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Fruit-piercing moths of genus *Eudocima* Billberg, 1820 (Lepidoptera: Erebidae: Calpinae) in Nepal, and an observation of sweet orange losses due to *E. phalonia* in Sindhuli, Nepal

SAMUDRA LAL JOSHI[1,*] and DEBRAJ ADHIKARI[2]

[1]National Entomology Research Center, Nepal Agricultural Research Council, Khumaltar, Lalitpur, Nepal
[2]Plant Quarantine and Pesticide Management Centre, Hariharbhawan, Lalitpur, Nepal

[*]**E-mail**: joshisamudra1134@gmail.com

ABSTRACT: Fruit-piercing moths are developing serious insect pests in the horticultural fruits of Nepal. Asia, Africa and Australia, in global scenario, are suffering of these moth pests in horticulture. An authentic documentation developed of these pests out of different scattered scientific sources in Nepal and published elsewhere is the objective of this review paper. Analytical results of the dominantly primary fruit-piercing moth species of genus *Eudocima* Billberg, 1820 recorded in the national physiological regions in course of the moth surveys and their collections by the national and international institutions on the spatial duration from 1968 to 1998 are presented in this paper. Eight species of *Eudocima*, namely *E. homaena* (Hubner), *E. hypermnestra* (Stoll), *E. materna* (Linnaeus), *E. okurai* (Okano), *E. phalonia* (Linnaeus), *E. salaminia* (Cramer), *E. sikhimensis* (Butler) and *E. tyrannus* (Guenee) are found spread over the different altitude regimes of the physiological regions ranging from 450 to 3540 m of four provinces, namely Koshi, Madhesh Pradesh, Bagmati and Gandaki of Nepal. Siwalik hill (200-1000 m), Middle hill (1000-2000 m), Upper hill (2000-3000 m) and High mountain (3000-4000 m) of the country, respectively, are found to exist fruit piercing moths, *E. homaena*, *E. hypermnestra*, *E. phalonia*, and *E. salaminia* (4 species); *E. homaena*, *E. materna, E. okurai, E. phalonia, E. salaminia, E. sikhimensis* and *E. tyrannus* (7 species); *homaena*, *E. materna, E. phalonia*, *E. salaminia, E. sikhimensis* and *E. tyrannus* (6 species), and *E. materna, E. phalonia,* and *E. salaminia* (3 species). *E. phalonia* and *E. salaminia* moths are reportedly existed right from Siwalik hill to High mountain physiological regions of Nepal. A preliminary estimate of sweet orange (*Citrus sinensis*) mean loss in the selected orchards during the local outbreak in 2023 of *E. phalonia* in the Kamalamai Municipality, Ward 3 and Golanjor Rural Municipality, Wards 2, 4 and 5 of Sindhuli district was 82.0 ± 5.8%.

Keywords: Nepal, citrus, *Eudocima* spp., fruit piercing moth, horticulture

INTRODUCTION

Globally there are 47 reported species of fruit piercing moths of genus *Eudocima* Billberg, 1820 (Lepidoptera: Erebidae: Calpinae) (Zilli *et al.,* 2017; Zaspel and Branham, 2008; Zilli and Hogenes, 2002; Reeves *et al.,* 2017), and Nepal enlists 8 species out of them (Joshi and Manandhar, 2001; Joshi and Adhikari, 2024; Bänziger, 1987; Haruta, 1993, 1994; Yoshimoto, 1995, 1998). *E. apta* (Walker [1885], a tropical fruit-piercing moth occurring in Central America, northern South America and the Caribbean, is recently recorded (in 2016) for the first time in Florida, USA (Reeves *et al.,* 2017). *E. apta* is also reported in USA as far north as Vermont (Gilligan and Passoa, 2014).

Eudocima spp. are frequently occurring fruit-piercing moths damaging to horticultural fruits in the Asian countries and the Pacific islands (Vargas-Fonseca *et al.,* 2020), Africa, South America, South-east Asia and Australia (Hattori, 1969). These moths are polyphagous, and, reportedly, feed on at least 50 cultivated fruit crops (Fay, 2002; Davis *et al.,* 2005; Reeves *et al.,* 2017). Fruits damages incurred of these moths fetch 19 to 95% depending on an abundance of moths in the fruit orchards (Fay and Halfpapp, 2006). Highly sclerotized proboscis often equipped with barb, hooks or cutting ridges is a special moth part of these calpine moths that enable them to pierce into skin and feed on the fluids of fruits (Hilgartner *et al.,* 2007; Zaspel *et al.,* 2011). The moths of genus *Eudocima* remain active during September to November and most fruit damages occur in orchards in this duration (Bhumannavar and Viraktamath, 2012). The fruit-piercing moths are the strong flyers, and cover a long distance from orchards to their breeding grounds (Bosch, 1970).

MATERIALS AND METHODS

With an objective to assess the present status of fruit-piercing moths of *Eudocima* spp. in Nepal, this review paper has been scripted with the help of pertinent

research papers developed of Banziger (1987) and six volumes of Toshiro Haruta edited, "Moths of Nepal, 1992, 1993, 1994, 1995, 1998 and 2000. National Entomology Research Centre (NERC) published, "Reference Insects of Nepal" is also referred for the collected and preserved *Eudocima* spp. specimens in the Entomology Museum, NERC, Nepal Agricultural Research Council, Khumaltar, Lalitpur, Nepal. Research materials supportive to the Nepalese *Eudocima* spp. have been collected from the online placed research papers in Journals by virtue of the Google Scholar search machine. Similarly, the latest reports on the local outbreak of *Eudocima phalonia* in the command area of Junar (Sweet orange) Superzone, Prime Minister Agriculture Development Project, Sindhulimadi, Sindhuli, Bagmati Pradesh are also the referred materials for the paper. Also included is the *E. phalonia* outbreak status report of the Nepal Government's Plant Protection Officer in the Plant Quarantine and Pesticide Management Centre, Ministry of Agriculture and Livestock Development, Nepal.

RESULTS AND DISCUSSION

A checklist of *Eudocima* species (Lepidoptera: Erebidae: Calpinae) from Nepal

1. *Eudocima homaena* (Hübner, [1823] 1816) (= *Othreis homaena,* [1816])

Distribution: Nepal (Chitrei, Pheksinda and Okhaldhunga, Koshi Pradesh) (Haruta, 1994).

Distribution elsewhere: India, Sri Lanka, Myanmar, Taiwan, the Nicobars, Peninsular Malaysia, Borneo, the Philippines and Christmas Island (Wikipedia, 2021; Zilli *et al.,* 2017)

Remark: First record from Chitrei, 2450 m, 1♀, 28. vi 1963 (Haruta, 1994).

2. *E. hypermnestra* (Stoll, 1780)

Distribution: Nepal (Godak, Koshi Pradesh) (Yoshimoto, 1995).

Distribution elsewhere: India, Sri Lanka, Thailand (Zhang, 1994)

Remark: First record from Godak, 450 m, 1♀, 1♀, 3-5. i. 1994 (K. Suzuki) (Yoshimoto, 1995).

3. *E. materna* (Linnaeus, 1767)

Distribution: Nepal (Phulchoki, Lalitpur, Bagmati Pradesh; Taplejung, Chitrei, Koshi Pradesh; Langtang, Rasuwa, Bagmati Pradesh) (Haruta, 1993; Haruta, 1994; Yoshimoto, 1995; Banziger, 1987).

Distribution elsewhere: India, Sri Lanka, Australia, Fiji, New Zealand, Venezuela, Sierra Leone, Zimbabwe; widespread in old world tropics (Zhang, 1994).

Remark: First record from Chitrei, 2450 m: 1♂, 1 ♀. 28-29, vi. 1963 (Haruta, 1994).

4. *E. okurai* (Okano, 1964)

Distribution: Nepal (Godavari, Lalitpur, Bagmati Pradesh) (Banziger, 1987; Haruta, 1993).

Distribution elsewhere: Taiwan; Oriental distribution (Zilli and Hogenes, 2002).

Remark: First record from Godavari, 1520-1570 m: 26 ♂, 1 ♀. Sept. 1984 to June-July, 1985; found piercing plums and peaches (Banziger, 1987). Larvae of *E. okurai* reared on *Holboellia latifolia* (Lardizabalaceae) developed a life of 5-6 days egg stage, 3-7 days larval stage and 14-16 days pupal stage in Nepal. Larve rejected plants were *B. asiatica*, *M. napaulensis*, *M. siamensis*, (Berberidaceae), *Cocculus laurifolius, C. orbiculatus* (= *trilobus*), *Percampylus glaucus, St. elegans, St. oblate* (= *St. kerrii*), *Tinomiscium petiolare*, *Tinospora baenzigeri*, *Tinos. crispa*, and *Tinos. sinensis* (Banziger, 1987).

5. *E. phalonia* (Linnaeus) (= *Othreis fullonia* [Clerk])

Distribution: Nepal (Godavari and Phulchoki, Lalitpur, Bagmati Pradesh (Joshi and Manandhar, 2001; Haruta, 1993; Banziger, 1987); Godak, Pheksinda, Basantapur and Chitrei, Koshi Pradesh; Jiri and Sindhulimadi, Bagmati Pradesh) (Haruta, 1994); Pokhara, Kaski, Gandaki Province (Yoshimoto, 1998); Dhungeni, Dhading and Langtang, Rasuwa, Bagmati Pradesh (Yoshimoto, 1995)).

Distribution elsewhere: Southeast Asia, Australia, New Zealand and the Pacific (Waterhouse, 1997)

Remark: First record from National Botanical Garden, Godavari, 1515 m; 1 specimen, 16.viii. 1968 (N. Kumar) (Joshi and Manandhar, 2001). Recent host plants of *E. phalonia* included 62 species of fruits and weeds (Plantwise Plus, 2020). The moths (n = 5) observed piercing peach, 16, 22, 26, 30.6.1985 in Phulchoki, Lalitpur (Banziger, 1987).

6. *E. salaminia* (Cramer, [1777])

Distribution: Nepal (Godavari and Phulchoki, Lalitpur, Bagmati Pradesh (Haruta, 1993; Banziger, 1987); Pheksinda, Basantpur and Chitrei, Koshi Predesh (Haruta, 1994); Pokhara, Kaski, Gandaki Pradesh (Yoshimoto, 1998); Dhungeni, Dhading, Rasuwa, Bagmati Pradesh (Yoshimoto, 1995).

Distribution elsewhere: Indo-Australian tropics (Australia, Fiji, New Zealand, India, Pakistan, Papua New Guinea, Sri Lanka, and Vanuatu) (Holloway, 2005).

Remark: First record from. Godavari, 3 specimens, 14.9.84, 28.6. and 2. 7 .85; 2 specimens from mercury vapour lamp, 20. and 27.8.84, 1520-1570 m; found piercing plum, peach and *Rubus acuminatus* (sanu ainsalu) (Banziger, 1987). Larvae of *E. salaminia* found eating on *Stephania japonica* (Menispermaceae) in Sauraha (150 m, Terai), Chitwan, Bagmati Province and Godavari (Banziger, 1987).

7. *E. sikhimensis* (Butler, 1895) (= *Adris sikhimensis*)

Distribution: Nepal (Chitrei and Okhaldhunga, Koshi Pradesh) (Haruta, 1994).

Distribution elsewhere: Indo-Australian tropics (Australia, Fiji, New Zealand, India, Pakistan, Papua New Guinea, Sri Lanka, and Vanuatu) (Holloway, 2005).

Remark: First record from Okhaldhunga, 1700 m: 1 ♂, 17. ix 1990 (Haruta, 1994).

8. *E. tyrannus* (Guenee, 1852) (= *Adris tyrannus* [Guenee])

Distribution: Nepal (Godavari and Phulchoki, Lalitpur, Bagmati Pradesh) (Haruta, 1993; Banziger, 1987).

Distribution elsewhere: India (Hampson 1894), Russia (Zaspel and Brahman 2008).

Remark: First record from Godavari 1 specimen from mercury vapour lamp, 20.8.84, 1520-1570 m; found 29 specimens piercing plum and peach, and 2 specimens piercing berries of

Rubus acuminatus (sanu ainselu) (Banziger, 1987). Larvae of *E. tyrannus* found eating on *Berberis asiatica* (Berberidaceae) in Nagarjung Forest (1650-1850 m), Kathmandu, above Sundarijal (1600 m), Kathmandu; on *Mahonia napaulensis* and *B. asiatica* (Berberidaceae) in Godavari (1520 m), Lalitpur: on *Holboellia latifolia* (Lardizabalaceae) in Phulchoki (2000 m), Lalitpur (Banziger, 1987).

Fruit-piercing moths of genus *Eudocima* Billberg, 1820 in different altitude regimes in Nepal (1968 to 1998)

The distribution of eight species of fruit-piercing moths in the genus *Eudocima* Billberg, 1820 with reference to different altitude regimes ingrained in the physiographical regions, namely Terai plain (Below 200 m), Siwalik hill (200-1000 m), Middle hill (1000-2000 m), Upper hill (2000-3000 m) and High mountain (3000-4000 m) is presented in Table 1. The described fruit-piercing moths, namely *E. homaena, E. hypermnestra, E. maternal, E. okurai, E. phalonia, E. salaminia, E. sikhimensis* and *E. tyrannus* are recorded in different places in Siwalik hill, Middle hill, Upper hill and High mountain of Nepal from 1968 to 1998 (Joshi and Manandhar, 2001; Joshi and Adhikari, 2024; Bänziger, 1987; Haruta, 1993, 1994; Yoshimoto, 1995, 1998).

1. *E. homaena*

E. homaena revealed it being a fruit-piercing moth preferring to ecological habitats of Siwalik hill (1000 m), Middle hill (1700 m) and Upper hill (2450 m), respectively, in Pheksinda, Okhaldhunga and Chitrei, Koshi Pradesh) (Haruta, 1994) (Table 1).

2. *E. hypermnestra*

E. hypermnestra preferred to an ecological habitat of Siwalik hill (450 m) in Godak, Koshi Pradesh (Yoshimoto, 1995) (Table 1).

3. *E. materna*

E. materna revealed it being a fruit-piercing moth preferring to ecological habitats of Middle hill (1800 m), Upper hill (2450 m) and High mountain (3500 m), respectively, in Taplejung (Koshi Pradesh), Chitrei (Koshi Pradesh) and Phulchoki (Bagmati Pradesh), and Langtang, Rasuwa, Bagmati Pradesh) (Haruta, 1993, 1994; Yoshimoto, 1995; Banziger, 1987) (Table 1).

4. *E. okurai*

E. okurai preferred to an ecological habitat of Middle hill (1520-1570 to1600 m) in Godavari and Godavari (near), Lalitpur, Bagmati Pradesh (Haruta, 1993; Banziger, 1987) (Table 1).

5. *Eudocima phalonia*

E. phalonia revealed it being a fruit-piercing moth preferring to ecological habitats of Siwalik hill (450 to1000 m), Middle hill (1515 to 1600 m), Upper hill (2275 to 2450 m) and High mountain (3540 m), respectively, in Godak + Sindhulimadi, Sindhuli, Bagmati Pradesh + Pheksinda + Pokhara; Godavari; Phulchoki + Basantpur + Jiri + Chitrei: Langtang + Dhungeni. (Banziger, 1987; Joshi and Manandhar, 2001; Haruta, 1993, 1994; Yoshimoto, 1995, 1998) (Table 1).

6. *E. salaminia*

E. salaminia revealed it being a fruit-piercing moth preferring to ecological habitats of Siwalik hill (850 to1000 m), Middle hill (1520 to 1600 m), Upper hill (2275 to 2450 m) and High mountain (3540 m), respectively, in Pokhara + Pheksinda; Godavari; Phulchoki + Basantpur + Chitrei: Dhungeni. (Banziger, 1987; Haruta, 1993, 1994; Yoshimoto, 1995, 1998) (Table 1).

7. *E. sikhimensis*

E. sikhimensis preferred to ecological habitats of Middle hill (1700 m) in Okhaldhunga and Upper Hill (2450 m) in Chitrei (Haruta, 1994) (Table 1).

8. *E. tyrannus*

E. sikhimensis preferred to ecological habitats of Middle hill (1520-1600 m) in Godavar and Upper Hill (2075- 2275 m) in Phulchoki (Haruta, 1993; Banziger, 1987) (Table 1).

The fruit-piercing moth, *E. phalonia* in Nepal

E. phalonia, then named as *Othreis fullonia* Clerk, has been reported in Nepal from Godavari, Lalitpur as early as in 1968 (Joshi and Manandhar, 2001). *E. phalonia* is a noted economic pest of horticultural fruits in the tropical and subtropical areas of Africa, Asia and Oceania (Cochereau, 1977; Denton *et al.,* 1999). This species of fruit-piercing moth has been ranked as the fourth worst insect among 157 insect pests in agriculture in the South-West Pacific Region that includes part of Southeast Asia, Australia, New Zealand and the Pacific (Waterhouse, 1997). Most fruits and some vegetables are its principal host crops (Waterhouse, 1997). Recent host plants of *E. phalonia* included 62 species of fruits and weeds (Plantwise Plus, 2020). Outbreak of this species of fruit-piercing moth depletes the fruit harvest to a tune of more than 80% (Cochereau, 1977; Cotterell, 1940; Box, 1941; Dodia *et al.,* 1986). This moth is of migratory in nature with a possession of an inherent capability of powerful flying (Sands and Schotz, 1991).

Host adaptation of, *E. phalonia*

Indigenous wild plants are the main feeding host plants to the larvae of the fruit-piercing moths (Neubecker, 1962; Forsyth, 1966). The host plants to larvae of *E. phalonia* belong to only the vines of the family Menispermaceae (the moonseed plants) in Asia, Africa and Australia (Reddy, *et al.,* 2005; Ramkumar *et al.,* 2010; Muniappan *et al.,* 1994). *Anamirta cocculus, Cocculus hirsutus, Stephania glabra, S. glandulifera, S, japonica, Tiliacora acuminata, Tinospora cordifolia, T. sinensis* are some of the moonseed plants in Nepal (Shrestha, 1998) which are potential host plants for the larvae of *E. phalonia*. The larvae of *E. phalonia* are also reported to thrive on *Leea indica* (Vitaceae) as an alternative host plant in Malaysia and Thailand (Leong and Roland, 2011; Roland *et al.,* 2012). Nepal also has *L. indica* along with a couple of its different species like *L. acquata*

Table 1. Distribution of fruit-piercing moths of genus *Eudocima* in physiographic regions of Nepal, 1968 to 1998.

Physiographic region (MASL)	*Eudomica* sp. fruit-piercing moth							
	E.homaena	***E.hypermnestra***	***E.materna***	***E.okurai***	***E.phalonia***	***E.salaminia***	***E.sikhimensis***	***E.tyrannus***
Terai plain (Below 200)						150 m*		
Siwalik hill (200-1000)	1000	450			450, 500, 850, 1000	850, 1000		
Middle hill (1000-2000)	1700		1800	1520 to 1600	1515, 1600	1570, 1600	1700	1520, 1600,
Upper hill (2000-3000)	2450 m		2450		2100, 2075-2275, 2350, 2450, 2650	2275, 2350 2450	2450	2075- 2275
High mountain (3000-4000)			3500		3500, 3540	3540		
Himalaya (Above 4000)								

masl = meter above sea level
Data source: (Bänziger, 1987; Haruta, 1993, 1994; Yoshimoto, 1995, 1998).
*Larva on *Stephanis japonica* (Menispermaceae)

and *L. macrophylla* (Shrestha, 1998). The plants of genus *Erythrina* (Fabaceae) are the principal host plants to the larvae of *E. phalonia* in countries in the Pacific Region where several plants belonging to the Menispermaceae are present but decline feeding on them (Cochereau, 1977; Muniappan *et al.,* 1994; Muniappan *et al.,* 2002; Reddy *et al.,* 2007; Reddy *et al.,* 2005). The plants of genus *Erythrina* (Fabaceae), namely *E. arborescens, E. stricta* and *E. suberosa* are also present in Nepal (Shrestha, 1998). The *E. phalonia* moths (n = 5) are observed piercing peach in Phulchoki, Lalitpur (Banziger, 1987).

Local outbreak of *E. phalonia* in citrus orchards, Sindhuli, Nepal

Recently, in 2019, a multitude of fruit-piercing moths was observed in a mean-looking status in sweet oranges in the citrus orchards in Sindhuli district, Nepal (Joshi and Adhikari, 2019). The targeted moth was indentified *E. phalonia* (Fig. 1a) with the help of DNA bar-coding procedure conducted in Nepal that the sequence can be accessed in NCBI Genbank with accession no. PP101850.1 for *Eudocima phalonia* (NCBI, 2024). Local outbreak of *E. phalonia* was experienced in the citrus orchards in Golanjor Rural Municipality, and Kamalamai Municipality, Sidhuli district in 2023. Mean estimated loss of sweet oranges in Golanjor Rural Municipality and Kamalamai Municipality, in Sindhuli was $\bar{x} = 82.0 \pm 5.8$ (Table 2; Fig. 1b, Fig. 2). Likewise, the damage caused by this pest was reported and resulted in substantial citrus fruit losses. In order to protect citrus fruit, concerned stakeholders in the district are working for an adoption of applicable recommended management measures.

Fig. 1. (a) Fruit-piercing moth, *Eudocima phalonica*, and (b) the sweet orange losses incurred of this moth in Golanjor citrus orchards, Sindhuli, Bagmati Pradesh, Nepal

Fig. 2. Sweet orange fruits damaged of *E. phalonia* fruit-piercing moths in Golanjor citrus orchards, Sindhuli, Bagmati Pradesh, Nepal

Table 2. Estimated yield losses caused by fruit-piercing moth, *E. phalonia,* incurred sweet orange losses in some parts of Nepal, 2023

Orchard owner	Locality	Number of productive trees	Estimated fruit loss (%)
Gorakh Shrestha	Kamalamai-3, Swara	30	80
Prakash Lungeli	Golanjor-5, Chisapani	15	90
Dipak Sapkota	Golanjor-5, Khaniakharka	40	60

Ambika Thapa	Golanjor-5, Chisapani	115	60
Kalpana Bhujel	Golanjor-5, Nayakharka (Kaphalbotebari)	192	98
Bishnu Lal Shrestha	Golanjor-4, Pheda (Lamidanda pakha)	200	97
Lal Bahadur Shrestha	Golanjor-4, Pheda	18	98
Yadav Thapa	Golanjor-2, Bhadaure (Pipalbotegairabari)	190	60
Yam Bahadur Sinjali	Golanjor-4, Tamaure (Maibari)	200	95
Mean estimated fruit loss (%±SE)			**$\bar{x}$ = 82.0 ± 5.8**

Source: Junar Superzone, PMAMP, PIU, Sindhuli (2023); modified).

CONCLUSION

Fruit-piercing moths, particularly the species of the genus *Eudocima*, pose a significant and emerging threat to fruit crops in Nepal, as well as in Asia, Africa, and Australia. This review has synthesized and documented a diversity of eight primary fruit-piercing moths among *Eudocima* spp. (globally 47 spp.), namely *Eudocima homaena, E. hypermnestra, E. materna, E. okurai, E. phalonia, E. salaminia, E. sikhimensis* and *E. tyrannus,* and their distribution across different altitudinal regimes ingrained in the physiographical regions of Nepal, from the Terai plain (150 m) to the High mountains (3540 m). Notably, *E. phalonia* is found highly frequented fruit-piercing moth from the Siwalik hill (450 -1000 m) to the High Mountain (3540 m) in Nepal. Likewise, *E. salaminia* is found frequented from the Terai plain (150 m) to the High Mountain (3540 m). Wild flora consisting of *Anamirta cocculus, Cocculus hirsutus, Stephania glabra, S. glandulifera, S, japonica, Tiliacora acuminata, Tinospora cordifolia, T. sinensis* (family Menispermaceae) are found to be the potential host plants to the larvae of the most prevalent *Eudocima phalonia* fruit-piercing moth in Nepal. Similarly, alternative wild host plants for the larvae of *E. phalonia,* namely *Leea indica*, *L. acquata* and *L. macrophylla* (Vitaceae) and *Erythrina arborescens, E. stricta and E. suberosa* (Fabaceae) are also naturally available in the wilds of Nepal. The severe impact of fruit piercing moth is evidenced by the estimated 82.0 ± 5.8% loss of sweet oranges in the selected orchards during a local outbreak of *E. phalonia* in Sindhuli district in 2023. As this pest continues to threaten fruit production, it is imperative to strengthen monitoring, research, and integrated pest management strategies to mitigate the future fruit damage, and protect Nepal's horticultural industry.

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