CROP POLLINATION AND THE FLOWER RELATIONSHIPS OF THE WILD BEES OF LUDHIANA, INDIA (Hymenoptera: Apoidea)[1]

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ABSTRACT

At Ludhiana (Punjab) India, 97 species of bees were collected from crops, garden flowers and wild flowers. The relationship between the climate, flowering seasons of plants and periods of activity of associated bees is described. Bees belonging to primarily holarctic genera appeared on the winter annuals and cold-weather crops; during the warm season a greater variety of bees was on the tropical crops. Various wild bees were more numerous than *Apis* spp. on sunn hemp, gram, sarson, taramira, pomegranate and eggplant.

There is much published information on the flower relationships of wild bees and their actual or potential use as agents of crop pollination in the temperate regions of the world (Bohart, 1957, 1960; Linsley, 1958; Popov, 1956). Species of *Megachile*, *Nomia*, and *Bombus* have been semi-domesticated because they were found to be more effective than honeybees, under certain conditions, for increasing, through cross-pollination, the seed yields of alfalfa and red clover (Bohart, 1960). Relatively little is known of pollination by the insect visitors to tropical crops, especially those in Africa and south Asia where improved yields of food crops are urgently needed.

Since most pollination research in India has been concerned with the behavior of honeybees (mainly *Apis mellifera* L. and *A. indica* F.), the study of the flower relationships and ecology of numerous potentially useful species of wild bees has been largely neglected. Rahman (1940) made a detailed study of the behavior of a large variety of insects visiting flowers of toria and sarson (*Brassica* spp.). He found *Andrena ilerda* Cam. and *Apis florea* F., in that order, to be the most abundant and effective pollinators of toria; on sarson, *Apis florea* was more abundant than *Halictus* sp. or *Andrena ilerda*. Six other species of *Andrena*, *Halictus salsettensis* Ckll., three species of *Colletes*, *Xylocopa nasalis* Westw., *Ceratina binghami* Ckll., three species of *Nomada* and *Anthophora vedetta* Nur. were less frequent visitors to toria and sarson at Lyallpur.

Maxwell-Lefroy and Howlett (1909) mentioned *Lithurge atratus* Sm. and *Halictus senescens* (Burkill, in Maxwell-Lefroy and Howlett) as visitors to cotton flowers. Khan and Afzal (1950a, b) reported *Apis dorsata* F. and *Anthophora confusa* Sm. in that order, to be the most active agents of cross-pollination in cotton. They also obtained *Nomada*

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sp., *Andrena ilerda*, *Apis florea*, *Halictus salsettensis*, *Megachile lanata* F. and *Andrena* spp. from cotton flowers. Sidhu and Singh (1961) found *Apis dorsata*, *A. indica*, *A. florea*, *Megachile chlorigaster* Cam., *M. lanata*, *M. femorata* Sm., *Halictus* sp., *Coelioxys decipiens* Spin. and two species of *Nomia* pollinating cotton flowers at Ludhiana. *Apis* spp. were the most numerous and effective, followed by *Megachile*.

Burkill (in Maxwell-Lefroy and Howlett, 1909) states that *Xylocopa* spp. are the most important flower-visiting insects in India and that *X. latipes* (Dr.) and *X. aestuans* (L.) are more active on sunn hemp than *Apis florea*.

Because no collection of all the wild bees visiting crops and wild flowers of a restricted area in India had been previously undertaken, this survey was made. Between 7 September 1964 and 1 June 1965, wild bees were collected by net at intervals of two or three days. Relative pollinating efficiency of various species was not estimated. More than 95% of the bees were collected on the approximately 600 hectare property of Punjab Agricultural University, consisting of experimental farms, horticultural garden and campus, located at the edge of the city of Ludhiana (75°-51′ E, 30°-55′ N). The remaining bees in this survey were collected at farms near Ludhiana. This area in Punjab, on the level Indo-gangetic plain about 60 km south of the Himalayas, has a semiarid, subtropical climate, with distinct periods of dry (September–July) and cold (November–February) weather. Rainfall, in 1958–62, averaged 78.39 cm annually; 60.26 cm of this falling during the monsoon (July–September) and 4.27 cm in January (Figure 1).

There are two fairly distinct flowering seasons among the wild herbaceous plants of this region. The largest number of species blooms from January to April following vegetative growth during the relatively moist winter. Many of these are winter annuals, belonging to primarily temperate-zone families (e.g., Cruciferae, Polygonaceae, Umbelliferae) or to genera occurring mainly in temperate regions (see Kashyap, 1936). It is at this time that many crops typical of temperate regions (i.e., "rabi" crops) bloom, including cruciferous crops, most legumes (*Melilotus*, *Trigonella*, *Trifolium*, *Cicer*) chicory, onion, lettuce, carrot and other umbelliferae.

A flowering season (June to October) follows vegetative growth during the monsoon among many plants belonging primarily to tropical families (e.g., Capparidaceae, Zygophyllaceae, Cucurbitaceae) or belonging to tropical genera of widely distributed families (e.g., *Crotalaria*, *Indigofera*, *Tephrosia* of the Leguminosae). At this time, characteristically tropical or warm-weather ("kharif") crops mature and bloom, such as sunn hemp, eggplant, cotton and gourds.

Many fruit trees, although of subtropical or tropical genera, bloom in early spring (e.g., orange, pomegranate, mango and guava). Other tropical trees and shrubs bloom at various times during the warm season (February–October).

Associated with these flowering seasons are four groups of bees

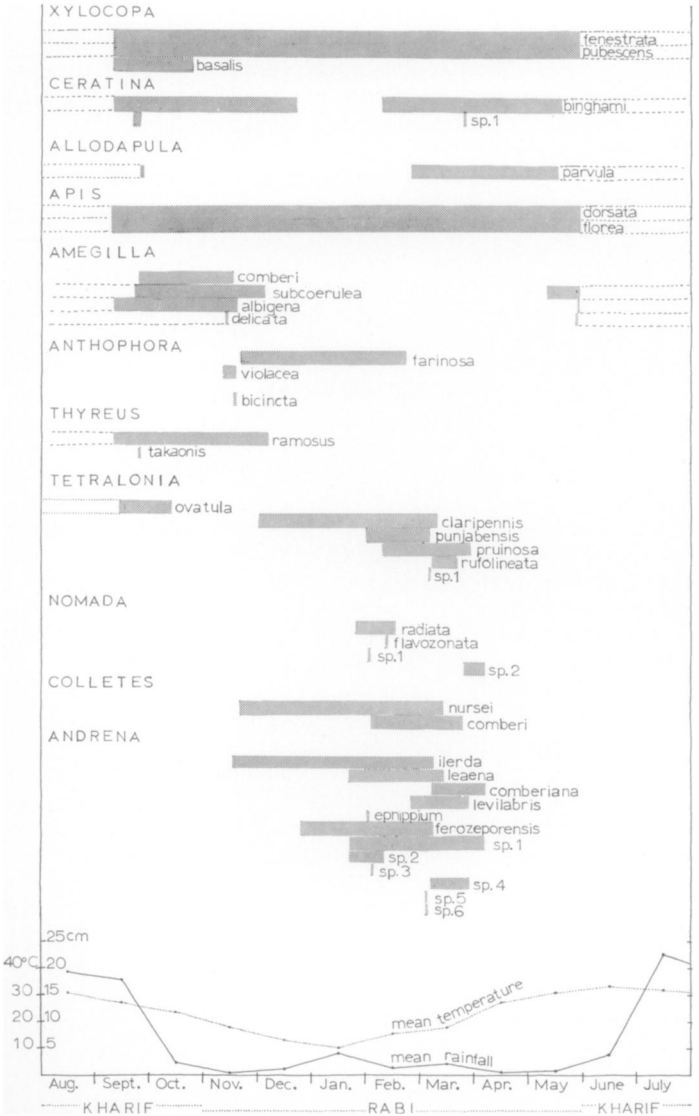
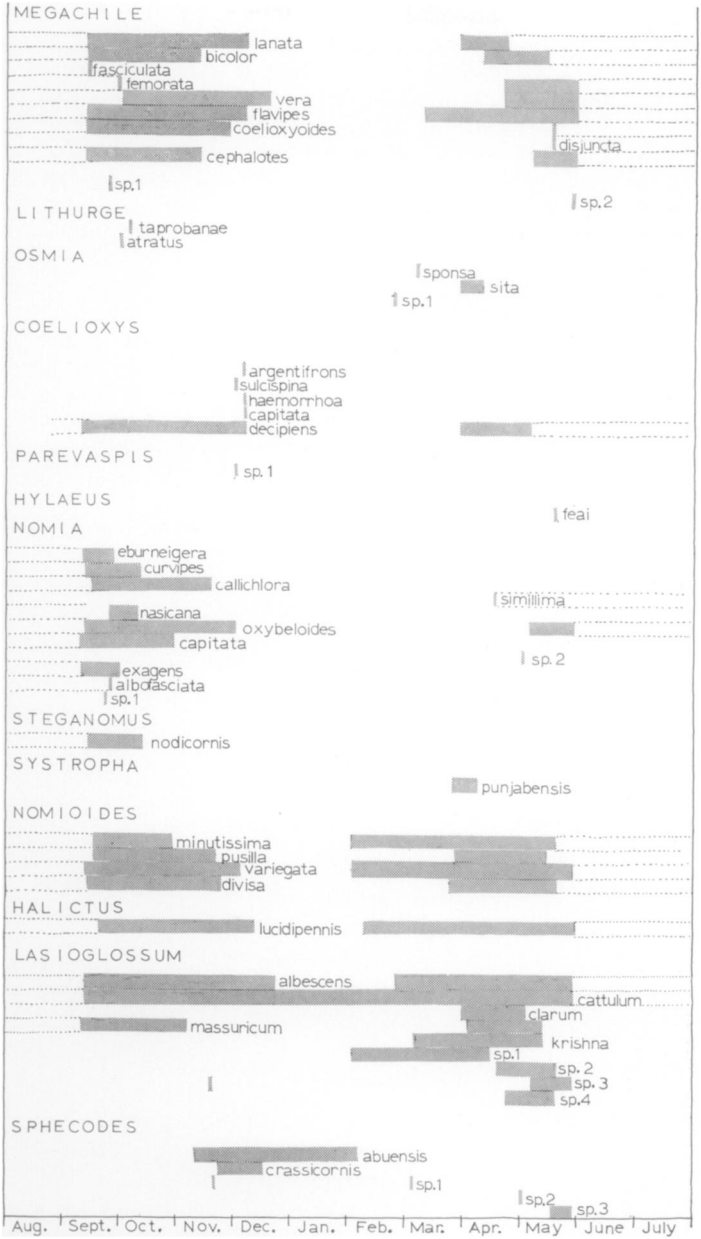


FIG. 1. Relationship between temperature, rainfall, crops and the seasonal activity of wild bees at Ludhiana. Stippled areas represent known periods of bee activity; dashed lines indicate probable continued activity.

Source of meteorological data: Agricultural Officers' Handbook, 1965. Punjab Agricultural University Press, Ludhiana. 170 pp.



(Figure 1). In winter and early spring, apparently univoltine bees belonging to the primarily holarctic genera *Andrena*, *Osmia*, and *Nomada*, also all *Colletes* and *Anthophora*, most species of *Tetralonia* and some species of Halictinae appear exclusively on the rabi crops and winter annuals.

A second group of bees appearing on both rabi and kharif crops are multivoltine species that maintain some activity, at least on warm days, throughout the year. This group includes *Xylocopa fenestrata* F. and *X. pubescens* Spin., *Apis* spp. and *Lasioglossum* (*Ctenonomia*) *cattulum* Vach.

The third group of bees, appearing in the spring, at the end of the rabi season and active on kharif crops throughout the warm weather, are apparently multivoltine species that hibernate during winter. This group includes most *Megachile, Coelioxyx* and *Amegilla,* one species of *Nomia* and many Halictinae.

The fourth group, appearing on crops in summer during or after the monsoon, includes apparently univoltine species of *Nomia*, *Lithurge*, *Steganomus nodicornis* Sm., *Tetralonia ovatula* Cam. and *Megachile fasciculata* Sm.

A total of 97 species of bees was collected from nests and flowers at Ludhiana, as follows: XYLOCOPIDAE: *Xylocopa fenestrata* F., ♂, ♀ (active all year); *Xylocopa basalis* Sm. ♀ (12 Sept., 22 Oct.); *Xylocopa pubescens* Spin. ♂, ♀ (all year); *Ceratina binghami* Ckll. ♂, ♀ (8 Feb.–16 Dec.); *Allodapula parvula* Sm. ♂, ♀ (24 Feb.–5 Oct.); *Ceratina* sp. 1 ♀ (March, Sept.); APIDAE: *Apis dorsata* F. ☿ (all year); *Apis indica* F. ☿ (domesticated, 5 March–18 Nov.); *Apis florea* F. ☿ (all year); ANTHOPHORIDAE: *Tetralonia pruinosa* Cam. ♀ (8 Feb.–29 March); *Tetralonia claripennis* Cam. ♂ (1 Dec.–8 March); *Tetralonia ovatula* Cam. ♀ (14 Sept.–10 Oct.); *Tetralonia* sp. 1 (near *T. diana* Nur.), ♀ (6 March); *Tetralonia rufolineata* Cam. ♀ (6–11 March); *Tetralonia punjabensis* Cam. ♂ (1 Feb.–6 March); *Amegilla comberi* Ckll. ♀, ♂ (22 Sept.–16 Nov.); *Amegilla subcoerulea* Lep. ♀ (12 May–18 Dec.); *Amegilla albigena* Lep. ♀ (25 May–18 Nov.); *Amegilla delicata* Ckll. ♀ (25 May–15 Nov.); *Anthophora farinosa* Klug. ♀, ♂ (19 Nov.–♀ Feb.); *Anthophora violacea* Lep. ♂ (10–16 Nov.); *A.* (*Habropoda*) *bicincta* F. (16 Nov.); *Thyreus ramosus* Lep. ♀, ♂ (12 Sept.–5 Dec.); *Thyreus takaonis* Ckll. ♀ (24 Sept.); *Nomada flavozonata* Nur. ♀ (10 Feb.); *Nomada radiata* Nur. ♀, ♂ (4 Nov.–16 Feb.); *Nomada* sp. 1 ♀ (2 Feb.); (?) *Nomada* sp. 2 ♀ (22 Mar.–5 Apr.); ANDRENIDAE: *Andrena ilerda* Cam. ♀, ♂ (18 Nov.–6 March); *Andrena comberiana* Ckll. ♀ (8 March–7 April); *Andrena leaena* Cam. ♀, ♂ (22 Jan.–12 March); *Andrena levilabris* Cam. ♀ (29 Feb.–24 March); *Andrena ephippium* Spin. ♂ (2 Feb.); *Andrena ferozeporensis* Cam. ♂ (16 Dec.–6 Mar.); and 6 undetermined species of *Andrena*: sp. 1, ♀ (22 Jan.–8 April); sp. 2, ♀ (22 Jan.–27 Feb.); sp. 3, ♂ (2 Feb.); sp. 4, ♀ (6–27 March); sp. 5, ♀ (3 March); sp. 6, ♂ (3 March). COLLETIDAE: *Colletes nursei* Cam. ♀, ♂ (19 Nov.–12 March); *Colletes comberi* Ckll. ♀, ♂ (6

Feb.–22 March); *Hylaeus* (?) *feai* Vach. ♂ (17 May). MEGACHILIDAE: *Megachile fasciculata* Sm. ♀, ♂ (13 Sept.); *Megachile bicolor* F. ♀, ♂ (8 April–10 Nov.); *Megachile lanata* F. ♀, ♂ (27 March–4 Dec.); *Megachile femorata* Sm. ♀ (20 April–1 Oct.); *Megachile vera* Nur. ♀, ♂ (20 April–17 Dec.); *Megachile flavipes* Spin. ♀, ♂ (8 Feb.–5 Dec.); *Megachile coelioxyoides* Bingh. (? = *M. rotundata* F.) ♀ (15 May–26 Nov.); *Megachile disjuncta* F. ♂ (1 May); *Megachile cephalotes* Sm. ♀, ♂ (5 May–10 Nov); 2 undetermined species of *Megachile*: sp. 1, ♂ (23 Sept.), sp. 2, ♀ (27 Apr.–25 May); *Osmia sponsa* Nur. ♀ (6 March); *Osmia sita* Nur. ♀ (27 March–8 April); *Osmia* sp. 1 ♂ (21 Feb.); *Parevaspis* sp. 1 (near *P. carbonaria* Sm.), ♀ (1 Dec.); *Lithurge taprobanae* Cam. ♀ (3 Oct.); *Lithurge atratus* Sm. ♀, ♂ (15 Sept.–1 Oct.); *Coelioxys capitata* Sm. ♂ (4 Dec.); *Coelioxys haemorrhoa* Foerst. ♀, ♂ (4 Dec.); *Coelioxys sulcispina* Cam. ♀ (1 Dec.); *Coelioxys argentifrons* Sm. ♀ (4 Dec.); *Coelioxys decipiens* Spin. ♀ (27 March–4 Dec.). HALICTIDAE: *Steganomus nodicornis* Sm. ♀, ♂ (14 Sept.–10 Oct.); *Nomia eburneigera* Ckll. ♀, ♂ (12–27 Sept.); *Nomia curvipes* F. ♀, ♂ (14 Sept.–10 Oct.); *Nomia callichlora* Ckll. ♀, ♂ (16 Sept.–17 Nov.); *Nomia simillima* Sm. ♂ (16 April); *Nomia nasicana* Ckll. ♀ (23 Sept.–8 Oct.); *Nomia oxybeloides* Sm. ♀, ♂ (5 May–1 Dec.); *Nomia capitata* Sm. ♀, ♂ (8 Sept.–28 Oct.); *Nomia exagens* Walk. ♀ (11–29 Sept.); *Nomia* (?) *albofasciata* Sm. ♀ (23 Sept.); *Nomia* sp. 1, ♀ (22 Sept.); *Nomia* sp. 2 (near *N. mediorufa*), ♀ (1 May); *Systropha punjabensis* Batra & Michener ♀, ♂ (22 March–7 April); *Nomioides minutissima* (Rossi) ♀, ♂ (2 Feb.–18 Oct.); *Nomioides pusilla* Blüth. ♀, ♂ (24 Mar.–19 Nov.); *Nomioides variegata* (Oliv.) ♀, ♂ (2 Feb.–4 Dec.); *Nomioides divisa* Cam. ♀, ♂ (22 March–28 Nov.); *Halictus lucidipennis* Sm. ♀, ♂ (8 Feb.–13 Dec.); *Lasioglossum massuricum* Blüth. ♀ (5 April–5 Nov.); *Lasioglossum clarum* Nur. ♀ (1 April–3 May); *Lasioglossum krishna* Nur. ♀ (6 March–12 May); *Lasioglossum albescens* Sm. ♀, ♂ (24 Feb.–20 Dec.); *Lasioglossum cattulum* Vach. ♀, ♂ (all year); 4 undetermined species of *Lasioglossum*: sp. 1, (*Evylaeus*) ♀ (2 Feb.–15 April); sp. 2, ♀ (17 April–17 May); sp. 3, ♂ (5 May–18 Nov.); sp. 4, ♂ (21 April–17 May); *Sphecodes abuensis* Nur. ♀, ♂ (10 Nov.–6 Feb); *Sphecodes crassicornis* Sm. ♂ (22 Nov.–16 Dec.; 10 May); 3 undetermined species of *Sphecodes*: sp. 1, ♀ (3 March, 19 Nov.); sp. 2, ♀ (1 May); sp. 3, ♂ (4 Dec., 17–27 May). Representatives of each species have been deposited in the Snow Entomological Museum at The University of Kansas and duplicate specimens of many species are at Punjab Agricultural University.

Relatively few species of wild bees were collected at Ludhiana compared with some similarly local surveys in the United States (439 species at Riverside, California, 300 at Carlinville, Illinois), but the number of species was comparable to that in the southeastern United States (104 species at Hattiesburg, Mississippi, 65 species in southern Florida) and at Mt. Vishnevaya, Russia (120–140 species) (see Linsley, 1958). Ac-

cording to Michener (1965), there is a single paleotropical bee fauna, richest in Africa and becoming poorer eastward through the Oriental region.

Bees (except for *Apis* spp.) were remarkably scarce at Ludhiana compared with populations in similar cultivated areas of Europe or the United States. This was surprising because wild bees are usually most numerous in arid or semiarid regions (Linsley, 1958). Uncultivated land at Ludhiana was constantly disturbed by intensive grazing and by harvesting of the remaining sparse vegetation for fodder, leaving few wild flowering plants to maintain bee populations. Cultivated areas were usually irrigated, this perhaps destroying nests in the soil of fields. Few trees grow in this area; dead wood and brush are collected for firewood leaving relatively few nesting sites for the wood-boring or twig-dwelling bees (thatched roofs provided nesting sites for some). Wild bees, however, seemed relatively numerous in less-populated forested mountainous areas of India (Kakanakote in Mysore State, Punjab and Uttar Pradesh Himalayas). Competition for food with the numerous, active workers of *Apis dorsata* and *A. florea* in the plains, and with *A. indica* in the Himalayas may be an additional factor limiting populations of wild bees.

Following are lists of bees visiting various crops and of wild flowers visited by non-*Apis* bees. *Apis* spp. were not as abundant as certain other species of bees on sunn hemp, sarson, taramira, eggplant, gram and pomegranate; perhaps it would be helpful to explore the possibility of domesticating these species.

Crops visited by wild bees at Ludhiana (♀, ♂, female without pollen or male on flowers; ♀p, female on flowers has pollen on scopa; ** species very abundant; * species moderately abundant; [m] species apparently monolectic; [+] insects other than bees numerous on flowers; [x] plant requires cross-pollination for maximum seed yield.)

KHARIF CROPS

CUCURBITACEAE

[+]*Luffa cylindrica* (L.) M. Roem. (Ghiya tori), flowering in August–November.

1. ****Xylocopa fenestrata*** ♀, ♀p, ♂
2. ***X. pubescens*** ♀, ♀p, ♂
3. ***X. basalis*** ♀
4. ***Ceratina binghami*** ♀, ♀p, ♂
5. ***Ceratina*** sp. 1 ♀p
6. ***Allodapula parvula*** ♀, ♀p
7. ****Tetralonia ovatula*** ♀, ♀p
8. ***Thyreus ramosus*** ♂
9. ***T. takaonis*** ♀
10. ***Amegilla comberi*** ♀, ♂
11. ***A. subcoerulea*** ♀
12. ***A. albigena*** ♀, ♀p, ♂
13. ***Apis dorsata*** ☿
14. ****A. florea*** ☿, ☿p
15. ***Megachile bicolor*** ♂
16. ***M. lanata*** ♀, ♂
17. ***M. femorata*** ♀p
18. ***M. flavipes*** ♀, ♀p, ♂
19. ****M. coelioxyoides*** ♀, ♀p
20. ***Steganomus nodicornis*** ♀p, ♂
21. ****Nomia eburneigera*** ♀p
22. **[m]**N. curvipes*** ♀p, ♂
23. ***N. oxybeloides*** ♀, ♀p
24. ***N. exagens*** ♀, ♀p
25. ***N. albofasciata*** ♀
26. ***Nomioides minutissima*** ♀p
27. ***N. pusilla*** ♀, ♀p, ♂
28. ***N. variegata*** ♀, ♂

29. **N. divisa* ♀p, ♂
30. *Halictus lucidipennis* ♀p
31. *Lasioglossum massuricum* ♀
32. ***L. albescens* ♀, ♀p, ♂
33. ***L. cattulum* ♀, ♀p, ♂

Momordica charantia L. (Karela) flowering in May–July.

1. *Nomiodes variegata* ♂
2. *Lasioglossum cattulum* ♀, ♂

[x]*Cucumis melo* L. (Cantaloup) flowering in May–July.

1. *Nomioides variegata* ♂
2. *Halictus lucidipennis* ♀, ♀p, ♂
3. *Lasioglossum cattulum* ♂
4. **Apis florea* ☿
5. *A. dorsata* ☿

Citrullus vulgaris Schrod. (Watermelon) flowering in May–June.

1. *Nomioides variegata* ♀, ♂
2. *Lasioglossum* sp. 3 ♂
3. *Apis florea* ☿

[x]*Cucurbita maxima* Duch. (Vegetable marrow) flowering in May.

1. ***Apis florea* ☿
2. **A. dorsata* ☿
3. *Nomia oxybeloides* ♀p
4. *Nomioides minutissima* ♀
5. *N. variegata* ♀, ♂
6. *N. divisa* ♂
7. *Lasioglossum massuricum* ♀
8. **L. cattulum* ♀, ♀p, ♂
9. *Lasioglossum* sp. 4 ♂

SOLANACEAE

Solanum melongena L. (Eggplant or Brinjal) flowering in June–December.

1. **Xylocopa fenestrata* ♀pb
2. *X. pubescens* ♀
3. *Ceratina binghami* ♂
4. **Amegilla delicata* ♀, ♀p
5. *A. subcoerulea* ♀, ♀pb
6. *A. albigena* ♀
7. *Apis dorsata* ☿, ☿p
8. *A. florea* ☿p
9. *Megachile cephalotes* ♀
10. *Nomia callichlora* ♀pb
11. *N. nasicana* ♀p
12. **N. oxybeloides* ♀pb
13. **Lasioglossum cattulum* ♀pb

b: Bees buzzed to release pollen from the anthers.

LEGUMINOSAE

Crotalaria juncea L. (Sunn hemp) flowering in August–September.

1. *Xylocopa fenestrata* ♀
2. *Ceratina binghami* ♀
3. **Apis florea* ☿, ☿p
4. [m]****Megachile fasciculata* ♀, ♀p, ♂
5. *M. bicolor* ♀
6. ***M. lanata* ♀, ♀p, ♂
7. *M. cephalotes* ♀p

RABI CROPS

CRUCIFERAE

[x, +]*Brassica napus* L. var. *dichotoma* Prain (Toria), flowering in November–December.

1. *Xylocopa pubescens* ♀
2. *Ceratina binghami* ♀
3. *Amegilla albigena* ♀, ♂
4. ***Apis dorsata* ☿, ☿p
5. **A. indica* ☿, ☿p
6. ***A. florea* ☿, ☿p
7. ***Andrena ilerda* ♀, ♀p, ♂
8. *Colletes nursei* ♀
9. *Nomioides divisa* ♂
10. **Lasioglossum cattulum* ♀, ♀p, ♂
11. **L. albescens* ♀, ♀p, ♂
12. *Sphecodes abuensis* ♀

x,+*Brassica campestris* L. var. *sarson* Prain (Sarson) flowering in January–April.

1. *Xylocopa fenestrata* ♀, ♂
2. *X. pubescens* ♀
3. *Tetralonia claripennis* ♂
4. *T. punjabensis* ♂
5. *T. pruinosa* ♀p
6. *Apis dorsata* ☿p
7. **A. florea* ☿
8. ***Andrena ilerda* ♀, ♀p, ♂
9. ***A. leaena* ♀, ♀p, ♂
10. **Andrena* sp. 1 ♀, ♀p
11. *Andrena* sp. 2 ♀, ♀p
12. *A. ephippium* ♂
13. *A. ferozeporensis* ♀, ♂
14. *Andrena* sp. 3 ♂
15. **Colletes nursei* ♀, ♂
16. *Nomioides minutissima* ♀, ♀p
17. *N. pusilla* ♀p
18. *N. variegata* ♀, ♀p
19. *N. divisa* ♀p
20. *Halictus lucidipennis* ♀p
21. *Lasioglossum cattulum* ♀, ♀p
22. *Lasioglossum* (*Evylaeus*) sp. 1 ♀, ♀p
23. *Nomada radiata* ♀
24. *Nomada* sp. 1 ♀

x,+*Brassica oleracea* L. (Cabbage and Cauliflower) flowering in December.

1. *Ceratina binghami* ♀
2. **Apis dorsata* ☿
3. *A. indica* ☿
4. *Andrena ilerda* ♀, ♀p, ♂
5. **Lasioglossum cattulum* ♀p, ♀, ♂
6. **L. albescens* ♀, ♂

Eruca sativa Lam. (Taramira) flowering in January–February.

1. *Apis dorsata* ☿
2. *A. florea* ☿
3. **Andrena ilerda* ♀, ♀p, ♂
4. **Colletes nursei* ♀, ♀p, ♂

Other bees conspicuously absent.

x*Raphanus sativus* L. (Radish) flowering in March–April.

1. *Tetralonia pruinosa* ♀p
2. *Apis indica* ☿p
3. *Andrena leaena* ♀p
4. *Colletes nursei* ♀p
5. ***Nomioides variegata* ♀, ♀p
6. *N. divisa* ♂
7. *Halictus lucidipennis* ♀
8. *Lasioglossum massuricum* ♀
9. *L. cattulum* ♀, ♀p
10. *Lasioglossum* (*Evylaeus*) sp. 1 ♀, ♀p

LEGUMINOSAE

Cicer arietinum L. (Gram or Chola) flowering in February–March.

1. *Xylocopa fenestrata* ♂
2. *X. pubescens* ♂
3. **Tetralonia pruinosa* ♀, ♀p
4. *T. claripennis* ♂
5. m*Tetralonia* sp. 1 ♀, ♀p
6. m**T. rufolineata* ♀p
7. *T. punjabensis* ♂
8. *Nomada radiata* ♀
9. *Apis dorsata* ☿
10. **A. indica* ☿
11. *A. florea* ☿p
12. *Andrena comberiana* ♀
13. m**Andrena* sp. 4 ♀, ♀p
14. **A. levilabris* ♀p
15. *Colletes nursei* ♂
16. *Osmia sponsa* ♀p
17. *Megachile flavipes* ♀p

x*Trifolium alexandrinum* L. (Berseem or Egyptian clover) flowering in March.

1. ***Apis florea* ☿
2. *Ceratina binghami* ♀p, ♂

Other bees conspicuously absent.

x,+*Trifolium hybridum* L. (Chitalla or Alsike clover) flowering in April–May.

1. *Xylocopa fenestrata* ♂
2. *X. pubescens* ♀
3. ***Apis dorsata* ☿, ☿p
4. **A. florea* ☿
5. **A. indica* ☿
6. **Megachile femorata* ♀, ♀p
7. *M. vera* ♀
8. **M. flavipes* ♀, ♀p, ♂

9. *M. cephalotes* ♀p
10. *Nomia oxybeloides* ♀, ♀p, ♂
11. *Nomioides pusilla* ♀
12. ***N. variegata* ♀, ♂
13. **Halictus lucidipennis* ♀, ♀p, ♂
14. *Lasioglossum massuricum* ♀
15. *Lasioglossum* sp. 2 ♂
16. *Lasioglossum* sp. 3 ♂
17. ***Lasioglossum cattulum* ♀, ♀p, ♂
18. *Sphecodes crassicornis* ♂
19. *Lasioglossum* sp. 4 ♂

Melilotus indica (L.) All. (Senji) flowering in February–March.

1. **Apis florea* ☿
2. *Andrena leaena* ♀, ♀p
3. *Andrena* sp. 5 ♀
4. *A. levilabris* ♀
5. *Andrena* sp. 1 ♀
6. *A. ferozeporensis* ♂
7. *Andrena* sp. 6 ♂
8. *Colletes nursei* ♂
9. *Lasioglossum krishna* ♀p
10. *L. cattulum* ♀
11. *Lasioglossum* sp. 1 ♀p

COMPOSITAE

Cichorium intybus L. (Chicory) flowering in April–May.

1. *Xylocopa fenestrata* ♂
2. ***Nomioides variegata* ♀, ♀p, ♂
3. *Halictus lucidipennis* ♀
4. *Lasioglossum cattulum* ♀
5. *Lasioglossum* sp. 4 ♀

LILIACEAE

+*Allium cepa* L. (Onion) flowering in April.

1. ***Apis dorsata* ☿
2. **A. florea* ☿

Other bees conspicuously absent.

UMBELLIFERAE

x, +*Daucus carota* L. var. *sativa* DC (Carrot) flowering in May.

1. *Ceratina binghami* ♂
2. *Allodapula parvula* ♀, ♀p, ♂
3. ***Apis florea* ☿
4. *Megachile coelioxyoides* ♀
5. **Nomioides minutissima* ♀, ♀p, ♂
6. **N. pusilla* ♀, ♂
7. **N. variegata* ♂
8. **N. divisa* ♀, ♂
9. *Halictus lucidipennis* ♀, ♀p, ♂
10. *Lasioglossum* sp. 2 ♂
11. *Lasioglossum cattulum* ♀p
12. *Lasioglossum* sp. 4 ♂
13. *Sphecodes* sp. 1 ♂
14. *Sphecodes* sp. 3 ♂
15. *Hylaeus feai* ♂

+*Trachyspermum ammi* (L.) Sprague (Jowain) flowering in April.

1. *Apis florea* ☿
2. *A. dorsata* ☿
3. *Andrena* sp. 1 ♀, ♀p
4. *Nomioides variegata* ♀, ♂
5. *Halictus lucidipennis* ♀p
6. *Lasioglossum cattulum* ♀
7. **Lasioglossum* sp. 4 ♂

ORCHARD CROPS

ANACARDIACEAE

+*Mangifera indica* L. (Mango) flowering in April.

1. *Xylocopa fenestrata* ♀, ♂
2. **Apis dorsata* ☿
3. *A. indica* ☿
4. **A. florea* ☿
5. *Megachile bicolor* ♀
6. *M. lanata* ♀
7. *Nomia simillima* ♀
8. *Nomioides divisa* ♂
9. *Lasioglossum cattulum* ♀
10. *Lasioglossum* sp. 1 ♀p
11. *Lasioglossum* sp. 4 ♂

PUNICACEAE

†*Punica granatum* L. (Pomegranate or Anar) flowering in April–May.

1. *Apis florea* ☿
2. *Megachile femorata* ♀p
3. ***Nomioides minutissima* ♀, ♀p
4. *N. pusilla* ♀p, ♂
5. *N. variegata* ♀, ♀p, ♂
6. ***N. divisa* ♀, ♀p, ♂
7. *Halictus lucidipennis* ♀p
8. *Lasioglossum clarum* ♀, ♀p
9. **L. cattulum* ♀, ♀p, ♂
10. *L. albescens* ♀, ♀p, ♂

MYRTACEAE

Psidium guajava L. (Guava) flowering in April.

1. *Xylocopa fenestrata* ♀, ♀p
2. *Megachile lanata* ♀p

Other bees conspicuously absent.

RUTACEAE

Citrus sinensis (L.) Osbeck (Orange or Malta) flowering in March.

1. **Apis dorsata* ☿
2. *Lasioglossum cattulum* ♀p

Other bees conspicuously absent.

ROSACEAE

Malus sylvestris L. (Apple) flowering in February.

1. *Colletes nursei* ♂
2. *Lasioglossum cattulum* ♂

Other bees conspicuously absent.

ADDITIONAL PLANTS VISITED

XYLOCOPIDAE

Xylocopa fenestrata: *Helianthus* cult., ♀; marigold cult., ♀, ♂.
Xylocopa pubescens: *Helianthus* cult., ♀, ♂; marigold cult., ♀; yellow cosmos cult., ♂.
Ceratina binghami: marigold cult., ♀, ♂; pink cosmos cult., ♀; *Convolvulus arvensis*, ♀; *Vernonia cinerea*, ♀, ♂; *Rhynchosia aurea*, ♀; *Ocimum basilicum*, ♀, ♂; *yellow cosmos* cult., ♀; *Calendula officinalis* cult., ♀, ♂; *Antirrhinum* cult., ♀, ♀p, ♂; *Heliotropium eichwaldii*, ♀, ♂; *Tephrosia pumila*, ♀, ♂; *Alyssum* cult., ♂; *Launea nudicaulis*, ♂; *Hypericum* cult., ♂.
Ceratina sp. 1: *Heliotropium strigosum*, ♀p.
Allodapula parvula: *Alyssum* cult., ♂.

ANTHOPHORIDAE

Tetralonia pruinosa: *Farsetia jacquemontii*, ♀, ♀p; *Convolvulus arvensis*, ♀; *Launea nudicaulis*, ♀; pink cosmos cult., ♀.
Tetralonia claripennis: marigold cult., ♂; *Launea nudicaulis*, ♂; pink cosmos cult., ♂.
Tetralonia punjabensis: pink cosmos cult., ♂; marigold cult., ♂; *Launea nudicaulis*, ♂.
Habropoda bicincta: *Ocimum basilicum*, ♀.
Anthophora violacea: *Ocimum basilicum*, ♂; pink cosmos cult., ♂.
Anthophora farinosa: *Ocimum basilicum*, ♂; (?) *Osmanthus*, ♀.
Amegilla comberi: *Ocimum basilicum*, ♀, ♀p, ♂; *Duranta repens*, ♂.
Amegilla subcoerulea: *Ocimum basilicum*, ♀.
Amegilla albigena: *Ocimum basilicum*, ♀.
Thyreus ramosus: yellow cosmos, ♂; marigold, ♀.
Nomada flavozonata: *Polygonum plebejum*, ♀.
Nomada radiata: *Alyssum* cult., ♀, ♂.
(?) *Nomada* sp. 2: *Launea nudicaulis*, ♀; *Calendula officinalis*, ♀; *Antirrhinum* cult., ♀.

ANDRENIDAE

Andrena ilerda: *Farsetia jacquemontii*, ♀p, ♂; marigold cult., ♀, ♂.
Andrena leaena: marigold cult., ♀; *Alyssum* cult., ♀, ♀p; *Calendula officinalis*, ♂.
Andrena levilabris: *Asphondelus tenuifolius*, ♀p; *Calendula officinalis*, ♀p.
Andrena sp. 1.: wild umbelliferae, ♀p.
Andrena ferozeporensis: marigold cult., ♂; pink cosmos cult., ♂; *Farsetia jacquemontii*, ♂.

COLLETIDAE

Colletes nursei: marigold cult., ♂.
[m]*Colletes comberi*: *Farsetia jacquemontii*, ♀p, ♂.

MEGACHILIDAE

Megachile bicolor: *Hypericum* cult., ♀, ♀p, ♀ cutting leaf; marigold cult., ♂; *Lathyrus* cult., ♀p; *Rhynchosia aurea*, ♀p, ♂.
Megachile lanata: *Lathyrus* cult., ♀, ♂; *Tephrosia pumila*, ♂; *Rhynchosia aurea*, ♀, ♀p, ♂; yellow cosmos cult., ♀.
Megachile femorata: *Indigofera linifolia*, ♀, ♀p; *Antirrhinum* cult., ♀p; *Helianthus* cult., ♀; pink cosmos cult., ♀p; *Hypericum* cult., ♀.
Megachile vera: zinnia cult., ♀p; *Helianthus* cult., ♀; marigold cult., ♀, ♂; phlox cult., ♀p; *Ocimum basilicum*, ♂.
Megachile sp. 1: *Tephrosia pumila*.
Megachile flavipes: *Rhynchosia aurea*, ♀, ♀p, ♂; *Hypericum* cult., ♂; yellow cosmos cult., ♀; marigold cult., ♂; *Ocimum basilicum*, ♀, ♀p; *Tephrosia pumila*, ♀, ♀p, ♂; *Heliotropium strigosum*, ♀; *Calendula officinalis* cult., ♂.
Megachile coelioxyoides: *Nepeta cataria* cult., ♀p; yellow cosmos cult., ♀; *Solanum xanthocarpum*, ♀p; *Rhynchosia aurea*, ♀p; *Vernonia cinerea*, ♀.
Megachile cephalotes: *Poinsettia* cult., ♀p, ♂; *Tephrosia pumila*, ♀, ♀p, ♂; *Hypericum* cult., ♀; yellow cosmos cult., ♀.
Osmia sita: *Calendula officinalis* cult., ♀p; pink cosmos cult., ♀p.
Osmia sp. 1: *Calendula officinalis*, ♂.
Parevaspis sp. 1: marigold cult., ♀.
Coelioxys capitata: marigold cult., ♂.
Coelioxys haemorrhoa: marigold cult., ♀.
Coelioxys sulcispina: marigold cult., ♀.
Coelioxys argentifrons: marigold cult., ♂.
Coelioxys decipiens: marigold cult., ♀; *Tephrosia pumila*, ♀; also ♀ from nest of *Megachile flavipes*.
Lithurge atratus: yellow cosmos cult., ♀; *Tephrosia pumila*, ♂.

HALICTIDAE

[m]*Systropha punjabensis*: *Convolvulus arvensis*, ♂.
Steganomus nodicornis:*Tephrosia pumila*, ♀, ♀p, ♂.
Nomia eburneigera: *Tephrosia pumila*, ♂.
Nomia callichlora: *Rhynchosia aurea*, ♀p, ♂; *Solanum xanthocarpum*, ♀p; *Tephrosia pumila*, ♂.
Nomia oxybeloides: *Solanum xanthocarpum*, ♀p; marigold cult., ♀; *Nepeta cataria* cult., ♀, ♀p, ♂; *Euphorbia pilulifera*, ♂; *Tribulus terrestris*, ♀p; *Indigofera linifolia*, ♀, ♀p; *Vernonia cinerea*, ♀p, ♂.
Nomia capitata: *Indigofera linifolia*, ♀, ♀p; *Heliotropium strigosum*, ♀, ♂.
Nomia sp. 2: *Hypericum* cult., ♀.
Nomia exagens: *Tribulus terrestris*, ♀.
Nomioides minutissima: *Heliotropium strigosum*, ♀, ♂; *Carthamus oxyacantha*, ♀; *Hypericum* cult., ♀, ♀p, ♂; *Antirrhinum* cult., ♀; *Euphorbia dracunculoides*, ♀p; *Polygonum plebejum*, ♀p; *Convolvulus arvensis*, ♀p.

Nomioides pusilla: *Tribulus terrestris*, ♀; *Heliotropium strigosum*, ♂; *Hypericum* cult., ♀, ♀p, ♂; *Helianthus* cult., ♀; *Polygonum plebejum*, ♀, ♀p, ♂; cockscomb cult., ♀.
Nomioides variegata: *Helianthus* cult., ♀, ♀p, ♂; *Polygonum plebejum*, ♀, ♂; *Calendula officinalis* cult., ♀p; marigold cult., ♀, ♂; *Poinsettia* cult., ♀, ♀p; *Tribulus terrestris*, ♀, ♀p, ♂; yellow cosmos cult., ♂; *Hypericum* cult., ♂.
Nomioides divisa: marigold cult., ♀, ♂; *Tribulus terrestris*, ♂; *Indigofera linifolia*, ♂; yellow cosmos cult., ♂; *Poinsettia* cult., ♂; *Polygonum plebejum*, ♀; *Portulaca* cult., ♀; *Hypericum* cult., ♀, ♀p, ♂.
Halictus lucidipennis: *Tribulus terrestris*, ♀, ♀p; *Rhynchosia pumila*, ♀, ♀p; *Calendula officinalis* cult., ♀p; *Heliotropium strigosum*, ♀, ♀p, ♂; yellow cosmos cult., ♀p; *Convolvulus arvensis*, ♀p; *Vernonia cinerea*, ♀p; *Portulaca* cult., ♀p; *Antirrhinum* cult., ♀; *Heliotropium eichwaldii*, ♂; marigold cult., ♂; *Helianthus* cult., ♀, ♀p; *Launea nudicaulis*, ♀p, ♂.
Lasioglossum massuricum: *Polygonum plebejum*, ♀.
Lasioglossum sp. 2: *Polygonum plebejum*, ♂.
Lasioglossum krishna: *Hypericum* cult., ♀.
Lasioglossum sp. 3: *Launea nudicaulis*, ♂.
Lasioglossum sp. 4: *Helianthus* cult., ♂; *Hypericum* cult., ♂.
Lasioglossum cattulum: *Ocimum basilicum*, ♀; cockscomb cult., ♀, ♀p; marigold cult., ♀, ♀p, ♂; yellow cosmos cult., ♀p; *Polygonum plebejum*, ♀, ♀p; *Calendula officinalis* cult., ♀, ♀p, ♂; *Hypericum* cult., ♀, ♂; *Alyssum* cult., ♀; *Launea nudicaulis*, ♀; *Convolvulus arvensis*, ♀, ♀p; *Portulaca* cult., ♀, ♂; *Indigofera linifolia*, ♀; *Helianthus* cult., ♀p; *Solanum xanthocarpum*, ♀p.
Lasioglossum albescens: *Poinsettia* cult., ♀p, ♂; *Ocimum basilicum*, ♀p; *Farsetia jacquemontii* ♀p; *Alyssum* cult., ♀; yellow cosmos cult., ♀, ♀p; marigold cult., ♀, ♀p, ♂; *Helianthus* cult., ♀p; *Portulaca* cult., ♀p; zinnia cult., ♀p.
Lasioglossum (*Evylaeus*) sp. 1: marigold cult., ♀; *Calendula officinalis* cult., ♀, ♀p; *Launea nudicaulis*, ♀, ♀p.
Sphecodes abuensis: marigold cult., ♀, ♂; *Farsetia jacquemontii*, ♀; *Poinsettia* cult., ♀.
Sphecodes crassicornis: marigold cult., ♂.
Sphecodes sp. 1: *Alyssum* cult., ♀.
Sphecodes sp. 3: *Heliotropium strigosum*, ♂; marigold cult., ♂.

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LITERATURE CITED

Bohart, G. E. 1957. Pollination of alfalfa and red clover. Ann. Rev. Entomol. 2:355–380.

———. 1960. Insect pollination of forage legumes. Bee World 41:57–64, 85–97.

Kashyap, S. R. 1936. Lahore District Flora. Punjab Univ. Press, Lahore. 285 pp.

Khan, A. H., and M. Afzal. 1950a. Natural crossing in cotton in western Punjab. IV. Agents of natural crossing. Agron. J. 42:236–238.

———. 1950b. Vicinism in cotton. Indian Cotton Growing Rev. 4:227–239.

Linsley, E. G. 1958. The ecology of solitary bees. Hilgardia 27(19):543–599.

Maxwell-Lefroy, H., and E. M. Howlett. 1909. Indian Insect Life. Thacker, Spink and Co., Calcutta and Simla. 786 pp.

Michener, C. D. 1965. A classification of the bees of the Australian and South Pacific regions. Bull. Amer. Mus. Nat. Hist. 130:1–362, plates 1–15.

Popov, V. V. 1956. Bees, their relation to melittophilous plants and the problem of alfalfa pollination. Entomol. Rev. U. S. S. R. 35:528–598.

Rahman, K. A. 1940. Insect pollinators of toria (*Brassica napus* L. var. *dichotoma* Prain) and sarson (*B. campestris* L. var. *sarson* Prain) at Lyallpur. Indian J. Agri. Sci. 10:422–447.

Sidhu, A. S., and S. Singh. 1961. Studies on agents of cross pollination in cotton. Indian Cotton Growing Rev. 15(6):341–353.

SOME NOTES ON THE BIOLOGY OF THE BLUE SWEAT BEE, *LASIOGLOSSUM COERULEUM* (Apoidea: Halictidae)[1]

KARL A. STOCKHAMMER

ABSTRACT

The halictid, *Lasioglossum* (*Dialictus*) *coeruleum* (Robertson), observed in northeastern Kansas, nests in decaying logs and limbs of trees lying on the floor of deciduous forest. The nests are started in abandoned insect burrows or other preformed spaces, and expand from there into the surrounding rotted phloem or xylem in the course of further construction. Although the nests of *L. coeruleum* show the same structural elements as those of soil-nesting *Lasioglossum,* they are markedly variable in shape according to the form of the occupied cavities and the availability of chewable substrate. Like many other *Lasioglossum* species, *L. coeruleum* constructs dependent cells in the sense of Malyshev. In spring the nests are built by overwintered females which emerged at the end of the previous summer and were fertilized prior to hibernation. The offspring raised by these females include males, and fertilized young females at the beginning of July. These females are capable of founding new nests but they also may remain in the nests of their mothers as replacement queens. Sterile workers were also found in summer nests.

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