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OUTBREAK OF ARMY WORM, *LEUCANIA ALBISTIGMA* MOORE ON MAIZE WITH NOTES ON TAXONOMY AND MANAGEMENT

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ABSTRACT

Army worms and cut worms are pests of crops and assume serious pest status occasionally causing significant damage to agricultural crops. Present study report the incidence and taxonomic identity of the pest which occurred in outbreak form causing severe defoliation on maize over 1000 ha in Shivamogga district of Karnataka. Infestation was also noticed on the adjoining fields of sorghum and rice at negligible level. Through morphological characters including genitalia and DNA barcoding, the taxonomic identity of *Leucania albistigma* Moore (Lepidoptera: Noctuidae) as army worm in outbreak form is reported herewith for the first time from India. As its taxonomic information was scanty, redescription of all the stages has been provided. DNA barcoding and phylogenetic analysis revealed that species of the genera *Leucania* have a close relationship with those of *Mythimna*. Spatial distribution indices analysed indicated the uniform distribution in soil but aggregated distribution on maize. Select insecticides were evaluated in field targeting larvae with spray and with poison bait in randomised block design. Treatments with poison bait outperformed spray formulations, indicating that the larval behaviour could be exploited for management. Species of army worms are polyphagous and occur frequently in the Indian subcontinent, the taxonomic, ecological and management studies undertaken in the present study forms a basis for future monitoring of species identity and outbreaks on cereal crops.

Key words: Army worm, *Leucania albistigma, Mythimna, Spodoptera*, maize, sorgun, rice, mtCOI sequences, redescription, larva, spatial distribution

The army worms (Lepidoptera: Noctuidae) with high larval densities have plagued the world becoming serious pests. The army worms are polyphagous, mostly prefer cereals, pastures and forage crops (Sharma et al., 2002). Although species belonging to the genera *Mythimna* and *Spodoptera* are widely reported as army worms or cut worms, the information on other genera occurring in outbreak form is not clear. As reported from Australia, sugarcane army worm *Leucania loreyi* was considered as the only army worm infesting graminaceous crops (Edwards, 1992). Earlier, when the common names list of Australian insects were revised it were recognised that all specimens examined from Australia were *Leucania loreyimima* rather than *Leucania loreyi* (Gay, 1966). Similarly, when *Spodoptera frugiperda* (J E Smith) was first reported from India during 2018 (Sharanabasappa et al., 2018), the outbreaks were initially speculated to be caused by the oriental army worm *Mythimna separata* recorded in 2017 (Divya et al., 2021). These demonstrate that taxonomic studies are necessary, even if the pest is well known. Maize is the a major crop in India, and is ranked 4th in the world and is cultivated in 9.2 million ha as of 2020 and Karnataka state represents highest area. After invasion and establishment, *S. frugiperda* becomes the only major pest in India due to cannibalistic nature and early habitat occupancy of maize whorl (Divya et al., 2021; Kalleshwaraswamy et al., 2023). Any addition to the pest complex on maize will have drastic effect on its productivity.

Following the request of maize growers and Karnataka State Department of Agriculture (KSDA) officials, field visits were conducted to analyse the army worm incidence in Shivamogga district of Karnataka. Total defoliation leaving only the stem and the midrib was observed. There was a control failure in many fields, though farmers used insecticidal sprays. Discussion indicated that they sprayed lamdacyahalothrin, chlorpyriphos and chlorantraniprole were sprayed without the desirable results once or twice in a short span of a week. The probable reason for failure is the

behaviour of larvae which hides during day in soil and avoid feeding on sprayed plants. As against previous reports, wherein outbreaks were noticed in the kharif season, outbreak was noticed in summer season (April, 2022), which is unexpected. Previous reports suggest that years of heavy rainfall with a preceding history of drought for few years is the precursor for abnormal multiplication of *M. separata* which is obviously assumed to occur in outbreak form and cause serious loss in maize (Thakur et al., 1987; Sharma et al., 2002). Same is the case with *Spodoptera exempta* in Africa (Janssen, 1992). This unexpected occurrence led us to look for taxonomic aspects of the specimens from localities where outbreak was found. The larval and adult morphology when analysed, surprisingly, it was different from that of *M. separata*. Through morphological and molecular confirmation, herewith the outbreak of *L. albistigma* is reported in the major maize growing area for the first time which was hitherto unknown. Further, spatial distribution of larva was assessed in the fields where severe outbreak was noticed and select insecticides were evaluated as spray and as poison bait.

MATERIALS AND METHODS

Roving surveys were undertaken in the maize fields of outbreak areas in Shivamogga district of Karnataka, India. Infestation level in the localities surveyed are given in Table 1. The crop surveyed was 60-70 days old, and both in sprayed and unsprayed fields, the larvae were rarely found on plants except few hiding at the junction of cob and stem. Hence, in each locality, number of larvae/ 1 ft x 1 ft x 5 cm (LBH) area in soil were counted in four sampling units. In each locality, the total area showing defoliation was recorded, alongwith type of damage. The larvae and pupa were collected, reared to adults and egg, larval and pupal description was provided. Dissection of male genitalia was performed following protocols of Shashank and Ramamurthy (2014), Zeiss - Stemi 508 stereozoom microscope and images were taken with Leica M-205C auto montage stereo microscope. Voucher specimen, along with the dissected genitalia in micro vials with glycerine, was stored at the Insect Systematics Laboratory, Department of Entomology, College of Agriculture, KSNUAHS, Shivamogga. The genitalia were compared with previous descriptions (Yoshimoto,

Table 1. Density of *L. albistriga* larvae in crops observed

Locality	GPS coordinates	Crop age	Area surveyed (in ha)	No. of larvae/ 1 ft x 1 ft x 5 cm (LBH) area in soil*
	Maize			
Soraba taluk: Shivamogga District				
Shakunavallli	14°63'N 75°10'E	65	10.5	8.00
Shankarikoppa	14°60'N' 75°08'E	78	6.0	8.25
Aralethalaggadde	14°61N 75°05'E	64	2.5	8.25
Devarahosakoppa	14°62N' 75°09'E	70	3.0	7.75
Kodikoppa	14°60N' 75°08'E	68	1.0	5.25
Doddathalagadde	14°60N' 75°09'E	65	2.25	8.50
Thalagunda	14°58N' 75°06'E	70	1.5	7.00
Jade	14°57N' 75°04'E	64	2.5	8.75
	Sorghum			
Shakunavallli	14°63'N 75°11'E	50	1.5	6.00
Shankarikoppa	14°60'N' 75°10'E	45	1.0	3.50
	Rice			
Thalagunda	14°58N' 75°08'E	55	0.5	1.00
Jade	14°57N' 75°10'E	50	0.25	0.50
Bhadaravathi taluk: Shivamogga District				
Dodderi camp	13°84' N 75 °81'E	70	1.0	5.25
Gangooru	13°83' N'75°84'E	68	2.5	6.35

*Mean of four sampling units

1994). The images of morphological characters were also shared with recognised noctuid taxonomist, Dr. Albert Legrain, Quai du Halage, 10, 4681-Hermalle, Liège, Belgium for confirming species identity.

The genomic DNA was isolated from the larvae following standard procedure of Sutrisno (2012) with slight modification. The 5'-end marker region mtCO1 was amplified using the Folmer primer pair (LCO1490 and HCO2198) in the Applied Biosystem master cycler. The collected larval samples were used in replication to extract DNA and amplify mtCOI gene. The amplified products were sequenced at Barcode Biosciences, Bengaluru. The electropherograms obtained were checked for ambiguous bases in BioEdit 7.2 and the sequences were edited to remove ambiguous bases. The edited sequences were used to check the homology with the sequences already available in the NCBI's GenBank database and their accession numbers obtained from the NCBI's GenBank and Barcode of Life Database (BOLD). These mtCOI sequences and other army worm species extracted from GenBank were analysed in MEGA X (Kumar et al., 2018). The sequences of 15 species of the genera *Leucania, M. seperata* and *M. reversa*, two species of the genera *Spodoptera* viz., *S. litura* and (MG783870) *S. frugiperda* (MN640598) with *Bombyx mori* used as outgroup were retrieved from GenBank. The sequences were first aligned in Clustal W multiple alignment in BioEdit 7.2 and the aligned sequences were used to construct the phylogenetic tree. The evolutionary history was inferred using the Maximum Likelihood method with Jukes-Cantor model (Jukes and Cantor, 1969).

Due to complete defoliation of maize, the maize growers were panic-stricken and resorted to spraying insecticides and there was a control failure. The probable reason could be behaviour of larvae which hides during day in soil and may avoid sprayed plants. In sprayed fields, feeding symptoms on low grown weeds such as *Cynodon dactylon* (L), *Setaria viridis* (L) and *Echinochloa colona* (L) was observed. Both in sprayed and unsprayed fields, larvae were rarely found on plants except few hiding at the junction of cob and stem. To find out the reason for the inefficacy of spray, spatial dispersion of larvae in soil and on plants was analysed. An infested maize field was selected for spatial dispersion analysis at Shakunavalli. Number of larvae in quadrats of 1 m^2 were counted at 10m interval in a 40 m x 100 m grid for 40 samples in soil and on plants. For observation in soil, in each quadrat, 1 ft x 1 ft x 5 cm (LBH) was dug and number of larvae were counted. For observation on plant, in the middle of each quadrat, number of larvae were counted on five selected plants. Means ($x\square$) and variances (S^2) of these counts were computed followed by spatial distribution indices viz., 1. Index of dispersion (ID): The index of dispersion can be calculated through variance to-mean ratio namely, $S^2/x\square = 1$ random, <1 regular and >1 aggregated (where S^2 =sample variance; $x\square$=sample mean) (Kuno, 1991). 2. Green's index [$GI = S^2/x\square)-1)/n-1$]: The measure obtained through the above said equation are indicative of aggregation if values are positive, negative values indicative of uniformity, and negative values closer to 0 indicate randomness (Green, 1966). 3. Index of mean clumping (I_{DM}) = ($S^2/x\square$)-1: The David and Moore index of clumping values increases with aggregation. If the index value = 0, the distribution is random; and positive value shows negative binomial (aggregated) and negative one shows positive binomial (regular) (David and Moore, 1954). 4. Index of patchiness IP= ($x\square + S^2/x\square$)-1/$x\square$=IMC/$x\square$: This index proposed by Lloyd (1967) indicates possible effect of mutual interference or competition among individuals. The values are indicative of 1= random, <1 = regular and > 1 = aggregated (Lloyd, 1967).

Due to severe defoliation, farmers resorted to insecticide spray but there was a control failure. This led us to evaluate the efficacy of some select insecticides. Four insecticides as spray formulations and another insecticide chlorpyriphos mixed with bait were selected with four replications in a randomized complete design. Each replicated plot size was 5 x 6 m and sampling for larvae was also done in a replicated plot in soil as mentioned in spatial distribution studies. Larval count data was taken in soil rather than on plants consequent to the results obtained in spatial distribution studies wherein uniform distribution of larvae was not observed on plants. To avoid error counts taken in soil were considered to be best sample rather than counts on plants. In each replication, 1 ft x 1 ft x 5 cm (LBH) was dug and larvae counted and used for Tukey's statistical test. Insecticide applications were carried out during evening hour using a high volume knapsack sprayer fitted with a hollow cone nozzle at 400 ℓ/ ha. The poison bait treatment consisted of 50 kg rice bran, four kg jaggery dissolved in eight ℓ of water for 1 ha and 250 ml chlorpyriphos 20EC for and calculated proportionately to the plot size. This is based on Hiremath et al. (1992) who used poison bait for *M. separata*. Bait was prepared a day before application and allowed for fermentation in an airtight container for 24 hr. The bait thus prepared was mixed with chlorpyriphos during evening and

sprinkled uniformly in field. The larval counts from soil (1 ft x1 ft x 5 cm (LBH) were transformed with square root (x + 0.5). Data were subjected to analysis ANOVA and treatments were compared by Tukey's test (p = 0.05) using SPSS software (Version 16.0).

RESULTS AND DISCUSSION

Incidence of *L. albistigma* was observed mainly on maize and sorghum and partially on rice in two taluks of Shivamogga district namely Soraba and Bhadravathi. Large area (over 1000 ha) was under maize in these two taluks grown under irrigated condition and there was total defoliation in most fields (Fig. 1a) leaving only midrib and main stem (Fig. 1b) but cobs were also bored (Fig. 1c) indicating the out break. The larvae were rarely found on plants except few larvae hiding at the junction of cob and stem (Fig. 1d). But larvae in high density were found in soil when clods were disturbed (Fig. 1e) and also in neighbouring non-maize fields underneath plants in soil (Fig. 1f). Most of the larvae observed were well grown. None of the pupae was found in soil when visit was made on 24.iv. 2022 but were collected during second visit made on 28.iv.2022 (Fig. 1g), indicating only a single generation. Sorghum fields adjoining were also severely infested with complete defoliation (Fig. 1h) whereas partial damage was observed on rice (Fig. 1i) but larval presence was not observed on plants. Although few larvae were recovered on maize plants during day time, high density of larvae was found in soil. The number of larvae/ ft^2 within a depth of 5 cm varied from 5.25 to 8.75. Initial defoliation was found in the lower part of the plant (Fig. 1j), extending to upper part within 2-3 days leading to complete defoliation. Larvae and pupae were reared to adults in lab and allowed for egg laying. Eggs were observed to be laid in groups, spherical and milky white(Fig. 2a). Larvae were having a total of five white lines, a dorsal, two subdorsal and three lateral lines (Fig. 2b, 2c). The dorsal white line has light grey to dark grey external margin; inner edge of

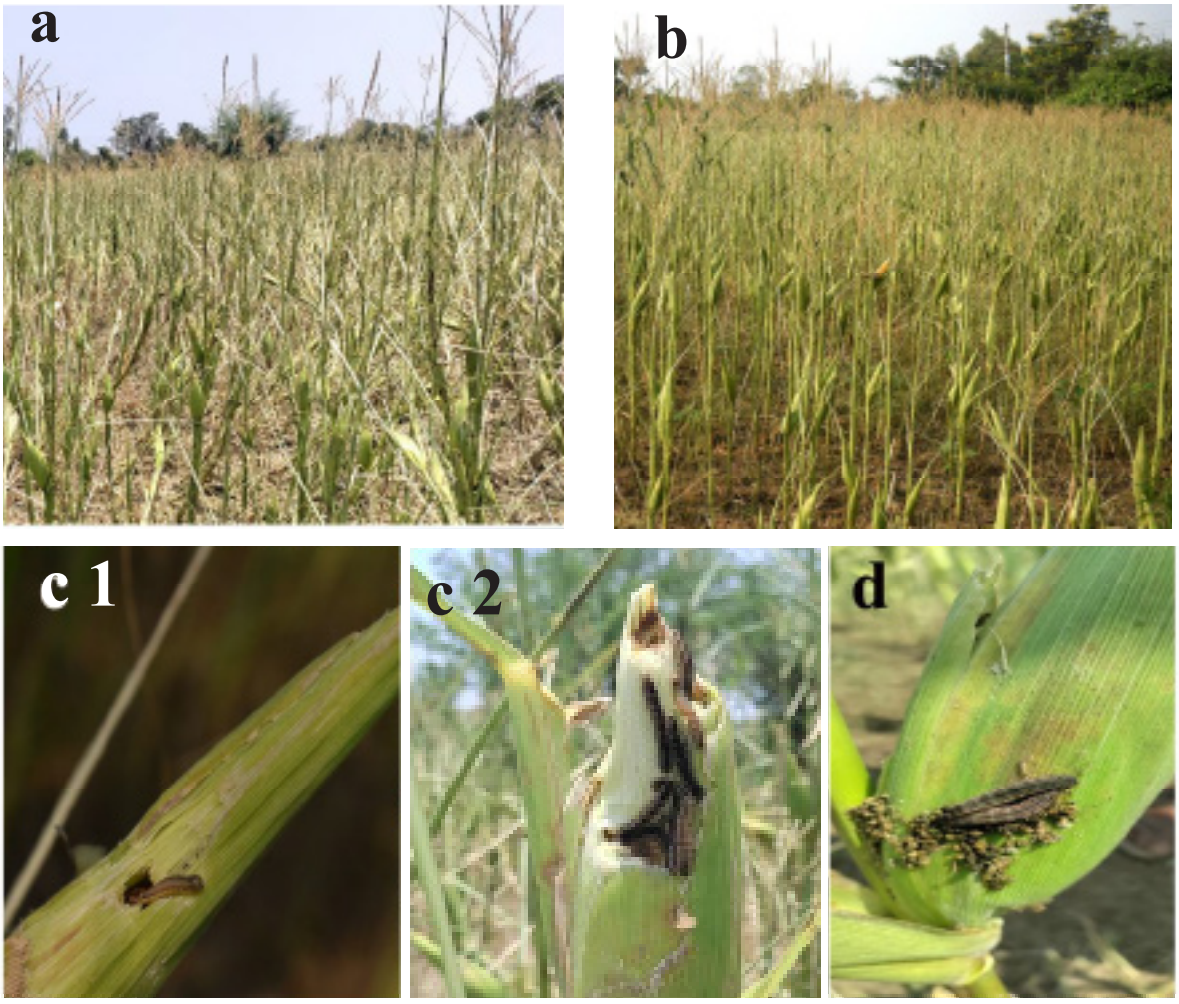

Fig. 1a-d. Incidence and damage of *L. albistigma*; a) Complete defoliation in maize; b) Feeding leaving only midrib and main stem; c 1 and c 2) Boring on cobs; d) Larvae hiding at the junction of cob and stem

subdorsal white lines have black strips in each thoracic and abdominal segment, more prominent in abdomen than in thorax (Fig. 2b); laterally, two orange stripes separated by a middle dark stripes run along the body and each stripes lined white (Fig. 2c); three lateral white lines, one runs on supraspiracular region, one spiracular and one subspiracular (Fig 2c). Pupae shiny dark brown (Fig. 2d) and pupated in an earthen cocoon (Fig. 1g). Adults pale brownish ochreous (Fig. 2e).

Redescription

Adult

Head: Rusty brown (Fig. 3a), frons covered by yellowish to rusty black scales. Compound eyes globular, densely hairy. Labial palpus short and upturned. Antenna filiform, dorsally covered by dark and light brown scales (Fig. 3d). Thorax: Beige with two dorsal longitudinal greyish-black lines (Fig. 3a); with some black-tipped scales on tegula; legs greyish with meso- and metatibial spurs. Female with three frenulum (Fig. 3c). Forewing: Length 12.8–14.2 mm in males (n = 6), 13.6–15.8 mm in females (n = 5). Dark brownish forewings longer than wide, costal margin nearly straight and the apex slightly rounded (Fig. 3b and 3f); veins and its branches with brownish grey small spots distributed mainly along the median

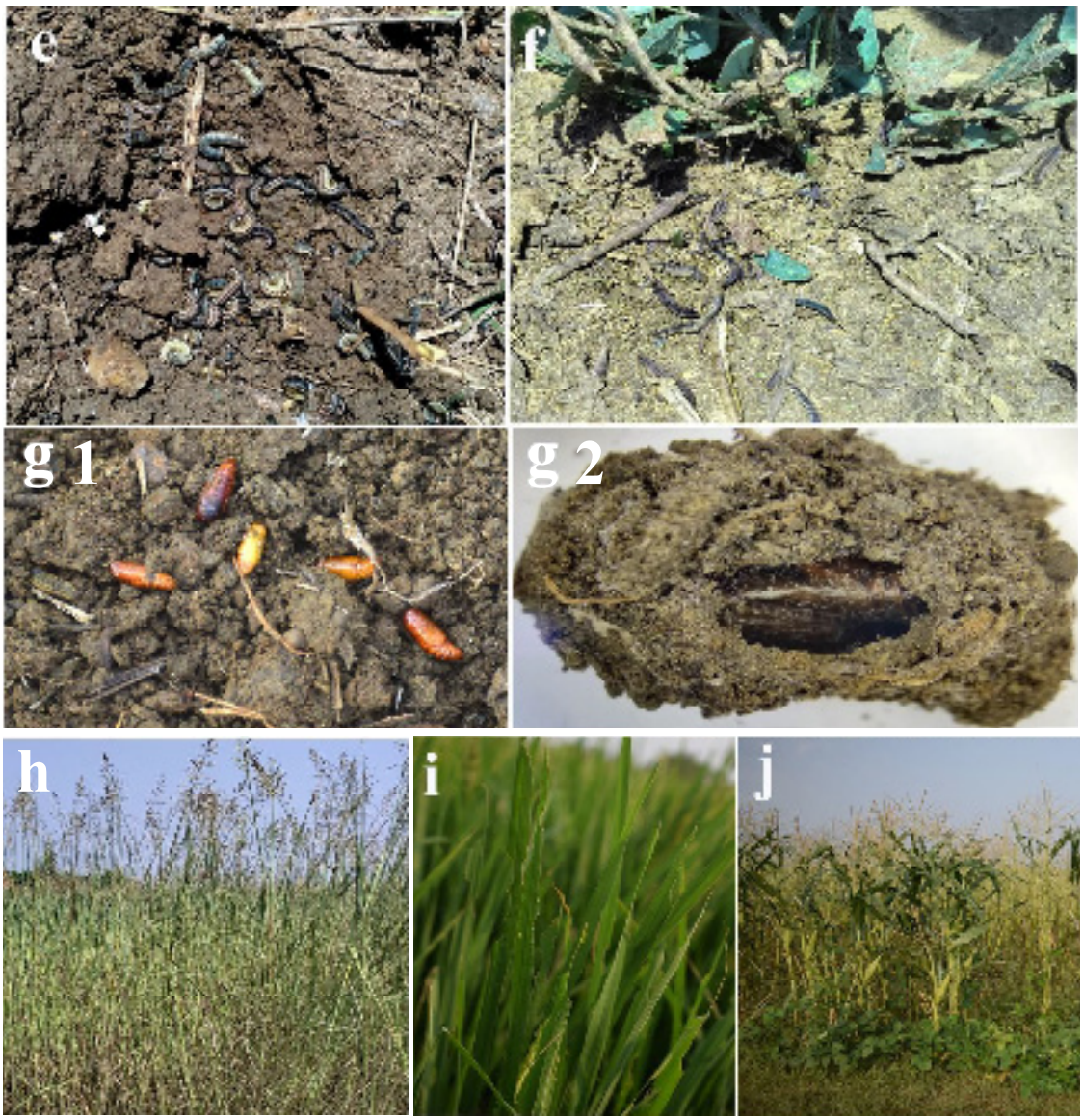

Fig. 1e-j. Incidence and damage of *L. albistigma* (contd...). e) Larvae in soil below the clods; f) Larvae underneath plants on soil; g 1 and g 2) Pupae in soil; h) Complete defoliation in sorghum; i) Partial damage on rice; j) Defoliation in the lower part of the plant

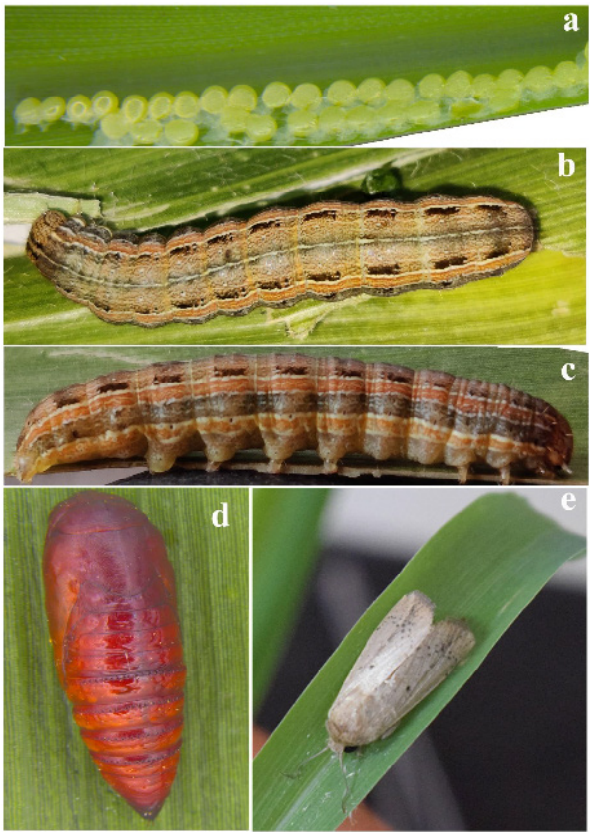

Fig. 2. Morphology of stages of *L. albistigma*; a) Eggs; b & c) Larvae with a total of five white lines; d) black strips in thoracic and abdominal segments; e) Adult

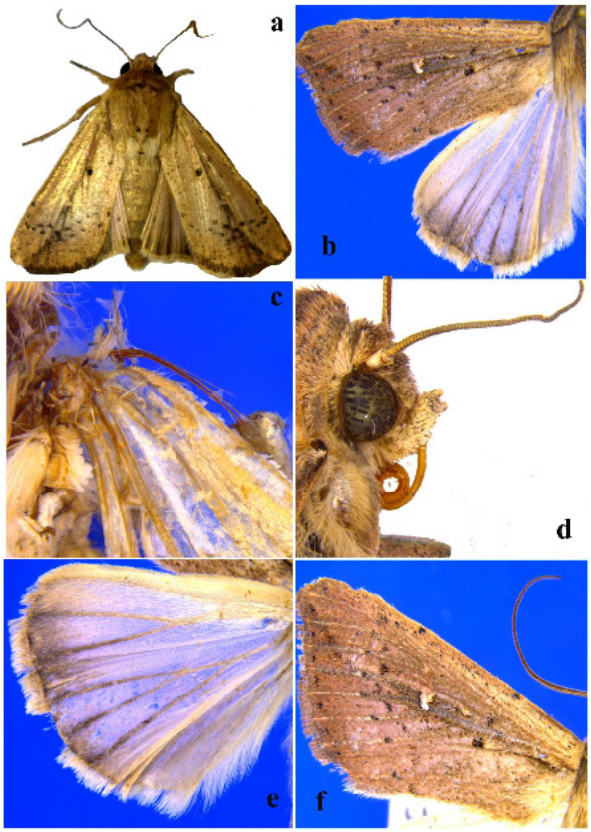

Fig. 3. Morphological description of adult *L. albistigma*. a) Head of adult; b & f) costal margin of forewing; c) Frenulum; d) Antenna; e) Hindwing

region; an indefinite curvilinear row of small black specks arranged along the postdiscal region; black spot in middle of the cell and white spot at discal region (Fig. 3b). Hindwing ovoid, costal margin straight, pale white with the outer third shaded with dull greyish shade. Outer margin black in the space between veins; fringe grey at apex (Fig. 3e).

Male genitalia: Uncus long, slender, pointed at the end, more than half the length of tegumen. Vulva large broad and rounded at apex, sacculus rounded, broad basally, editum short; clasper narrow, pointed, longer than its base, ventral tip produced into thorn-like projection; ampulla slender and thinner, similar size as digitus; digitus robust, short, not pointed, shorter than clasper; cucullus knob-like, expanded distally with spine like setae (Fig. 4a). Aedeagus small and cylinder shaped sclerotized with one big and numerous small cornuti (Fig. 4b). Male genitalia dissected was compared with the previous description of Yoshimoto (1994) and confirmed it as *L. albistigma.* Dr. Albert Legrain also identified it as *L. albistigma* based on the genitalia plates shared through e-mail.

Female genitalia: Papilla analis triangular; with longer anterior apophysis. Ductus bursae shorter, narrowed and sclerotized. Appendix bursae bent left and coiled with broad proximal area. Corpus bursae short oval - shaped without signum (Fig. 4c).

The difficulty in identifying species from immature stage led to exploring the mtCO1 five-marker region and obtaining from accession numbers ON435707 and ON534021 NCBI's Genbank and the BOLD, respectively. The nucleotide composition analysis revealed that the sequence of *L. albistigma* has 69.53% of A+T and 30.47% of G+C. The sequence has 28.85% Adenine, 16.21% cytosine, 14.26% guanine and 40.68% Thymine. The sequence showed 96.34% identity to *L. inseuta* followed by 96.01% to *L. commoides* and 95.84% to *L. obsolete* thereby confirming the genus to *Leucania*. The database lacks the sequence information on *L. albistigma.* Phylogenetic tree was constructed using the sequences of *L. albistigma* submitted along with 15 species from the same genera (*Leucania*) and those of four species of *Mythimna* and two species *Spodoptera*. *Bombyx mori* was used as an outgroup.

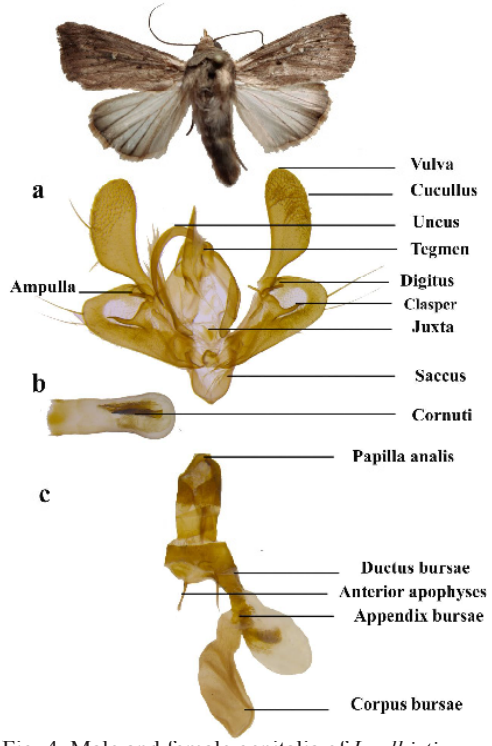

Fig. 4. Male and female genitalia of *L. albistigma.*
a) Male genitalia; b) Aedeagus; c) Female genitalia

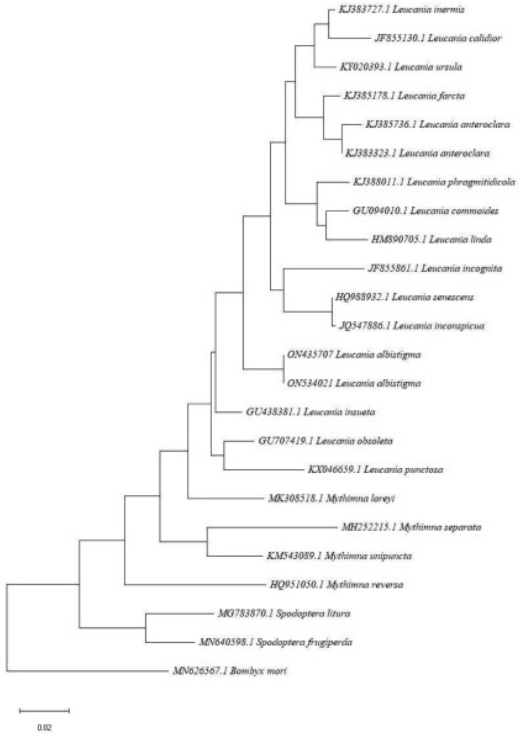

Fig. 5. Phylogenetic tree of species of army worm *Leucania Mythimna, Spodoptera*

The tree was divided into two clades, where species of *Spodoptera* viz., *S. litura* and *S. frugiperda* was grouped together in a clade (Fig. 5). The species belonging to *Mythimna* viz., *M. loreyi, M. unipuncta, M. seperata* and *M. reversa* and the species belonging to *Leucania* viz., *L. inermis, L. calidior, L. ursula, L. farcta, L. anteroclara, L. phragmitidicola, L. commoides, L. linda, L. incognita, Leucania senescens, L. inconspicua, L. insueta, L. obsolete, L. punctosa* and *L. albistigma* grouped into a single clade. The species *L. albistigma* was found clustering with those of belonging to *Leucania*. It was also observed that species of *Leucania* has a close relationship with those of *Mythimna* which are morphologically similar making their identification complex. Thus, the sequence submitted will help in accurate identification of *L. albistigma*.

Spatial distribution of larvae on maize and in soil indicated aggregated distribution in maize plant and in contrast an uniform distribution in soil. Index of dispersion: *L. albistigma* larvae were aggregated in maize crop (VMR>1) but had a more uniform (VMR<1) one in soil; Green's index (GI): Positive values are indicative of aggregation in maize (GI >1) and negative values indicative of uniformity in soil (GI<0); Index of mean clumping (I_{DM}): Positive values are indicative of aggregation in maize (I_{DM}>1) and negative values are indicative of uniformity in soil (I_{DM}<0); Index of patchiness (IP): *L. albistigma* larvae were aggregated in maize crop (IP>1) had a more uniform one in soil (IP<1). The variance to mean ratio ($S^2/x\square$) was greater than one, indicating an aggregated distribution of larvae in maize, whereas it was more uniform ($S^2/x\square$< 1) in soil. Analysis of all four indices verified the status aggregation of *L. albistigma* larvae on maize and uniform distribution in soil (Table 2). Thus, it is presumed that sampling in soil is more reliable indicator of population density rather than counts on the plants. Hence, for insecticide evaluation, sampling was done in soil only.

The insecticides when evaluated under field conditions in natural infestation indicated that number of larvae/ sampling unit did not differ significantly (p = 0.065) at one day before treatment but there was a significant (p = 0.000) difference at three and seven days after spray. After three days of treatment, the lowest number of larvae was recorded in the treatment applied with poison bait (rice bran + jaggery + chlorpyriphos) (1.18 larvae/ sampling unit) followed by chlorantraniliprole (2.75 larvae). The treatments emamectin benzoate (3.18 larvae/ sampling unit) and spinetoram (3.31 larvae) were on par with both chlorantraniliprole and lamda cyhalothrin (3.50) which

Table 2. Spatial distribution of *L. albistigma*

	No. of individuals	Distribution index				
		Index of dispersion (ID)	Green's index (GI)	Index of mean crowding (IMC)	Index of mean clumping (I_{DM})	Index of patchiness (IP)
Maize crop	389	6.81	0.15	15.53	5.81	1.59
Soil	585	0.98	-0.001	20.23	-0.02	0.99

Table 3. Evaluation of insecticides against *L. albistigma* (spray and poison bait)

Treatments	Number of larvae/ sampling unit*		
	1 DBT	3 DAT	7 DAT
T_1 : Emamectin benzoate 5 SG @ 0.4 gm/ L	8.06 (3.01)	3.18^{bc} (2.04)	2.56^{c} (1.88)
T_2 : Lamda cyalothrin 5 EC @ 0.5 ml/ L	8.00 (2.999)	3.50^{c} (2.11)	2.37^{bc} (1.82)
T_3 : Spinetoram 11.7 SC @ 0.8 ml/ L	7.00 (2.82)	3.31^{bc} (2.07)	1.93^{bc} (1.71)
T_4 : Chlorantraniliprole 18.5 SC @ 0.4 ml/ L	6.93 (2.81)	2.75^{b} (1.93)	1.68^{b} (1.63)
T_5 : Poison bait (rice bran +jaggery+chlorpyriphos 20 EC @ 50 kg: 2 kg: 250 ml/ ha)	7.00 (2.82)	1.18^{a} (1.47)	0.00^{a} (1.00)
p value	0.065	0.000	0.00

*No. of larvae/ sampling unit in each replication taken in soil in a square foot area at a depth of 5 cm; Figures in parentheses square root transformed values; Mean values followed by different letters significantly different-Tukey's test ($p \leq 0.05$).

was the least effective. Seven days after treatment, there was no live larvae in the treatment applied with poison bait. The treatment chlorantraniliprole (2.75 larvae) was the best after poison bait. The treatments spinetoram (1.93 larvae) and lamda cyhalothrin (2.37 larvae) were on par with both chlorantraniliprole and emamectin benzoate, and emamectin benzoate showed the least efficacy. Thus, poison bait was the best treatment followed by chlorantraniliprole.

This study is the first detailed record of occurrence of an army worm which is hitherto unknown in outbreak form. The species identity was confirmed with morphological and molecular characters, and comparing with first description from Moore (1881). In India, so far no species of *Leucania* has been reported to occur in outbreak form. One possible reason could be that the field entomologists wrongly concluding it as *Mythimna* without taxonomic identification. Originally, the *L. albistigma* was collected and described from only one locality of Darjeeling (Moore 1881), i.e., adjacent to Nepal and in Nepal (Yoshimoto 1994). No authenticated reference of its presence is known from any part of India. This report of occurrence of over large area is a caution to growers and policy makers as its outbreak may be repeated. There is need for coordinated efforts to understand the reasons for outbreaks and evolving management plans. Previous studies on the army worms' feeding behaviour indicate that the larvae initially eliminate lower leaves has been similar in this species too. The defoliation in the lower part of the plant will not reduce yield much (Douglas et al. 1981) and that the leaves of top portion are able to compensate for defoliation by increased dry matter accumulation (Hoyt and Bradfield 1962; Allison and Watson 1966; Hill and Atkins 1982). This aspect is encouraging considering similar type of feeding activity observed in *L. albistigma* providing a little scope for employing immediate management strategies thus reducing effect on yield. Other than maize, the pest was currently found feeding on sorghum and rice in adjoining fields under natural conditions. The larval presence on rice could not be observed probably due to nocturnal habit of larvae and no hiding sites such as junction of stem and cob like in case of maize. As the army worm outbreaks are common in cereal crops in India, taxonomic identification is a prerequisite to know which species is causing damage and to take up species-specific management strategies.

In order to develop control tactics, rapid and accurate

identification is crucial. In the present study, taxonomic identification was based on both morphological and molecular identification. Sequence of *L. albistigma* submitted to the Genbank and BOLD for the first time will be available in public domain. *Leucania* is a worldwide noctuid genus encompassing up to 340 species (Adams, 2001; Cocco et al., 2019; Calora, 1966). The taxonomy of the genus is well studied in the Neotropical region (Adams, 2001) and same is not the case with South and Southeast Asia. Of these 340, only few have been documented with biological or natural history. Few species of *Leucania* have been found feeding on maize and other cereals in different parts of the world (Cocco et al., 2019). Moore (1881) describes 20 new species from India under the genus *Leucania* and a hand written plate is provided in his first description. Further, Yoshimoto (1994) provided genitalia description and confirmed *L. albistigma* from Nepal. After this, no clear taxonomic description has been provided for *L. albistigma* and morphological description provided herein will be useful for future.

Spatial distribution analysis done now might contribute to the management of *L. albistigma* through right deployment of IPM measures. Understanding spatial distributions helps in the prediction and management of pest populations through precise sampling and decision-making procedures (Ribeiro et al., 2020). Spatial distribution analysis yields characteristic parameters of a species (Taylor, 1984). In this case, insecticidal control failures led us to understand the spatial distribution, bringing out the aggregated distribution of *L. albistigma* larvae on maize and uniform distribution in soil. It was presumed that these contracts in the distribution of larvae and then nocturnal feeding activity is the reason for failure of insecticides applied as spray. Hence, insecticides were evaluated as sprays along with poison bait. Because of innate behaviour of army worms hiding in soil could be the reason for complete mortality of larvae in the poison baited fields compared to spray treatments. The larvae were found hiding in soil during day time when growers spray insecticides. The larval feeding was also noticed in low growing graminaceous weeds and could be the probable reason that larvae might survive without feeding on sprayed plants. But the poison bait treated plots were completely devoid of larvae in soil and on plants due to attraction and killing indicating larval behaviour could be exploited for successful management.

In general, army worm outbreak is a frequent problem causing severe loss in cereal crops including maize, rice and sorghum (Sharma et al., 2002). However, all previous reports of outbreak were due to the *M. separata*; outbreaks had been known from Andhra Pradesh during 1977, 1978, and 1981; and during 1980/ 1981 at Dharwad, Karnataka (Sharma and Davies, 1983); during 1983 at Kullu, Himachal Pradesh (Thakur et al., 1987), and during 1984 at Hissar, Haryana (Singh et al., 1987). The outbreak during 2017 had not been reported clearly in but the invasion of *S. frugiperda* is widely known and studied in India. Maize is a second most important cereal in India followed by rice. Following recent invasion of *S. frugiperda* into India, the economics of expenditure has already increased for maize cultivation (Sharanabasappa et al, 2021). Any addition to the pest complex due to outbreak of this kind reported here has drastic impact on maize cultivation in India. Although *L. albistriga* had been known from Darjeeling from India long back, the occurence of *L. albistigma* in outbreak form reported here is for the first time. Morphological characters including male and female genitalia provided here form the basis for easy identification. The study also evaluates the spatial distribution of larvae during outbreak and use of larval behaviour in management. Complete mortality was observed in poison baiting. Future research may be aimed at identifying the distribution of *L. albistigma* in India, factors responsible for outbreak, natural enemies and evolving management IPM strategies.

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AUTHOR CONTRIBUTION STATEMENT

CMK conceived and designed research. CMK, KR, KJM, GD, GAM, BR, AM, PSP conducted experiments. SKR and HBM analysed the data. PRS confirmed the species identity. CMK wrote the manuscript. All authors read and approved the manuscript.

CONFLICT OF INTEREST

No conflict of interest.

REFERENCES

Khandelwal P, Choudhury D, Ajanta B, Reddy M K, Gupta G P, Banerjee N. 2004. Insecticidal pilin subunit from the insect pathogen *Xenorhabdus nematophila*. Journal of Bacteriology 186(19): 6465-6476.

Adams M S. 2001. A revision of the moth genus *Leucania* Ochsenheimer in the Antilles (Insecta: Lepidoptera: Noctuidae). Annals of Carnegie Museum 70(3): 179-220.

Allison J C S, Watson D J. 1966. The production and distribution of dry matter in maize after flowering. Annals of Botany 30(3): 365-381.

Calora F B. 1966. A revision of the species of the *Leucania* complex occurring in the Philippines. Philippine Agriculturist 50: 633-728.

Cocco J, Dolibaina D R, Casagrande M M, Specht A, Foerster L A. 2019. First records of *Leucania rawlinsi* Adams and *L. senescens* Möschler (Lepidoptera: Noctuidae) in Brazil: redescription, potential association with Bt maize, larval parasitoids, and spatial and temporal distribution. Zootaxa 4604(3): 441-460.

David F N, Moore P G. 1954. Notes on contagious distributions in plant populations. Annals of Botany 18(1): 47-53.

Divya J, Kalleshwaraswamy C M, Mallikarjuna H B, Deshmukh S. 2021. Does recently invaded fall armyworm, *Spodoptera frugiperda* displace native lepidopteran pests of maize in India?. Current Science 120(8): 1358.

Douglas J A, Kain W M, Dyson C B. 1981. Effect of time and extent of defoliation on grain yield of maize in relation to cosmopolitan army worm (*Mythimna separata* (Walker)) damage. New Zealand Journal of Agricultural Research 24(2): 247-250.

Edwards E W. 1992. A second sugarcane armyworm (*Leucanialoreyi* (Duponchel)) from Australia and the identity of *L. loreyimima* Rungs (Lepidoptera: Noctuidae). Journal of the Australian entomological society 31: 105-108.

GAY F J. 1966. Scientific and common names of insects and allied forms occurring in Australia. Bulletin 285. CSIRO, Melbourne.

Green R H. 1966. Measurement of non-randomness in spatial distributions. Researches on Population Ecology. 8: 1-7.

Hill M G, Atkins A W. 1982. Effects of defoliation by cosmopolitan armyworm, *Mythimna separata* (Walker) on maize yield. New Zealand Journal of Agricultural Research 25: 251-254.

Hiremath I G, Bhuti S G, Lingappa S. 1992. Ecobiology and management of *Mythimna separate* (Walker). Karnataka Journal of Agricultural Sciences 5(1): 38-44.

Hoyt P, Bradfield R. 1962. Effect of varying leaf area by partial defoliation and plant density on dry matter production in corn. Agronomy Journal 54(6): 523-525.

Janssen J A M. 1992. Why do droughts often result in devastating insect epidemics? The African armyworm, *Spodoptera exempta* (Walker), as an example. In, S B J Menken, J H Visser, P Harrewijn (eds.), Proceedings. 8th International symposium on insect-plant relationships. Kluwer Academic Publishers, Dordrecht. pp. 49-51.

Jukes T H, Cantor C R. 1969. Evolution of protein molecules. H N Munro (ed.) Mammalian protein metabolism. Academic Press, New York. pp. 21-132

Kalleshwaraswamy C M, Divya J, Mallikarjuna H B, Sharanabasappa S D, Sunil C. 2023. Cannibalistic nature and time of habitat occupancy of invasive maize fall armyworm, *Spodoptera frugiperda* are the key factors for competitive displacement of native stem borer, *Sesamia inferens* in India. Current Science 124: 348-354.

Kumar S, Stecher G, Li M, Knyaz C, Tamura K. 2018. MEGA X: molecular evolutionary genetics analysis across computing platforms. Molecular Biology and Evolution 35(6): 1547.

Kuno E. 1991. Sampling and analysis of insect populations. Annual Review of Entomology 36: 285-304.

Lloyd M. 1967. Mean crowding. Journal of Animal Ecology 36: 1-30.

Moore F. 1881. Descriptions of new genera and species of Asiatic nocturnal Lepidoptera. Proceedings of the Zoological Society of London 49(2): 326-380.

Ribeiro A V, Ramos R S, de Araújo T A, Soares J R, Paes J D S, de Araújo V C, Picanço M C. 2020. Spatial distribution and colonization pattern of *Bemisia tabaci* in tropical tomato crops. Pest Management Science 77: 2087-2096.

Sharanabasappa, Kalleshwaraswamy C M, Asokan R, Mahadevaswamy H M, Maruthi M S, Pavithra H B, Hegde K, Navi S, Prabhu S T, Georg G. 2018. First Report of the Fall Armyworm, *Spodoptera frugiperda* (J E Smith) (Lepidoptera, Noctuidae), an Alien invasive pest on Maize in India. Pest Management in Horticultural Ecosystems 24(1): 23-29.

Sharanabasappa S D, Kalleshwaraswamy C M, Prasanna B M, Sannathimmappa H G, Kavyashree B A, Sharath K N, Pradeep P, Patil K K R. 2021. Economic analysis of pesticide expenditure for managing the invasive fall armyworm, *Spodoptera frugiperda* (J. E. Smith) by maize farmers in Karnataka, India. Current Science 121(11): 1487-1491.

Sharma H C, Sullivan, D J, Bhatnagar V S. 2002. Population dynamics and natural mortality factors of the Oriental armyworm, *Mythimna separata* (Lepidoptera: Noctuidae), in South-Central India. Crop Protection 21: 721-732.

Sharma H C, Davies J C. 1983. The oriental armyworm, *Mythimna separata* (Walk.), distribution, biology and control, a literature review. Miscellaneous Report No. 59, Centre for Overseas Pest Research, London, UK.

Shashank P R, Ramamurthy V V. 2014. Redescription of *Odontodesaleuca* Guenée (Lepidoptera: Euteliidae: Stictopterinae) including intraspecific variation in wing pattern. Entomological News 124(2): 131-138.

Singh R, Mrig K K, Chaudhary J P. 1987. Incidence and survival of *Mythimna* species on cereal crops in Hisar. Indian Journal of Agricultural Sciences 57: 59-60.

Sutrisno H. 2012. A preliminary study on macro-moth diversity at the base of Foja Mountain Nature Reserve: Kwerba village, Membramo Raya, Papua. Zoo Indonesia 21(1): 117.

Taylor. 1984. Assessing and interpreting the spatial distributions of insect populations. Annual Review of Entomology 29: 321-57.

Thakur J N, Rawat U S, Pawar A D. 1987. First record of armyworm, *Mythimna separata* (Haworth) as a serious pest of maize in Kullu (HP) India and recommendations for its integrated management. Tropical Pest Management 33: 173-175.

Yoshimoto H. 1994. Noctuidae. In, Haruta T. (ed.) Moths of Nepal, part 3 Tinea 14 (Suppl. 2): 95-139.

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