Fauna associated with wheat cultivation in high altitudes of the Nilgiris, India

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Wheat cultivation in southern India is unique as it is grown in high altitudes (1500 m amsl), surrounded by the pristine environment of the Western Ghats. Also, it can be grown throughout the year, unlike only once a year in India's central and northern plains. The faunal pressure on wheat cultivation in southern India is different from the other wheat-growing regions in the country. However, information on faunal diversity associated with wheat crops in this unique ecosystem is meagre. Hence, the present study aimed to acquire knowledge based on the fauna associated with and their influence on wheat cultivation in the Nilgiris, Tamil Nadu, South India. Our results indicated that the phylum Arthropoda dominated the ecosystem with 61 species, followed by the Chordata with 41 species, and the Nematoda with 22 species. The coleopterans were found to be dominant among arthropods followed by lepidopterans. In chordates, small birds such as spotted munia and common rosefinch were observed often, while among the Nematoda, the plant-parasitic order Tylenchida topped the list. During different phases of cultivation, the overall diversity was highest during the early stages of the crop and least during the vegetative phase. This study also highlights the human–animal interaction in the context of agriculture, as it was observed that the damage caused by Nilgiri gaur, spotted munia and common rosefinch was one of the major reasons for non-preference of wheat crops by the farmers besides the lack of cost-effective technologies to ward-off wild animals. This initiative may encourage researchers to perform more comprehensive studies on the faunal diversity of the entire crop-growing areas in the southern hill regions of India.

Keywords: Agroecosystem, animals, biodiversity, birds, nematodes, wheat.

WHEAT is the main cereal crop in India, occupying an area of 29.8 m ha. The production of wheat in the country has increased significantly from 69.35 MT in 2005–06 to 107.59 MT in 2019–20 (ref. 1). As wheat crop requires cold temperatures for its growth and development, the distribution of the wheat area is restricted to central and North India. However, facilitated by the natural low temperatures at high altitudes, the crop can be grown throughout the year in the southern hill zone, including the Nilgiris, Palani and Kodaikanal hills of India. Samai or little millet (Panicum sumatrense Roth ex Roem. et Schult.), ragi or finger millet (*Eleusine coracana* Gaertn.), barley (*Hordeum* vulgare L.), maize (*Zea mays* L.), amaranth (*Amaranthus* sp. L.), korali (*Setaria glauca* (L.) P. Beauv.) and scarlet runner beans (*Phaseolus coccineus* L.) are some of the traditional crops grown in the southern hills as mixed farming. Among the wheat crops, bread wheat (*Triticum aestivum* L.) was introduced to the locals by the British, while the origin of samba wheat (*Triticum dicoccum* Schrank ex Schübl.) in the Nilgiris is unclear. In the barley group (*Hordeum* sp.), the akki ganji, six-rowed naked kind and badaga ganji, six-rowed kind are considered indigenous to the Nilgiris[2]. Although the British introduced several varieties of wheat and barley to the region, poor agricultural practices by local farmers and admixture resulted in a loss of purity in the seeds. Further, the native population preferred wheat seeds with inseparable glumes (*T. dicoccum*), as it's hardiness given protection from birds, animals and insects during the later stage of the crop. This has led to the making of several wheat-based food items like sweet dosa (pothittu) and *dicoccum* wheat laddu (kadimittu), which are unique to the Nilgiris. Moreover, the southern hills, especially the Nilgiris, are among the few places where wheat can be grown year-round. The continuous possibility of wheat cultivation along with high humidity and low temperature have made this place a natural phytotron for all the three rusts of wheat, viz. leaf, stripe and stem rust caused by *Puccinia triticina* f. sp. *tritici* Erikss., *P. striiformis* f. sp. *tritici* Westend. and *P. graminis* f. sp. *tritici* Pers. respectively. To harness the benefits of the natural occurrence of all

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three wheat rusts in India's rust-resistant breeding programme, the ICAR-Indian Agricultural Research Institute (IARI), Regional Station, Wellington was established (1954) and has bloomed into an excellent off-season nursery. The introduction of high-yielding crops such as tea, coffee, exotic fruits and vegetables gradually reduced the area under wheat cultivation in the Nilgiris. However, in this Regional Station, wheat has been grown continuously for the past seven decades to meet the requirement of breeding rust-resistant wheat varieties.

The geographical advantage of the Nilgiris is that it remains cool in the summer because of the altitude and is relatively warm because of the latitude. Such pleasant weather throughout the year and the pristine hilly tracts make it home to numerous flora and fauna. Moreover, the Nilgiris forms a part of the Western Ghats, one of the world's biodiversity hotspots[3]. However, the altered cropping system, cropping sequence and intensive agronomic practice driven by commercial interests has modified the floral and faunal diversity, dynamics and inter-relationship of agricultural crops. However, this aspect is often ignored and rarely addressed. Hence this study was undertaken to document the overall faunal diversity and dynamics of the wheat crops at high altitudes of the Nilgiris, to make an inventory and generate baseline data for future studies.

Materials and methods

Location

The research station (ICAR-IARI, Regional Station, Wellington) is located at an altitude of 1850 m amsl, in an area of 17.6 ha. The station serves as a natural phytotron facility for wheat rust resistance breeding; hence the wheat crop has been maintained continuously since 1954. Barley, oats, mustard, potato, linseed, carrot and other *Brassica* species are the other crops grown in and around the wheat crop in this station. The soil type is sandy clay loam with a pH range 4.5–6, electrical conductivity range 0.05–0.18 and soil organic carbon of 0.4–1.8%.

Quantification of nematodes

The soil samples for nematode assessment were collected randomly from the wheat rhizosphere (*T. dicoccum* variety HW1098), during the vegetative stage of the crop (21 to 60 DAS) at different locations in the Institute covering 1 acre at monthly intervals from June 2018 to May 2019. Soil samples were collected at a depth of 10–20 cm from the study site using a hand trowel, each containing a composite of 3–5 random subsamples. These were mixed to make a composite sample and 100 cm^3 of soil were taken for further processing. The hand trowel was sterilized with 70% ethanol before leaving the sampling site. The samples were placed in polyethylene bags to minimize dehydration, tagged with labels providing all the necessary information and transported to the laboratory. The soil samples for the population dynamics study were collected from a similar location as mentioned above in a zigzag pattern (ten samples) at monthly intervals from June 2018 to May 2019.

All the soil samples were processed for nematode extraction by Cobb's sieving and decanting method[4]. Identification was made by fixing, processing the nematode to dehydration and slide preparation as described by Seinhorst[5]. Identification up to the generic level was made using the taxonomic key described in the literature[6–10]. For quantification, the nematodes were fixed using hot TAF (triethanol amine formalin) and stored in 50 ml centrifuge tubes. Then they were pipetted into the Sedgewick rafter counting chamber and counted under a compound microscope (Nikon E 600)[11]. The nematodes were categorized into four feeding groups, namely herbivore, bacterivore, fungivore and omnivore–predator for estimating the diversity[12]. Computation of diversity indices and analysis were done using Paleontological Statistical Software (PAST V3).

Quantification of arthropods

Observation of insect species in wheat crops grown at high altitudes was done during different phases like land preparation, germination, vegetative, reproductive and post-harvest. The sampling was done using sweep nets in vegetation and aerial nets in a transect walk manner between 11 am and 3 pm during bright sunny days[13,14]. Butterflies, bees and other arthropods like spiders were sampled by the targeted sighting, aerial netting and sweeping on vegetation[15–17]. The collected samples from the wheat fields were pooled, sorted, labelled and preserved for identification[15]. In total, six observations were taken in each study phase at random intervals. The insect samples were identified by the taxonomists at ICAR-National Bureau of Agricultural Insect Resources, Bengaluru and by us.

Quantification of birds and other animals

The documentation of birds was done using visible observation in the wheat fields of ICAR-IARI research farm at Wellington for three years. For each species visited, we recorded the bird herd and activities[18]. During each cropping season, the birds were observed for 1 h during a ten-day period. The bird species were identified and cross-checked with the *Handbook of the Birds of India and Pakistan*[19]. The documentation of higher animals was done in the same manner as that of the birds, and the identification of animals and snakes was done by experts through the Forest Department official and on-line resources (www.indiansnakes.org).

Results and discussion

In the high altitudes of the Nilgiris, 124 fauna were observed in wheat crop fields. Among them, 61 belonged to the phylum Arthropoda, 41 to Chordata and 22 to Nematoda.

Nematode diversity and dynamics associated with wheat

A total of 22 nematode genera have been encountered in the present study from the wheat rhizosphere regions at a depth of 10–20 cm. Among them, 11 belonged to plant feeders (herbivores), viz. *Pratylenchus* sp., *Helicotylenchus* sp., *Paratylenchus* sp., *Tylenchus* sp., *Meloidogyne* sp., *Hemicycliophora* sp., *Hoplolaimus* sp., *Trichodorus* sp., *Xiphinema* sp., *Tylenchorhynchus* sp. and *Globodera* sp.; three belonged to fungal feeders, viz. *Aphelenchus* sp., *Aphelenchoides* sp. and *Filenchus* sp.; three belonged to bacterial feeders, viz. *Rhabditis* sp., *Acrobelis* sp. and *Wilsonema* sp. and five belonged to the omnivore–predator complex, viz. *Diptherophora* sp., Dorylaimida, *Monohystera* sp., *Mononchus* sp. and an unidentified nematode.

Among the plant feeder nematodes, *Pratylenchus* sp. was observed as the most abundant genus (monthly average of 106.94 nematodes per 100 cm^3 soil), followed by *Helicotylenchus* sp. (52.78 nematodes per 100 cm^3 soil), *Tylenchorhynchus* sp. (11.11 nematodes per 100 cm^3 soil), and *Criconema* sp. (11.11 nematodes per 100 cm^3 soil). The dynamics of the plant-feeding (herbivore), bacterial-feeding (bacterivore) and fungal-feeding (fungivore) nematodes showed a positive correlation ($P < 0.05$) with the total nematode population. However, the omnivore–predator group and nematode trophic group (NTG) diversity (Shannon index, *H*) did not show any significant correlation with the total nematode population (Figure 1). Though NTG diversity was calculated, the species diversity of nematodes associated with wheat crops could not be compared due to lack of information, but it may be assumed that the diversity varies considerably with habitat, area and the number of individuals.

The present study revealed that lesion nematode, *Pratylenchus* sp. was an important nematode for wheat crop. Its occurrence was ubiquitous and it was found in almost all collection sites, followed by the spiral nematode *Helicotylenchus* sp. Though *Meloidogyne* sp. was found in the soil samples, the root gall symptoms were not observed in wheat crops. The root-knot nematode population in the soil might be due to the presence of susceptible weed hosts such as *Bidens pilosa* L., *Galinsoga parviflora* Cav., *Verbena bonariensis* L., *Solanum mauritianum* Scop., *Xerochrysum bracteatum* (Vent.) Tzyelev, *Impatiens balsamina* L., *Silene conoidea* L., *Solanum nigrum* L., *Parthenium hysterophorus* L. and *Veronica peduncularis* M. Bieb[20]. Golden cyst nematodes were observed in the fields. This might be the result of potato crops grown earlier in the same fields. Interestingly, *Wilsonema* sp., a bacterial feeder, was also reported from the wheat rhizosphere in this region, having previously been reported only from Firozabad district, Uttar Pradesh, India[21].

Arthropod diversity and dynamics associated with wheat

Among the arthropods, class Insecta dominated the wheat ecosystem in high altitudes with 49 species belonging to 7 different orders, namely Lepidoptera (19 species), Coleoptera (15 species), Hymenoptera (6 species), Orthoptera (4 species), Hemiptera (2 species), Diptera (2 species) and Dermaptera (1 species; Figure 2). This was followed by class Arachnida with 11 species, including 10 spider species, viz. *Araneus* sp. Clerck, *Neoscona* sp. E. Simon, *Neoscona theisi* Walckenaer, *Rhene flavigera* (C. L. Koch), *Phintella coonooriensis* Prószyński, *Telamonia dimidiata* Simon, *Oxyopes hindostanicus* Pocock, *Pardosa pseudoannulata* (Bösenberg and Strand), *Pardosa* sp. C. L. Koch, and *Gnaphosa* sp. Latreille, and a scorpion species. One species from class Malacostraca (sow bugs) was observed during different phases of the wheat crop, commonly during the rainy season beneath the decomposing plant materials. The scorpions observed during compost application probably came along with the farmyard manure (FYM) from the

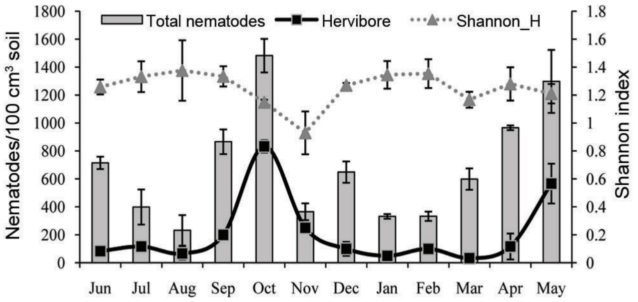

Figure 1. Population dynamics of plant and soil nematodes associated with wheat crop.

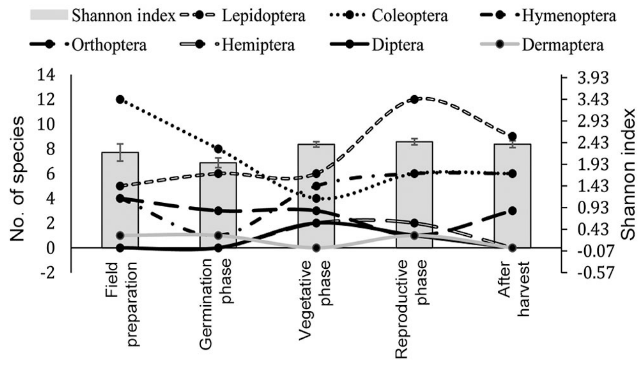

Figure 2. Insect diversity and order-wise dynamics of species richness during different stages of wheat crop.

Table 1. Relative percentage of lepidopteran species observed during different stages in the high-altitude wheat ecosystem

Lepidopteran species	Relative percentage				
	Field preparation	Germination	Vegetative phase	Reproductive phase	After harvest
Papilio polymnestor	0.00	0.00	0.00	100.00	0.00
Azanus ubaldus	13.64	13.64	22.73	18.18	31.82
Eurema hecabe	21.43	7.14	28.57	14.29	28.57
Catopsilia pomona	0.00	0.00	0.00	0.00	100.00
Phalanta phalantha	0.00	0.00	50.00	0.00	50.00
Papilio polytes	0.00	0.00	0.00	0.00	100.00
Mycalesis mineus	22.22	22.22	0.00	22.22	33.33
Junonia lemonias	25.00	25.00	0.00	0.00	50.00
Papilio demoleus	0.00	0.00	0.00	0.00	100.00
Vanessa cardui	0.00	0.00	100.00	0.00	0.00
Pseudozizeeria maha	0.00	11.11	11.11	33.33	44.44
Papilio paris	0.00	0.00	0.00	100.00	0.00
Utetheisa pulchella	0.00	0.00	0.00	100.00	0.00
Deilephila rivularis	0.00	0.00	50.00	50.00	0.00
Spodoptera sp.	0.00	0.00	0.00	100.00	0.00
Amata huebneri	25.00	25.00	0.00	50.00	0.00
Nepita conferta	0.00	0.00	0.00	100.00	0.00
Marumba dyras	0.00	0.00	0.00	100.00	0.00
Spilosoma obliqua	0.00	0.00	0.00	100.00	0.00

Table 2. Relative percentage of coleopteran species observed during different stages in the high-altitude wheat ecosystem

Coleopteran species	Relative percentage				
	Field preparation	Germination	Vegetative phase	Reproductive phase	After harvest
Altica sp.	21.21	9.09	18.18	27.27	24.24
Chrysomela sp.	22.22	11.11	22.22	44.44	0.00
Lanelater sp.	66.67	33.33	0.00	0.00	0.00
Luperomorpha sp.	14.29	28.57	42.86	7.14	7.14
Tribolium sp.	0.00	0.00	0.00	0.00	100.00
Oryctes rhinoceros	100.00	0.00	0.00	0.00	0.00
Adoretus sp.	100.00	0.00	0.00	0.00	0.00
Anomala communis	100.00	0.00	0.00	0.00	0.00
Anomalochela bicolor	100.00	0.00	0.00	0.00	0.00
Holotrichia sp.	33.33	66.67	0.00	0.00	0.00
Maladera sp.	50.00	50.00	0.00	0.00	0.00
Cheilomenes sexmaculata	16.67	16.67	33.33	16.67	16.67
Coccinella septempunctuata	20.00	20.00	0.00	20.00	40.00
Myllocerus subfasciatus	0.00	0.00	0.00	100.00	0.00
Psitophilus oryzae	0.00	0.00	0.00	0.00	100.00

foothills. The dominance of phytophagous and other saprophagous species indicates the richness of vegetation and organic litter.

Nineteen species of lepidopterans were found in the collections. The catches during the reproductive stages exclusively consisted of moths of *Spilosoma obliqua* (Walker), *Marumba dyras* (Walker), *Nepita conferta* (Walker), *Spodoptera* sp., *Utetheisa pulchella* (Linnaeus), and butterflies of *Papilio paris* Linnaeus and *Papilio polymnestor* Cramer. The swallow tails *Papilio demoleus* Linnaeus and *Papilio polytes* Linnaeus, and common emigrant *Catopsilia pomona* (Fabricius) were observed throughout the after harvest phase of this ecosystem. A vegetative phase was encountered with nymphalids *Vanessa cardui* Linnaeus and *Phalanta phalantha* Drury, followed by the sphinx moth, *Deilephila rivularis* (Boisduval, Table 1).

In the order Coleoptera, the adult rice weevil *Sitophilus oryzae* Linnaeus and red flour beetle *Tribolium* sp. Macleoy were found only during after harvest stage, while the ash weevil *Myllocerus subfasciatus* Guerin was found only during the reproductive phase of the wheat crop. The common leaf beetles like *Chrysomela* sp. Linnaeus and *Altica* sp. Geoffroy were noticed during the reproductive phase along with other predaceous beetles like *Coccinella septempunctata* (Linnaeus) and *Cheilomenes sexmaculata* Fabricius. The rhinoceros beetle *Oryctes rhinoceros* (Linnaeus) were found to spread through poorly processed FYM supplied from the foothills. The white grub species *Adoretus* sp. Laporte and *Anomala communis* Burmeister were found only during the field preparation stage. Scarabaeid beetles like *Holotrichia* sp. Hope and *Maladera* sp. Mulsant and Rey dominated throughout the germination stage, followed by *Lanelater* sp. Arnett and *Luperomorpha xanthodera* Fairmaire. During the vegetative phase, the beetle *L. xanthodera* was commonly observed, followed by *C. sexmaculata*, *Chrysomela* sp. and *Altica* sp. (Table 2).

Six bee species were recorded visiting the wheat ecosystem during the survey. All of them were observed in catches of reproductive and after-harvest stages. The subsocial bee *Ceratina bryanti* Cockerell was found in catches throughout the study period in all the stages of observation. The rock bee *Apis dorsata* Fabricius and the Indian bee *Apis cerana indica* (Fabricius) were found in the catches of all the stages except the field preparation and germination phase. The little bee *Apis florea* Fabricius and a blue-banded bee *Amegilla* sp. were observed in all the stages, except the germination phase (Figure 3).

Four species of orthopterans, including grasshoppers and crickets, were found in the catches during the field preparation stage. The grasshopper *Cyrtacanthacris tatarica* (Linnaeus) was prominent in all five phases of the study. Also, the *Atractomorpha* sp. and cricket *Tettigonia viridissima* (Linnaeus) were found in all the stages, except the reproductive phase. The king cricket (unidentified) was found only during the field preparation phase (Figure 3).

Hemipterans like *Nezara viridula* (Linnaeus) and *Agonoscelis nubilis* (Fabricius) were observed during the vegetative and reproductive stages. An unidentified earwig species was found during field preparation, germination and reproductive stages. The flies, *Tipula* sp. and *Mycodiplosis coniophaga* (Winnertz, which feeds on rust pustules) were rarely observed during the vegetative stage. *Rhopalosiphum padi* Linnaeus and *Sitobion miscanthi* (Takahashi) were the two aphid species found in wheat crops mainly in the field borders and polyhouses (Figure 4).

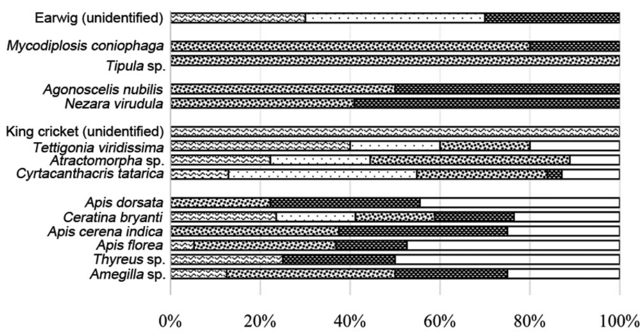

Figure 3. Relative percentage of Hymenoptera, Orthoptera, Hemiptera, Diptera and Dermaptera species observed during different stages in the high-altitude wheat ecosystem.

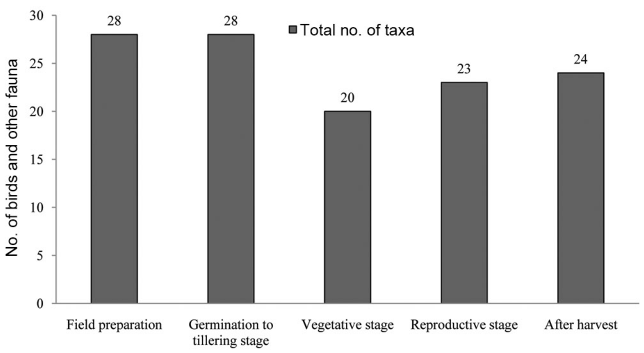

Figure 4. Number of birds and other animals at different stages of wheat crop.

Chordata diversity associated with wheat in high altitudes

Out of the 41 species of Chordata observed under the high-altitude wheat ecosystem of the Nilgiris, 26 belonged to the class Aves, 10 to Mammalia, 4 belonged to Reptilia and 1 to Amphibia (Table 3). The highest number of taxa was observed in the early phase of the crop (Figure 4). The spotted munia and common rose finch are serious pests of wheat in hilly areas. These two bird species visited the wheat fields in small flocks of 5–12 numbers and fed on wheat grains during the late dough stage, causing severe yield loss. If small fields are unprotected, birds may damage the entire crop both by feeding and shattering while sitting on the spikelet. Among the wheat crops, more bird damage was noticed in the awnless wheat variety. All the other avian species, excluding spotted munia and common rose finch, did not damage the wheat crops (Table 3). These birds help in controlling the insect pest population of wheat and other crops of the region. The avian diversity in wheat crop[22] and its role in the natural regulation of *Helicoverpa armigera* (Hubner) in Gujarat, India has been well documented[23].

The Spotted dove and blue rock pigeon were observed to feed on the grains available on the ground at the time of sowing and the scattered grains after harvesting. The peafowl visited the fields when humans were absent and fed mainly on the scattered grains after harvest (Figure 5). The peafowl, which prefers low altitude[24] was frequently observed at altitudes more than 1850 m amsl in the Western Ghats[25,26]; this may be due to climate change or habitat loss[27].

The Nilgiri gaur preferred the wheat crop (*T. dicoccum* and *T. aestivum*) mainly during the vegetative stage. However, the presence of dense awns in *T. dicoccum* gives protection to some extent against the Nilgiri Gaur in the latter stage of the crop. Barking deer rarely visited the wheat fields, and fed mainly on grass and other shrubs in bunds and border areas. Monkeys, especially *Rhesus macaque* (Zimmermann) were observed to feed on wheat panicles, though wheat does not form the main constituent of their food bouquet in this region. The wild boars preferred to feed on rhizomes of *Cyperus* weeds grown inside the wheat fields and their entry after rainfall sometimes led to trampling damage to wheat crops. Field rats reside in the bunds (terrace walls) of all fields. They cut the wheat culms along with panicles and stored them in their maze. Squirrels generally target fields near buildings or trees, and they

Table 3. Sighting of avian species and other animals in the wheat ecosystem at high altitudes of the Nilgiris, Tamil Nadu

Common name	Scientific name	Trophic group	Sighting	Crop stage
Barking deer	*Muntiacus muntjac*	Herbivore	Rare	1–5
Bison/gaur	*Bos gaurus*	Herbivore	Occasional	2–3
Cat (wild cat)	*Felis chaus*	Carnivore	Rare	1–5
Indian grey mongoose	*Herpestes edwardsii*	Omnivore	Occasional	1–5
Indian crested porcupine	*Hystrix indica*	Omnivore	Rare	1–5
Rodent (field rat)	*Rattus rattus*	Omnivore	Common	3–5
Rodent (squirrels)	*Funambulus pennantii*	Herbivore	Common	1–5
Buff-striped keelback snake	*Amphiesma stolatum*	Carnivore	Occasional	1–5
Green keelback snake	*Rhabdophis plumbicolor*	Carnivore	Rare	1–5
Indian rat snake	*Ptyas mucosa*	Carnivore	Common	1–5
Nilgiri burrowing snake	*Plectrurus perrotetii*	Carnivore	Occasional	1
Nilgiri tahr	*Nilgiritragus hylocrius*	Herbivore	Rare	1–5
Wild boar	*Sus scrofa*	Omnivore	Occasional	1–5
Black-naped hare	*Lepus nigricollis*	Herbivore	Rare	1–2
Common Indian toad	*Duttaphrynus melanostictus*	Omnivore	Common	1–5
Ashy prinia	*Prinia socialis*	Insectivore	Occasional	1–5
Nilgiri black bird	*Turdus simillimus*	Omnivore	Occasional	1–5
Black-shouldered kite	*Elanus caeruleus*	Carnivore	Occasional	1–5
Blue-rock pigeon	*Columba livia*	Omnivore	Common	1–5
Bush lark	*Mirafra erythroptera*	Omnivore	Common	1–5
Common rose finch	*Carpodacus erythrinus*	Omnivore	Common	5
Great tit	*Parus cinereus*	Omnivore	Occasional	1–5
Hoopoe	*Upupa epops*	Omnivore	Common	1–5
House crow	*Corvus splendens*	Omnivore	Common	1–5
House sparrow	*Passer domesticus*	Omnivore	Common	1–5
Jungle babbler	*Turdoides striata*	Omnivore	Rare	1–5
Jungle crow	*Corvus macrorhynchos*	Omnivore	Common	1–5
Jungle myna	*Acridotheres fuscus*	Omnivore	Common	1–5
Grey wagtail	*Motacilla cinerea*	Carnivore	Common	1–5
Long-tailed shrike	*Lanius schach*	Carnivore	Common	1–5
Painted bush quail	*Perdicula erythrorhyncha*	Omnivore	Common	1–5
Pea fowl	*Pavo cristatus*	Omnivore	Occasional	5
Pied bushchat	*Saxicola caprata*	Omnivore	Common	1–5
Red-vented bulbul	*Pycnonotus cafer*	Omnivore	Common	1–5
Red-whiskered bulbul	*Pycnonotus jocosus*	Omnivore	Common	1–5
Skylark	*Alauda arvensis*	Omnivore	Occasional	1–5
Spotted dove	*Streptopelia chinensis*	Omnivore	Common	1–5
White-throated fantail	*Rhipidura albogularis*	Omnivore	Common	1–5
Yellow wagtail	*Motacilla flava*	Omnivore	Common	1–5
Nilgiri blue flycatcher	*Eumyias albicaudatus*	Omnivore	Occasional	1–5
Spotted/scaly breasted munia	*Lonchura punctulata*	Omnivore	Common	4–5

Crop stages: 1, Field preparation; 2, Germination; 3, Vegetative phase; 4, Reproductive phase and 5, After harvest.

prefer to nudge the germinating seeds. Black-naped hare was a rare visitor and preferred to eat only barley crops at the vegetative stage before internode formation. Out of 180 snake species reported from the Nilgiris[28], four, namely the Indian rat snake, buff-striped keel-back, green keel-back and the Nilgiri burrowing snake, were observed in the wheat fields. Rodents and common Indian toads in wheat fields were the primary prey of the Indian rat snake, keel-backs and Indian grey mongoose. The endemic Nilgiri burrowing snake, which prefers subterranean life, was observed while undertaking intercultural field operations such as forking and hoeing.

Among all the fauna documented from the wheat fields, the menace caused by the Nilgiri gaur, spotted munia, and common rose finch was notable. The frequent damage of wheat crops by the Nilgiri gaur and birds during frontline demonstration trials in the Southern Hill Zone has been well documented[29]. Moreover, the proximity of cultivable lands to reserve forests, crop cover, nearby water source and low precipitation increase the frequency of animals encountered in agricultural fields[30]. In addition, the absence of cost-effective techniques to ward-off wild animals and the drudgery involved in manual bird scaring have forced the farmers to grow other high-remunerative vegetable crops.

Conclusion

This study provides detailed information on the fauna associated with wheat crops in the southern hilly region. This

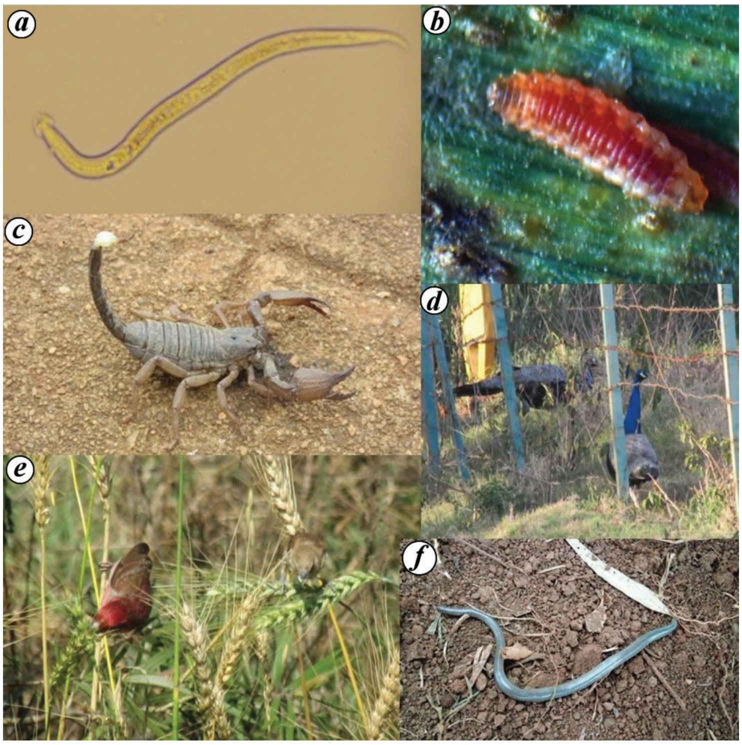

Figure 5. Biodiversity in the wheat ecosystem of the Western Ghats. ***a***, *Wilsonema* sp.; ***b***, *Mycodiplosis coniophaga*; ***c***, Scorpion carried along with FYM from low-altitude regions; ***d***, Peafowl found at an altitude of 1850 m; ***e***, Rose finch feeding on wheat grains; ***f***, Perrotet's shield tail.

will be helpful for the local farmers and entrepreneurs to take up necessary management interventions during wheat cultivation. Among all the fauna documented from the wheat fields, the menace caused by the Nilgiri gaur, spotted munia and common rose finch, is main reason for the non-preference of wheat crop by the farmers. Another reason is the availability of other high-remunerative crops. However, these input-intensive vegetable crops support less biodiversity and hence the traditional cereal crops like wheat, ragi and samai have to find a place back in the farmer's cropping sequence for environmental safety and sustainability. The overall biodiversity data collected during this study can help devise sustainable crop management strategies for wheat. Further, information on native biodiversity associated with wheat in high altitudes will benefit researchers in the future, in addition to promoting wheat crops to the non-traditional areas of the southern hills of Tamil Nadu.

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ACKNOWLEDGEMENTS. We thank the scientists of ICAR-National Bureau of Agricultural Insect Resources, Bengaluru for confirming the identification of insects and spiders, http://indiansnakes.org/ for the identification of snakes; Mr Stanley, J. F. and Mr Krishnan for assistance during the collection and documentation of the fauna; Dr P. Nallathambi and Dr J. Nanjundan (ICAR-Indian Agricultural Research Institute (IARI), RS, Wellington) for useful comments on an earlier version of the manuscript. This research was supported under ICAR-IARI projects.

Received 11 August 2022; revised accepted 25 October 2022

doi: 10.18520/cs/v124/i4/426-433