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Taxonomic redescription of the rice weevil (*Sitophilus oryzae*)

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Abstract
The taxonomic study was based on the 27 specimens of *Sitophilus oryzae* collected from different region of Kerala. Depending upon the morphological variations within the species, specimens were pooled into two different groups. Detailed description of all the taxonomic characters like head, rostrum, (dorsal and lateral), antennae, pronotum, elytron, femur, tibia, tarsus, venter and genitalia were studied and presented with 33 illustrations and 22 line diagrams. Taxonomic description of the species are supplemented with standard taxonomic terminology along with genital characters and loaded with the morphometric ratios. The taxonomic study revealed that, morphological variations present among the groups may be due to environmental conditions, availability of food, and moisture content of grains on which they are feeding on. All the variations within the species were depicted with the differential distinguishing characters along with line diagrams.

Keywords: Taxonomy, redescription, *Sitophilus oryzae*, Rhynchophorinae, rice weevil, stored pest

Introduction
The species constituting under the genus *Sitophilus* are one of the notorious pests of stored gains, cereals, and seeds (Zimmerman, 1968b) [17]. Among which rice weevil, (*Sitophilus oryzae* (Linnaeus)) is one of the most cosmopolitan species and a serious pest of cereal grains and products (Kuschel, 1961) [7] and larvae complete its development inside a seed kernel or equivalent products (Koehler, 1994) [6]. *Sitophilus oryzae* was first proposed by Linnaeus in the genus *Curculio* later many synonyms were proposed. Finally Schoenherr (1838) [4] proposed the genus *Sitophilus* for these stored grain pests. Motschulsky (1855) [10], described the maize weevil as, *Sitophilus oryzae* var. *zeamais* collected from corn plants in Cayenne. This species have great morphological similarities with the rice weevil and that's why they were confused in identification in past, or considered as the morphs (Kuschel, 1961 [7]; Plarre, 2010) [11]. Thus these two weevils were termed as the "sister species" or "sibling species" representing their uttermost similarities (Plarre, 2010) [11]. Kuschel (1961) [7] revised the synonyms of *Sitophilus oryzae* complex and taken sibling species as separate species, providing keys for these two species.
A review work done on the taxonomy of these genera indicates that there are inadequacies which need to be addressed for streamlining the salient aspects. The available taxonomic information on is limited and lacking in essential diagnostic characters especially on genitalia, taxonomic terminology and require redefinition. Even in those where detailed descriptions are available, these are lacking in morphometric ratios and need for more material and information. The genitalia diagrams available are incomplete, descriptions and diagrams are unsatisfactory. Keeping these in view, the present study is proposed to bridge glaring lacuna of taxonomic knowledge for important species *Sitophilus oryzae*. These weevils were collected from household and shops from different zones of Kerala and specimens were segregated into different groups owing to their morphological variations. Groups were named in the alphabetical order as Group A and Group B as per the number of variations.

Methodology
Live insects were collected from different agroecological zones of Kerala which later pinned, dried and stored for further studies. Collected specimens were run through the keys (Kuschel, 1961) [7] and specimens were identified. Further the identified specimens apparently resembling were pooled together according to morphological variations, and thus morphologically different groups were identified within the species. An accession number was allotted to both population (group).

The general morphological characters and genitalia were studied with the help of Leica M80 stereo zoom microscope. Photographs of habitus and genitalia were captured, using software Leica Application Suite (LAS) V4.4. The total length given in the description is excluding the rostrum, and standard length from anterior margin of pronotum to the end of pygidium. The illustrations were made by using tube fitted with a camera lucida and the scale of magnification are provided in the illustrations. For male and female genitalia study, terminologies of Kuschel, (1961) [7], Supare *et al*., (1990) [14] and Thompson (1992) were followed. Genitalic studies were carried out by the standard method of Supare *et al*., (1990) [14].

Results

***Sitophilus oryzae* (Linnaeus)**

(Plates 1)

Synonyms: *Curculio oryzae* Linnaeus, 1763: 395; Fabricius, 1801: 438 (*Calandra*); Herbst, 1795: 18 (*Rhynchophorus*); Gyllenhal in Schoenherr, 1838: 981

Curculio ferugilegus DeGeer, 1781: 273; Csiki, 1936: 76

Calandra minor Sasaki, 1899: 485; Kuschel, 1961: 243

Calandra sasakii Takahashi, 1928: 164; Kuschel, 1961: 243

Sphenophorus quadriguttatus Montrouzier, 1860: 910; Kuschel, 1961: 243

Diagnostic Characters

Black to ferrugineus in colour, size not more than 3mm. Rostrum straight in lateral view with base continuous with head; eyes clearly visible in dorsal view. Pygidium with a basal (dorsal), longitudinal sulcus into which the elytral sutural margins "lock"; small, grain infesting species. Upper aedeagus surface evnly convex, without longitudinal line. Microsculpture (punctures) on prothorax and elytron are more alutaceous.

Description

General colour black to ferrugineus, antennae and tarsi brown (Plate 1, b, e). *Head* moderately punctate at crown region, punctations dense near eye, 3.34× as broad as long; 0.27× as long as and 2.78× as broad as rostrum. *Eyes* subdorsal, well visible in dorsal view, ventrally approximating, 3.11× as long as broad. *Rostrum* 0.72× as long as head and pronotum combined, 1.28× as long as broad basally; base 1.50× as broad as apex, rostrum not curved ventrally, continuous with head without any basal constriction, with sides moderately concave from scrobes to apex; middle to apex with minute punctures; remaining portion of dorsum coarsely and in part confluently punctured; punctures arranged in two rows on either side from base to apex, either of row meets at base, forming distinct groove; outer groove meet in between eyes; grooves in males more prominent. *Scrobe* concave laterally, enclosed dorsally, 4.1× as long as broad (Plate 1, A, B, C, D). *Antennae* brown, inserted 0.125× of length from base of rostrum; scape clavate, 0.61× as long as funicle and club combined; funicle comprise of six antennomeres; antennomere II, III, IV and VI subequally long, I antennomere, 1.25 × and 1.5× as long as II, and V, respectively; antennomere I, II, III, IV and V subequally broad, antennomere VI, 1.33 × as broad as each antennomere, antennomeres contains setae; club subconical, 0.67× club glabrous basally, 1.92× as long as broad, row of setae encircling joint between the club (Plate 1, E).

Prothorax 1.1× as long as broad basally; base 1.58× as broad as apex; anterior margin subtruncate, moderately constricted subapically, posterior margin bisinuate and truncated at middle, punctures on dorsum individually discrete, moderately coarse, apart by 0.5× of diameter on disc, except the apical thin margin; setae borne by punctures inconspicuous (Plate 1, F). *Scutellum* rectangular, 1.34× as broad as long.

Elytra punctatostriate, subparallel sided, 2.51× as long as broad, basally 1.10× and 1.61× as broad as middle and apex; striae well impressed, 1.81× as broad as interstriae, punctures continuous not clearly separated from each other, setae small, very fine and inconspicuous and similar to that on pronotum; red to yellow spots of varying size on each elytron, may vary in size (Plate 1, J).

Sternum. Prosternum with convex, punctures as on pronotum, prointercoxal process impressed with punctures; mesointercoxal process apically distinctly arcuate, metasternum depressed in middle; prosternum 2.35× as long as mesosternum and 1.69× as long as metasternum.

Legs moderate, rather slender; pro, meso, and metacoaxa apart by 0.48×, 0.37× and 0.72× breadth of procoxa, mesocoxae and metacoxae respectively. Femur laterally flattened, moderately punctate, setae on punctures inconspicuous; metafemur 1.13× and 1.28× as long as pro and mesofemur respectively (Plate 1, G, H, I). Tibiae slender, with very fine microsculpture; protibia 1.38× and 1.23× as long as meso and metatibia respectively; uncinated, with sharp uncus arising from inner apical angle; sparsely punctate, setae small, very fine and inconspicuous, grooved beneath, ventrally dentate, providing serrated appearance; premucro at outer apical angle (Plate 1, K, L, M). tarsi of all three legs subequal, tarsal segment I and II subequal, III tarsus 1.33× as long and as broad as II conspicuous third tarsi bilobed (Plate 1, N, O, P).

Venter coarsely punctate, first sternite with depression in middle, rest of the sternites convexly raised. V sternite, 1.11×, 1.21×, 1.92× and 2.0× as long as I, II, III and IV respectively (Plate 1, R). *Pygidium* visible, 1.0 × as long as broad, medially sulcate, punctate, setae borne on punctures.

Female genitalia: Spermatheca C shaped with or without gland, proximal arm as long and as broad as distal arm, angle between proximal and distal arms obtuse. Sternite eight "Y" shaped with a strip like broad shaft, 4.5× as long as broad at base; broadest at base, 4.5× as broad as apex, base truncated, forming two arms, arms 0.2× as long as total length (Plate 1, R, W).

Male genitalia: Aedeagus with median lobe arcuate in profile, evenly convex in cross-section; pedon with longitudinal sulci, apophysis 0.9× as long as median lobe. Tegmen 0.92× as long as median lobe; tegminal plate broad, flag like, rounded at apex, 1.2× as broad as tegminal sclerites; tegminal apodeme slender and widened towards apex (Plate 1, S, T, U, V, X, Y, Z, a).

Total length: 2.30-2.73±0.11 mm; *Standard length*: 2.08-2.45±0.13 mm; *Breadth*: 1.20-1.42±0.13 mm.

Specimens examined: 11♀, 16♂, INDIA: Kerala: Kasargod: Padannakad, N 12° 15.423' E 075° 07.018', 23 m, 17.xii.2014, Coll. Arun. Singh, Host: *Oryza sativa* L.; 5♀, 4♂, Wayanad: RARS Ambalavayal, N 11°28.160' E 076°29.553′, 12.ix.2015, 883 m, Coll. Arun Singh, Host: *Oryza sativa* L.; 7♀, 3♂, Palakkad: RARS Pattambi, N 10°48.781' E 76°11.506', 12.ix.2015, 54 m, Coll. Arun Singh, Host: *Oryza sativa* L.; 2♀, 3♂, Kottayam: RARS Kumarakom, N 09°37.650' E 076°25.871', 04.vii.2015, 3 m, Coll. Arun Singh, Host: *Oryza sativa* L.; 7♀, 3♂, Trivandrum: RARS Vellayani, N 08°25.74006'; 076°59.17194', 28m; 23.x.2014, Coll. Arun Singh, Host: *Oryza sativa* L.

Distribution: Cosmopolitan

Remarks: Protibia with sharp premucro, 0.52× as long as uncus. All collected specimens were segregated into two different groups owing to their colouration and elytral spots. Groups were named in the alphabatcal order as Group A and Group B. Above description is based on individuals of Group A. In total 61 specimens studied under Group A. Differential distinguishing characters of three groups are compared in Table 5. The variations among these three groups can be discussed as follows:

Variation I (Group B)

(Plate 1, C, D)

Remarks: In total 48 specimens studied under this group.The characters of this group are similar with the Group A in many extents, the variations among the groups are colour and yellow spots on elytron is not prominent as in case of Group A.

General colour black to dull brown with antennae and tarsi darker than group A (Plate 37, A, B).

Genitalia: There are no variations in genitalia observed.

Total length: 2.40-2.80±0.19 mm; *Standard length*: 2.20-2.62±0.16 mm; *Breadth*: 1.23-1.40±0.14 mm.

Specimens examined: 10♀, 7♂, INDIA: Kerala: Kasargod: Padannakad, N 12° 15.423' E 075° 07.018', 23 m, 17.xii.2014, Coll. Arun. Singh, Host: *Oryza sativa* L.; 8♀, 8♂, Wayanad: RARS Ambalavayal, N 11°28.160' E 076°29.553′, 12.ix.2015, 883 m, Coll. Arun Singh, Host: *Oryza sativa* L.; 3♀, 5♂, Kottayam: RARS Kumarakom, N 09°37.650' E 076°25.871', 18.ix.2015, 3 m, Coll. Arun Singh, Host: *Oryza sativa* L.; 2♀, 5♂, Alappuzha: ORARS Kayamkulam, N 09°10.57992' E 076°31.03746', 20.ix.2015, 2 m, Coll. Arun Singh, Host: *Oryza sativa* L.

Sexual diamorphism

Sexes can be separated out easily by the shape of rostrum and arrangement of punctations on rostrum. Females can be separated by having slender and longer rostrum than male. Males with thick-stout rostrum, widened at middle as compaired to female with more prominent punctures. Distance from scrobe to apex of rostrum 1.10× as long as of males, whereas distance from base of rostrum to scrobe in female is 0.90× as long as in male. Two rows of puntrues extend backward and meet individually at interocular region forming two distinct grooves. Grooves are more prominent in case of males and outer groove extend deep in interocular region (Plate 1, A, B, C, D).

Table 8: Comparison between differential distinguishing characters of two groups of *Sitophilus oryzae* (Linnaeus)

Characters	Grpup A	Group B
General body colour	Black to ferrugineus in colour, comparatively shiny with lighter antennae and tarsi	Black to dull brown in colour, with darker antennae and tarsi
Pronotum colour	Yellow spots on elytron is prominent and clearly visible	Yellow spots on elytron very light or may not be visible clearly

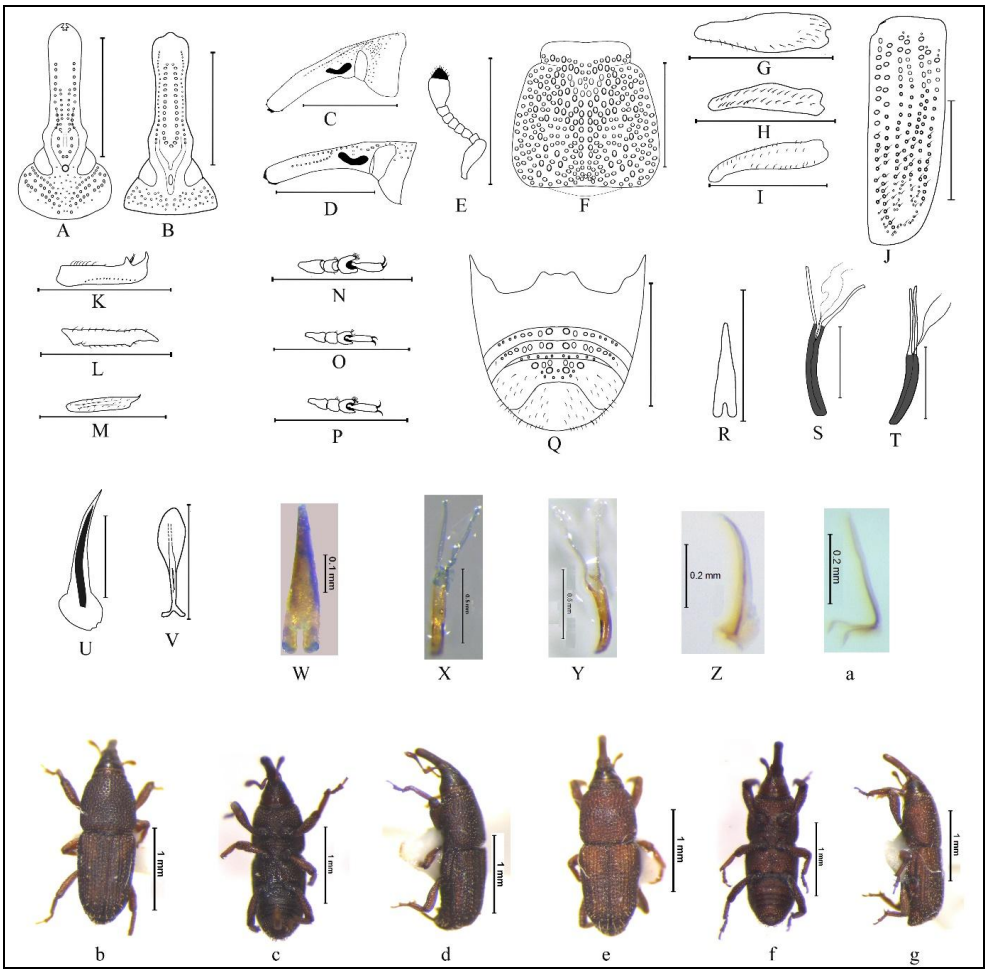

Plate 1: *Sitophilus oryzae:* (A)-(B) Rostrum, Dorsal view; (A) ♀; (B) ♂; (C)-(D) Rostrum Lateral view; (C) ♀; (D) ♂; (E) Antenna; (F) Pronotum, dorsal view; (G) Profemur; (H) Mesofemur; (I) Metafemur; (J) Elytron; (K) Protibia; (L) Mesotibia; (M) Metatibia; (N) Protarsus; (O) Mesotarsus; (P) Metatarsus; (Q) Venter; (R)-(a) Genitalia; (R), (W) Spiculum ventrale; (S), (X) Aedeagus, dorsal; (T), (Y) Aedeagus, ventral; (U), (Z) Side arm; (V), (a) Tegmen; Habitus dorsal view, dorsal view and dorsal view; (A)-(C) Group A; (D)-(F) Group B.

Conclusion

The characters which separates it from other species of genus are: prothorax and elytra with more alutaceous; dorsum dull; aedeagus convex throughout length, without two distinct longitudinal impressions. Dorsal punctures arranged in two rows on either side from base to apex, either of row meets at base, forming distinct groove; outer groove meet in between eyes; grooves in males more prominent (Plate 1, A, B). Elytral punctures are continuous in interstriae, not clearly separated from each other, small setae arising from punctures; setae, very fine and inconspicuous and similar to that on pronotum, more toward apical end; red to yellow spots of varying size on each elytron, may vary in size (Plate 1, b-g). Yellow spots on elytron is prominent in case of Group A (Plate 1, b-g).

Variation among the groups may be due to the temperature under the storage facility as well as in the field conditions (for on field infestation). Variations may also be due to the composition of food material or host plants (rice, wheat, maize, cowpea, pulses, etc.) on which they fed.

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