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Taxonomic Description for Identification of *Spodoptera frugiperda* (J.E. Smith) and *Spodoptera litura* (Fabricius)

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***Abstract*:** The fall armyworm, a polyphagous pest is of major economic importance worldwide. This study presents a comparative analysis of the taxonomic characters of two species belonging to genus *Spodoptera i.e., S. frugiperda* and *S. litura* (Noctuidae: Lepidoptera). These two species are re-described based on morphological taxonomic characters of adult, larval and pupal stages, as well as the male and female genitalia. *Spodoptera litura* is also a major pest of several economically important crops in Asia, across diverse crop ecosystems in India. Its close resemblance with *S. frugiperda* in larval stages necessitates precise taxonomic identification for effective management. Photographic illustrations and descriptions are provided for both species.

***Keywords*:** Taxonomy, *Spodoptera*, Chaetotaxy, Genitalia, Crochets, Morphology

The word Noctuidae (owlet moths, cutworms or armyworms) is derived from the name of the type genus *Noctua*, which is the Latin name for the little owl, the names "armyworms" and "cutworms" are based on the behaviour of the larvae of this group, which can occur in destructive swarms and cut the stems of plants (Regier et al., 2017). Currently, Noctuidae is the second largest family in Noctuoidea, with about 1,089 genera and 11,772 species worldwide (Zhang 2011). The genus *Spodoptera* was first described by Guenee in 1852.About thirty species are distributed across six continents (Meagher et al., 2008, Nagoshi et al., 2011, Mahmoud et al., 2020). Many species are considered as threat to agriculture around the world. The caterpillars of *Spodoptera* are highly polyphagous, nocturnal insect pest with wide host range over 40 families of dicotyledonous plants and therefore, has huge potential to invade new areas and to adapt to new climatic and ecological situations.

The fall armyworm (FAW), *Spodoptera frugiperda* (J.E.Smith) (Lepidoptera: Noctuidae) is invasive, highly polyphagous insect pest originating from the tropical and sub-tropical regions of the America, where it has more than 350 different host plants under 76 different families including both crop and non-crop species (Montezano et al., 2018). It expanded its habitat to two more continents (Early et al., 2018, Nagoshi et al., 2018, Pogue 2002). The incursion of Fall armyworm as an invasive pest was first reported in India 2018 in the maize fields of College Farm, University of Agricultural and Horticultural Sciences (UAHS), Shivamogga, Karnataka (Sharanabasappa et al., 2018, ICAR-NBAIR Pest alert, 2018, Shylesha et al., 2018). The pest has also been reported on different crops from all states of India (Chormule et al., 2019a, 2019b, Srikanth et al., 2019, Bhavani et al., 2019). The larvae of *S. frugiperda* causing extensive damage to economically important crops *viz.,* maize (77.2%), sorghum (60.1%), rice, sugarcane, cabbage, soybean, tomato etc. (Georgen et al., 2016, Burtet et al., 2017, Capinera, 2017, Sisodiya et al., 2018, Lamsal et al., 2020). As it is a major pest of many crop ecosystems in subtropical India, highlights the need for accurate species identification.

Tobacco cutworm, *S. litura* is a major pest of several economically important crops in Asia, particularly cotton, groundnut, and vegetables. Its close resemblance with *S. frugiperda* in larval stages necessitates precise taxonomic identification for effective management. Therefore, the present investigation aims to know the morphological and taxonomic characters of the genus *Spodoptera*, *i.e., S. frugiperda* and *S. litura* at different stages of its growth along with their genital characters.

MATERIAL AND METHODS

Different life stages (eggs and larva) of *S. litura* and *S. frugiperda* were collected during *Rabi* 2019-20 from the experimental and farmer's fields (longitude 83.94^{0,} latitude 18.38^{0}) and brought to laboratory, Department of Entomology, College of Agriculture, Naira, Srikakulam, Andhra Pradesh. The host plant, castor (*Ricinus communis*) leaves used for rearing larvae and feed is changed every day. The culture was maintained by providing fresh leaves until pre pupal stage under room temperature (27^{0}c and 65-70% RH). At pre-pupal stage larvae transferred to the bed of soil was laid at the bottom of cages to facilitate pupation and covered with muslin cloth, tied with rubber band.

Processing and preservation: The emerged adults were

collected and killed using a cotton swab dipped in ethyl acetate and pinned through thorax using nickel coated entomological pins. The adult specimens were dried in hot air oven at 40˚ C and preserved in insect wooden cabinet boxes (45 cm x 30 cm) for further study. The larvae at each instar were processed and preserved in K.A.A.D mixture, using the ingredients kerosene-1 part, 95 per cent ethyl alcohol- 7 parts, glacial acetic acid- 2 parts and dioxane-1 part and stored in glass jar and labelled. Each specimen was labelled with the details pertaining to date of collection, locality, name of collector and host.

Morphological and genital studies: The procedure advocated by Knight (1965), Rose and Pathania (2003) were followed for mounting, chaetotaxy, abdominal segments, crochets on ventral prolegs of larvae and for genitalia studies, for accurate identification of the adult species, the male and female genitalia were dissected out under the Luxeo 4D Stereo Zoom Binocular Microscope by using minutons following the technique given by Knight (1965).

Illustrations and photography: The photographs of specific characters of larvae, pupae, genitalia and adult wings of both male and female were taken using camera. The photographs of chaetotaxy of thoracic segments, 3rd abdominal segment, arrangement of crochets on the ventral prolegs and genital structures with the help of Olympus Trinocular Research Microscope. The dissected genital structures and illustrations were also made with the help of same microscope using micap 3.6 digital camera attachment using the software under 40 to 100X magnification. All the measurements expressed in cm or mm, using micrometry under Stereo Zoom Binocular Microscope.The drawings were made on tracing paper by using Rotring tikky graphic pen. Identification of adult specimens was done by comparison with photographic plates and various online resources available, using the EPPO bulletin, 2015.

RESULTS AND DISCUSSION

Two species belong to genus *Spodoptera viz.*, *S. frugiperda* and *S. litura* were observed for their morphological and genital characters along with larval taxonomic characters of each instar.

***Spodoptera frugiperda* (J.E. Smith 1797)**

Common name: Fall armyworm, Alfalfa worm, corn leafworm, cotton leafworm, grass worm, maize budworm, wheat cutworm.

Morphological Characters

Larva: The 1st instar larva (L_1) very tiny with large black head and the body light greenish colour covered with minute black hairs (Plate 1A). The length of the body is about 0.7 mm. The Second instar (L_2) is measures approximately about 12 to 15 mm length. Head is amber to cream coloured with blackish brown head capsule. Body pale white to yellowish and a brown tinge on the dorsum and also with faint white dorsal and sub-dorsal lines are present. A pinkish line below the spiracle, especially on the posterior abdominal segments (Plate 1B). The 3rd instar (L_3) is in light green to cream coloured with three longitudinally light lines. At this stage body colour changes from pale white to greenish brown. White lines on dorsal and subdorsal areas are plainly visible and the black spots became prominent. The length of body is about 21 to 23 mm. The 4th instar larvae (L_4) body colour varied from olive brown to dark brownish with red pigmentation. The dorsal and sub-dorsal white lines are also become conspicuous. The body length is about 24 to 27 mm. The body of 5th instar larvae (L_5) attained grayish brown to cream colour on the dorsal side and on ventral and sub-ventral sides are greenish. Head with dark brown areas and is in brick red colour. Body length is about 26 to 29 mm.

The 6th larval instar (L_6) is stout and bulged with dark grey head. Body is smooth with clear distinct segmentation. The body is grayish brown to reddish cream on the dorsum and lateral white lines with ventral, sub-ventral sides greenish mottled with reddish brown colour. The mature larva has an inverted **'Y'**- shaped white marking on the head (Plate 1D) and distinct dark spots on the body. On the dorsum of 8th abdominal segment four black spots arranged in square pattern and on remaining segments spots are in trapezoidal shape as shown in Plate 1C. The length of larvae at this stage is 32 to 36 mm.

Chaetotaxy of Thoracic and Abdominal Segments

Thorax: On first thoracic segment SD_1 and SD_2 setae are present on a joint pinaculum at ventral to thoracic shield and at ventral side of the thoracic shield. On prothoracic shield dorsal setae XD_1, XD_2 and dorsal setae D_1, D_2 are present. L_1 and L_2 setae are hair like and situated on ventral margin of spiracular line (Plate 1G). But the L_3 setae is about half the length of L_1 and L_2. On meso and meta thoracic segments spiracles are absent. The crochets on 3rd to 6th abdominal segments are arranged in uniordinal mesoseries heteroideous pattern (Plate 1E, F).

Abdomen: Third abdominal segment with dorsal setae D1, D2 are arranged in trapezoidal pattern. SD_1 is present just above to the spiracle and also with subventral setae SV_1, SV_2, SV_3 and lateral setae L_1, L_2 and L_3 (Plate 1H). The present observations of larval morphological characters, chaetotaxy and crochets arrangement on the ventral prolegs are in parallel with the earlier studies Pogue (2002), EPPO (2015), Shylesha et al. (2018), Venkateshwarlu et al. (2018) Bhavani et al. (2019), Lestari et al. (2020), Kalyan et al. (2020) and Henaish and Elmetwaly (2020).

Pupa: Reddish brown pupa with white tinge. It is measured

about 15-18 mm in length, with a cremaster consisting of two spines are about 0.5 mm long. The observations are in conformity with findings of Sharanabasappa et al. (2018) and Manjula et al. (2019).

Adult: In males, front wings are darker than females. The forewings are with discrete markings of light grayish brown shades and with white patch near apical margin. Reniform spot is indistinct at the center of the wing, partially outlined in black with small "V"- shaped marking (Plate 1I). Orbicular spot is in light brown colour, oval and oblique in shape with strongly contrasting crosswise lines and also with a row of small black hour-glass shaped markings near the apical margin of wing. Measurements- body length: 1.5- 2.0 cm; front wing length: 1.4 – 1.6 cm; hind wing length: 1.1- 1.3 cm; wing span: 2.9 – 3.2 cm.

In female, body is robust when compared to males. The female forewing is without reniform spot and contrasting markings near the apical margin. Forewing is imprecise with uniform grayish brown to fine mottling of gray colour (Plate 1J). Orbicular spot is obliquely elongated, narrowly outlined in black with a pale rim in the region of the dark center. The hind wings of male and female are silver -white in colour with partial narrow light brown to pale gray border. Measurements- body length: 1.5 1.7 cm; front wing length: 1.4 – 1.5 cm; hind wing length: 1.2 – 1.4 cm; wing span: 3.2 to 3.4 cm. The described results are in conformity with earlier studies Oliver and Chapin (1981), Pogue (2002), Brambila (2013), Manjula et al. (2019), Bhavani et al. (2019), Sharanabasappa et al. (2018) and Henaish and Elmetwaly (2020).

Genitalia: The male genitalia is characterized by the coremata is with single lobe (Plate 1K) and adeagus well developed. Valve is broad, almost quadrate with tiny clavus. The female genitalia is identified by ostium bursa ventral plate height is greater than width (Plate 1L), ventro lateral ductus bursae are short and completely sclerotized. Appendix bursae are partially sclerotized. The bulbous corpus bursae length is less than the width. The results of genital characters were in conformity with the observations of Oliver and Chapin (1981), Brambila (2013), Ganiger et al. (2018), Bhavani et al. (2019), Sharanabasappa et al. (2018) and Henaish and Elmetwaly (2020).

***Spodoptera litura* (Fabricius 1775)**

Common name: Tobacco cutworm, cotton leaf worm, tropical armyworm, tobacco caterpillar.

Morphological Characters

Larva: The newly emerged 1st instar (L_1) is light green to yellow in colour with black head as shown in Plate 2A; an amber-brown spot is below SD_1 at first abdominal segment, this spot later on develop into a large dark lateral spot. The length of larvae is about 0.7 to 0.9 mm. The 2nd and 3rd instar larvae (L_2, L_3) are recognized by increasing size of dark spot SD1 on first abdominal segment (Plate 2B). As it grows the spot turned into black colour at early 2nd instar and become more prominent during 3rd instar stage. On the 2nd and 3rd thoracic segment and at eighth abdominal segment dark spots develop at D1 position and also small black dorsal spots develop on the other segments. The second instar length is about 8 to 10 mm. Dark spot on 2nd and 3rd thoracic segments turns into yellow to white dot by the end of 3rd stage, except dark spot on eighth abdominal segment. Small yellow to white dots at the base of black patches present on 2nd and 3rd thoracic segments (Plate 2C). The dark lateral spot on first abdominal segment extend laterally (Plate 2D).

The third instar is 9-13 mm in length. The 4th instar larvae (L_4) are in brown or greenish colour with brown to black coloured head. The body is stout and about 25 to 30 mm in length. The dark patches on dorsal side, most prominently on 1st and 8th abdominal segments with yellow or orange mid dorsal line (Plate 2C).

The older instars like 5th and 6th are stout, cylindrical and reddish brown in colour. Two black dorsal patches on meso and meta thoracic segments. Larvae have orange mid dorsal line and sub dorsal line marked by yellow and orange spots. Mid dorsal stripe and dorsolateral stripes are yellow with black segmental spots. Late instar has dark patches on first and eighth abdominal segments (Plate 2D). The full grown larvae are about 39-42 mm length.

Chaetotaxy of Thoracic and Abdominal Segments

Thorax: On prothoracic segment shield highly sclerotised, anterior dorsal setae XD_1, XD_2 and dorsal setae D_1, D_2 are distinct on prothoracic shield. Sub ventral setae SV_1 and SV_2 are distinct (Plate 2F). Lateral setae L_1, L_2 with microscopic setae MV_1, ventral seta V_1 present. Mesothorax with dorsal setae D_1, D_2 and sub dorsal setae SD_1, SD_2 distinct. Lateral setae L_1, L_2 and L_3 present. Sub ventral seta SV_1, ventral seta V_1 and microscopic setae MV_1 and MV_2 present. Black dorsal patches on 2nd and 3rd thoracic segment are smaller than the patches present on the first abdominal segment.

Abdomen: Third abdominal segment is with dorsal setae D_1 and D_2. Sub dorsal seta SD_1 distinct. Lateral setae L_1, L_2 and L_3 present below the spiracle. Sub ventral setae SV_1, SV_2 and SV_3 and ventral seta V_1 are present (Plate 2G). Crochets on prolegs are arranged in uniordinal mesoseries heteroideous pattern as shown in Plate 2E.All the described larval and chaetotaxy characters are in concurrence with the findings of Arunasri (2006) and Giligan and Passoa (2014).

Pupa: The *S. litura* pupa is brown in colour and about 15-22 mm in length. It has a cremaster consisting of two spines of about 0.5 mm long (Plate 2H). The pupal characters are in corroboration with EPPO (2015).

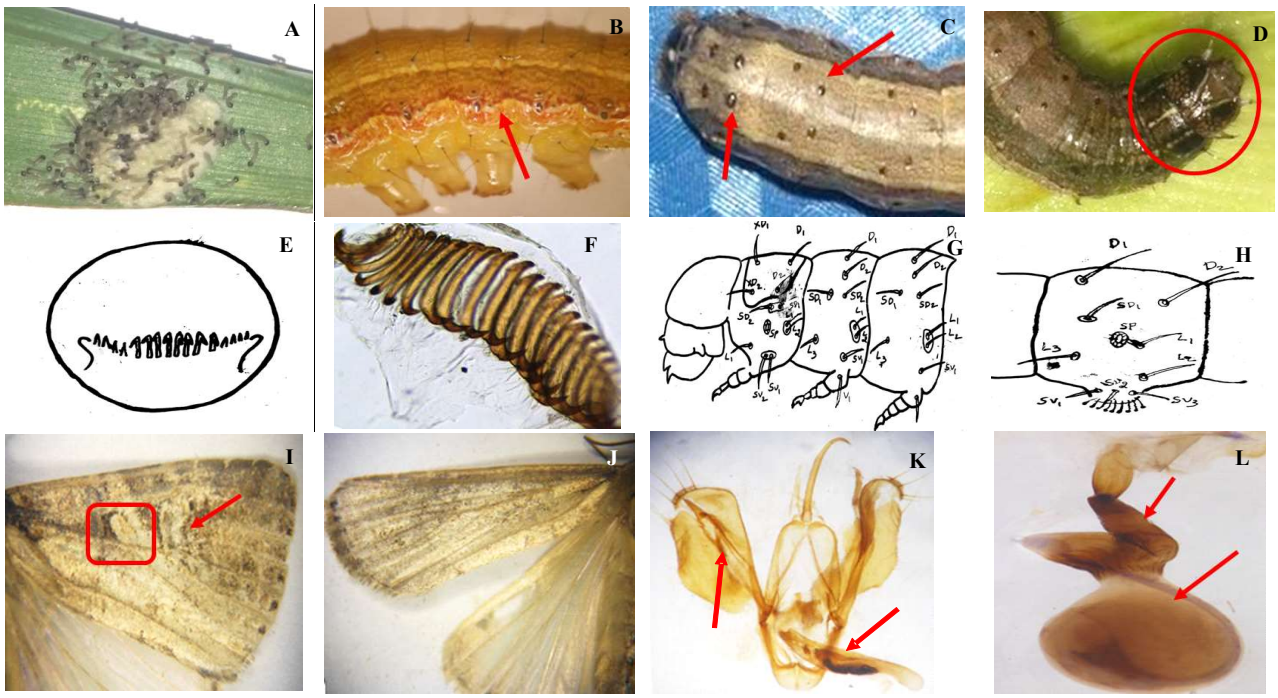

Plate. 1. *Spodoptera frugiperda* (A-L) A. First instar with black head; B. Pinkish line below the spiracle; C. Four black spots on 8th segment in perfect square shape and on remaining segments in trapezoid shape; D. An inverted "Y"- shaped white marking on head; E&F. Uniordinal mesoseries heteroideous type of crochets; G. Chaetotaxy of thoracic segments; H. Chaetotaxy of 3rd abdominal segments; I. Fore wing of male; J. Forewing of female with orbicular spot and 'V' shaped reniform spot; K. Male genitalia coremata with single lobe; L. Female genitalia corpus bursae is short and ductus bursae is short and completely sclerotized

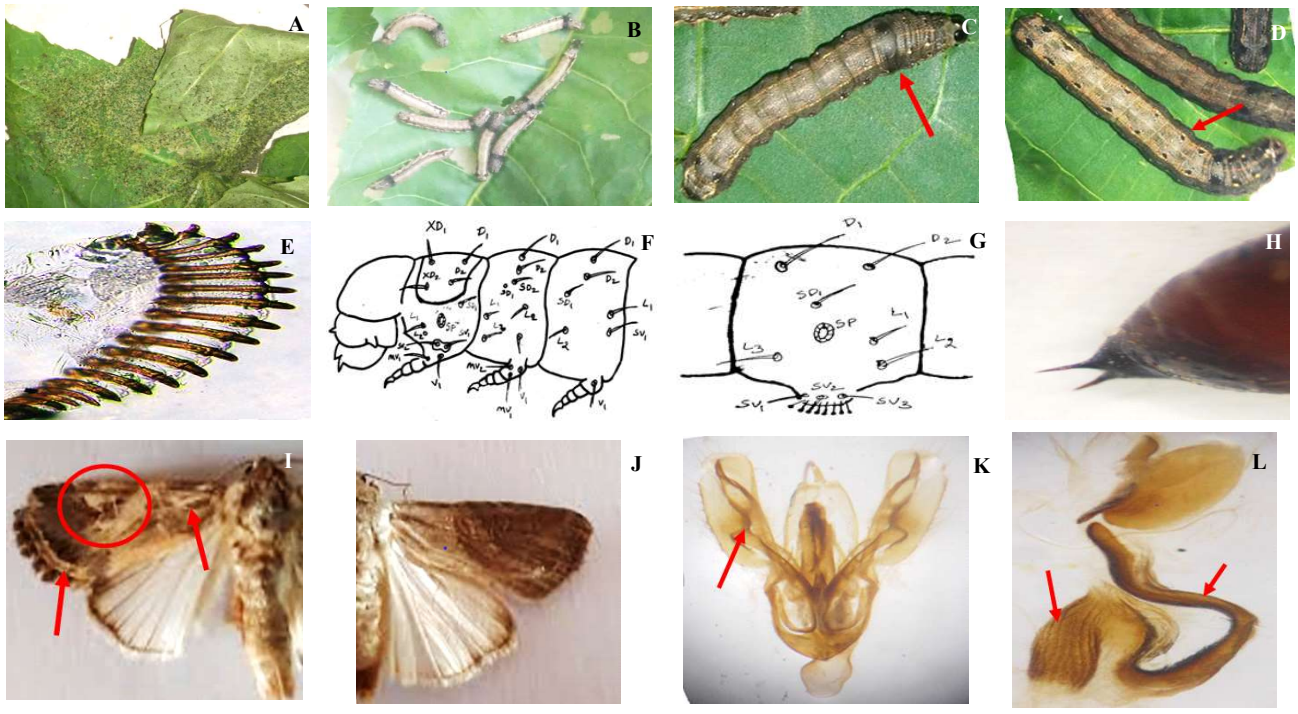

Plate. 2. *Spodoptera litura* (A-L) A. first instars in light green -yellow colour with black head; B. Second instar; C. dark spot on first abdominal segment; D. 2nd, 3rd thoracic segments and all abdominal segments with yellow to white dots; E. crochets in uniordinal mesoseries heteroideous; F. Chaetotaxy of thoracic segments; G. chaetotaxy of 3rd abdominal segment; H. pupa of *S. frugiperda* and *S. litura* with a pair of spines; I. fore wing of male with reniform spot and white fork; J. fore wing of female; K. male genitalia coremata with two lobes; L. female genitalia with long corpus bursae and heavily sclerotized ductus bursae

Adult: The adult male body length is 1.3 cm, fore wing length is 1.4 cm, hind wing length is 1.0 cm and wing span is about 3.2 cm. The adult forewing with a brown reniform spot, with a white margined light brown area at tips, is like a letter "A" as shown in Plate 2I. Orbicular spot is elongate, narrow, oblique trapezoid, light brown and with a light brown center outlined with white border and a row of dark hour-glass shape markings along the outer margin of wing (Plate 2I). Hind wings are opalescent and semi hyaline white with dark brown patch on the margin.

The adult female moth is robust and the body length is 1.4 cm, forewing length 1.6 cm, hind wing length 1.2 cm and wing span 3.3 cm; forewing is without a large yellowish or light brown patch (Plate 2J). These identified characters are in compliance with the observations of Pogue (2002), Brambila (2013), Muddasur and Venkateshalu (2017) and Manjula et al., (2019).

Genitalia: Male genitalia characters are depicted as the coremata with two lobes; one is shorter and another longer and uncus is long and slightly curved (Plate 2K).Valve is elongated, well differentiated with two windows, among them one is triangular and another in rectangular shape separated by a right angle at the center. The female genitalia consist of corpus bursae which is bulbous and its length is two folds more than the width with striate convolutions (Plate 2L). Ductus bursae are heavily sclerotized and its length is three times greater than width and ostium bursae is broad, less sclerotised. The descriptions of the present investigation are in conformity with the findings of Brambila (2009), EPPO (2015) and Ganiger et al. (2018).

CONCLUSIONS

The present study provides a comparative taxonomic description of two species of *Spodoptera viz., S. frugiperda, S. litura* highlighting diagnostic morphological, morphometrics and genital characters of each species across larval, pupal, adult, and genital stages with their key characters. Clear differences such as the inverted "Y" mark on the head and square arrangement of spots on the 8th abdominal segment in *S. frugiperda*, and the prominent lateral abdominal spot and double-lobed coremata in *S. litura*, enable reliable species separation. These diagnostic characters are particularly important for rapid field identification and accurate taxonomic confirmation, which in turn support timely pest monitoring and management strategies. As both species are highly destructive polyphagous pests, precise species identification is essential for implementing effective control measures and preventing economic losses in diverse cropping systems.

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