

New Country Records and Annotated Checklist of the Dacine Fruit Flies (Diptera: Tephritidae: Dacini) of Nepal

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Abstract. Preliminary surveys for Dacine fruit flies were carried out in May 2015 and June 2017, with male lure (cue-lure, methyl eugenol, zingerone) traps maintained at 55 sites, (110–1,780 m elevation range), comprised mostly of Nepal Agricultural Research Council research stations. Twenty species were collected, including 11 new country occurrence and 2 new male lure association records. The most common species were fruit pests *Bactrocera dorsalis* (60.4% of all captures) and *B. zonata* (15.2%), and cucurbit pests *Zeugodacus tau* (9.5%) and *Z. cucurbitae* (8.7%). We present an annotated checklist of the 26 species now known to occur in Nepal, including 5 fruit and 6 cucurbit pests.

Introduction

The tribe Dacini is a large and diverse group of tropical fruit flies with frugivorous and florivorous larvae, many of which are severe invasive pests that limit commercial and subsistence fruit production (Vargas et al. 2015). The native range of the 940 recognized species covers the Old World tropics. Among these, fifteen are known to be present in Nepal (Hardy 1964, Kapoor 1979, Argawal and Sueyoshi 2005, Ito 2011, Drew and Romig 2013, Sharma et al. 2015, Adhikari et al. 2018, Acharya and Adhikari 2019). We report here the results from a preliminary survey carried out in agricultural environments that yielded new country records. Many more species will likely be discovered, including undescribed new species, once extensive surveys are initiated in the rich Nepalese montane forest environments.

Materials and Methods

We maintained, for a period of 6–14 days in June 2017, 50 sets of three traps baited with the fruit fly male lures cue-lure, methyl eugenol, and zingerone. Traps were built out of 120 ml polypropylene containers (Globe Scientific 5915 Polypropylene Specimen Container), with two 2-cm diameter circular lateral holes for fly entry, drilled just below the lid threading (Fig. 1 in Leblanc et al. 2015). For cue-lure and methyl eugenol traps, a commercially available lure plug containing 2 grams of lure (Scentry Biologicals, Billings, Montana, USA) and a 10x15-mm strip containing 10% dichlorvos (2,2-dichlorovinyl dimethyl phosphate) (Vaportape® II, Hercon Environmental, Emingsville, Pennsylvania, USA) were suspended from the trap's ceiling with a hook made of tie wire. For zingerone-baited traps, the plug was replaced by a 15-mm-long cotton

dental wick dipped in zingerone (vanillylacetone) (Sigma-Aldrich, St. Louis, Missouri, USA) melted in a beaker over a hotplate, and left to solidify in the wick. A solution of 25% propylene glycol (Better World Manufacturing, Fresno, CA) was used to preserve captured flies, which were transferred to 95% ethanol and kept in a freezer for DNA extraction.

We selected sites among the following Nepal Agricultural Research Council (NARC) stations (Fig. 1), to cover a broad range of elevations (110–1,780 m) and maintain traps in proximity of forest environments: National Wheat Research Program (Bhairahawa) (2 sites), National Maize Research Program (Rampur) (2 sites) and adjacent Agriculture and Forestry University (3 sites), Honeybee Development Centre (Bhandara) (3 sites), Agriculture Research Station (Goat) (Bandipur) (7 sites), Horticulture Research Station and adjacent National Tea and Coffee Development Board, regional office (Pokhara) (4 sites each), Godawari Beekeeping Development Section (3 sites) and nearby NARC Fisheries Research Division (3 sites) and College Nandhara (1 site) (Kathmandu), Lalitpur NARC Entomology Division and surroundings (3 sites) (Kathmandu), and Regional Agricultural Research Station, Lumle (10 sites). Additionally, we maintained 5 sites in Sunwal Municipality (Nawalparasi District), in a rural village

and its adjacent community forests. Data from a preliminary one-week assessment in Sunwal (May 2015), with traps at 5 sites, is also included in this paper. We identified collected flies using the keys published by Drew and Romig (2016).

Results

In total, we collected 9,865 flies, identified to 20 species. Of these, 11 are new country occurrence records, which increases the number of Dacine fruit flies present in Nepal to 26, listed below. Among these are 5 fruit pests and 6 cucurbit pests. These new records, along with previously published ones (Agarwal and Sueyoshi 2005, David and Ramani 2011, Drew and Romig 2013, David et al. 2016, 2017, Leblanc et al. 2018b, 2019), brings the number of species known in the Indian subcontinent (excluding Andaman and Nicobar) to 111. The most common species were fruit pests *Bactrocera dorsalis* (60.4% of all captures) and *B. zonata* (15.2%), and cucurbit pests *Zeugodacus tau* (9.5%) and *Z. cucurbitae* (8.7%). Altitudinal gradients patterns for individual species (Figure 2 and notes below) are consistent with those documented for the same species in Taiwan (Dooreenweerd et al. 2019). *Bactrocera dorsalis* and *Z. tau* are predominant at low and mid elevations and uncommon high elevations, whereas *Z. cucurbitae*, *B. zonata*, *B. nigrifacia* and *Z.*

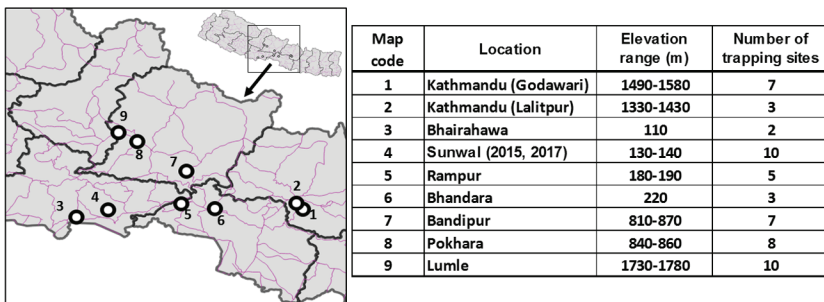


Figure 1. Location, elevation range and number of trapping sites during fruit fly surveys carried out in May 2015 (in Sunwal) and June 2017 (all 9 locations).

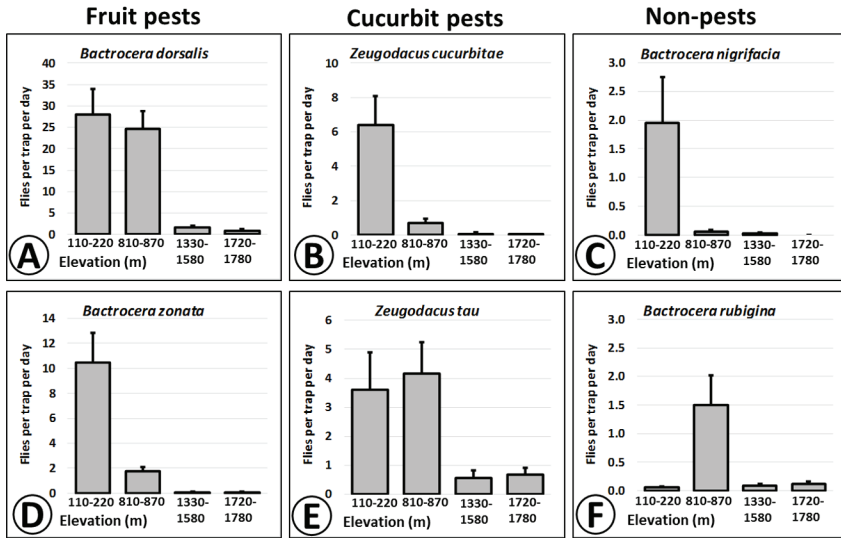


Figure 2. Mean (\pm SE) captures (flies per trap per day) at four elevation ranges in Nepal for polyphagous fruit pests *Bactrocera dorsalis* (A) and *B. zonata* (D), cucurbit fruit pests *Zeugodacus cucurbitae* (B) and *Z. tau* (E), and non-pest *B. nigrifacia* (C) and *B. rubigina* (F).

caudatus quickly drop in numbers at much lower elevations. Other species, namely *B. minax* and *Z. scutellaris*, are found mostly or solely at higher elevations. The mid-elevation peak for *B. rubigina* may be due to locally abundant host material, because that species is also very common and widespread at low elevations, such as in Bangladesh (Leblanc et al. 2013).

Annotated Checklist and New Country Records

Bactrocera abbreviata (Hardy 1974). Distribution: China (Hong Kong), Thailand, Philippines (Drew and Romig 2013), Vietnam (Leblanc et al. 2018), Bangladesh (Leblanc et al. 2019), Nepal (**NEW COUNTRY RECORD**). Lure: zingerone (Doorenweerd et al. 2018). Hosts: *Chionanthus ramiflorus* and *Olea salicifolia* (Oleaceae) (Allwood et al. 1999). Nepal survey: Seven specimens collected in Rampur (1), Bandipur (1), Pokhara (4), and Kathmandu (1). Note: This species may be

a junior synonym on *B. bipustulata* (Bezzi, 1914) (Doorenweerd et al. 2018), a species known from India and Sri Lanka.

Bactrocera aethriobasis (Hardy 1973). Distribution: Bhutan, Thailand, Vietnam, Peninsular Malaysia (Drew and Romig 2013), India (David et al. 2017), Nepal (**NEW COUNTRY RECORD**). Lure: Methyl eugenol. Host: *Azadirachta indica* (Meliaceae) (Drew and Romig 2013). Nepal survey: Nine specimens in Sunwal.

Bactrocera correcta (Bezzi 1916). Distribution: Widespread in Asia, from Pakistan east to Vietnam and south to Peninsular Malaysia (Drew and Romig 2013). Lure: methyl eugenol. Hosts: A polyphagous pest of cultivated fruits, bred from 73 hosts in 35 families (Allwood et al. 1999, Liquido et al. 2016a). Nepal survey: Not collected.

Bactrocera digressa Radhakrishnan, 1999. Distribution: India (Drew and Romig 2013), Bangladesh (Leblanc et al. 2019), Nepal (**NEW COUNTRY**

RECORD). Lures: cue-lure, zingerone (Dooreenweerd et al. 2018). Host: *Alangium salviifolium* (Cornaceae) (David and Ramani 2011). Nepal survey: 36 specimens collected in Sunwal (25), Rampur (4), Bandipur (2), and Pokhara (7).

Bactrocera dorsalis (Hendel 1912). Distribution: widespread through tropical Asia, from Pakistan to Taiwan and south to New Guinea; introduced to Africa and various islands in the Indian and Pacific Oceans (see map in Vargas et al. 2015). Lures: methyl eugenol, zingerone. Hosts: A highly polyphagous fruit pest with reliable published records for 490 hosts in 81 families (Allwood et al. 1999, Liquido et al. 2019b). Nepal survey: The most abundant species, with 5,956 specimens collected at all sites, though uncommon at high elevations (Fig. 1A). Note: *Bactrocera dorsalis* in Nepal exhibits a broad range of scutum and abdomen color variation, similar to that documented in Bangladesh and Africa (Leblanc et al. 2013).

Bactrocera minax (Enderlein 1920). Distribution: Higher elevations in northern India, Nepal, Bhutan, and southern China (see map in Vargas et al. 2015). Lure: None recorded. Hosts: A severe pest of citrus fruits, with 13 host species in the genera *Citrus* and *Fortunella* (Rutaceae) (Allwood et al. 1999, Chang et al. 2018). Nepal survey: None collected. Notes: The most severe fruit fly pest of Citrus crops in the country, rather than *B. dorsalis*, and distributed in the mid elevation hills of eastern Nepal (Acharya and Adhikari 2019). Adults are most common in June and July, and start ovipositing in young developing fruits, causing at least 60% premature fruit drop for sweet orange (Adhikari et al. 2018, Acharya and Adhikari 2019). Losses at harvest time can be as high as 97% on sweet orange and 15% on mandarin (Sharma et al. 2015). Specimens of this species collected in December 1984 from sweet orange in Helambu (Sindhupalchock

District) were erroneously identified and reported as *Bactrocera tsuneonis* (Miyake) (Joshi and Manandhar 2001). Subsequent extensive surveys (SB, unpublished) have established that only *B. minax*, and not *B. tsuneonis*, is present in Nepal.

Bactrocera nigrifacia Zhang, Ji and Chen 2011. Distribution: China and Thailand (Drew and Romig 2013), Cambodia (Leblanc et al. 2016), Taiwan (Dooreenweerd et al. 2019), Bangladesh (Leblanc et al. 2019), Nepal (**NEW COUNTRY RECORD**). Lure: cue-lure. Hosts: *Callicarpa arborea* (Lamiaceae), *Capparis sepiaria* (Capparaceae), *Zehneria wallichii* (Cucurbitaceae), and *Flueggea virosa* (Phyllanthaceae) (Drew and Romig 2013). Nepal survey: 256 specimens, collected, mostly at lower elevations (Fig. 2C) (only 8 specimens at higher elevations and none in Lumle).

Bactrocera rubigina (Wang and Zhao 1989). Distribution: Bhutan, China, Thailand, Vietnam (Drew and Romig 2013), India (David et al. 2017), Taiwan (Dooreenweerd et al. 2019), Sri Lanka (Leblanc et al. 2018b), Bangladesh (Leblanc et al. 2019), Nepal (**NEW COUNTRY RECORD**). Lures: Cue-lure, zingerone (Dooreenweerd et al. 2018). Host: *Litsea verticillata* (Lauraceae) (Liang et al., 1993). Nepal survey: 171 specimens, collected mostly at mid elevations (Fig. 2F). Note: Surveys in recent years have greatly expanded the distribution of this commonly encountered species, far beyond the range of its known host, suggesting an association with an unknown, likely more common and widespread host.

Bactrocera syzygii White and Tsuruta 2001. Distribution: Sri Lanka (Drew and Romig 2013), India (David et al. 2017), Vietnam (Leblanc et al. 2018a), Bangladesh (Leblanc et al. 2019), Nepal (**NEW COUNTRY RECORD**). Lure: Zingerone (Dooreenweerd et al. 2018). Host: *Syzygium jambos* (Myrtaceae) (Tsuruta & White 2001). Nepal survey: Four specimens in

Rampur and two in Bandipur.

Bactrocera tuberculata (Bezzi 1916). Distribution: Bhutan, Myanmar, China, Thailand, Vietnam (Drew et al. 2013), India (David et al. 2017), Bangladesh (Leblanc et al. 2019), Nepal (**NEW COUNTRY RECORD**). Lure: Methyl eugenol. Hosts: A moderate pest of cultivated fruit, bred from 10 host species in 8 families (Allwood et al. 1999). Nepal survey: Small numbers collected in Sunwal (10 specimens), Bandipur (15), Pokhara (8), and Kathmandu (3).

Bactrocera zonata (Saunders 1842). Distribution: Pakistan, India, Sri Lanka, Bhutan, Bangladesh, Myanmar, Thailand, Laos, Vietnam (Agarwal and Sueyoshi 2005, Drew and Romig 2013), Nepal (Sharma et al. 2015); introduced to Mauritius, north Africa and middle East. Lure: Methyl eugenol. Hosts: A broadly polyphagous fruit pest bred from 54 hosts in 23 families (Allwood et al. 1999, Culliney et al. 2017). Nepal survey: Common and widespread at lower elevations, with 1,495 specimens collected during the survey, and rare at higher elevations (Fig. 2D), with only 11 specimens trapped in Kathmandu and 3 in Lumle.

Zeugodacus caudatus (Fabricius 1805). Distribution: India, Sri Lanka, Nepal, Bangladesh, Myanmar, China, Thailand, Vietnam, Taiwan, Malaysia (Peninsular, East), Brunei, Indonesia (Agarwal and Sueyoshi 2005, Drew & Romig 2013), Cambodia (Leblanc et al. 2016). Lure: Cue-lure. Host: Male flowers of *Cucurbita moschata* (Cucurbitaceae) (Allwood et al. 1999). Nepal survey: 19 specimens collected at lower elevations in Sunwal (5), Rampur (9), and Bhandara (5).

Zeugodacus cucurbitae (Coquillett 1899). Distribution: widespread throughout tropical Asia, from Pakistan to Taiwan and south to New Guinea and Solomon Islands; introduced to Africa, the middle East, and various islands in the Indian and

Pacific Oceans (see map in Vargas et al. 2015). Lures: Cue-lure, zingerone. Hosts: A severe pest of cucurbit crops, also bred from a diversity of other families, with a total of 136 hosts in 30 families (Allwood et al. 1999, McQuate et al. 2016). Nepal survey: A widespread species (856 specimens collected), though common only at lower elevations (Fig. 1B).

Zeugodacus diversus (Coquillett 1904). Distribution: Pakistan, India, Sri Lanka, Nepal, China, Thailand, Vietnam (Drew and Romig 2013), Bangladesh (Leblanc et al. 2019). Lures: Weak attraction to methyl eugenol and much stronger attraction to methyl-isoeugenol (Royer et al. 2018). Hosts: Bred from flowers of nine species of Cucurbitaceae (Allwood et al., 1999), but also known to secondarily feed on and damage fruits as well (Liquido et al. 2019a). Nepal survey: Widespread species, though collected in small numbers due to weak attraction to methyl eugenol used in surveys. Specimens collected in Bhairahawa (1), Rampur (3), Bandipur (1), Pokhara (4), and Kathmandu (7).

Zeugodacus duplicatus (Bezzi 1916). Distribution: India, Sri Lanka (Drew and Romig 2013), Nepal (**NEW COUNTRY RECORD**). Lure: Cue-lure (**NEW LURE RECORD**). Hosts: No reliable host record. Nepal survey: One specimen collected in a cue-lure trap in Bhairahawa.

Zeugodacus luteicinctus Ito 2011. Distribution: Nepal (Ito 2011). Lure: None recorded. Host: None recorded. Nepal survey: Not collected. Note: Described from a single female collected in 1962. Nearly identical to and possibly conspecific with *Z. yoshimotoi* (Doorenweerd et al. 2018).

Zeugodacus scutellaris (Bezzi 1913). Distribution: Pakistan, India, Nepal, Bhutan, Myanmar, China, Thailand, Vietnam, Peninsular Malaysia (Agarwal and Sueyoshi 2005, Drew and Romig 2013). Lure: Cue-lure. Hosts: Bred from flowers of *Cucurbita maxima*, *C. moschata*, *La-*

genaria siceraria, and *Zehneria wallichii* (Cucurbitaceae) (Allwood et al., 1999). Nepal survey: 33 specimens collected, at higher elevations, in Bandipur (1), Pokhara (5), Kathmandu (16), and Lumle (11).

Zeugodacus tau (Walker 1849). Distribution: India (including Andaman and Nicobar), Sri Lanka, Bhutan, Myanmar, China, Thailand, Vietnam, Taiwan, Malaysia (Peninsular, East), Singapore, Brunei, Indonesia (Agarwal and Sueyoshi 2005, Drew and Romig 2013), Cambodia, Laos (Leblanc et al. 2016), Bangladesh (Leblanc et al. 2019), Nepal (Sharma et al. 2015). Lure: Cue-lure. Hosts: Primarily a pest of cucurbit fruits, though its host range is much broader, as it has been bred from 77 hosts in 23 families (Liquido et al. 2016b). Nepal survey: Widespread and common (937 specimens collected), especially at lower elevations (Fig. 2E).

Zeugodacus yoshimotoi (Hardy 1973). Distribution: India, Nepal, Bhutan, Vietnam, Thailand, (Agarwal and Sueyoshi 2005, Drew and Romig 2013), China (Leblanc et al. 2016). Lure: Cue-lure. Hosts: None recorded. Nepal survey: A few specimens trapped at higher elevations in Bandipur (10), Pokhara (7), and Lumle (3). Note: This species was first collected in Kathmandu in 1988 (Drew and Romig 2013). As noted earlier, *Z. luteicinctus*, collected in 1962 and described as new by Ito (2011), may be conspecific with *Z. yoshimotoi* (Doorenweerd et al. 2018).

Zeugodacus zahadi (Mahmood 1999). Distribution: Pakistan, India, Sri Lanka, Bhutan, Myanmar (Drew and Romig 2013). Lure: Cue-lure. Hosts: None recorded. Nepal survey: None collected. Note: Published records from Nepal and Vietnam require confirmation, as no specimens with specific collecting information were cited for these countries in the original description (Drew and Romig 2013). This species may actually be a junior synonym of *Z. tau* (Drew and

Romig 2013, Doorenweerd et al. 2018).

Dacus feijeni White 1998. Distribution: Bhutan (Drew and Romig 2013), Nepal (**NEW COUNTRY RECORD**). Lure: Cue-lure. Hosts: None recorded. Nepal survey: Four specimens collected in Bandipur.

Dacus longicornis (Wiedemann 1830). Distribution: India, Sri Lanka, Bhutan, Myanmar, China, Thailand, Laos, Vietnam, Malaysia (Peninsular, East), Brunei, Philippines, Indonesia (Drew et al. 1998, Agarwal and Sueyoshi 2005, Drew and Romig 2013), Nepal (Adhiraki et al. 2018), Bangladesh (Leblanc et al. 2019). Lure: Cue-lure. Hosts: A moderate cucurbit pest bred from fruits of *Luffa acutangula*, *L. cylindrica*, *Zehneria wallichii*, and *Trichosanthes cucumerina* (Cucurbitaceae) (Allwood et al. 1999). Nepal survey: Three specimens collected in Sunwal.

Dacus maculipterus Drew and Hancock 1998. Distribution: Thailand (Drew and Romig 2013), Nepal (**NEW COUNTRY RECORD**). Lure: Methyl eugenol (**NEW LURE RECORD**). Host: None recorded. Nepal survey: One specimen in Lumle in a methyl eugenol trap, an infrequent though not unprecedented lure association for *Dacus*.

Dacus polistiformis (Senior-White 1922). Distribution: India, Nepal, China (Drew and Romig 2013). Lure: None recorded. Host: *Oxystelma esculentum* (Apocynaceae) (Drew et al. 1998). Nepal survey: None collected. Note: Nepalese material of this species was originally described by Hardy (1964) as (now synonymous) *Callantra nepalensis*.

Dacus succaelestis Ito 2011. Distribution: Nepal (Ito 2011). Lure: None recorded. Host: None recorded. Nepal survey: None collected. Note: Species described out of a single specimen collected in 1962, with no reference to Drew et al. (1998) revision of Asian *Dacus*. May turn out to be conspecific with a known species when

Holotype is examined.

Dacus trimacula Wang 1990. Distribution: China (Drew and Romig 2013), Nepal (**NEW COUNTRY RECORD**). Lure: Cue-lure, zingerone (Dooreenweerd et al. 2018). Host: None recorded. Nepal survey: Two specimens in Bandipur and one in Pokhara.

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