

Biology and morphometrical analysis of rice weevil, *Sitophilus oryzae* (L.) (Coleoptera, Curculionidae) on different stored cereals

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ABSTRACT: Experimental rearing of *Sitophilus oryzae* (L.) in eight different cereals such as rice, wheat, oats, barley, sorghum, maize, finger millet and pearl millet has revealed that the pest can complete lifecycle in all of them. Rice and maize are found to be providing optimum living conditions to the pest and within them it can complete its lifecycle in 41 to 45 days, in maize with a mean shortest developmental duration of 40.72 days (egg 6.52, larva 28.45 and pupa 5.75 days). Maize was found to provide more viable living conditions than rice, as adults and developing stages of *S. oryzae* reared in it was significantly larger with higher adult longevity (female 18.60 days, male 12.56 days) compared to other cereals. In contrast, oats caused longest developmental period of 66.47 days (egg 13.70, larva 42.46, pupa 10.31 days), with female and male longevity reduced to 8.50 and 6.50 days respectively, and noticeable production of miniature adults due to developmental stress. Comparison with span of lifecycle in rice, rearing in wheat resulted delay of 6 days but pearl millet and barley caused delay of 12 days, finger millet resulted 16 days of delay in development while oats extended development by nearly 24 days beyond any cereal. In accordance with increase in developmental delay, body size decreased significantly across cereals, with smallest larval and adult dimensions recorded in oats. The sex ratio also varied, peaking in maize (M:F=1:1.92) and declining sharply in oats (M:F=1:0.074). Similarly, total life span was shortest in maize (female 59.42; male 54.07 days) and longest in oats (female 76.21; male 58.30 days). Morphometric observations showed that early and late instar larva measured 0.30-0.85 and 0.80-2.13mm respectively, pupae 2.58-3.77 and adults 2.60-4.53mm, with maize consistently producing the largest dimensions. Head capsule width of larval instars, a marker of health and viability prospective adults developed in maize, is significantly higher than those larvae developed in rice. © 2025 Association for Advancement of Entomology

KEY WORDS: Storage pest, adult size, delayed development, adult longevity, head capsule width

INTRODUCTION

Cereal grains, being botanically caryopses of the

Poaceae family, form nearly 90 per cent of the total caloric consumption worldwide and are the major staple diets in varied agrarian economies (Sarwar,

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2013). India holds the position of being the second-largest cereal-producing country in the world and an important exporter, with production levels exceeding 288 million metric tons in 2022-23 (webindia, 2004). Coarse grains such as rice, maize, sorghum, millets, wheat, barley, oats, and finger millet are important in Odisha. These grains have high nutritional density (65-75% starch, 6-12% protein, and 1-5% lipids), all underpinning the food security and dietary standards in peri-urban and rural communities (Webindia123, 2024). Cereal grains, despite their nutritional and economic importance, have been found with very high susceptibility to post-harvest losses caused by storage insect pests. Of these, the rice weevil, *Sitophilus oryzae* (L.) (Coleoptera, Curculionidae), is a major grain pest that causes severe qualitative as well as quantitative damage. The cosmopolitan pest is pantropical in distribution and has remarkable ecological adaptability, infesting rice, also cause sporadic infestation in wheat, maize, barley, oats, and many coarse cereals in the field and storage situations (Togola *et al.*, 2013; Binseena *et al.*, 2018). Its endophytic lifestyle, where larvae grow and feed inside the grain and short generational turnover allow for exponential population increase under optimal storage conditions (Aitken, 1975; Longstaff, 1981). Symptoms of infestation include hollow grains, powdery frass residues, high moisture content, and characteristic odour, which can lead up to 80 per cent weight loss during prolonged storage and improper management (Park *et al.*, 2004; Beckett *et al.*, 2007). Host-specificity influences developmental rate, body size and sex ratio, thereby impacting the extent and duration post harvest damages. The host range breadth of the pest is wide, has cryptic internal larval development wherein eggs, larva and pupae remain concealed within the grain kernels (Gvozdenac *et al.*, 2020) with varied and cereal type-dependent life history characters. Therefore, the aim is to study the lifecycle pathway, morphometric characters, biological and developmental features of the rice weevil (*S. oryzae*) among major cereals.

MATERIALS AND METHODS

Laboratory investigation was carried out to study

the biology and morphological characteristics of the test insect, rice weevil, on eight different cereals in the Department of Entomology, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, during 2023-2024.

Adult rice weevils were collected from infested rice and reared in sterilised jars following standard methods (Strong *et al.*, 1967; Bhandari, 2012; Sahoo, 2017; Pandey, 2019), maintained at controlled laboratory conditions at $30 \pm 2^\circ\text{C}$; 90 ± 2 per cent relative humidity (RH) with fresh grains added periodically to sustain the culture. For experimentation, whole grains of eight cereals were used: rice (*Oryza sativa*), wheat (*Triticum aestivum*), oats (*Avena sativa*), barley (*Hordeum vulgare*), sorghum (*Sorghum bicolor*), maize (*Zea mays*), finger millet (*Eleusine coracana*) and pearl millet (*Pennisetum glaucum*). The grains were disinfected at 55°C for 4 hours, and then stored in zip lock bags with small holes for air circulation. For each cereal type, 50g of grain were placed in containers with five beetle pairs, covered with muslin cloth, and maintained at $30 \pm 2^\circ\text{C}$ and 70 per cent RH. After 7 days, beetles were removed, and the experiment was replicated thrice.

Morphological features of developmental stages: Daily observations were made on egg deposition, adult emergence, and longevity. (From each experimental set, 30 grains per cereal type were dissected daily to record the precise timing of embryonic development, larval development, and pupation events.) Trinocular stereo zoom microscope (SZ-61, Olympus) with a DGI digital camera and Scope Photo v3.1 software was used to identify, measure, and photograph the developmental stages - lengths of larval instars, pupae, adults (male and female), and head capsule widths of early and late instar grubs.

Acid fuchsin staining was used for detection of the egg plugs deposited by rice weevil (Holloway, 1985; Renuka *et al.*, 2023). The first instar larvae of *S. oryzae* were identified based on their distinct shape and size of the head capsule, i.e; small, white, and possessing head capsule width (HCW) of approximately 0.20–0.25mm, with simple setae and a thin body, whereas the final (fourth) instar larvae

being larger in size relatively (HCW 0.70–0.85mm), more robust, and heavily sclerotized, showing prominent segmentation and fully developed mandibles (O'Donnell, 1967; Okram and Hath, 2019; Sharma *et al.*, 2025).

Morphological features that differentiated male and female pupae of *S. oryzae* include the structure of the pygidium, abdominal tergites: males exhibit a longer and partially membranous pygidium with specific bifurcated setae and a flanged posterior margin, while females possess a notched posterior margin and lack bifurcation, with the pygidium mostly retracted and concealed under the propygidium (Omar, 2012). Sexes (adult) were identified by rostrum structure - males having a thicker, less curved rostrum (Fox *et al.*, 2003; Omar, 2012; Azis and Kasim, 2020).

Development stages of rice weevil were tracked through both non-destructive and destructive sampling (grain dissection) due to its endophytic nature during its immature stages within grains. Embryonic development completion and hatching were followed by monitoring with acid fuchsin staining to observe egg plugs or identification of egg plug disappearance and larval feeding tunnel initiation (Holloway, 1985; Renuka *et al.*, 2023). Development from first instar to completely developed larva was determined through regular dissections in which growth in head capsule width and body length was taken into account to differentiate successive instars of the larvae (O'Donnell, 1967; Okram and Hath, 2019; Sharma *et al.*, 2025). Pupation was recognized by the discovery of an immobile, non-feeding pupal stage in the dissection of grains, with pupae easily distinguishable from larval instars in morphology and developmental level (Okram and Hath, 2019). Finally, eclosion or the emergence of adult weevils was ascertained by visual sighting of exit holes on the grains/the sight of adult beetles on the storage substrate after daily observation or scheduled sampling.

Statistical analysis: The observations on developmental stages, length, and parts of the rice weevil were analyzed using one-way ANOVA in a completely randomized design, with standard error

of mean (SEM) and critical difference (CD) calculated for interpretation of biological variation through partitioning of various components (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Biology of rice weevil on different stored cereals:

Embryonic development: The incubation period of the rice weevil was examined across various stored cereals using the acid fuchsin method where, the gelatinous egg plugs exhibited a deep cherry-red color, while the feeding sites displayed a light pink hue, indicating the presence of eggs. The data revealed a significant variation in the incubation period, ranging from 6.52 to 13.70 days, with the longest periods observed in oats (13.70 days) and finger millet (12.16 days), which were statistically similar. In contrast, the shortest incubation period (6.52 days) was noted in maize (Table 1), these observations aligns with findings of Singh *et al.* (2017), who reported an incubation period of 6 to 7 days for rice weevils on the rice cultivar Pusa-221. Additionally, Meghwal (2010) found that the incubation period for rice weevils extended to 7 days on maize at a temperature of 26°C and RH of 65 per cent.

Larval development: The larval stage lasted between 28.45 days and 42.46 days. The longest larval duration was observed in oats (42.46 days), which was comparable to that in finger millet (39.22 days). In contrast, the shortest larval period occurred when the weevils were reared in maize (28.45 days), followed closely by rice (28.98 days) and wheat (33.37 days), which were also similar in duration. Jadhav (2006) previously noted that the larvae underwent four instars, with their larval period ranging from 21 to 30 days and an average of 25.8 ± 3.70 days for those on maize (Table 1). Likewise, Bheemanna (1986) reported a larval period of 25 to 34 days in the CSH-5 sorghum hybrid.

Pupal development: The maximum pupal period was observed in oats (10.31days) and minimum period was observed in maize (5.75days) followed

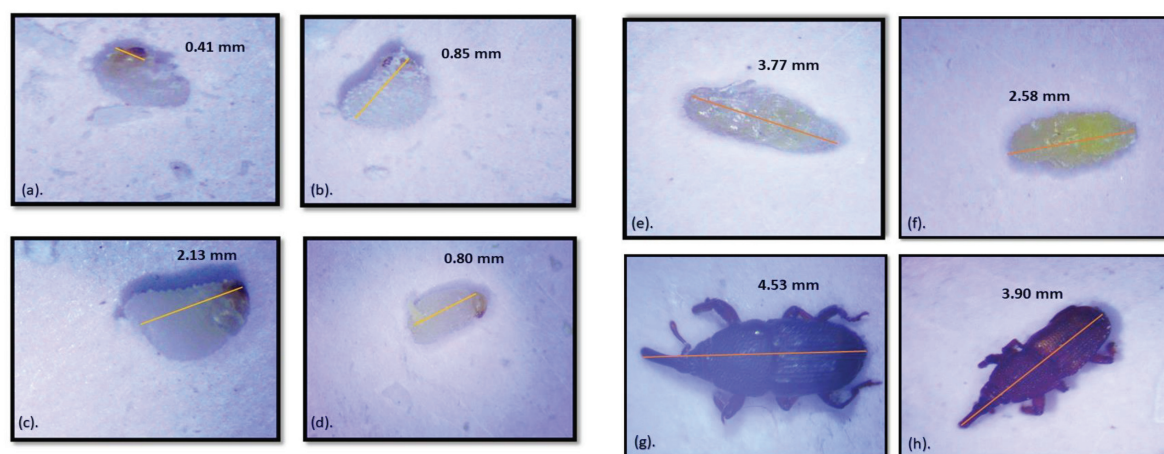


Fig.1 Morphometrics of larval, pupal and adult stages of rice weevil, *Sitophilus oryzae* (L.). (a) Early instar head capsule width (in Maize), (b) Early instar body length (in Maize), (c) Late instar body length (in Maize), (d) Late instar body length (in Oats), (e) Female pupa (in Maize), (f) Male pupa (in Oats), (g) Female adult (in Maize), (h) Male adult (in Maize)]

by rice (6.43days) and wheat (6.85days) which were at par. Swamy *et al.* (2014) observed the pupal period of rice weevil ranged from 8 to 11days on maize which supported the pupal period reported in this experiment with varying from 5.75 days to 10.31days (Table 1). Further, this was well supported by the findings of Kumar *et al.* (2016) who reported the rice weevil completed its pupal period within 6.75 to 7.08 days in wheat.

Span of lifecycle: The total development period was lowest on maize (40.72days) and rice (43.87days), whereas highest in oats (66.47days) which was at par with finger millet (59.68days). This indicated that the developmental period was significantly affected by the diet they consumed (Table 1). The present result confirmed the findings of Akthar *et al.* (2017) recorded the total development on rice and wheat is 37 and 36 days respectively and likewise, development period in maize ranging from 39.00 to 45.00 days on different maize hybrids was observed by Yevoor (2003).

Longevity of weevils: From the data it was evident that the adult female lived longer than male. The results showed that female had a maximum longevity in maize with (18.60 days) and minimum in oats (8.50days) followed by finger millet (9.75 days) which was comparatively longer than the

male weevil which has shorter longevity of in oats (6.50 days) and at par with finger millet (7.50 days) and maximum longevity in maize 12.56 days followed by rice (10.27 days) and wheat (9.80 days) (Table 1). The present findings align with previous studies reporting consistently higher longevity in adult females than males across various cereals. Okram *et al.* (2019) observed female and male lifespan of 14.47 ± 0.69 and 12.98 ± 0.98 days respectively on stored rice, while Yevoor (2003) reported 9.50 and 7.32 days on maize; and Rojasara and Patel (2020) recorded 8.6 ± 0.82 and 5.8 ± 0.82 days on Jaya rice.

The total life cycle of males and females also varied, in which male had a shorter life time than female. Life cycle of female weevil was maximum (76.21days) in oats, which was more than the male on oats (71.15days) followed by finger millet (71.76days). The shortest life cycle of female was on maize (59.42days) followed by rice (59.71days) and wheat (67.12days) which were at par. The life cycle of male was the longest in oats (71.15days) and the shortest on maize (54.07days) followed by wheat (58.30days) and rice (58.35days) (Table 1). Okram *et al.* (2019) reported total life cycles of 50.35 ± 1.85 days for males and 51.84 ± 1.56 days for females across a temperature range of 12.39-27.89°C and 58.33-88.81 RH; Rojasara and

Table 1. Duration of developmental stages, adult longevity, life cycle (days) and sex ratio of *Sitophilus oryzae* (L.) on different stored cereals

Cereals	Duration of stages				Adult longevity/ life cycle				Sex ratio (M:F)
	ED	LD	PD	TDP	AL(F)	AL(M)	LC(F)	LC(M)	
Rice	8.46	28.98	6.43	43.87	15.40	10.27	59.71	58.35	1:1.78
Wheat	9.24	33.37	6.85	49.46	13.20	9.80	67.12	58.30	1:1.56
Oats	13.70	42.46	10.31	66.47	8.50	6.50	76.21	71.15	1:0.74
Barley	11.26	39.19	6.27	56.71	11.60	8.50	67.17	59.50	1:1.38
Sorghum	9.50	37.97	7.14	54.60	12.50	8.72	69.25	60.03	1:1.42
Maize	6.52	28.45	5.75	40.72	18.60	12.56	59.42	54.07	1:1.92
Finger millet	12.16	39.22	8.30	59.68	9.75	7.50	71.76	63.40	1:1.09
Pearl millet	11.40	37.48	6.27	55.15	10.50	7.90	70.95	61.13	1:1.22
SE(m)±	0.53	1.97	0.37	2.70	0.49	0.37	3.43	3.02	
CD (0.05%)	1.60	5.93	1.12	8.19	1.47	1.13	10.29	9.05	

ED – Egg development; LD – Larva development; PD – Pupal development; TDP – Total developmental period; AL(F) – Adult longevity (Female); AL(M) – Adult longevity (Male); LC(F) – Life cycle (Female); LC(M) – Life cycle (Male)

Patel (2020) recorded significantly longer durations on Jaya rice (83.12/ $\pm$ 4.43 days for males and 110.8/ $\pm$ 3.35 days for females), while Bheemanna (1986) observed 38–53 days on sorghum, and Kundu *et al.* (2018) found 40.00/ $\pm$ 0.82 and 53.43/ $\pm$ 0.61 days for males and females, respectively, in DPW-62150 wheat.

Morphology of rice weevil on different cereals:

Morphometric analysis of developing stages:

Larval instar length varied with the cereal type, ranging from 0.30–0.85mm in early instars, with the maximum recorded in maize (0.85/ mm; Fig. 1b) followed by rice (0.74mm) and wheat (0.65mm), and the minimum in oats (0.30mm) and finger millet (0.31mm); late instars ranged from 0.80–2.13mm, with the highest in maize (2.13mm; Fig. 1c) followed by rice (1.90mm) and wheat (1.70mm), and the lowest in oats (0.80mm) and finger millet (0.93mm) (Fig. 1d, Table 2). These findings align with Rojasara and Patel (2020), who reported instar lengths from 0.56/ $\pm$ 0.01mm to 2.18/ $\pm$ 0.01mm, Singh *et al.* (2017) who recorded an average larval length of 2.9/ $\pm$ 0.2mm, and Hazarika (2001) who noted freshly emerged and mature larvae measured 1.4/ $\pm$ 0.21mm and 2.5/ $\pm$ 0.23mm, respectively.

Head capsule width of early and late larval instars varied across cereals, ranging from 0.23–0.41/ mm, with the maximum in maize (0.41/ mm) (Fig. 1.a) at par with rice (0.38/ mm), and the minimum in oats (0.23/ mm); for late instars, the smallest width was also in oats (0.24/ mm), followed by finger millet (0.29/ mm), while the highest was recorded in maize (0.73/ mm), followed by rice (0.55/ mm) and wheat (0.42/ mm). These results are consistent with Hazarika (2001), who reported head capsule widths of 0.21/ $\pm$ 0.02/ mm in early and 0.62/ $\pm$ 0.02/ mm in late instars, and with Rojasara and Patel (2020), who documented widths of 0.44/ $\pm$ 0.01/ mm to 0.57/ $\pm$ 0.06/ mm across four larval instars in Jaya rice.

The length of pupae differed between sexes in cereal crops, with females consistently being longer than males (Table 2). The maximum male pupal length was recorded in maize (3.27/ mm), followed by rice (3.12mm) and wheat (3.07mm), while the minimum was in oats (2.58/ mm) (Fig. 1f), followed by finger millet (2.78mm) and pearl millet (2.85mm). Female pupae showed maximum length in maize (3.77mm; Fig. 1e) and minimum in oats (2.67mm), comparable to finger millet (2.71mm). These findings align with Jadav (2006), who

reported pupal lengths of 3.41–3.46mm in maize, and Rojasara and Patel (2020) recorded 2.24–2.40mm in Jaya rice.

Morphometric analysis of adult weevils:

Average adult body length ranged from 2.60–3.90mm, with the maximum recorded in maize (3.90/mm) (Fig. 1h), followed by rice (3.48mm) and wheat (3.17mm), and the minimum in oats (2.60mm), at par with finger millet (2.70mm) and pearl millet (2.87mm); female adults were longer, with the highest length in maize (4.53mm) (Fig. 1g) and the lowest in oats (2.77mm), followed by finger millet (2.87mm) and pearl millet (2.93mm), which were statistically similar. These observations are in line with Choudhury and Chakraborty (2014), who reported male and female lengths of 2.9 ± 0.6 and 2.8 ± 0.6 mm, respectively, on Sambha Mashuri rice whereas, Thakkar and Parikh (2020) noted male and female lengths respectively of 3.18 ± 0.26 and 4.28 ± 0.76 mm on rice, and 3.43 ± 0.17 and 4.6 ± 0.41 mm on maize.

During the experiment, embryonic development (ED), larval development (LD), and pupal development (PD) on rice were seen to amount to a developmental period of 43.87 days, adult

longevity of females and males being 15.40 and 10.27 days, respectively, and a sex ratio of 1:1.78 (M:F). Comparison with other grains showed maize to have considerably shorter development times (40.72 days), greater adult longevity (18.60 days for females, 12.56 days for males), and greater male-female sex ratio (1:1.92), making it a more appropriate host compared to rice, although rice is highly favored since it hosts comparatively quick development and strong adult longevity. On the contrary, cereals like oats had extended developmental periods (66.47 days) and decreased survivorship as adults, suggesting retarded or delayed growth on these mediums.

Morphometric analysis of rice weevil reveals tremendous body length and head capsule width variation according to cereal host. Maize accommodated the maximum body measurements throughout larval instars (early: 0.85mm; late: 2.13mm), pupae (male: 3.90mm; female: 4.53mm), and adult weevils (male HCW: 0.41mm; female HCW: 0.73mm), which reflects the ideal nutritional and physical conditions to grow. Rice, the main diet, also gave comparatively large dimensions (early larva 0.74mm; late larva 1.90mm; pupae male 3.48mm, female 3.53mm) which were much larger

Table 2. Morphometrics of developmental stages of *Sitophilus oryzae* (L.) on different stored cereals

Cereals	Body length(mm)						HCWL (mm)	
	Larval instar		Pupa		Adult weevil			
	Early	Late	Male	Female	Male	Female	Early	Late
Rice	0.74	1.90	3.12	3.35	3.48	3.53	0.38	0.55
Wheat	0.65	1.70	3.07	3.31	3.17	3.33	0.34	0.42
Oats	0.30	0.80	2.58	2.67	2.60	2.77	0.23	0.24
Barley	0.44	1.30	2.91	3.15	2.90	3.03	0.30	0.34
Sorghum	0.56	1.60	2.97	3.25	3.07	3.20	0.32	0.39
Maize	0.85	2.13	3.27	3.77	3.90	4.53	0.41	0.73
Finger millet	0.31	0.93	2.78	2.71	2.70	2.87	0.28	0.28
Pearl millet	0.38	1.20	2.85	2.81	2.87	2.93	0.29	0.32
SE(m)±	0.025	0.061	0.142	0.222	0.097	0.089	0.008	0.022
C.D(0.05%)	0.08	0.18	0.42	0.67	0.29	0.27	0.03	0.07

HCWL - Head capsule width of larval instar (mm)

than those found on oats, where smaller body sizes (early larva 0.30mm; late larva 0.80mm; pupae male 2.60mm, female 2.77mm) reflect developmental stress. The statistically significant morphometric differences ($P < 0.05$) mirror host suitability differences that presumably affect the biological fitness and infestation potential of rice weevil on various cereals. Morphometric differences align with differences in developmental durations and longevity of adults, further indicating that maize and rice are the most suitable hosts for the rice weevil among the cereals examined. These observations are essential for developing host-specific pest management approaches targeting highly susceptible grains during storage.

Based on the observed patterns of development, it can scientifically be affirmed that *S. oryzae* has a shorter developmental period and achieves much larger body and head capsule sizes when cultured on rice and maize than in other tested cereals. These measures strongly suggest that rice and maize are the optimal and preferred hosts of this pest, most probably because of their optimum nutritional and biochemical composition favorable to growth and increased fitness. Consequently, the cereals warrant highest-priority storage vigilance and selective management interventions to avert exacerbated infestation threats.

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