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Economically Important Insects on Cruciferous Crops (Brassicaceae): An Updated Insect Inventory

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This inventory provides a comprehensive list of 286 agriculturally important insect species from cruciferous crops (bok choy, broccoli, brussels sprouts, cabbage, cauliflower, kale, mustard, radish, rapeseed, and toria), spanning 10 orders: Coleoptera, Dermaptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera, Neuroptera, Odonata, Orthoptera, and Thysanoptera. These species belong to 53 families, with Coccinellidae comprising the most species (39), followed by Syrphidae (22) and Apidae (20). Functional diversity analysis highlights that foliage feeders dominate the pest category (52%), while nymphal-adult predators make up the majority of natural enemies (45%). Larval parasitoids and pupal parasitoids account for 27% and 10%, respectively. Hymenoptera (51%) leads among pollinators, followed by Lepidoptera (21%) and Diptera (17%). This first-of-its-kind inventory serves as a valuable resource for field entomologists and other stakeholders in pest management and conservation strategies.

Keywords: Checklist, Crucifers, Natural enemies, Pestiferous, Pollinators

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BACKGROUND

Cruciferous plants belong to the family Brassicaceae consisting of one of the most important groups of winter season crops (Kumaranag et al. 2014) which include many edible oil plants, vegetables, and feed plants (Al-Shehbaz et al. 2006). Vegetables such as Broccoli, Cabbage, Cauliflower, Turnip and Oilseeds like Mustard comprise the major share of crucifers in the world. Crucifers are full of vitamins such as vitamin K and C along with dietary fibers, anti-oxidant, anti-inflammatory (Singh et al. 2001; Steinbrecher and Linseisen 2009) as well as detoxifying properties due to high sulfur and vitamin C contents (Kusznierewicz et al. 2008). Crucifers are especially known for their anti-carcinogenic properties, as they contain Isothiocyanates and Indole-3-Carbinol which has been exclusively studied through experimental *in-vivo* and *in-vitro* carcinogenesis models (Murillo and Mehta 2001). These crops are used all over the world for eating as raw salad or cooked preparations.

However, the productivity of these crops is considered to be low (Rasool and Lone 2022) as various biotic and abiotic stresses have a detrimental impact on both of their production and quality. Earlier in India, more than 30 insects were recorded from cruciferous vegetables only (Lal 1990) of which most were classified as major pests. It includes diamondback moth (*Plutella xylostella*), head borer (*Hellula undalis*), cabbage butterfly (*Pieris brassicae*), aphids (*Lipaphis erysimi*, *Brevicoryne brassicae*), semilooper (*Trichoplusia ni*) etc (Baidoo and Adam 2012; Baidoo and Mochiah 2016). Among these, diamondback moth is the most devastating pest of cruciferous vegetables as it causes significant yield losses varying from 31–100% (Chaubey and Murthy 2018). Farias and co-workers (2020) noted that the pest could cause a yield loss of up to 92% in Cabbage, 75% in Broccoli, and 30% in cauliflower depending upon the variety and extent of infestation. Raja et al. (2014) recorded 11 insect pests of crucifers from Tamilnadu of which diamondback moth and head borer cause enormous yield loss in the tropics and sub-tropics (Grzywacz et al. 2010; Furlong et al. 2013; Labou et al. 2017). In India, it has been estimated that 50-80% of annual loss in marketable yield is due to the infestation of insect pests in cruciferous vegetables (Devjani and Singh 1999; Krishnamoorthy 2004). Flea beetles and mustard sawflies are considered two of the major pests of cruciferous crops (Pradhan et al. 2020) during their early stages as they feed on the leaves by making holes, and the effective area of photosynthesis is reduced. Flea beetle was not considered serious pests previously but recent reports indicate it as an emerging menace of most of the crucifer growing regions, especially Northern India (Anooj et al. 2020). Biodiversity of flea beetles was studied in Kashmir Valley where four species of these beetles had been reported of which *Phyllotreta striolata* was the predominant one (Rather et al. 2017). Aphids and several pentatomid bugs are important sap-sucking insects. Aphids not only, suck the sap and destroy a plant's vitality, but also they transmit viral diseases (Yadav and Rathee 2020) like- Cauliflower Mosaic Virus (CaMV) which significantly reduces the crop yield (Haas et al. 2002). Several species of aphids are associated with cruciferous vegetables of which *Brachycaudus helichrysi, Brevicoryne brassicae*, *Lipaphis erysimi*, and *Myzus persicae* are important. Several Pentatomid bugs also damage the crop in different stages of growth, however, *Bagrada hilaris* is the most damaging one as it kills the seedlings, reduces plant stands and severely stunts the surviving plants during early stages (Reed et al. 2013; Huang et al. 2014). Also, in some plants, bug feeding stimulates growth of secondary shoots leading to unmarketable produce due to undersized heads (Joseph et al. 2017). Other insect pests including several cutworms, grasshoppers, thrips, weevils etc. may be found sporadically in the crop fields, and under suitable environmental conditions, they have a massive potential to damage the crops.

Several insect predators including different species of ladybird beetles, hover flies, green lacewings, spiders and parasitoid wasps are also evident in the crucifer fields. Among predators, ladybird beetles are the most dominant (Obrycki et al. 2009). A complex of ladybird beetles is reported on cruciferous crops of which *Brumoides suturalis*, *Cheilomenes sexmaculata*, *Coccinella septempunctata*, *C. transversalis*, *C. undecimpunctata*, *Micraspis discolor*, *Scymnusp pyrocheilus,* and *S. xerampelinus* are the most important (Chaudhary and Singh 2012; Bhowmik et al. 2014). Larvae of syrphids such as- *Betasyrphus serarius*, *Episyrphus balteatus*, *Metasyrphus confractor*, *Paragus serratus, Sphaerophoria indiana* are well-known aphid feeders (Pradhan et al. 2020).

There are almost 90 nominal species of parasitoids attacking different stages of insect pests which are known to be associated with cruciferous agro ecosystem (Azidah et al. 2000). Among them, *Apanteles* sp. (Hymenoptera: Braconidae); *Diadegma semiclausum*, *D. rapi*, *D. mollipla* (Hymenoptera: Ichneumonidae) and *Oomyzus sokolowskii* (Hymenoptera: Eulophidae) are mostly evident in reports (Saini et al. 2019).

Besides insect pests, crucifer ecosystem also harbours several pollinators and beneficial insects that are extremely invaluable in-terms of their ecosystem services they render. Many *Brassica* species depend on insect pollinators for pollen transfer, benefiting from their abundant floral resources and high-sugar nectar (Thom et al. 2018; Indora et al. 2023). More than 50 pollinator species have been recorded (Atmowidi et al. 2007; Shakeel et al. 2019; Divekar et al. 2023; Prajula et al. 2023), including honeybees such as *Apis mellifera*, *A. cerana indica*, *A. dorsata*, and *A. florea* (Abrol 2007), as well as various non-*Apis* bees from families like Megachilidae, Halictidae, Pompilidae, Sphecidae, Formicidae, Ichneumonidae, Vespidae, and Scoliidae (Devi et al. 2017; Hossain et al. 2021). Hoverflies also contribute significantly to pollination (Badenes-Pérez 2022). Additionally, some Lepidopterans, ladybird beetles, and stink bugs are associated with crucifers, though their roles in pollination remain unclear (Subedi and Subedi 2019). Notably, insect-mediated cross-pollination of rapeseed (*Brassica campestris* var. *toria*) has been shown to increase yield by an impressive 133.33% compared to self-pollination (Ahmed and Rehman 2002).

Knowledge and information regarding the agriculturally important insects associated with cruciferous crops is vital for their management and conservation. To help different stakeholders involved in pest management and conservation this updated inventory of important insect pests, natural enemies, and insect pollinators on crucifers is important.

MATERIALS AND METHODS

This compilation provides comprehensive information on agriculturally important insects associated with crucifers all over the world. The documentation of information was done as per available literature regarding the aforementioned subject. First, a base list was developed by reviewing historical literature, including research articles, catalogues, and theses from 1901-2000. This foundational list was subsequently updated with more recent publications (2001-present) to reflect the latest data on nomenclature, and functional roles of the insects. We utilized various authentic databases and compendiums like- "HOSTS" (Robinson et al. 2010), "Centre for Agriculture and Bioscience International" (CABI), "Global Biodiversity Information Facility" (GBIF) to verify and enhance our information. These resources provided current distribution records and helped in ensuring the accuracy of our data. Distributions of the insects were categorized on a global basis using four indexing terminologies *viz*.

a. Worldwide- It indicates the insect is found everywhere across the world.

b. Widespread- It suggests the insect is found across various regions of a country or continent.

c. Localized- It implies that the insect is mainly confined to some particular regions like- a state or a province or even a part of a country, indicating its special ecological requirements.

d. Sporadic- It signifies that the insect has an irregular distribution with scattered populations.

The grouping of insects had been done according to their taxonomic hierarchies. This organization was presented alphabetically by order, family, and species respectively. This compilation was grouped into three comprehensive categories such as, pests, natural enemies, and insect pollinators associated with cruciferous crops and presented in tabulated forms. All the lists comprised of scientific names, distributions, and corresponding references. Apart from these, the nature of damage along with the damaging stage and status were mentioned in the pest checklist. The pest status is represented by two common terminologies *viz.* 'Major' and 'Minor' based on their current severity, as per different literature and online databases. The term "Major" was used for those causing significant economic damage (> 10%) and the insects where comparatively less economic damage had been reported, were written as "Minor" (Ragumoorthi et al. 2020). Further, these terminologies were supported by qualitative assessments from the present literature, available in Google Scholar and online databases. Similarly, the documentation includes lists of natural enemies, such as predators and parasitoids, along with details of their distribution, prey or host range, and the specific developmental stages they target (e.g., egg, larva, or pupa). Additionally, pollinators, including *Apis* and non-*Apis* bees, as well as other foraging insects, were recorded with information on their distribution and foraging purpose. For cases where information was incomplete or unavailable, these entries were marked with a 'dash' (-) in the supplementary material.

RESULTS

Inventory of agriculturally important insects associated with cruciferous crops

As per our survey of literature, databases, and compendiums, we have accumulated a total of 286 agriculturally important insects associated with cruciferous crops worldwide of which 106 are pests, 87 are natural enemies, and 93 are pollinators and flower visitors, as shown in figure 1. These insects belong to 10 orders and 53 families. The different insect pest species (Table S1), natural enemies (Table S2) and insect pollinators (Table S3) associated with crucifer crops are provided with their distribution, functional details, references etc.

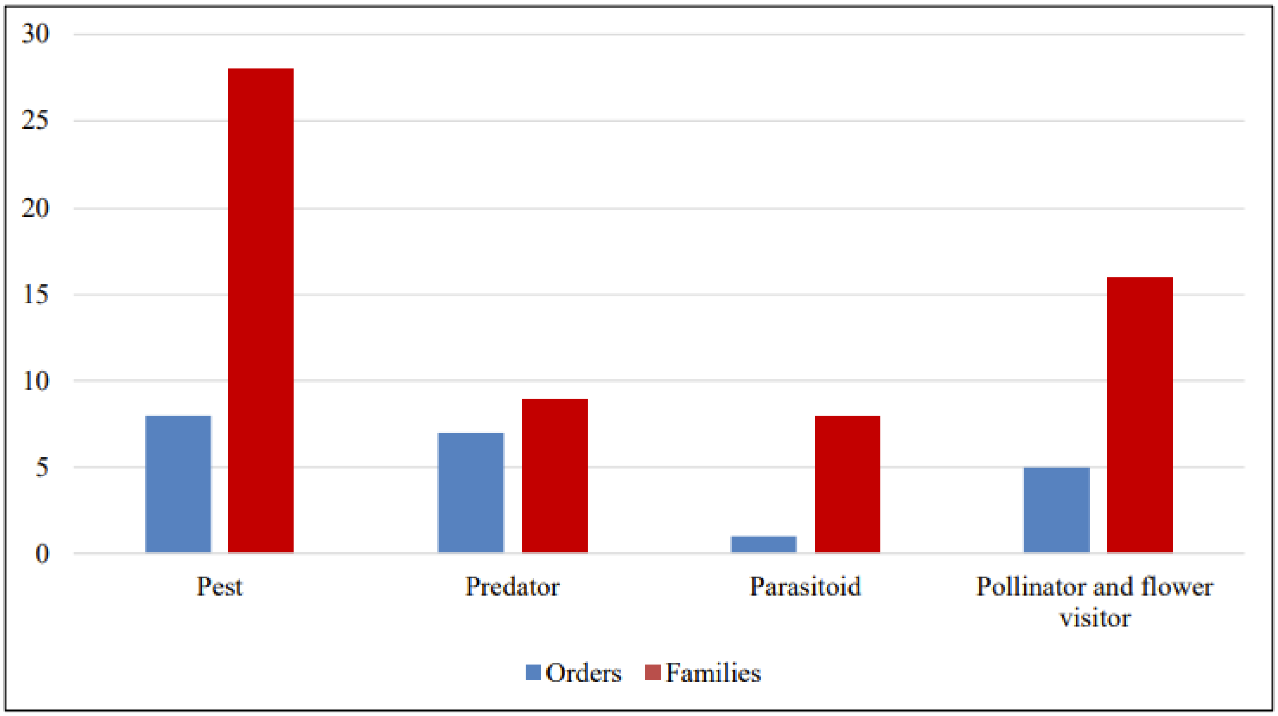

Fig 1. Order and familial diversity of different agriculturally important insect fauna in crucifers.

Table 1. The compilation of species richness of different agriculturally important insects recorded in cruciferous crops

Order	Superfamily	Family	No. of Species	No. of Species/ Order
Coleoptera	Chrysomeloidea	Chrysomelidae	10	62
	Cucujoidea	Coccinellidae	39	
	Curculionoidea	Curculionidae	6	
		Nitidulidae	1	
	Scarabaeoidea	Scarabaeidae	6	
Dermaptera	Forficuloidea	Forficulidae	1	1
Diptera	Agromyzoidea	Agromyzidae	5	36
	Muscoidea	Anthomyiidae	6	
		Muscidae	1	
	Sciaroidea	Cecidomyiidae	1	
	Syrphoidea	Syrphidae	22	
	Tipuloidea	Tipulidae	1	
Hemiptera	Aleyrodoidea	Aleyrodidae	1	27
	Aphidoidea	Aphididae	5	
	Cicadelloidea	Cicadellidae	3	
	Cimicoidea	Miridae	2	
	Coreoidea	Coreidae	1	
	Pentatomoidea	Pentatomidae	14	
	Reduvioidea	Reduviidae	1	
Hymenoptera	Apoidea	Andrenidae	3	94
		Apidae	20	
		Halictidae	9	
		Megachilidae	6	
	Chalcidoidea	Aphelinidae	1	
		Chalcididae	6	
		Eulophidae	1	
		Pteromalidae	3	
		Trichogrammatidae	3	
	Formicoidea	Formicidae	2	
	Ichneumomoidea	Braconidae	16	
		Ichneumonidae	11	
	Pompiloidea	Pompilidae	1	
	Scelionoidea	Scelionidae	1	
	Scolioidea	Scoliidae	3	
	Tenthridinoidea	Tenthridinidae	3	
	Vespoidea	Vespidae	5	
Lepidoptera	Gelechioidea	Gelechiidae	2	57
	Hesperioidea	Hesperiidae	1	
	Noctuoidea	Erebidae	3	
		Noctuidae	18	
	Papilionoidea	Lycaenidae	2	
		Nymphalidae	9	
		Papilionidae	1	
		Pieridae	16	
	Pyraloidea	Crambidae	4	
	Yponomeutoidea	Plutellidae	1	
Neuroptera	Chrysopoidea	Chrysopidae	1	1
Odonata	Gomphoidea	Gomphidae	1	2
	Libelluloidea	Libellulidae	1	
Orthoptera	Acridoidea	Acrididae	2	3
	Tetrigoidea	Tetrigidae	1	
Thysanoptera	Aeolothripoidea	Aeolothripidae	1	3
	Thripoidea	Thripidae	2	
Total				**286**

Study of species richness of agriculturally important insects associated with crucifers

An overall study regarding the total number of species, and number of species per order along with their superfamilies and families have been carried out and illustrated in figures 2, 3 and table 1. Among these, maximum number of species fall under the family Coccinellidae (39 species), followed by Syrphidae (22 species), Apidae (20 species), Noctuidae (18 species), Braconidae and Pieridae (16 species each), Pentatomidae (14 species), and Ichneumonidae (11 species). Others with one or few species are Agromyzidae, Aleyrodidae, Andrenidae, Anthomyiidae, Aphididae, Cecidomyiidae, Cicadellidae, Coreidae, Curculionidae, Forficulidae, Halictidae, Megachilidae, Miridae, Muscidae, Nitidulidae, Reduviidae, Scarabaeidae, Tipulidae etc, as shown in table 1. The species diversity across different families within a order is also illustrated in figure 4.

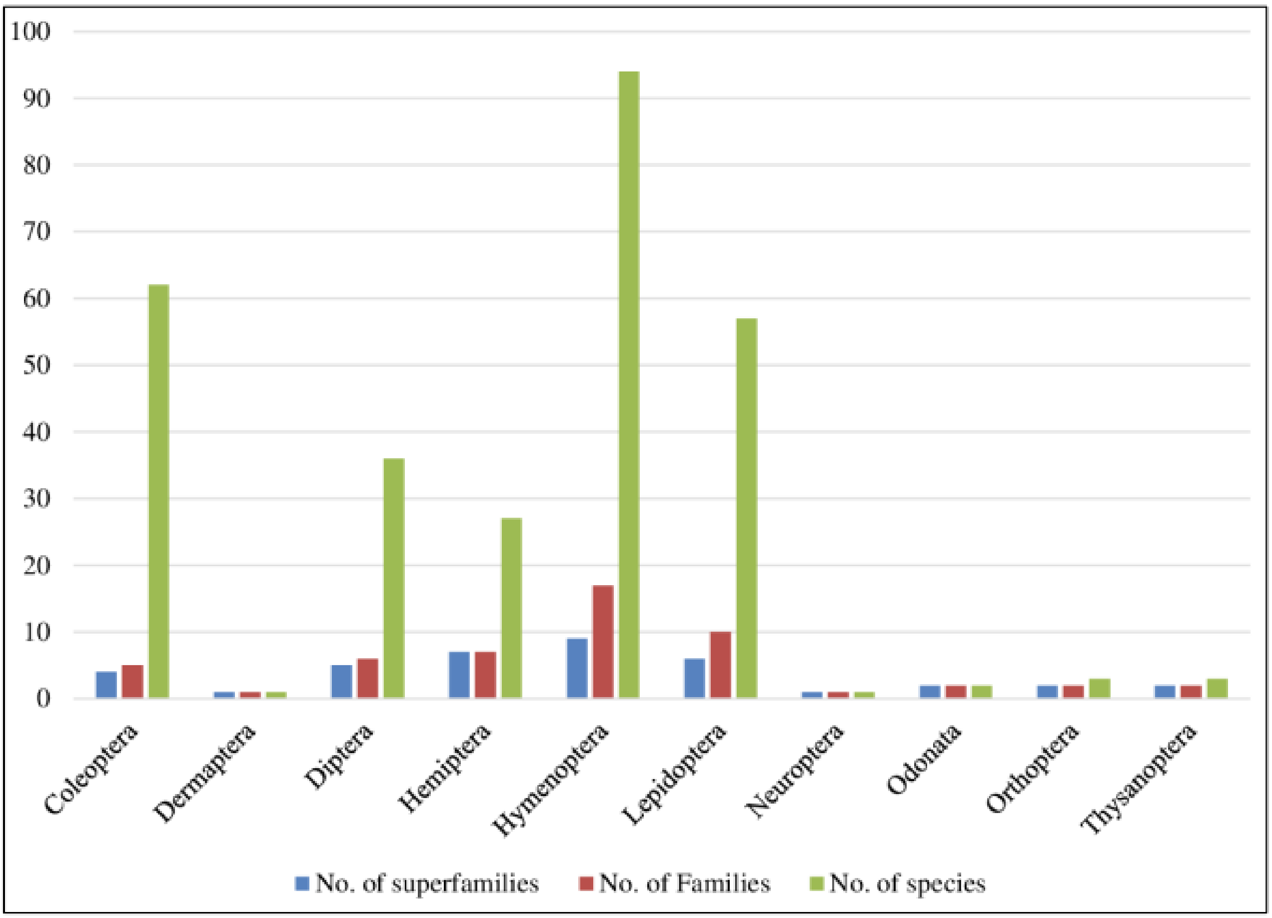

Fig. 2. Superfamilial, familial, and species diversity of different agriculturally important insect orders in crucifer field. Order Hymenoptera accounts for the highest diversity in terms of superfamilies, families, and species.

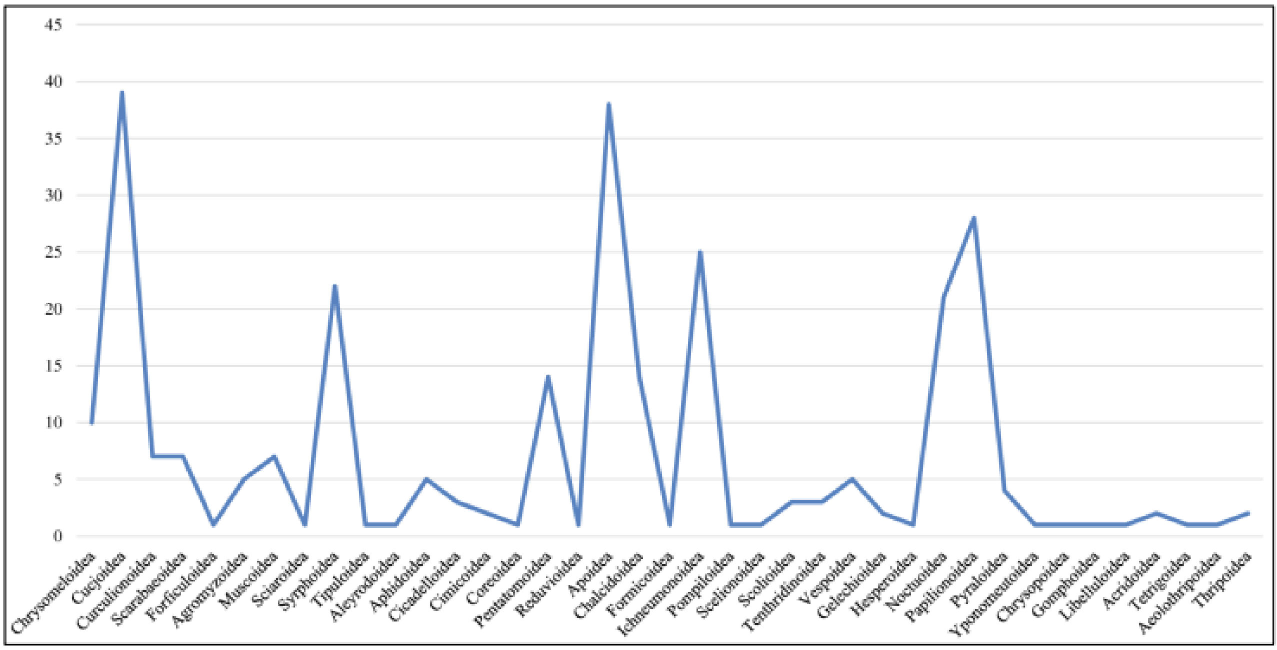

Fig. 3. Total number of insect species recorded in different superfamilies. Cucujoidea has the highest species richness among all the superfamilies (13.6%) followed by Apoidea (13.3%) and Papilionoidea (9.8%).

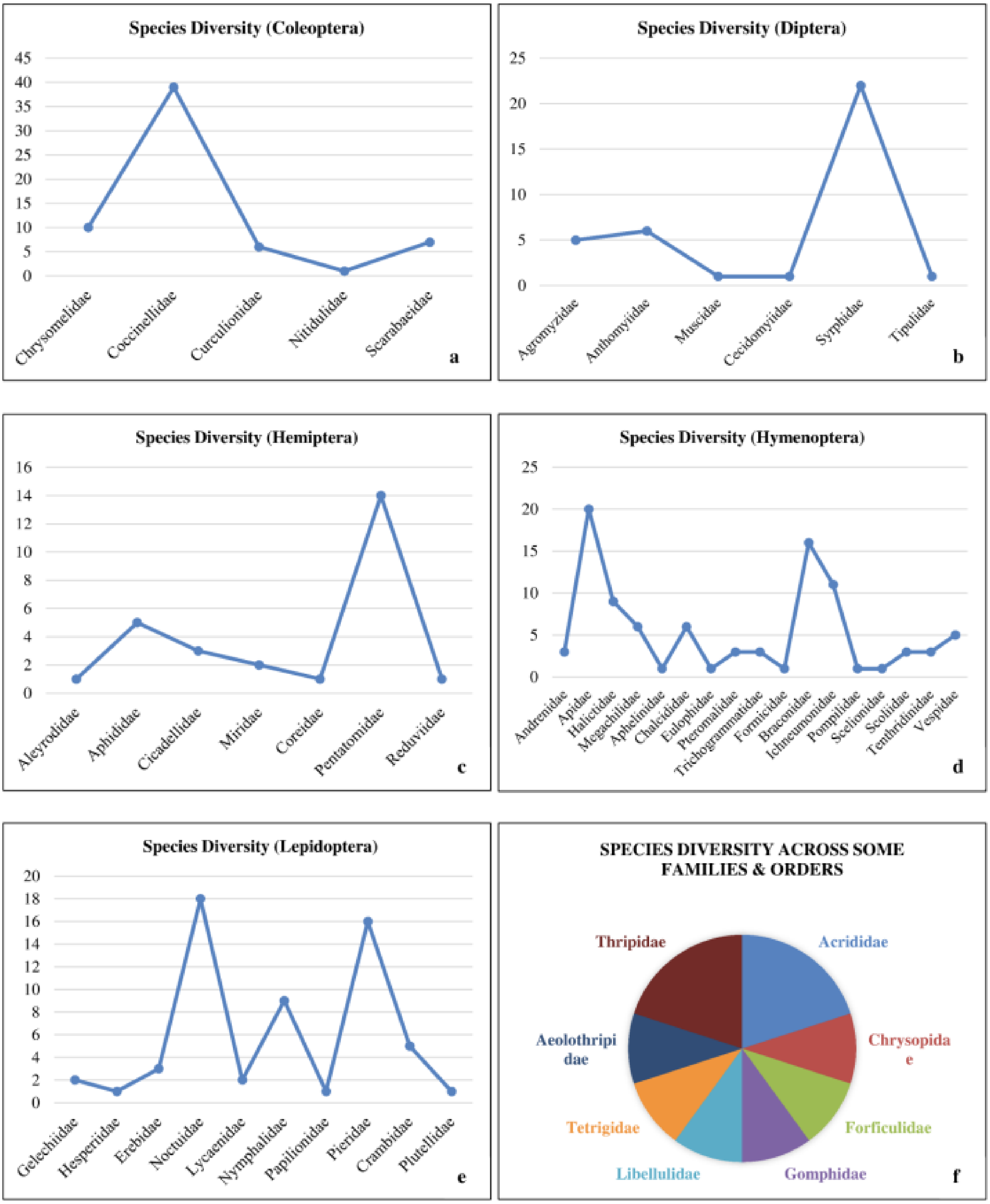

Fig. 4. Species diversity across different agriculturally important insect orders associated with crucifers. a. Coleoptera, b. Diptera, c. Hemiptera, d. Hymenoptera, e. Lepidoptera, f. Other orders and families.

In terms of functional diversity, among the pests, majority are leaf feeders (52%) followed by pod and inflorescence along with leaf, pod, inflorescence, root eaters (18%) (Fig. 5). Most of the natural enemies are either predators of soft-bodied insects (45%) or parasitoids of lepidopteran larvae (27%) followed by pupal parasitoids (10%) and nymphal-adult parasitoids (9%) (Fig. 6). Pollinators are mostly from the order, Hymenoptera (51%) however, we have recorded ample number of pollinators from the Lepidoptera too (21%) (Fig. 7).

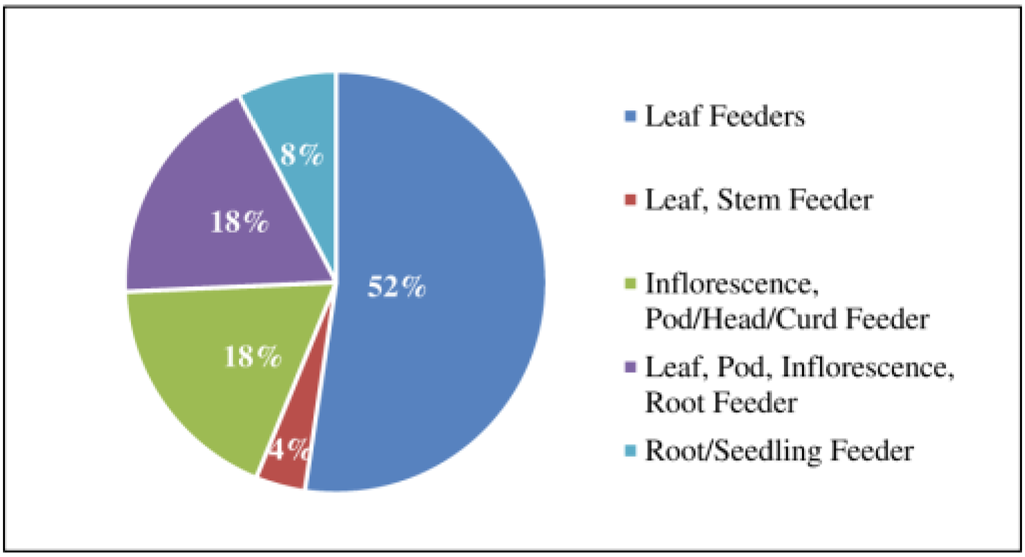

Fig. 5. Functional diversity of different insect pests recorded in crucifer field.

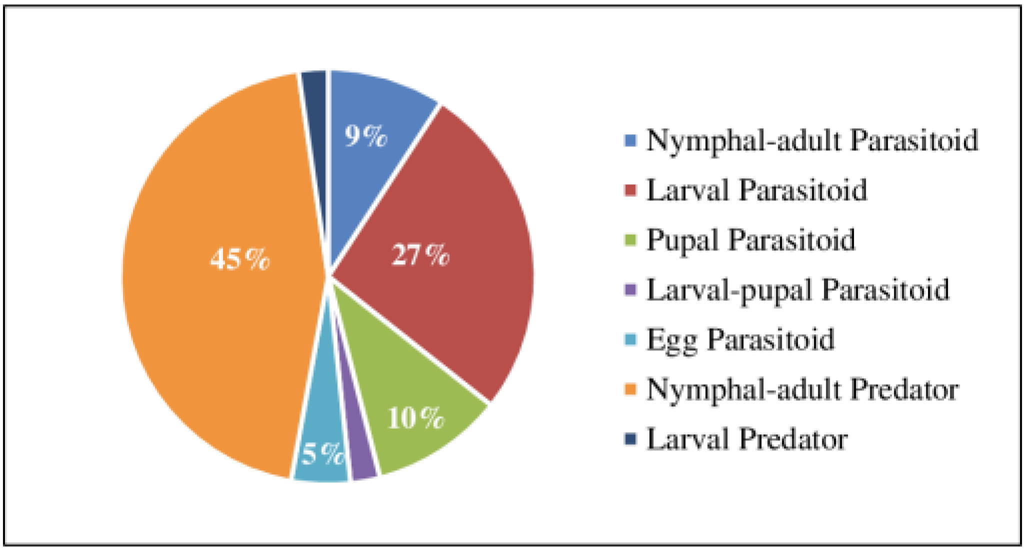

Fig. 6. Functional diversity of different natural enemies in crucifer agroecosystem.

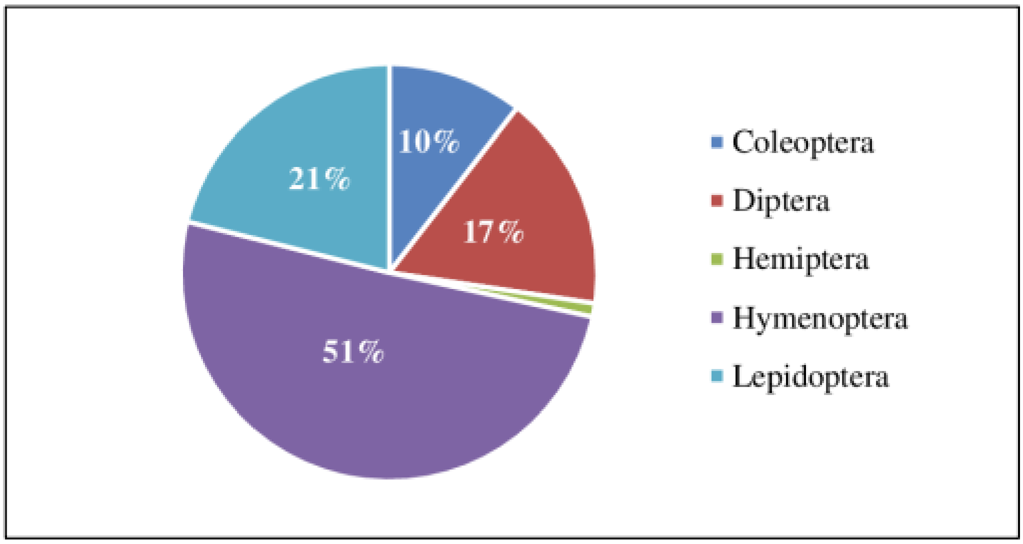

Fig. 7. Functional diversity of insect pollinators in crucifer fields belonging to different orders.

DISCUSSION

Insects constitute a major portion of the biodiversity of agricultural ecosystems, serving indispensable ecological functions as herbivores, food source of other vertebrates and invertebrates (Vaughan 1997) and some of them are significant pollinators. Therefore, to understand the biodiversity of any agroecosystem, baseline data on species occurrence is very important.

The present comprehensive inventory is an exhaustive exploration of literature including catalogues, research articles, reviews on different taxa, thesis, along with the compilation of data from different online databases. This is not only confined to the taxonomic level but also accounts for the functional roles of the insects in crucifer ecosystem. Previously, Sharma and Ramamurthy (2009) and Kumar et al. (2010) studied diversity of pestiferous insects associated with vegetables and *Syzygium cumini* respectively. However, the documented insect diversity within cruciferous crops highlights insects of different trophic levels, indicating complex ecological interactions, particularly in-terms of co-existence of pests and their natural enemies. For instance, the presence of aphids, *Brevicoryne brassicae* as pests is often counterbalanced by predatory insects such as *Coccinella septempunctata* and parasitoids like- *Diaretiella rapae*, contributing to natural pest suppression (Ahuja et al. 2011). Additionally, pollinators such as syrphid flies and honeybees play a crucial role in maintaining stability of ecosystem as well as increasing yield through enhanced pollination efficiency (Dar et al. 2017). Changes in environmental conditions, including climate shifts and intensive pesticide use, can disrupt these interactions, potentially leading to pest outbreaks and biodiversity loss (Skendžić et al. 2021). A recent study in India documented a similar arthropod pest complex and associated natural enemies across various phenological stages of *Withania somnifera*, highlighting the dynamic nature of species interactions (Kedar et al. 2024). By providing a comprehensive inventory of insect species associated with cruciferous crops, this study enhances the understanding of the ecological roles of these species, their interactions within agroecosystems, and the potential implications for pest management and conservation strategies. The findings can serve as a baseline for monitoring biodiversity shifts due to environmental changes and inform sustainable agricultural practices aimed at balancing pest control and biodiversity conservation.

Therefore, a comprehensive insect inventory combining both taxonomic and functional diversity of agriculturally important insect species is quite unique. The difficulty of amalgamation of raw data regarding taxonomy and ecological roles of insects, probably due to fewer technical workers and shortage of time, is a major roadblock in assessing the overall field situation of an agricultural ecosystem. This study may fill this gap and encourage others regarding the need to connect taxonomy of insects along with their functional roles in the near future.

CONCLUSIONS

This comprehensive study yields an inventory of 286 agriculturally important insects associated with cruciferous crops all over the world. The current study is not only focusing on the pests but also on the beneficial insect fauna present in the crucifer agroecosystem. Therefore, this study reflects the species richness of insects associated with crucifers. After the compilation of all the species, some diversity studies are also performed to get a broad functional overview. So, this compilation may be a great source to carry forward further works by entomologists, taxonomists, biologists, and environmentalists.

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Authors' contributions: Sourav Chakrabarty (SC) contributed to literature collection and acquisition, data analysis, writing the original manuscript. Pathour R Shashank (PRS) contributed to conceptualization, study design, data curation, writing: reviewing and editing the manuscript and funding acquisition.

Competing interests: SC and PRS declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Availability of data and materials: All the data related to the study are provided in the manuscript and supplementary material.

Consent for publication: Not applicable.

Ethics approval consent to participate: Not applicable.

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Supplementary materials

Table S1. Inventory of insect pests associated with cruciferous crops. (download)

Table S2. Inventory of different insect natural enemies recorded in cruciferous crops. (download)

Table S3. Inventory of insect pollinators and flower visitors associated with cruciferous crops. (download)