus oryzae* (L.) in Meghalaya" at the Entomology laboratory of School of Crop Protection, CPGS-AS, CAU (I), Umiam, Meghalaya from 2021-2023 to find the biology of Rice weevil, *Sitophilus oryzae* (L.) The experiment was laid out in the ambient condition of the laboratory following in a Completely Randomized Design (CRD), the treatments were replicated for three times and one way ANOVA was performed. The results of present study showed that the morphometrics of the eggs, larva and pupa were found to be smallest at 20±1°C and largest at 30±1°C. The mean incubation period of eggs of *S. oryzae* was shortest (4.5±0.5) days at 30±1°C and longest (6.93±0.4) days at 20±1°C. The mean hatching percentage of eggs of *S. oryzae* was maximum (75.83±2.9) per cent at 30±1°C and minimum (29.17±3.4) at 20±1°C. The longest duration of total larval period was recorded at 20±1°C (43.77±2.10 days) and shortest at 30±1°C (22.63±1.5 days). Pupal period occupied as 10.33±0.83 days highest at 20±1°C and lowest at 30±1°C as 5.60±0.36 days. The ovipositional period was found to be longest at 64.4±3.9 days at 20±1°C and shortest at 39.4±2.0 days at 30±1°C. It is concluded that the variety Jowain white showed higher percent weight loss at 30 days (9.5±0.2), 60 days (15.2±0.1) and 90 days (20.4±0.2). The variety Lakang baleigh shows least susceptible index 6.6±1.9. Growth index was found to be highest in the cultivar Mynri umiam (1.90±0.08). Per cent infestation was recorded to be highest in the variety Pnah sticky (25.5±9.5). The study suggests that prolonged storage of rice in lower temperature is beneficial and among the local varieties taken Lakang baleigh was found to be relatively resistant to the pest *S. oryzae*.

1. Introduction

Rice (*Oryza sativa* L.) is the primary grain crop for more than 50% of the world's population. Rice provides 60% of the food intake in Southeast Asia and about 35% in East Asia and South Asia. Damage to storage structures quantitative loss, direct feeding of insect cause loss in weight of the stored grains. Rice weevil causes approx.10-40% loss annually in India (Nanda *et al*.,2012). At present different kinds of preventive and curative control have been used for a long time, but have serious drawbacks (Sharaby, 1988). But the indiscriminate use of chemical pesticides in storage has given rise to many well-known serious problems including resistance of pest species, toxic residues in stored products, increasing cost of application, environmental pollution, hazards from handling etc. (Khanam *et al*. 1990, Ahmed *et al*. 1981). The residues of chemical insecticides remain in

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stored grain and also in the environment. Besides this, reports are also available on the efficacy of different plant products such as oils (Chander et al. 1991, Singh et al. 1990). But plant oils are not always available, not good in efficacy, have pungent smell. Hence, search for the alternative method of rice weevil control utilizing some non-toxic, environment friendly and human health hazard free methods are being persuaded now-a-days. Here need for screening of naturally resistant indigenous varieties arises.

2. Materials and methods

Research studies on Biology at Different Temperature Regimes and Screening of Indigenous Stored Rice Cultivars against Rice weevil, *Sitophilus oryzae* (L.) in Meghalaya." were carried out during the year 2021-22 and 2022-23 at the laboratory of Department of Entomology, School of Crop Protection of College of Post Graduate Studies in Agricultural Sciences, Central Agricultural University (Imphal), Umiam, Meghalaya.

Study on biology of egg; Eggs were examined under microscope (Zeiss APO Sonnar Sterio Zoom Microscope T 2/135 mm with magnification 10x to 50x) for studying their color, shape and size along with measuring length and breadth of eggs. For the study of incubation period and hatchability of the eggs, counted number of freshly laid eggs were kept at different temperature i.e., 20±1°C, 25±1°C and 30±1°C. In order to determine the number of larval instars, the size of head capsule of individual larva was measured daily. Observations on number of instars, size of instars duration of instars and total larval period were recorded. Observations on pupal duration, color and size were recorded. Pre-ovipositional period, Ovipositional period and post-ovipositional period were also observed. The ability of the adults of *S. oryzae* to live in the presence or absence of food were determined. For varietal screening of different indigenous cultivars of stored rice grains against Rice weevils were done by election of varieties 9 number of indigenous varieties and 1 improved cultivar selected for the experimentation. Barang red, Jowain red, Mynri umiam, Pnah sticky, Jowain white, Lakang baso, Lakang balieh, Black rice, Sarang white and the improved variety CAU R1 were taken for study.

The growth index was calculated based on the formula given by Naveena et al. (2011).

Growth index = Survival percentage / Mean developmental period in days.

The number of adults were separated to determine sex ratio in different varieties. The fecundity of female as well as longevity of male and female were also recorded for each cultivar separately.

The susceptibility index of each variety was calculated by applying formula suggested by Dobie (1977).

Susceptibility index = Natural log F/D x 100

Where, F = Number of adults emerged; D = Mean developmental period Weight loss was worked out by using the formula given by (Adams and Schulton, 1978)

% weight loss = {(UND) – (DNU) / U (ND+NU)} × 100

Where, U - Weight of un infested grains (g)
NU - Number of un infested grains (n)
D - Weight of infested grains (g)
ND - Number of infested grains

The percentage of infestation was calculated by the formula

Percent infestation = {(no. of infested seeds)/(total no of seeds consumed)}×100

For statistical analysis 10 samples were taken for every parameter and 3 replications were made for each sample. The experiment was laid out in the ambient condition of the laboratory following in a Completely Randomized Design (CRD), the treatments were replicated for three times and one way ANOVA was performed. SPSS (Statistical Package for Social Sciences) software was used for statistical analysis

3. Results

3.1 Biology of Rice weevil, *S. oryzae* at different temperatures

During the studies on various aspects of biology of *S. oryzae* under laboratory condition, the duration and measurements of different stages were recorded and described below at different temperature regimes i.e., 20±1°C, 25±1°C and 30±1°C.

3.1.1 Egg

At 30±1°C mean length and breadth were found to be 0.36±0.01 mm and 0.19±0.02 mm respectively. The length ranged from 0.35-0.37 mm and breadth ranged from 0.16-0.22 mm (Table 1) (Figure 1). Table 2 showed mean incubation period of eggs of *S. oryzae* was shortest (4.5±0.5) days at 30±1°C and longest (6.93±0.4) days at 20±1°C. From Table 2 it's known that the hatching percentage of eggs of *S. oryzae* was maximum (75.83±2.9) per cent at 30±1°C and minimum (29.17±3.4) at 20±1°C.

3.1.2 Larva

The mean length of the larva measured longest (7.4±0.7) mm at 30±1°C (Table 3) (Figure 3) and total larval period was highest (43.77±2.10) days at 20±1°C (Table 4).

3.1.3 Pupa

The data on measurement of the pupa (Table 5) (Figure 4) revealed that at 20±1°C mean length and breadth of pupa was shortest (2.87±0.16) mm and (1.62±0.15) mm respectively.

The length ranged from 2.56- 3.08 mm and breadth ranged from 1.39-1.88 mm at 20±1°C. Pupal period was longest (10.33±0.83 days) at 20±1°C and shortest (5.6±0.36 days) at 30±1°C (Table 6).

3.1.4 Adult

From the table 7 and figure 7 it was found that Male longevity without food was longest (5.52±1.17 days) at 30±1°C and shortest (4.86±1.15 days) at 20±1°C. Male longevity with food was found to be longest (53.57±5.58 days) at 30±1°C and shortest (27.84±5.16 days) at 20±1°C. Female longevity without food was found to be longest (8.39±0.82 days) at 30±1°C and shortest (6.01±1.02 days) at 20±1°C. Female longevity with food was found to be longest (70.58±4.52 days) at 30±1°C and shortest (65.1±7.43 days) at 20±1°C. (Table 7) (Figure 6).

3.1.5 Pre-oviposition, oviposition and post-oviposition periods

The data presented in Table 8 revealed that at 20±1°C pre-oviposition, oviposition and post-oviposition periods were longest (6.43±0.9), (64.4±3.9) and (29 ± 2.1) days respectively and at 30±1°C pre-oviposition, oviposition and post-oviposition periods were shortest (4.9±1.1), (39.4±2.0) and (22.73±1.5) days respectively.

3.2 Screening of indigenous cultivars of rice against *S. oryzae*

Nine indigenous cultivars and one improved cultivar were screened against *S. oryzae*. The observations on per cent weight loss, susceptible index, growth index, longevity and sex ratio were taken into consideration to decide the susceptibility of rice cultivars to *S. oryza*.

3.2.1 Percent weight loss of cultivars by *S. oryzae*

The variety Sarang white has shown higher percent weight loss at 30 days (9.5±0.2), 60 days (15.2±0.1) and 90 days (20.4±0.2). (Table 9)

3.2.2 Susceptible index of cultivars by *S. oryzae*

The variety Jowain white has highest susceptible index 13.9±4.5 and the variety Lakang baleigh shows least susceptible index 6.6±1.9. (Table 10)

3.2.3 Growth index of *S. oryzae* w.r.t different cultivars

From the table 11 it can be seen that the growth index is highest in the variety Mynri Umiam (1.90±0.08) and lowest in Jowain red (1.25±0.04).

3.2.5 Adult longevity of *S. oryzae* (In days)

From the table 12 we found that in the variety Jowain white the adult longevity is highest in both male (54.0±2.0) and female (74.7±5.9).

3.2.6 Sex ratio of *S. oryzae*

From the Table 13 its seen that the sex ratio (male: female) is highest in Lakang baso and Pnah sticky (1.7:1).

Table 1. Morphometrics of egg of *S. oryzae*

Temperature	Morphometric of eggs			
	Length(mm)		Breadth(mm)	
	Mean ± SD	Range	Mean ± SD	Range
20±1^{0}C	0.33±0.01	0.32-0.35	0.11±0.01	0.09-0.14
25±1^{0}C	0.34±0.02	0.32-0.36	0.15±0.01	0.14-0.18
30±1^{0}C	0.36±0.01	0.35-0.37	0.19±0.02	0.16-0.22
SEd	0.34		0.16	
CD 5%	0.72		0.33	

Table 2: Incubation period of eggs (days) and Hatching percentage of eggs of *S. oryzae*

Temperature	Incubation period of eggs (days)	Hatching percentage of eggs (%)
	Mean ± SD	Mean ± SD
20±1^{0}C	6.93±0.4	29.17±3.4
25±1^{0}C	5.80±0.4	54.83±6.2
30±1^{0}C	4.50±0.5	75.83±2.9
SEd	5.84	56.74
CD 5%	12.20	118.37

Table 3. Morphometrics of Larva of *S. oryzae*

Temperature	1st instar larva		2nd instar larva		3rd instar larva		4th instar larva	
	Length	Breadth	Length	Breadth	Length	Breadth	Length	Breadth
20±1°C	0.25±0.01	0.09±0.01	0.28±0.02	0.11±0.02	5.06±0.2	1.83±0.2	1.4±0.1	0.45±0.06
25±1°C	0.33±0.03	0.11±0.02	0.45±0.05	0.17±0.04	5.9±0.48	2.1±0.3	1.6±0.18	0.6±0.1
30±1°C	0.39±0.04	0.19±0.03	0.53±0.05	0.19±0.04	7.4±0.7	2.7±0.7	2.03±0.4	0.76±0.17
SEd	0.33	0.14	0.42	0.16	6.25	2.30	1.76	0.63
CD 5%	0.69	0.29	0.89	0.35	13.04	4.79	3.67	1.32

Table 4. Average Larval period (days) of *S. oryzae*

Temperature	Larval period (Days)				Total larval period (days)
	1st instar	2nd instar	3rd instar	4th instar	
20±1°C	11.23±1.1	11.83±0.82	13.89±1.29	6.73±0.73	43.77±2.10
25±1°C	7.83±0.85	8.30±0.88	9.40±1.27	5.83±0.57	31.37±2.25
30±1°C	5.73±0.87	6.4±1.27	6.88±0.56	4.60±0.38	22.63±1.5
SEd	8.61	10.00	10.52	5.81	33.77
CD 5%	17.97	20.86	21.94	12.13	70.45

Table 5. Morphometrics of pupa of *S. oryzae*

Temperature	Length (mm)		Breadth (mm)	
	Mean ± SD	Range	Mean ± SD	Range
20±1°C	2.87±0.16	2.56-3.08	1.62±0.15	1.39-1.88
25±1°C	3.73±0.24	3.13-3.97	1.93±0.24	1.62-2.51
30±1°C	4.16±0.23	3.85-4.45	2.02±0.54	1.69-2.91
SEd	2.63		1.30	
CD 5%	5.47		2.84	

Table 6. Pupal period of *S. oryzae*

Temperature	Pupal period (in days)	
	Mean ± SD	Range
20±1°C	10.33±0.83	9.0-11.77
25±1°C	6.47±0.59	5.36-7.33
30±1°C	5.60±0.36	3.75-5.63
SEd	4.86	
CD 5%	10.60	

Table 7. Adult longevity of *S. oryzae*

Temperature	Adult longevity (Days) (Mean ± SD)			
	Male		Female	
	Without food	With food	Without food	With food
20±1℃	4.86±1.15	27.84±5.16	6.01±1.02	65.10±7.43
25±1℃	5.01±1.40	29.30±4.58	7.11±1.00	67.64±7.35
30±1℃	5.52±1.17	53.57±5.58	8.39±0.82	70.58±4.52
SEd	4.05	23.84	4.49	49.74
CD 5%	8.84	51.95	9.78	108.39

Table 8. Pre-oviposition, Oviposition and Post-oviposition period of *S. oryzae*

Temperature	Pre-ovipositional period (Days)	Ovipositional period (Days)	Post- ovipositional period (Days)
20±1℃	6.43±0.9	64.4±3.9	29±2.1
25±1℃	6.10±0.9	58.10±3.03	27.03±3.8
30±1℃	4.90±1.1	39.4±2.0	22.73±1.5
SEd	6.3	58.5	23.4
CD 5%	13.2	122.1	48.8

Table 9. Percent weight loss by *S. oryzae* in different rice cultivars

Sl. No.	Variety	At 30 days	At 60 days	At 90 days
1	Jowain red	4.5±0.4	7.5±0.4	12.3±0.2
2	Lakang baleigh	2.5±0.3	4.2±0.1	8.3±0.3

3	Lakang baso	2.3±0.2	6.4±0.3	11.7±0.2
4	Jowain white	9.5±0.2	15.2±0.1	20.4±0.2
5	Sarang white	0.5±0.1	4.7±0.1	8.4±0.2
6	Barang red	1.4±0.0	5.4±0.3	10.3±0.2
7	Black rice	3.3±0.1	6.3±0.1	12.5±0.3
8	Mynri umiam	2.1±0.0	5.4±0.1	10.6±0.2
9	Pnah sticky	5.3±0.1	9.3±0.2	15.8±0.5
10	CAU R1	0.7±0.1	4.8±0.0	9.4±0.1
SEd		2.9	5.4	8.8
CD 5%		8.6	15.8	26

Table 10. Susceptible index (SI) of indigenous cultivars by *S. oryzae*

Sl. No.	Variety	SI
1	Jowain red	13.1±1.9
2	Lakang baleigh	6.6±1.9
3	Lakang baso	12.7±0.0
4	Jowain white	13.9±4.5
5	Sarang white	7.9±4.2
6	Barang red	10.5±6.2
7	Black rice	12.9±4.3
8	Mynri umiam	11.6±1.0
9	Pnah sticky	13.6±1.5
10	CAU R1	9.4±1.3
	SEd	11.8
	CD 5%	24.6

Table 11. Growth index (GI) of *S. oryzae* w.r.t different cultivars

Sl. No.	Variety	GI
1	Jowain red	1.25±0.04
2	Lakang baleigh	1.34±0.31
3	Lakang baso	1.88±0.04
4	Jowain white	1.68±0.02
5	Sarang white	1.37±0.09
6	Barang red	1.77±0.15
7	Black rice	1.65±0.04

8	Mynri umiam	1.90±0.08
9	Pnah sticky	1.75±0.03
10	CAU R1	1.67±0.03
	SEd	1.6
	CD 5%	3.4

Table 4.12. Adult longevity (days) *S. oryzae*

Sl. No.	Variety	Male	Female
1	Jowain red	47.3±3.1	60.0±1.0
2	Lakang baleigh	34.0±1.0	59.3±1.5
3	Lakang baso	43.3±1.5	57.7±2.5
4	Jowain white	54.0±2.0	74.7±5.9
5	Sarang white	38.3±1.5	63.0±2.6
6	Barang red	41.3±2.1	59.0±6.2
7	Black rice	45.0±1.0	62.3±2.5
8	Mynri umiam	42.7±2.5	58.7±4.0
9	Pnah sticky	50.0±2.0	62.0±1.0
10	CAU R1	41.0±2.6	63.7±3.1
SEd		44.1	62.3
CD 5%		91.9	129.9

4.13. Sex ratio of *S. oryzae*

Sl. No.	Variety	Ratio (Male:Female)
1	Jowain red	1.3:1
2	Lakang baleigh	0.9:1
3	Lakang baso	1.7:1
4	Jowain white	0.9:1
5	Sarang white	1.1:1
6	Barang red	1.3:1
7	Black rice	1.5:1
8	Mynri umiam	0.6:1
9	Pnah sticky	1.7:1
10	CAU R1	1.2:1

Figure 1. Microscopic observation of newly hatched eggs

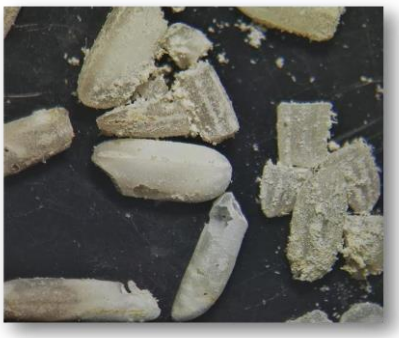

Figure 2 Infested Rice grains containing eggs of Rice weevil, *S. oryzae*

1st Instar Larva

2nd Instar Larva

3rd instar larva

4th instar larva

Figure 3. Larval instars of *S. oryzae* (1-4)

Figure 4. Pupa of *S. oryzae*

Figure 5. Adult emergence from rice grains

Figure 6. Adult weevil of *S. oryzae* (female)

Figure 7. Adult weevil *S. oryzae* (male)

4. Discussion

4.1 Biology of Rice weevil, *S. oryzae* at different temperature regimes i.e. 20±1°C, 25±1°C and 30±1°C

4.1.1 Biology of eggs of *S. oryzae*

The results on size of eggs are also in accordance with the findings of Sattigi (1982) and Bheemanna (1986). Females of *S. oryzae* laid eggs inside the cavity on the rice grains. It was seen that incubation period of eggs of *S. oryzae* was longest (6.9±0.4) days at 20±1°C. The incubation period as reported to be 5 to 9 day (Sattigi, 1982) is more or less in confirmation with present findings. It can be known that the hatching percentage of eggs of *S. oryzae* maximum (75.8±2.9) per cent at 30±1°C.

4.1.2 Biology of larva of *S. oryzae*

The length of the larva measured highest (7.4±0.7) mm at 30±1°C (Table 2) and total larval period was longest (43.77±2.10) days at 20±1°C. Similar observations have also been reported by Bheemanna (1986), Sattigi (1982) and Treiman (1937).

5.1.3 Biology of pupa of *S. oryzae*

Average pupal size measured smallest at 20±1°C in length (2.56±0.60 mm) and width (1.39±0.33 mm) (Table 3). Pupal period occupied as 11.3±32 days highest at 20±1°C and lowest at 30±1°C as 4.7±1.5 days. Similar observations were made by Wille (1923) and Wenholz (1927).

4.1.4 Biology of adult of *S. oryzae*

Male and female longevity found to be longest (53.0±5.6) and (72.17±5.3) at 30±1°C.The present findings draw the support of Bheemanna (1986) who observed adult longevity ranging from 14 to 165 day and 7 to 11 day with and without food, respectively. Sattigi (1982) reported that longevity of adult weevil ranging from 16 to 172 day with food. While, the longevity of adult male and female was 14 to 115 and 119 to 120 day, respectively.

4.1.5 Ovipositional period of *S. oryzae*

The highest average pre-oviposition, oviposition and post-oviposition (6.43±0.9), (64.4±3.9), (29±2.1) days at 20±1°C.Yevoor (2003) have made similar kind of observations.

4.2. Screening of indigenous cultivars of rice against *S. oryzae*

4.2.1 Percent weight loss of cultivars by *S. oryzae*

It is concluded that the variety Jowain white shows higher percent weight loss at 30 days (9.5±0.2), 60 days (15.2±0.1) and 90 days (20.4±0.2). Khaliq et al. (2013) showed similar results in KSK-133 (20.58%) and Basmati-515 (16.90%) followed by Basmati-2006 (13.033%), and Super Basmati (12.433%) at 28°C.

4.2.2 Susceptible index

The variety Jowain white had highest susceptible index 13.9±4.5 followed by Pnah sticky (13.6±1.5) Jowain red (13.1±1.9) and the variety Lakang baleigh showed least susceptible index 6.6±1.9. Kiran et al. (2019) showed Index of susceptibility (IS) as criteria for assessing the resistance or susceptibility of selected genotypes to *S. oryzae*.

4.2.3 Growth index of *S. oryzae* w.r.t different cultivars

Growth index was found to be highest in the cultivar Mynri umiam (1.90±0.08) followed by Lakang baso (1.88±0.04) followed by Barang red (1.77±0.15) at initial 30 days. Bhanderi and Radadia (2018) showed that growth index was the highest in genotype DJ 6514 (2.05) which was at par with SR 666 (2.04), SR 2460 (2.00) and SR 1905 (1.95) which were found significantly higher over rest of the genotypes. Since the genotype SR 770 had the lowest growth index (1.17) and was comparable to IS 6566 (1.18), ICSV 700 (1.20), and 168 II 108 (1.25), it was determined to be less suited for *S. oryzae*.

4.2.5 Adult longevity of *S. oryzae*

It was found that in the variety Jowain white the adult longevity was highest in both male (54.0±2.0) days and female (74.7±5.9) days. Pal et al. (2021) demonstrated similar results in which the highest weevil population over 90 days was recorded in Sambha Mansuli Sub-1 followed by Hardinath-2 and the least weevil population was found on Lalka Basmati followed by Bahuguni -2 in both test conditions.

4.2.6 Sex ratio

It was seen that the sex ratio (male: female) was highest in Lakang baso and Pnah sticky (1.7:1). The observations of Bhanderi and Radadia (2018) showed sex ratio of male: female of *S. oryzae* was 1:1.15. The females were more emerged as compared to the males.

5. Conclusion

Considering the results of the study, it could be concluded that temperature plays the major role in biology and reproduction. The temperature found to be most suitable for overall growth and development of rice weevil was 30±1°C and least favored was 20±1°C. It is evident from present study that the increase in temperature reduces the day required for completion of development and thereby there will be more number of generations per year. This not only results in higher insect population build up but also paves way to higher percent grain infestation during storage. Prolonged storage of rice in lower temperature is beneficial. Among The varieties studied for screening against Rice weevil it can be concluded that the variety taken Lakang baleigh was found to be relatively resistant to the pest *S. oryzae* as per observation taken on Per cent weight loss and susceptibility index. This research provides insights about the indigenous rice cultivars found in Meghalaya region which are naturally resistant or susceptible to the pest *S. oryzae*. Further studies can be done to find out factors aiding to the natural resistance/ susceptibility of the indigenous rice varieties with respect to the pest *S. oryzae*.

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7. References

Adams, J.M. and Schulten, G.G.M. (1978). Losses caused by insects, mites and microorganisms. In Harris, K.L. and Lindblad, C.J. (eds) post-harvest grain loss assessment methods. American Association of Cereal Chemists, USA. pp 83-93.

Ahmed, S.M., Chander, H. and Pereira, J. (1981). Insecticidal potential and biological activity of Indian indigenous plants against Musca domestica. Intl. Pest Control. 23: 170-175.

Bheemanna, M. (1986). Studies on biology of rice weevil, *Sitophilus oryzae* Linnaeus (Curculionidae: Coleptera) and host resistance in sorghum. M. Sc. (Agri.) Thesis University of Agricultural Sciences, Dharwad, pp 79.

Bhuiyah, M.I.M., Islam, N., Begum, A. and Karim, M.A. (1990). Biology of rice weevil, *Sitophilus oryzae* (Linnaeus). *Bangladesh J. Zool.*, 18 (1): 67-73.

Chander, H., Kulkarni, S.G. and Berry, S.K. (1991). Effectiveness of turmeric powder and mustard oil as protectant in stored milled rice against rice weevil, *Sitophilus oryzae* L. *Intl. Pest Control*. 33(4): 94-97.

Dobie, P. (1977). The contribution of the Tropical Stored Products Centre to the study of insect resistance in stored maize. *Trop. Stored Prod. Inf.,* 34: 7-22.

Dunna, V. and Roy, B. (2013). Rice, *Oryzae sativa* L., 4: 70-71

Khaliq, K., (2023), Varietal screening and development of rice weevil, *Sitophilus oryzae*, Int. J. Biosci.3 (9) 287-292.

Khanam, L.A.M., Talukder, D., Khan, A.R. and Rahman, S.M. (1990). Insecticidal properties of Royna, Aphanamixis polystachya against Tribolium confusum. D. J. Asiat. Soc. Bangladesh Sci. 16: 71-74.

Kurdikeri, M.B., Aswathaiah, B., Rajendraprasad, S., Katgal, R.D., and Aswathanarayana, S.C. (1993). Studies on relative seed damage - loss in weight and loss in viability caused by *Sitophilus oryzae* Linn. and *Rhizopertha dominica* Fabr. in maize hybrids. *Seed Resc.*, 21(2): 72-77.

Kiran, A.S., Angala, P.,(2020), Varietal preference of different rice genotypes by rice weevil Sitophilus oryzae (L.).

Lefevre, P.C. (1953). Etude de *Calandra oryzae* (L.) Sur sorgho (*Sorghum vulgare* Bert). *Bull. Agric. Congo. Belge*, 44: 1001-1046.

Lin, T. (1958). Bionomics studies of rice weevil, *Sitophilus oryzae* Linnaeus. *Agric. Resc.,* 8: 44-54.

Newman, L.J. (1927). Grain weevils. J. Dep. Agric., West. Aust., 4: 538- 545

Nanda, S.K., Vishwakarma, R.K., Bathla, H.V.L, Rai, A., and Chandra P (2012). Harvest and postharvest losses of major crops and livestock produce in India. All India Coordinated Research Project on Post Harvest Technology (ICAR), Ludhiana.

Naveena N. L., Jagadeesh Babu C. S., Sttdhirkumar S., and Prakash, k. (2011). Performance of *Callosobruchus theobrojnae* on different geno types of fieldbcan. Lablab purptircus *L. j. Entamol. Res*., 35:75-79

Nwana, I.E, and Akibo-Betts, D.T (1982). The resistance of some rice varieties to damage by *Sitophilus zeamais* Motsch., during storage. *Trop Stored Prod Inf.,* 43:10-15.

Okuni, T. (1924). Insect pests of stored grains in Formosa part I. *Res. I nst. Dept. Agric*., *Formosa, Rept.:* 1-16

Prakash, A., and Rao, J. (1983). Insect pests and their management in rice storage in India, presented in National Symposium on Maximizing Stabilizing of yields on rain feed rice production system held at CSRRI, Cuttack (India). Pp. 23-25.

Sattigi, H.N. (1982). Studies on the biology, chemical control of *Sitophilus oryzae* Linnaeus (Curculionidae: Coleoptera) and *Rhizopertha dominica* Fab. (Bostrychidae: Coleoptera) and residue analysis of insecticides. M.Sc. (Agric.) Thesis University of Agricultural Sciences, Dharwad, pp 153.

Sharaby, A. (1988). Evaluation of some Myrtaceae plant leaves as protectants of rice against the infestation of Sitophilus oryzae L. and S. granaries (Coleoptera*). Entomo*l. 59(2): 372.

Singh, J., Dhaliwal, G.S., Kumar, I., and Sidhu, G.S. (1990). Evaluation of eliterice genotypes against whorl, Maggot and Rice hispa. J. Insect Sci. 3(1): 102

Treiman, F.S. (1937). On the morphology and biology of Calandra oryzae (L.). *Trav. Zool. Biol. Acad. Sci*. Ukr., 14: 259-277.

Taylor, F. (1981) Ecology and evolution of physiological time in insects. *American Naturalist*.; 117:1–23.

Wenholz, H. (1927). Storage of maize in coastal districts. Agriculture Coloniale, New South Wales, 38: 255-261.

Wille, J. (1923). Contribution to the biology of rice weevil C. oryzae (L.). *Zeitschr. Angew. Ent*., 9: 333-342.

Yevoor, (2003). Biology and management of rice weevil, *Sitophilus oryzae* (Linn.) in maize grains. M. Sc. (Agri.) Thesis, University of Agricultural Sciences, Dharwad.