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Study on the biodiversity of insects in apple in mid hills of Meghalaya

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Abstract
North-Eastern hills region of India is very rich in fertile soil, biodiversity and conducive agro-climatic conditions that make them ideal for the production of horticultural crops. The present investigation was carried out to study the biodiversity of insects in apple in mid hills of Meghalaya during the year, 2018. Based on taxonomic classification, the insect species were placed into 7 different orders *viz.* Coleoptera (17), Hemiptera (11), Lepidoptera (6), Diptera (4), Hymenoptera (3), Dermeptera (1) and Orthoptera (1). Major insect pests recorded were Green apple aphid, Pale tussock moth, Tussock caterpillar, Giant looper and Cocoa tussock caterpillar and remaining 21 species as minor insect pests. Natural enemies observed were Parasitic braconid wasp, pupal parasitoid, Tachnid fly, Syrphid fly (maggots), Assassin bug, Earwig and four different species of Coccinellid beetles. Honey bees and Hoverfly visited as pollinators on few apple flowering plants. Also five insect species *viz.* Litchi trunk borer, Aquatic fire fly, Indian fire fly, Rice earhead bug and Melon fruit fly were found to be occasional visitors on apple plants. The findings obtained during the course of study will be helpful in understanding the biodiversity of insect fauna associated with apple plants and therefore having implications for taxonomy and pest management in apple particularly for this region.

Keywords: Biodiversity, insect pests, natural enemies, pollinators and occasional visitors

1. Introduction
Apple (*Malus sylvestris* Mill.) originated in Central Asia as a temperate fruit crop which requires about 800-1600 hours of chilling below 7 ^{0}C and grows well in temperate climatic zones and fulfils their requirement of chilling temperature. Apples are mostly preferred fruit by most of the national and international markets due to its nutritional value. Apple production Worldwide in 2017 was about 83.1 million tonnes, of which China accounts for 50% of the total production. India ranks fifth in terms of apple production with an average of 2.3 million tonnes, yield of 7.7 t/ha and land area of 3.0 lakhs ha, FAOSTAT [3]. In India, it is mostly grown in Jammu and Kashmir, Himachal Pradesh, Uttaranchal, Arunachal Pradesh, Sikkim and Nagaland. More than 7,500 apple cultivars, having a range of desired characteristics are known. Apple being the most important fruit crop grown in North Western Himalayan region of India is susceptible to variety of biotic and abiotic parameters that reduces directly or indirectly the life of trees as well the fruit yield. Low productivity of apple in North East region is may be due to the biotic and abiotic stresses like weather parameters, climatic conditions, insect pests, diseases and other unfavourable factors. A total of 4342 invertebrates constituting of 7 orders *viz.* Diptera, Coleoptera, Lepidoptera, Blattodea, Hymenoptera, Heteroptera and Orthoptera are reported in apple orchards of northwest Arkansas, Fayetteville, Johnson *et al* [11]. Approximately 100 species feed on the apple tree or fruit and more than 40 insect species are economically important and 10 insect species are considered as serious pest of apple, Teparkum [22]. Andreev *et al* [1] also reported aphid species *viz.* green apple aphid (*Aphis pomi* De Geer), Spirea aphid (*Aphis spiraecola*), rosy apple aphid (*Dysaphis pyri*) and woolly apple aphid (*Eriosoma lanigerum* Hausmann) in apple orchards of South Bulgaria. In Jammu and Kashmir apple is infested with more than 10 aphid species, Shah [19]. Green apple aphid is a major pest infesting apple orchards of different districts of Jammu and Kashmir region, Gupta and Tara [7]. A total of 1408 individuals of Coleoptera are reported in abandoned apple orchards of South Moravia, Czech Republic during 2010 and 2011, Stastna and Psota [20]. Other insects like Thrips, leaf rollers and tussock moth also infest the apple trees in Jammu and Kashmir but the losses due to these insects are less, Hussain *et al* [10]. Diversity of lepidopterans is highly established in abandoned and organic apple orchards of Bulgaria,

Peeva Velcheva [17]. A total of 8 lepidopteran insect pests *viz. Euproctis scintillans* Walker, *Lymantria obfuscata* Walker, *Calliteara pudibunda* Linneaus, *Thosea sinensis* Walker, *Altha nivea* Walker, *Malacosoma indica* Walker, *Hygroplasta spoliatella* Walker and *Ascotis seleneria* Denis & Schiffermuller are found attacking apple plantations in Jammu region, Gupta and Pathania [6]. Cocoa tussock moth (*Orgyia postica*) is also known to infest apple trees in Meghalaya region frequently from March to October, 2014, Chandra *et al* [2]. The most dominant predators reported are lady bird beetles in various apple orchards. (Frechette *et al* [4], Khan *et al* [12], Horton *et al* [8]). Syrphids are also considered as important predators feeding on aphids and are well known to regulate the prey population, Gontijo *et al* [5]. Mirid bugs are also an effective predator of various insect pests in abandoned apple orchards of Czech Republic, Hradil *et al* [9]. A total of 892 parasitoid wasps belonging to two dominant families *viz.* Aphelinidae with 6 species (280 wasps) followed by Eulophidae with 35 species (262 wasps) have been recorded in six apple orchards of Michigan, USA, Mates [14]. Insects, mainly bees, are also important pollinators of most of the fruit, nut, and vegetable crops (Klein *et al* [13]. *Apis cerana indica* is considered as frequent and dominant visitors of apple orchards (Mattu and Nirala [15], Raj *et al* [18], Tara *et al* [21]). A total of 12 species of occasional visitors are also reported from major districts of Kashmir, Mushtaq *et al* [16]. Hence the major objective of the investigation is to study the biodiversity of insects in apple in mid hills of Meghalaya. The results obtained during course of study will be useful for other research institutions in this region and for management as well as quarantine purpose.

2. Materials and Methods

2.1 Location and Site

"Study on the biodiversity of insects in apple in mid hills of Meghalaya" was carried out during the year, 2018 in experimental farm of College of Post Graduate Studies in Agricultural Sciences, CAU (Imphal), Umiam, Meghalaya located at an altitude of 1000m above mean sea level with $25^0$40'N latitude to $91^0$54'E longitude, respectively. The climatic condition in this area is of mid tropical zone with maximum temperature ranging from 28 ^{0}C to 33 ^{0}C and minimum temperature from 2 ^{0}C to 4 ^{0}C and with an average rainfall of 2000mm. The biodiversity of insects in apple in this area was observed throughout the year, 2018.

2.2 Sample Collection

Insects were collected from different low chilling varieties of apple *viz.* Gale gala, Red chief, Red scarlet, Tide's men Worchester and Anna Dorset which were brought from Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh and planted in the experimental farm of College of Post Graduate Studies in Agricultural Sciences, CAU (Imphal), Umiam, Meghalaya during January' 2017. Observations and collection of the insects were done on weekly basis throughout the year, 2018. Larger insects were collected by hand picking, small insects by using aspirator and flying insects with sweep net. Different life stages of insects were collected and the immature stages of the insects were reared in the Entomology Laboratory, School of Crop Protection for emergence of adults required for proper identification.

2.3 Species Identification

Insects collected were identified based on the established taxonomic keys and previously cited literatures. They were also confirmed with the specimens already present at the Insect museum of Division of Crop Protection (Entomology), ICAR Research Complex for North-Eastern hills region, Umiam, Meghalaya.

2.4 Preservation

Insects collected were dry preserved with proper spreading and pinning of the adult insects in insect box, whereas the soft bodied insects were preserved in vials with 70% ethanol and proper labelling with name of the species and other necessary details. Cataloguing and documentation of the collected insects were done through images and photographs.

3. Results and Discussion

In present investigation, a total of 150 insect specimens were collected comprising of 43 insect species. Of which 26 species of insect pests, 10 species of natural enemies, two species of pollinators and five species of insects as visitors were identified and documented (Table 1). Based on taxonomic classification, the insect species were placed in 7 different orders *viz.* Coleoptera (17), Hemiptera (11), Lepidoptera (6), Diptera (4), Hymenoptera (3), Dermeptera (1) and Orthoptera (1). The results obtained were closely associated with the work of Teparkum [22], who reported that 40 insect species are directly or indirectly associated with the apple crop. The present findings are also in similarity with the work of Johnson *et al* [11] who studied the diversity and abundance of invertebrates on apple and collected a total of seven orders of insects. In the present investigations, coleopteran insects were found dominant among all the insects in apple orchard similar to the findings of Stastna and Psota [20] who also reported the highest diversity of coleopterans in apple orchards of South Moravia. The major insect pests recorded on apple during 2018 were Green apple aphids (*Aphis pomi* De Geer), Pale tussock moth (*Calliteara pudibunda* Linneaus), Tussock moth (*Euproctis guttata* Collenette), Giant looper (*Ascotis selenaria* Denis & Schiffermuller) and Cocoa tussock moth (*Orgyia postica* Walker) (Plate No. 1 to Plate No. 5). The present investigations showed similarity with the results obtained by Peeva and Velcheva [17] who reported Giant looper and Pale tussock moth as major insect pests of apple orchards in Bulgaria. Andreev *et al* [1] also reported Green apple aphids as major insect pest in apple orchards of South Bulgaria. Gupta and Pathania [6] found Giant looper and Pale tussock moth as major insect pests in the apple orchards of Jammu region, India. Present findings also revealed that Green apple aphid and cocoa tussock moth were the most destructive pests of apple in this region. These findings are supported by Gupta and Tara [7] who reported green apple aphid as a major pest of apple in different districts of Jammu and Kashmir, India. Chandra *et al* [2] also reported cocoa tussock moth as a major insect pest of apple in Meghalaya region. In addition 21 minor insect pests (Plate No. 6 to Plate No. 26) were also recorded during the experimental period.

Natural enemies identified consists of one species each of parasitic braconid wasp (*Cotesia congregata*), pupal parasitoid (*Brachymeria perflavipes*), Assassin bug (*Cosmolestes picticeps*), syrphid fly maggot(Unidentified), Earwig (*Forficula auricularia*), and tachnid fly (*Cuphocera varia*) and 4 different species of Coccinellid beetles (Plate No.

27 to Plate No. 36). These results obtained were in conformity with the findings of Frechette *et al* [4], Khan *et al* [12], Horton *et al* [8] who reported Coccinellid beetles as the most dominant predators in apple orchards. Gontijo *et al* [5] also concluded that Coccinellidae and Syrphidae were the most common predators found in the apple orchards of Central Washington. Hradil *et al* [9] reported mirid bugs and coccinellid beetles present abundantly in apple orchards. The results obtained by Mates [14] were in disagreement with the present findings which might be due different geographical location and insect pests available in this area. Pollinators collected were Indian honey bee (*Apis cerana indica*) and hoverfly adult (*Syrphus* sp.) visiting a few flowers only on one flowering plant of apple (Plate No. 37 and Plate No. 38) and the findings were in conformity with the results obtained by Raj *et al* [18] who reported Indian honey bee as major insect pollinator visiting apple flowers frequently. Mattu and Nirala [15] and Tara *et al* [21] also reported Indian honey bee as frequent and dominant visitor of various apple orchards in Himachal Pradesh. Five insect species *viz.* Litchi trunk borer (*Aristobia testudo*), Aquatic fire fly (*Luciola ovalis*), Indian fire fly (*Luciola praeusta*), Rice earhead bug (*Leptocorisa acuta)* and Melon fruit fly (*Bactrocera cucurbitae)* were also observed visiting the apple plants occasionally during the course of study (Plate No. 39 to Plate No. 43) which is in agreement with the findings of Mushtaq *et al* [16] who reported 12 insect species visits occasionally in apple flowering plants.

4. Conclusion

Through the present investigation it is concluded that apple is infested by 26 species of insect pests throughout the year, 2018 of which five insect pests *viz.* Green apple aphids, Pale tussock moth, Tussock moth, Giant looper and Cocoa tussock moth were recorded as major pests and the remaining as minor pests, 10 as natural enemies, two as pollinators and five as occasional visitors. Hence additional studies can be performed to get a clear picture of insect pests associated with apple in this region and therefore implicating pest management strategies.

Table 1: Collection details of specimen during the year, 2018

Plate No.	Common name	Scientific name	Order	Family
Major insect pests				
1.	Green apple Aphid	*Aphis pomi* De Geer	Hemiptera	Aphididae
2.	Pale Tussock moth	*Calliteara pudibunda* Linneaus	Lepidoptera	Erebidae
3.	Tussock Moth	*Euproctis guttata* Collenette	Lepidoptera	Erebidae
4.	Giant looper	*Ascotis selenaria* Denis & Schiffermuller	Lepidoptera	Geometridae
5.	Cocoa tussock caterpillar	*Orgyia postica* Walker	Lepidoptera	Erebidae
Minor insect pests				
6.	Oriental beetle	*Anomala orientalis* Waterhouse	Coleoptera	Scarabaeidae
7.	Jumping Flea beetle	*Altica cyanea* Weber	Coleoptera	Chrysomellidae
8.	Japanese beetle	*Popilia japonica* Newman	Coleoptera	Scarabaeidae
9.	Red cross beetle	*Collops quadrimaculatus* Fabricius	Coleoptera	Melyridae
10.	Flea beetle	*Arthrotus flavocincta* Hope	Coleoptera	Chrysomellidae
11.	Long jointed beetle	*Lagria villosa* Fabricius	Coleoptera	Tenebrionidae
12.	May beetles	*Phyllophaga ephilida* Say	Coleoptera	Scarabaeidae
13.	Leaf Chafer Beetle	*Anomala dimidiata* Hope	Coleoptera	Scarabaeidae
14.	Mexican bean beetle	*Epilachna varivestis* Mulsant	Coleoptera	Coccinellidae
15.	Weevil	*Deiradolcus spinipectus* Pajni	Coleoptera	Curculionidae
16.	Common white mealybug	*Icerya seychellarum* Westwood	Hemiptera	Monophlebidae
17.	Tea bug	*Helopeltis bradyi* Waterhouse	Hemiptera	Miridae
18.	Red Cotton bug	*Dysdercus Koenigii* Fabricius	Hemiptera	Pyrrhocoridae
19.	Flatid plant hopper	*Ormenoides venusta* Melichar	Hemiptera	Flatidae
20.	Pod bug	*Anoplocnemis phasiana* Fabricius	Hemiptera	Coreidae
21.	Spittle bug	*Homalostethus tabulates* Lallemand	Hemiptera	Cercopidae
22.	Stink Bug	*Coridius chinensis* Dallas	Hemiptera	Pentatomidae
23.	Pyrrhocorid Bug	*Melamphaus rubrocinctus* Stal	Hemiptera	Pyrrhocoridae
24.	Black looper	*Hyposidra talaca* Walker	Lepidoptera	Geometridae
25.	Handmaiden Moth	*Amata bicincta* Kollar	Lepidoptera	Arctiidae
26.	Grasshopper	*Trilophida annulata* Thunberg	Orthoptera	Acrididae
Natural Enemies				
27.	Braconid wasp	*Cotesia congregata* Say	Hymenoptera	Braconidae
28.	Pupal Parasitoid	*Brachymeria perflavipes* Girault	Hymenoptera	Chalcididae
29.	Tachinid fly	*Cuphocera varia* Fabricius	Diptera	Tachinidae
30.	Syrphid fly	Unidentified	Diptera	Syrphidae
31.	Assassin bug	*Cosmolestes picticeps* Stal	Hemiptera	Reduviidae
32.	Earwig	*Forficula auricularia* Linneaus	Dermeptera	Forficulidae
33.	Lady bird beetle	*Coccinella septempunctata* Linneaus	Coleoptera	Coccinellidae
34.	Coccinellid beetle	*Harmonia eucharis* Mulsant	Coleoptera	Coccinellidae
35.	Coccinellid beetle	*Oenopia kirbyi* Mulsant	Coleoptera	Coccinellidae
36.	Coccinellid beetle	*Oenopia sexareata* Mulsant	Coleoptera	Coccinellidae
Pollinators				
37.	Indian honey bee	*Apis cerana indica* Fabricius	Hymenoptera	Apidae
38.	Hoverfly	*Syrphus ribesii* Linneaus	Diptera	Syrphidae
Occasional visitors				
39.	Litchi Trunk Borer	*Aristobia testudo* Voet	Coleoptera	Cerambycidae
40.	Aquatic Fire fly	*Luciola ovalis* Hope	Coleoptera	Lampyridae
41.	Indian Fire fly	*Luciola praeusta* Kiesenwetter	Coleoptera	Lampyridae
42.	Rice earhead bug	*Leptocorisa acuta* Thunberg	Hemiptera	Alydidae
43.	Melon Fruit fly	*Bactrocera cucurbitae* Coquillett	Diptera	Tephritidae

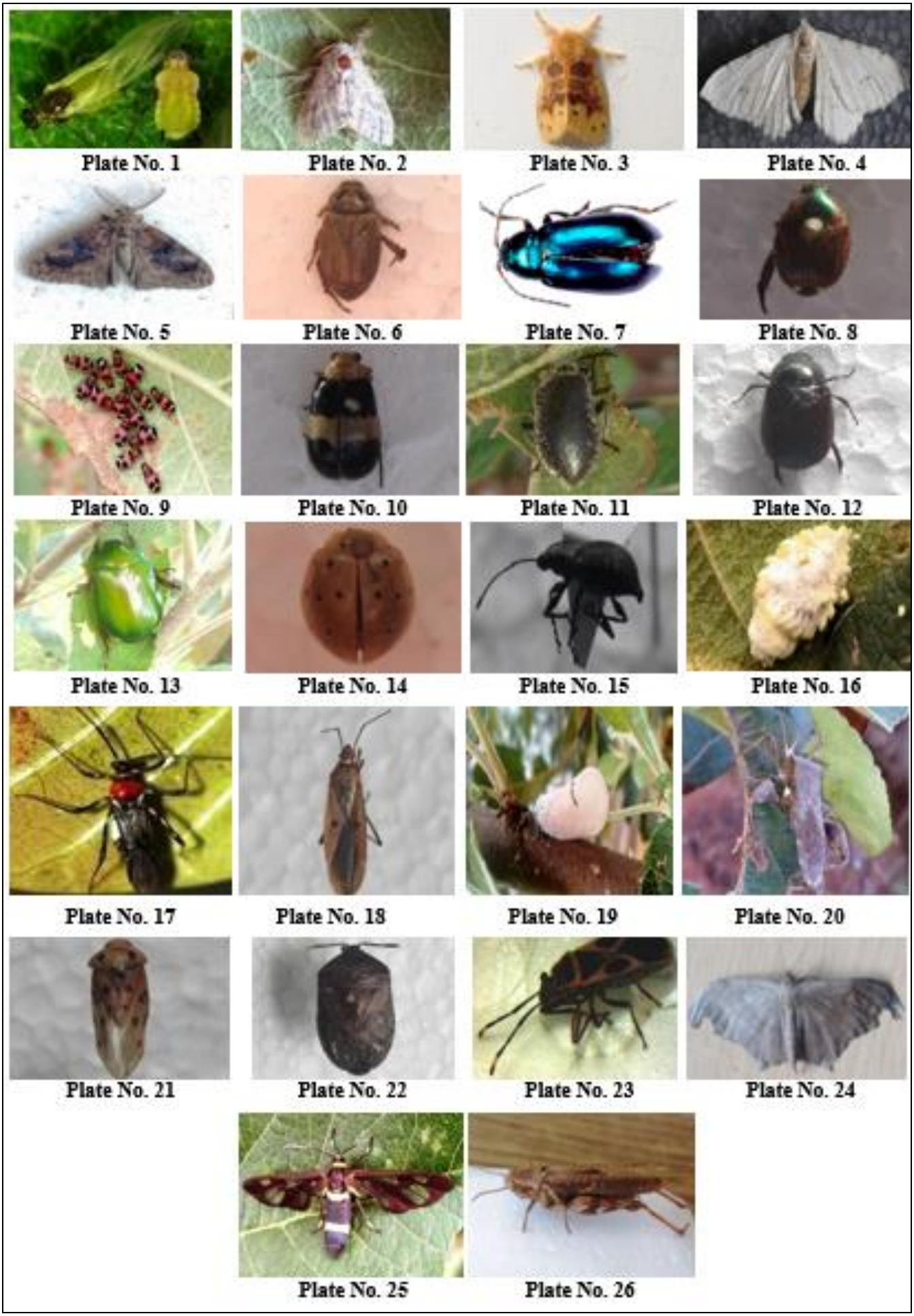

Fig 1: Biodiversity of insect pests in apple in mid hills of Meghalaya

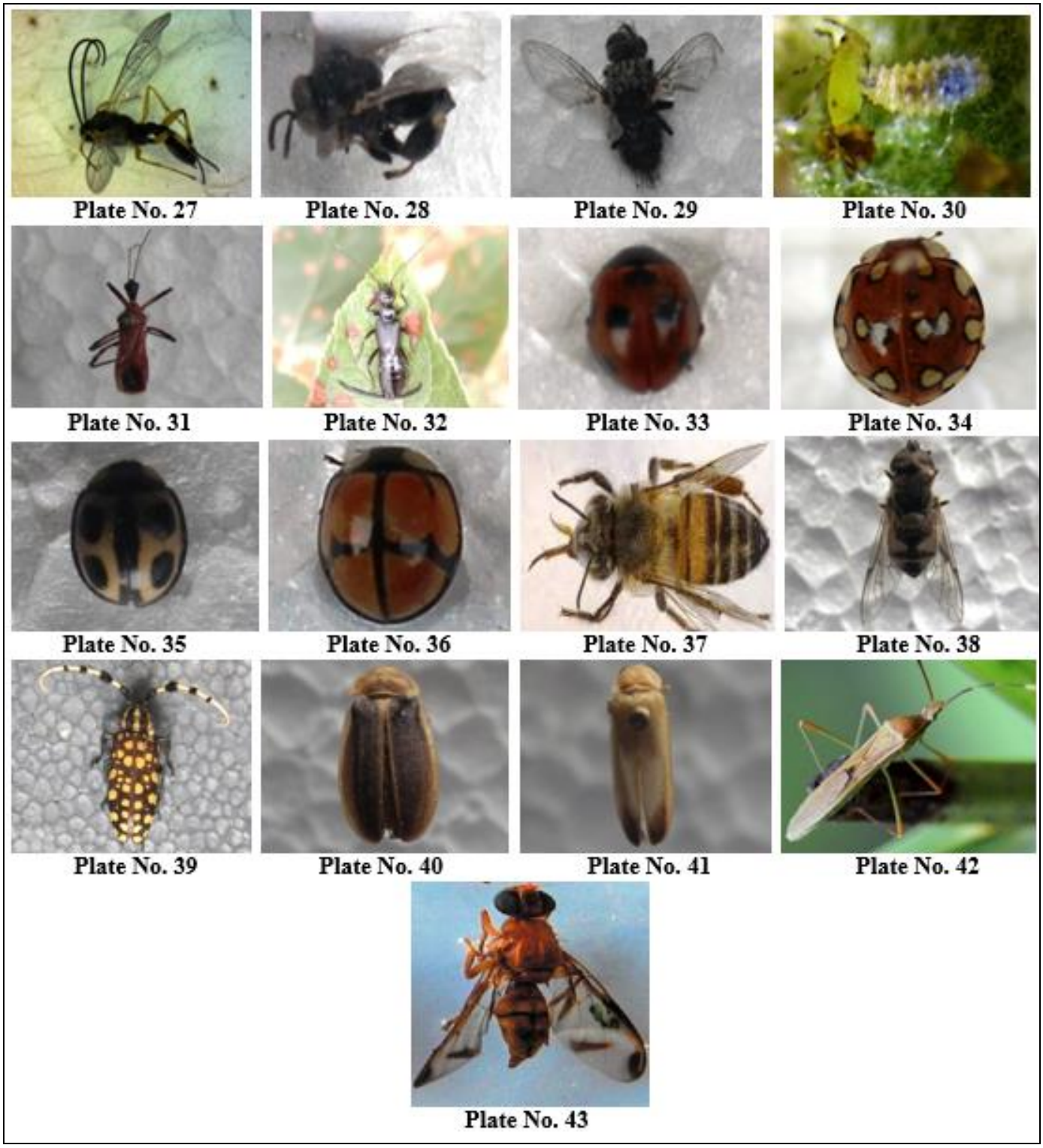

Fig 2: Biodiversity of natural enemies, pollinators and visitors in apple in mid hills of Meghalaya

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