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Inventory of Insects in Wheat Fields at Bajo, Wangdue, Bhutan

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Abstract

This documentation is about the diverse insect species of different ecological functions associated with winter wheat at ARDC Bajo in 2022. The insects were surveyed by visual observation, sweep netting and pitfall traps. Among the 95 different species recorded, 54 were pest species and 41 were beneficial insects. There were 35 species that infest wheat; *Sitobion miscanthi, Mythimna separata, Altica* sp., *Aulacophora indica, Monolepta signata, Camptopus* sp., *Leptocorisa acuta, Poophilus* sp., *Cofana unimaculata, Exitianus* sp., *Cletus punctiger, Graptostethus incertus, Eurydema pulchrum, Eysarcoris ventralis, Menida formosa, Nezara viridula, Nezara viridula* f. *viridula, Plautia* sp., *Nomophila noctuella, Scirpophaga incertulas, Helicoverpa armigera, Vanessa cardui, Acrida exaltata, Aiolopus thalassinus, Oxya velox, Patanga succincta, Trilophidia annulata, Oecanthus indicas, Atractomorpha acutipennis, Pyrgomorpha* sp., *Conocephalus fuscus, Conocephalus* sp., *Euconocephalus* sp., *Eupholidoptera* sp., and *Phaneroptera roseata.* Also, 41 natural enemy species were recorded. The parasitoid species were *Euthera fascipennis, Winthemia trinitatis, Agrypon sp., Delta campiniforme campaniforme, Gotra* sp., *Ischnojoppa luteator, Metopius* sp., *Pimpla* sp.. and *Pimpla pedalis.* The predatory species were *Cheilomenes sexmaculata, Coccinella septumpunctata, Coccinella transversalis, Coelophora bissellata, Cryptogonous quadriguttatus, Harmonia eucharis, Harmonia octamaculata, Harmonia sedecimnotata, Micraspis univittata, Oenopia dissecta, Oenopia sauzeti, Propylea luteopustalata, Scymnus (Scymnus) nubilus, Episyrphus balteatus, Episyrphus viridaureus, Eupeodes corollae, Microdon analis, Platycheirus scutatus, Sphaerophoria, Syrphus ribesii, Nabis capsiformis, Andrallus spinidens, Vilius melanopterus, Polistes* sp., *Chrysoperla* sp., *Hemerobius* sp., *Mantispa* sp., *Palpopleura sexmaculata, Pentala flavescens,* and *Conocephalus maculatus.* This study indicated that diverse insect species were associated with winter wheat. Of the pest species recorded, some are reported as major pests of wheat. Careful monitoring of the pest species and developing plans for their management, considering the beneficial species is suggested.

Keywords: *Parasitoids, pests, predators, Wangdue, wheat*

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Introduction

Wheat (*Triticum aestivum* Linnaeus) is a widely grown crop (FAOSTAT, 2019) for global food security (Shiferaw *et al.*, 2013). It is a staple food for 36% of the world population (Nadon & Thakur, 2019) contributing to around 20% of the total energy intake in the

human diet (Shakarami *et al*., 2020). Wheat is generally used as food (bread, noodles, biscuits, cakes, flour), feed grains, and fodder (Oleson, 1994; Duncan *et al*., 2020).

In 2019, Asia produced 337 million tonnes from 98 million hectares and Bhutan produced 1,319 tonnes from 1,004 hectares; yielding 1.3 tonnes per hectare (FAOSTAT, 2019). In Bhutan, wheat is widely cultivated in wetlands at mid and low elevations and drylands at higher elevations (Tshewang *et al*., 2018).

There are approximately 5.5 million insect species on Earth (Samways *et al*., 2020). More than 100 insect species infest wheat, reducing grain yield and/or quality thereby increasing its production costs (Hatchett *et al*., 2015). The majority of insect pests infesting wheat belong to the insect orders Hemiptera, Diptera, Coleoptera, Hymenoptera, Orthoptera, and Lepidoptera (Farook *et al*., 2019). These include aphids, termites, armyworms, pink stem borers, pod borers, and weevils which are important pests that inflict significant harm to wheat crops from seedling to maturity (Gaur & Mogalapu, 2018). These group of insect pests impedes wheat production (Ranjith *et al*., 2018; Larinfeli *et al*., 2019) by chewing, sucking, and boring into plant parts (Singh & Kaur, 2018). Socio-economic and biotic factors such as labour shortage, stripe rust and leaf rust are reported to constrain wheat production (Tshewang *et al*., 2018) but there are limited studies documenting insect pests affecting wheat in Bhutan.

Insects perform many important ecological functions (Sodhi *et al*., 2010) such as nutrient cycling, seed dispersal, bioturbation (Fincher *et al*., 1981; De Groot *et al*., 2002; Nichols *et al*., 2008), pollination (Gabriel & Tscharntke, 2007; Slade *et al*., 2016) and biological pest control (Trust, 2000; Brewer & Elliott, 2004; Bell *et al*., 2008; Lonsdorf *et al*., 2009). The green revolution associated with many adverse effects on the environment and food safety led to exploring the use of eco-friendly biological control (Halim *et al*., 2017) employing natural enemies such as parasitoids, predators, and entomopathogens explored as an alternative to reduce pesticide use for pest control (Letourneau *et al*., 2011; Ginting *et al*., 2020). The information on insect diversity and abundance is critical to formulating successful pest management tactics in light of the increasing demand and yield losses in grain and fodder. For successful implementation of biological control methods, understanding the relationships between pests, their natural enemies, plants and non-crop habitats is essential (Xie, 2015) and should be strived for, which currently is limited. Work on literature and documentation of the diverse insect species in the wheat agroecosystem is scarce in Bhutan.

Therefore, this study attempted to inventory the different insect species and identify their functions in the wheat agroecosystem of ARDC Bajo.

Materials and Methods

Study area and period

The study was conducted in the research field of Agriculture Research and Development Centre (ARDC), Bajo, Wangdue (27° 29' 21.16" N, 89° 53' 53.95" E) at 1200 m above sea level (m asl) during the winter season of 2022 from February to April 2022. The wheat cultivars grown in the station were Bumthang Kaa Drukchu, Bajosokha Kaa, and Gumasokha Kaa.

Insect sampling and collection

The wheat crop was at maximum tillering and panicle initiation stages during this study. Insects were collected using sweep nets, pitfall traps and hand-picking in the wheat field. Sweep netting was done from the plant canopy to the basal region, including interspaces between plants and surrounding weeds (Bakar & Khan, 2016). Each sweep consisted of 15 complete sweeps conducted at three days intervals. The pitfall traps (plastic cups of an inverted truncated cone shape, 250 ml) were set up at the four corners of the field. For accurate identification, immature stages of in-

sects were collected and reared. All the samples were collected during the morning hours from 8:00 to 11:00 am.

Methods of Insect Preservation and Identification

The collected samples from each selected field/terrace were kept separately in labelled containers. Small Coleoptera (beetles) were preserved as wet specimens with 85% alcohol (Siregar *et al.*, 2017) while most were preserved as dry specimen protocol (Upton & Chapman, 2010). Orthopteran (grasshoppers and crickets), Dipteran (flies), Hemipteran (bugs), and Lepidopteran (butterflies and moths) were pinned and oven-dried at 40-45 ° C in the laboratory, then placed in insect boxes with naphthalene balls. The samples were sorted, observed under a light microscope, and magnifying glass and identified using keys from various publications. Insect samples were catalogued and stored in the Plant Protection Laboratory, ARDC Bajo.

The observed insects were classified into pest species, beneficial species and unknown, depending on earlier records of their functions in an ecosystem. Pest species were sub-grouped into wheat pests and other pest species, depending on their infestation of wheat. Beneficial insects were sub-grouped into predatory species, parasitoid species, and general pollinators.

Results and Discussion

A total of 95 insects belonging to eight orders and 35 families were recorded. The insects were categorized either as pests (wheat and other pest species) or beneficial species (predators, parasitoids, and pollinators) based on their functions in the wheat agroecosystem. Of the recorded species, the majority (54%, *n* = 51 species) were pests. The number of species under separate orders with their major categories as pests and beneficial insects is presented in Annexure 1.

Pest species in wheat agro-ecosystem

There were 51 pest species associated with winter wheat at ARDC Bajo belonging to orders of Coleoptera, Diptera, Hemiptera, Lepidoptera, and Orthoptera. These pest species are presented as wheat pests and other pest species. The other pest species consisted of the species that were recorded in the wheat agroecosystem but no pest characteristics or available records as pests were available.

Insect species that infest wheat

Of the 51 insect pests, 34 species were pests of wheat. Under Coleoptera order, three Chrysomelids were observed i.e., *Aulacophora indica* (Gmelin, 1790), *Altica* sp. (Geoffroy, 1762) and *Monolepta signata* (Olivier, 1808). *Aulacophora indica* is reported as an important pest in cucurbits (Wang *et al*., 2020) as well as in maize and wheat. *Monolepta signata* and *Altica* sp. (Geoffroy, 1762) are reported to be minor pests of wheat in India (Nadon & Thakur, 2019).

Under Hemiptera order, the pest species were *Camptopus sp.* (Amyot & Audinet serville, 1843), *Leptocorisa acuta* (Thunberg, 1783), *Sitobion miscanthi* (Takahashi, 1921), *Poophilus* sp. (Walker), *Cofana unimaculata* (Signoret, 1854), *Exitianus* sp. (Ball, 1929), *Cletus punctiger* (Dallus, 1852), *Graptostethus incertus* (Walker, 1872), *Eysarcoris ventralis* (Westwood, 1837), *Menida formosa* (Westwood, 1837), *Nezara viridula* (Linnaeus, 1758), *Nezara viridula* f. *viridula* (Linnaeus), and *Plautia* sp. (Stal, 1867). *Camptopus* sp. and *Exitianus* sp. are reported to infest wheat and oats (Kumar *et al.,* 2019). *Leptocorisa acuta* (Thunberg, 1783) is a major pest of rice (Saraswati *et al*., 2021) and also feeds on wheat (Hill, 2008). *Sitobion miscanthi* (Takahashi, 1921) is recorded as a major pest infesting wheat in China, India, Australia and other tropical areas, causing significant damage (Srivastava & Singh, 2014; Li *et al.*, 2021). In India, more than 11 aphid species were recorded on wheat with four of them known to be dominant viz. *Sitobion avenae*, *S.*

miscanthi, *Rhopalosiphum maidis* and *R. padi* (Ahmad *et al.*, 2016; Nadon & Thakur, 2019). *Sitobion miscanthi* was recorded throughout the vegetative growth stages (peaking in mid-March) as reported by Muhammad (2012) depending on the availability of food and optimal temperature (Razaq & Ahmad, 2004). *Poophilus* sp. was recorded as a common pest of rice in India (Kanaparthi & Sabita, 2018; Saini *et al*., 2011). *Cletus punctiger* (Dallus, 1852), *Menida formosa* (Westwood, 1837), *Cofana unimaculata* (Signoret, 1854), and *Nezara viridula* (Linnaeus, 1758) were observed during the study. These pests were listed as minor pests in a survey of Meghalaya pest diversity associated with wheat (Nadon & Thakur, 2019). *Graptostethus incertus* Walker (1872) was recorded from the field and could be a potential pest as it is phytophagous (Mitra *et al.*, 2018). In Iran, *Eysarcoris ventralis* (Westwood, 1837) was recorded as a pest of wheat (Jalaeian *et al*., 2019). Most pentatomids are polyphagous, making them a major pest in wheat and a variety of crops (Panizzi, 1997).

Under the Lepidoptera order, *Nomophila noctuella* (Denis & Schiffermüller, 1785), *Scirpophaga incertulas* (Walker, 1863), *Mythimna separata* (Walker, 1865), *Helicoverpa armigera* (Hübner, 1808), and *Vanessa cardui* (Linnaeus, 1758) were recored. Wheat was also seen to be infested by *Nomophila noctuella* (Denis & Schiffermüller, 1785) larvae (Gözüaçık & Atay, 2016), while *Scirpophaga incertulas* (Walker, 1863) was observed as a major pest of rice in Asia region with some cases also being documented in wheat (Jeer *et al*., 2017). *Mythimna separata* a polyphagous pest at different instars was observed at the anthesis and maturity stages of winter wheat at ARDC Bajo in late March and early April. *M. separata* has been recorded as a major sporadic pest of cereals in Asia and Australia (Sharma *et al*., 2002; Ranjith *et al*., 2018) causing major damage to wheat production (Gaur & Mogalapu, 2018). Kumar *et al*. (2019) found *Helicoverpa armigera* (Hübner, 1808) as a prominent major pest in wheat but it was a minor pest in this study. *Vanessa cardui* (Linnaeus, 1758) is a pest of corn, alfalfa, sunflower, and beans but Salim *et al*. (2016) collected caterpillars of this pest from a wheat field.

For Orthoptera, *Acrida exaltata* (Walker, 1859), *Aiolopus thalassinus* (Fabricius, 1781), *Oxya velox* (Fabricius, 1787), *Patanga succincta* (Johannson, 1763), *Trilophidia annulata* (Thunberg, 1815), *Oecanthus indicas* (Saussure, 1878), *Atractomorpha acutipennis* (Guérin-Méneville, 1844), *Pyrgomorpha* sp. (Serville, 1838), *Conocephalus fuscus* (Fabricius, 1793), *Conocephalus* sp. (Thunberg, 1815), *Euconocephalus* sp. (Karny, 1907), *Eupholidoptera* sp. (Maran, 1953), and *Phaneroptera roseata* (Walker, 1869) were recorded. *Patanga succincta* (Johannson, 1763) is reported as a pest of wheat and many other crops (Srinivasan & Prabakar, 2013). *Odontotermes obesus* Ramb (termites), *Atherigona naqvii* Steyskal (shoot fly), *Petrobia latens* Muller (brown wheat mite), *Mythimna separata* Walker, *Sitobion avenae,* and *Aphis maidis* (wheat aphid) have all been found to attack wheat in India (Prakash *et al*., 2019b). *Pyrgomorpha* sp. is recorded as a wheat pest in Africa and Asia (Mariño-Pérez & Song, 2018). *Atractomorpha acutipennis* (Guérin-Méneville, 1844) is a pest which attacks the leaves of the Poaceae family and some other crops (Kekeunou *et al*., 2020). Two species of subfamily *Phaneropterinae*, *Phaneroptera roseata* (Walker, 1869), and *Phaeroptera spinosa* (Bey-Bienko, 1954) were found in the current study. *P. roseata* and *Euconocephalus* sp. are recorded as pests in wheat (Sultana & Wagan, 2015) but less information on the status of *P. spinosa*.

Other pest species

Seventeen pest species were also recorded from the wheat fields at ARDC Bajo, but infestation of the wheat is not known. Some of the species may probably be pests of wheat depending on their polyphagous nature and

attack on related crops.

Under Coleoptera, *Bruchidius mendosus* (Gyllenhal, 1839) was recorded *Teleopsis* sp. (Rondani, 1875), *Campiglossa* sp. (Rondani, 1870), *Dioxyna sororcula* (Wiedemann, 1830), *Ensina sonchi* (Linnaeus, 1767), *Metasphenisca reinhardi* (Wiedemann, 1824) and *Procecidochares atra* (Loew, 1862) were the Dipteran pests recorded.

Spilostethus hospes (Fabricius, 1794) and *Eurydema pulchrum* (Linnaeus, 1758) were the other pests species in Hemiptera. Under Lepidoptera, *Maruca vitrata* (Fabricius, 1787), *Syntomoides imaon* (Cramer, 1780), *Lampides boeticus* (Linnaeus, 1767), *Danaus chrysippus* (Linnaeus, 1758), *Colias eurytheme* (Boisduval, 1852), *Plutella xylostella* (Linnaeus, 1758), *Crombrugghia distans* (Zeller, 1847), and *Phaeroptera spinosa* (Bei-Bienko, 1954) were recorded.

Conocephalus (Anisoptera) *fuscus* Fabricius (1793) and *Conocephalus* sp. were collected from wheat and grasses, however, the pest status was not established (Sadiq *et al*., 2017). *Artona zebraica* Butler (1876) was reported as a pest of rice (Yusifov & Ahmadov, 2021).

Other species recorded are reported as pests in crops of different families. *Plutella xylostella* Linnaeus (1758) is a Brassicaceae-specific oligophagous pest (Farias *et al*., 2020), while *Syntomoides imaon* Cramer (1780) has been observed feeding on Anacardiaceae and Rutaceae (Waring, Thomas, & Li, 1997) but little is known about its pest status in wheat. *Danaus chrysippus* Linnaeus (1758) is reported as an important pest of *Calotropis procera* and *Lampides boeticus* Linnaeus (1767) as a pest of Leguminosae, Polygonaceae and Cruciferae (Golestaneh *et al*., 2009; Kavitha & Vijayaraghavan, 2018). *Maruca vitrata* Fabricius (1787) and *Colias eurytheme* Boisduval (1852) are mentioned as oligophagous pests of legume and alfalfa respectively (Ba *et al.,* 2019; Ehler, 2006). Jackson *et al*. (2011) mentioned *Procecidochares atra* Loew (1862), *Campiglossa sp.* and *Ensina sonchi* Linnaeus (1767) as a pest in Asteraceae. Cucurbitaceae was recorded as the host of *Dioxyna sororcula* Wiedemann (1830) (Prabhakar *et al.,* 2012). Although the host of *Metasphenisca reinhardi* Wiedemann (1824) has not been reported, larvae of the genus *Metasphenisca* have been recorded feeding on Acanthaceae seed and flower (Korneyev & Phauk, 2019). *Eurydema pulchrum* Linnaeus (1758) was reported as a pest of brassica in Asia (Akhter *et al*., 2015).

Beneficial insect species

A total of 41 beneficial insect species (Annexure 1) were associated with the winter wheat belonging to six orders and thirteen families. They were categorized as Predators (30 species), Parasitoids (9), and Pollinators (2 species).

Thirty-two percent of the beneficial insects recorded were Coleopteran with 13 species from Coccinellidae. Dipterans comprised 23% of the beneficial insects with ten species recorded from Tachinidae and Syrphidae. Hymenopterans accounted for 25% of the beneficial insect with nine species from Ichneumonidae and Vespidae. Neuroptera comprised 7% beneficial insects with three species from Mantispidae and Chrysopidae. Two species in Hemiptera from Pentatomidae and Nabidae and two species in Odonata under Libellulidae were recorded.

Predator species

The majority (44%) of the predator species collected were from the order Coleoptera (Coccinellidae). The Coccinellids recorded were *Cheilomenes sexmaculata* (Fabricius, 1781), *Coccinella septumpunctata* (Linnaeus, 1758), *Coccinella transversalis* (Fabricius, 1781), *Coelophora bissellata* (Mulsant, 1850), *Cryptogonous quadriguttatus* (Weise, 1895), *Harmonia eucharis* (Mulsant, 1853), *Harmonia octamaculata* (Fabricius, 1781), *Harmonia sedecimnotata* (Fabricius, 1801), *Micraspis univittata* (Hope, 1831), *Oenopia dissecta* (Mulsant), *Oenopia sauzeti* (Mulsant, 1866), *Propylea luteopustalata* (Mulsant, 1850), and *Scymnus (Scymnus) nubilus* (Mulsant, 1850).

Coccinellids were the largest group of Coleopteran predators (both larvae and adults), as it was also reported in mixed agroecosystems (Inayat *et al*., 2011; Yadav *et al*., 2018) especially in aphid-infested fields (Ali *et al*., 2018; Brohi *et al*., 2019; Dorji *et al*., 2019).

Besides Coleopteran species, predator species from Diptera were also recorded. All the Dipterans recorded were Syrphid flies. The Dipteran predators recorded were *Episyrphus balteatus* (De Geer, 1776), *Episyrphus viridaureus* (Wiedemann, 1824), *Eupeodes corollae* (Fabricius, 1794), *Microdon analis* (Macquart, 1842), *Platycheirus scutatus* (Meigen, 1822), *Sphaerophoria* sp. (Lepeletier and Serville, 1828), and *Syrphus ribesii* (Linnaeus, 1758). Although the numbers collected differed from our study, the family and the genus mentioned by Zheng *et al.* (2019) and Subhan (2016) were similar to those identified here. Both studies reported that the larvae belonging to the family Syrphidae are predators of homopteran insects and particularly the genus *Sphaerophoria*, *Episyrphus*, *Syrphus*, and *Baccha* were recorded as active predators of aphids and soft-bodied insects.

Other predators belonging to Hemiptera, Hymenoptera, Odonata, Neuroptera, and Orthoptera were also recorded. These predatory species were *Nabis capsiformis* (Germar, 1838), *Andrallus spinidens* (Fabricius, 1787), *Vilius melanopterus* (Stal, 1863), *Polistes* sp. (Latreille, 1802), *Chrysoperla* sp. (Steinmann, 1964), *Hemerobius* sp. (Linnaeus, 1758), *Mantispa* sp. (Illiger, 1798), *Palpopleura sexmaculata* (Fabricius, 1787), *Pentala flavescens* (Fabricius, 1798), and *Conocephalus maculatus* (Le Guillou, 1841).

Studies by Coscarón et al. (2015) reported that adult *Nabis capsiformis* effectively predates *Heliothis* spp. (eggs and larvae) and *Anticarsia gemmatalis* Hubner larvae. *Andrallus spinidens* Fabricius (1787) may be predating on stem borer species, although most other Hemipteran bugs are plant suckers (Biswas *et al*., 2014). *Pantala flavescens* Fabricius (Libellulidae: Odonata), usually the most dominant in numbers in different agro-ecosystems (Anbalagan *et al*., 2013) are voracious predators of adult stem borers and leaf folders, and nymphs of leaf and plant hoppers (Soniyagandhi & Kumar, 2014), which often cause unaccounted wheat yield losses. Under Neuroptera, *Chrysoperla* sp. and *Hemerobius* sp. were recorded as predator species that are voracious eaters of eggs and immature stages of insect pests (Dey, 2014). *C. maculatus* was the only species recorded in our study as the dominant predator from Orthoptera that feeds on eggs of stem borers, leaf defoliators and *Pomacea canaliculata* (CABI, 2022; Wongsiri *et al*., 1981) but it also feeds on plants, which appears at heading with an extensive outbreak at maturity (Sadou et.al., 2017). *Polistes* spp., a hymenopteran (besides the parasitoid hymenopterans) was also an important predator of lepidopteran pests (Southon *et al*., 2019).

Parasitoid species

The recorded parasitoids were largely from Hymenoptera (Ichneumonidae) and two from Diptera (Tachinidae) order. The Hymenopteran parasitoids were *Agrypon* sp. (Förster, 1860), *Delta campiniforme campaniforme* (Fabricius, 1775), *Gotra* sp., *Ischnojoppa luteator* (Fabricius, 1798), *Metopius* sp. (Panzer, 1806), *Pimpla pedalis* (Cresson, 1865), and *Pimpla* sp. (Fabricius, 1804). The Dipteran parasitoid species were *Euthera fascipennis* (Loew, 1854) and *Winthemia trinitatis* (Thompson, 1963).

As reported by Bortolotto *et al*. (2014), we found *Winthemia trinitatis* (Thompson, 1963), a parasitoid of the wheat armyworm. The authors also reported that *W. trinitatis* (Dipteran: Tachinidae) is a potential parasitoid of various other pests. The other Tachinid recorded (*Euthera fascipennis* Loew) is a potential parasitoid for pentatomids (Francati *et al*., 2017) including *Dolycoris baccarum* Linnaeus.

Other reports (Ghahari *et al*., 2008; Mahmoud, 2009; Yadav *et al*., 2018) show that the most common parasitoids of lepidopteran pests (of larval and pupal stages) recorded in

agriculture ecosystems are Hymenopterans (Brachonidae, Ichneumonidae and Scelionidae).

Pollinator species

Pollinators recorded from this study belonged to Hymenoptera (family; Apidae) and Diptera (family: Syrphidae). *Apis* spp. are the principal species that pollinate most of the economic plants worldwide (Atmowidi *et al*., 2008; Santa Anna-Aguayo *et al*., 2017). In addition to Apidae, adult syrphid flies also play an important economic role in pollination and they are considered the second pollinator of cultivated and wild plants after bees (Subhan, 2016).

Species of unknown function

Aglaomorpha plagiata (Walker, 1855), *Potanthus dara* (Kollar, 1842), and *Artona zebraica* (Butler, 1876) were the other species observed in this study. No documents were found for *Potanthus dara* (Kollar, 1842), *Aglaomorpha plagiata* (Walker, 1855), and *Crombrugghia distans* (Zeller, 1847) as pest or their occurrence in wheat. Further, no feeding on the wheat was observed during the study by these species.

Conclusion

A diverse insect species represented by 54 insect pests and 41 beneficial insects were associated with winter wheat at ARDC Bajo. There are several pest species in the area which are reported to be major pests of wheat and related crops, which might be problematic for wheat farmers if not monitored. Also, there are minor pest species that might surge in population and cause economic damage to wheat and other crops in the area. Therefore, timely monitoring of the population of the pest species, and infestations are recommended.

From this study, we also confirm that there is a good diversity of natural enemies associated with wheat at Bajo. Predators, parasitoids and pollinators were the groups of beneficial insects associated with wheat farming. Besides the Apidae, other families were all naturally occurring biological agents for pest control in the wheat field. While implementing pest management activities, considerations of beneficial species should be made. Natural enemy-friendly pest control measures should be prioritized, as natural enemies are the first line of defence against pests.

Since this study focused only on inventory, the authors recommend studies on species diversity and abundance, potential threats of species, and relations of different species concerning the wheat agroecosystem.

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Annexure 1: Different insect species in Wheat agroecosystem at ARDC Bajo

Sl.	Function	Order	Family	Scientific name
1	Pest (Wheat)	Hemiptera	Aphididae	*Sitobion miscanthi* (Takahashi, 1921)
2	Pest (Wheat)	Lepidoptera	Noctuidae	*Mythimna separata* (Walker, 1865)
3	Pest (Wheat)	Coleoptera	Chrysomelidae	*Altica* sp. (Geoffroy, 1762)
4	Pest (Wheat)	Coleoptera	Chrysomelidae	*Aulacophora indica (*Gmelin, 1790)
5	Pest (Wheat)	Coleoptera	Chrysomelidae	*Monolepta signata* (Olivier, 1808)
6	Pest (Wheat)	Hemiptera	Alydidae	*Camptopus* sp. (A*myot &* Audinet serville*,* 1843)
7	Pest (Wheat)	Hemiptera	Alydidae	*Leptocorisa acuta* (Thunberg, 1783)
8	Pest (Wheat)	Hemiptera	Aphrophoridae	*Poophilus* sp. (Walker)
9	Pest (Wheat)	Hemiptera	Cicadellidae	*Cofana unimaculata* (Signoret, 1854)
10	Pest (Wheat)	Hemiptera	Cicadellidae	*Exitianus* sp. (Ball, 1929)
11	Pest (Wheat)	Hemiptera	Coreidae	*Cletus punctiger* (Dallus,1852)
12	Pest (Wheat)	Hemiptera	Lygaeidae	*Graptostethus incertus* (Walker, 1872)
13	Pest (Wheat)	Hemiptera	Pentatomidae	*Eurydema pulchrum* (Linnaeus, 1758)
14	Pest (Wheat)	Hemiptera	Pentatomidae	*Eysarcoris ventralis* (Westwood, 1837)
15	Pest (Wheat)	Hemiptera	Pentatomidae	*Menida formosa* (Westwood,1837)
16	Pest (Wheat)	Hemiptera	Pentatomidae	*Nezara viridula* (Linnaeus, 1758)
17	Pest (Wheat)	Hemiptera	Pentatomidae	*Nezara viridula f. viridula* (Linnaeus)
18	Pest (Wheat)	Hemiptera	Pentatomidae	*Plautia* sp. (Stal, 1867)
19	Pest (Wheat)	Lepidoptera	Crambidae	*Nomophila noctuella (*Denis & Schiffermüller, 1785)
20	Pest (Wheat)	Lepidoptera	Crambidae	*Scirpophaga incertulas (*Walker, 1863)

21	Pest (Wheat)	Lepidoptera	Noctuidae	*Helicoverpa armigera* (Hübner, 1808)
22	Pest (Wheat)	Lepidoptera	Nymphalidae	*Vanessa cardui* (Linnaeus, 1758)
23	Pest (Wheat)	Orthoptera	Acrididae	*Acrida exaltata* (Walker, 1859)
24	Pest (Wheat)	Orthoptera	Acrididae	*Aiolopus thalassinus* (Fabricius, 1781)
25	Pest (Wheat)	Orthoptera	Acrididae	*Oxya velox* (Fabricius, 1787)
26	Pest (Wheat)	Orthoptera	Acrididae	*Patanga succincta* (Johannson, *1763*)
27	Pest (Wheat)	Orthoptera	Acrididae	*Trilophidia annulata* (Thunberg, 1815)
28	Pest (Wheat)	Orthoptera	Gryllidae	*Oecanthus indicas* (Saussure, 1878)
29	Pest (Wheat)	Orthoptera	Pyrgomorphidae	*Atractomorpha acutipennis* (Guérin-Méneville, 1844)
30	Pest (Wheat)	Orthoptera	Pyrgomorphidae	*Pyrgomorpha* sp. (Serville, 1838)
31	Pest (Wheat)	Orthoptera	Tettigoniidae	*Conocephalus fuscus* (Fabricius, *1793*)
32	Pest (Wheat)	Orthoptera	Tettigoniidae	*Conocephalus* sp. (Thunberg, 1815)
33	Pest (Wheat)	Orthoptera	Tettigoniidae	*Euconocephalus* sp. (H.H. Karny, 1907)
34	Pest (Wheat)	Orthoptera	Tettigoniidae	*Eupholidoptera* sp. (Maran, 1953)
35	Pest (Wheat)	Orthoptera	Tettigoniidae	*Phaneroptera roseata* (Walker, 1869)
36	Pest (Other pests)	Coleoptera	Chrysomelidae	*Bruchidius mendosus* (Gyllenhal, 1839)
37	Pest (Other pests)	Diptera	Diopsidae	*Teleopsis* sp. (Rondani, 1875)
38	Pest (Other pests)	Diptera	Tephritidae	*Campiglossa* sp. (Rondani, 1870)
39	Pest (Other pests)	Diptera	Tephritidae	*Dioxyna sororcula* (Wiedemann, 1830)
40	Pest (Other pests)	Diptera	Tephritidae	*Ensina sonchi* (Linnaeus, 1767)
41	Pest (Other pests)	Diptera	Tephritidae	*Metasphenisca reinhardi* (Wiedemann, 1824)
42	Pest (Other pests)	Diptera	Tephritidae	*Procecidochares atra* (Loew, 1862)
43	Pest (Other pests)	Hemiptera	Lygaeidae	*Spilostethus hospes* (Fabricius, 1794)
44	Pest (Other pests)	Lepidoptera	Crambidae	*Maruca vitrata* (Fabricius, 1787)
45	Pest (Other pests)	Lepidoptera	Erebidae	*Syntomoides imaon* (Cramer, 1780)
46	Pest (Other pests)	Lepidoptera	Lycaenidae	*Lampides boeticus* (Linnaeus, 1767)
47	Pest (Other pests)	Lepidoptera	Nymphalidae	*Danaus chrysippus* (Linnaeus, 1758)
48	Pest (Other pests)	Lepidoptera	Pieridae	*Colias eurytheme* (Boisduval, 1852)
49	Pest (Other pests)	Lepidoptera	Plutellidae	*Plutella xylostella* (Linnaeus, 1758)
50	Pest (Other pests)	Lepidoptera	Pterophoridae	*Crombrugghia distans* (Zeller, 1847)

51	Pest (Other pests)	Orthoptera	Tettigoniidae	*Phaeroptera spinosa* (Bei-Bienko, 1954)
52	Beneficial (Parasitoid)	Diptera	Tachinidae	*Euthera fascipennis* (Loew, 1854)
53	Beneficial (Parasitoid)	Diptera	Tachinidae	*Winthemia trinitatis* (Thompson, 1963)
54	Beneficial (Parasitoid)	Hymenoptera	Ichneumonidae	*Agrypon* sp. (Förster, 1860)
55	Beneficial (Parasitoid)	Hymenoptera	Ichneumonidae	*Delta campiniforme campaniforme* (Fabricius, 1775)
56	Beneficial (Parasitoid)	Hymenoptera	Ichneumonidae	*Gotra* sp.
57	Beneficial (Parasitoid)	Hymenoptera	Ichneumonidae	*Ischnojoppa luteator* (Fabricius, 1798)
58	Beneficial (Parasitoid)	Hymenoptera	Ichneumonidae	*Metopius* sp. (Panzer, 1806)
59	Beneficial (Parasitoid)	Hymenoptera	Ichneumonidae	*Pimpla pedalis* (Cresson, 1865)
60	Beneficial (Parasitoid)	Hymenoptera	Ichneumonidae	*Pimpla* sp. (Fabricius, 1804)
61	Beneficial (Predator)	Coleoptera	Coccinellidae	*Cheilomenes sexmaculata* (Fabricius, 1781)
62	Beneficial (Predator)	Coleoptera	Coccinellidae	*Coccinella septumpunctata* (Linnaeus, 1758)
63	Beneficial (Predator)	Coleoptera	Coccinellidae	*Coccinella transversalis* (Fabricius, 1781)
64	Beneficial (Predator)	Coleoptera	Coccinellidae	*Coelophora bissellata* (Mulsant, 1850)
65	Beneficial (Predator)	Coleoptera	Coccinellidae	*Cryptogonous quadriguttatus* (Weise, 1895)
66	Beneficial (Predator)	Coleoptera	Coccinellidae	*Harmonia eucharis* (Mulsant, 1853)
67	Beneficial (Predator)	Coleoptera	Coccinellidae	*Harmonia octamaculata* (Fabricius, 1781)
68	Beneficial (Predator)	Coleoptera	Coccinellidae	*Harmonia sedecimnotata* (Fabricius, 1801)
69	Beneficial (Predator)	Coleoptera	Coccinellidae	*Micraspis univittata* (Hope, 1831)
70	Beneficial (Predator)	Coleoptera	Coccinellidae	*Oenopia dissecta* (Mulsant)
71	Beneficial (Predator)	Coleoptera	Coccinellidae	*Oenopia sauzeti* (Mulsant, 1866)
72	Beneficial (Predator)	Coleoptera	Coccinellidae	*Propylea luteopustalata* (Mulsant, 1850)
73	Beneficial (Predator)	Coleoptera	Coccinellidae	*Scymnus (Scymnus) nubilus* (Mulsant, 1850)
74	Beneficial (Predator)	Diptera	Syrphidae	*Episyrphus balteatus* (De *Geer*, 1776)
75	Beneficial (Predator)	Diptera	Syrphidae	*Episyrphus viridaureus* (Wiedemann, 1824)
76	Beneficial (Predator)	Diptera	Syrphidae	*Eupeodes corollae* (Fabricius, 1794)
77	Beneficial (Predator)	Diptera	Syrphidae	*Microdon analis* (Macquart, 1842)
78	Beneficial (Predator)	Diptera	Syrphidae	*Platycheirus scutatus* (Meigen, 1822)
79	Beneficial (Predator)	Diptera	Syrphidae	*Sphaerophoria* (Lepeletier and Serville, 1828)
80	Beneficial (Predator)	Diptera	Syrphidae	*Syrphus ribesii* (Linnaeus, 1758)

81	Beneficial (Predator)	Hemiptera	Nabidae	*Nabis capsiformis (*Germar, 1838*)*
82	Beneficial (Predator)	Hemiptera	Pentatomidae	*Andrallus spinidens (*Fabricius, 1787*)*
83	Beneficial (Predator)	Hemiptera	Reduviidae	*Vilius melanopterus (*Stal, 1863*)*
84	Beneficial (Predator)	Hymenoptera	Vespidae	*Polistes* sp. *(*Latreille, 1802*)*
85	Beneficial (Predator)	Neuroptera	Chrysopidae	*Chrysoperla* sp. *(*Steinmann, 1964*)*
86	Beneficial (Predator)	Neuroptera	Chrysopidae	*Hemerobius* sp. *(*Linnaeus, 1758*)*
87	Beneficial (Predator)	Neuroptera	Mantispidae	*Mantispa* sp. *(*Illiger, 1798*)*
88	Beneficial (Predator)	Odonata	Libellulidae	*Palpopleura sexmaculata (*Fabricius, 1787*)*
89	Beneficial (Predator)	Odonata	Libellulidae	*Pentala flavescens (*Fabricius, 1798*)*
90	Beneficial (Predator)	Orthoptera	Tettigoniidae	*Conocephalus maculatus (*Le Guillou, 1841*)*
91	Beneficial (Pollinator)	Hymenoptera	Apidae	*Apis cera (*Fabricius, 1793*)*
92	Beneficial (Pollinator)	Hymenoptera	Apidae	*Apis mellifera mellifera (*Linnaeus, 1758*)*
93	Unknown function	Lepidoptera	Erebidae	*Aglaomorpha plagiata (*Walker, 1855*)*
94	Unknown function	Lepidoptera	Hesperiidae	*Potanthus dara (*Kollar, 1842*)*
95	Unknown function	Lepidoptera	Zygaenidae	*Artona zebraica (*Butler, 1876*)*