

Species Diversity and Community Structure of Arthropod Pests and Predators in Flax, *Linum Usitatissimum* L. from Darjeeling (India)

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ABSTRACT

The species richness and relative abundances of different aboveground plant-dwelling pest and predator species were assessed in flax (*Linum usitatissimum* L.) ecosystem under mid-hill conditions of eastern Himalayas. The experiment was conducted in winter seasons during 2004-2013 at the Regional Research Station (Hill Zone), Uttar Banga Krishi Viswavidyalaya, Kalimpong, West Bengal, India. Twenty five species of phytophagous arthropods under 13 families were observed belonging to 6 different orders. The gram pod borer, *Helicoverpa armigera* (Noctuidae: Lepidoptera), aphid, *Myzus persicae* (Aphididae: Hemiptera), shield bug, *Plautia fimbriata* (Pentatomidae: Hemiptera) and leaf webber, *Nacoleia* sp. (Pyralidae: Lepidoptera) were found as the most common and major insect of flax. In terms of species composition, Hemiptera and Lepidoptera occupied top position (nine species) while Coleoptera ranked second position (five species). By the size of population, aphid was found to be the most frequent species followed by shield bug and leaf webber. Although, the incidence of gram pod borer was low in the field, it was the major pest of flax in respect of bud and capsule damage. The Gini-Simpson index and Effective number of species for the pest faunal complex of flax was calculated as 0.914 and 11.628, respectively. Similarly, 16 species of predatory arthropods under nine families were observed belonging to 7 different orders. The lynx spider (17.24 %) and 7-spotted lady beetle (15.52 %) dominated the predatory community by sheer number. The Gini-Simpson index and Effective number of species for the predatory fauna was derived as 0.898 and 9.804, respectively.

Key words: Flax, pests, predators, species richness, abundance

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INTRODUCTION

Flax (*Linum usitatissimum* L.) is an oilseed and fibre crop [¹] that belongs to the family Linaceae. Flax is believed to have originated in Mediterranean regions and/or South-west Asia [²]. Oilseed varieties and fibre varieties are specialized development of this species. The cultivars grown for fibre purpose are tall growing with straight culms and have fewer secondary branches. Flax is a source of industrial fibres and, presently, flax fibres have become an important part of new composite materials utilized in automobile and constructive industries. It is a cool season crop and grows well during winter season in the mid-hill conditions of West Bengal, India.

Arthropods are important components of ecosystems occupying vital positions in food webs, dynamics of populations and communities. They play various roles in ecosystems acting as herbivores, predators, decomposers, parasitoids and pollinators [³]. The knowledge of population ecology of arthropods in an agro-ecosystem is of utmost importance for a clear understanding of the numerous relationships between crop plants, insects and natural enemies. The information regarding the diversity of arthropod in a particular agroecological condition is very much important for formulating suitable pest management strategies. Arthropods because of their small size, diversity and sensitivity to environmental variability, can be good indicators of habitat heterogeneity, ecosystem biodiversity, and environmental stress [⁴].

Population ecologist discussed diversity of arthropods in two aspects, the number of species present (i.e. species richness) and their relative abundance (i.e. dominance or evenness). The species diversity and their relative abundance in a community are measured mathematically by a number of diversity indices. Therefore, diversity indices provide more information about community composition than simply species richness; they also take the relative abundances of different species into account. Diversity indices provide important information about rarity and commonness of species in a community. The ability to quantify diversity in this way is an important tool for biologists trying to understand community structure. But, entropies such as the Shannon-Wiener and Gini-Simpson indices are not themselves diversities. Conversion of these indices to effective number of species is the key to a unified and intuitive interpretation of diversity [⁵].

The diversity of pests and predators in flax has earlier been studied by Deshmukh et al. [⁶], Malik [⁷], Prasad and Prasad [⁸] and Mishra and Ali [⁹] under varied agro-climatic conditions of India. However, such information with respect to flax agroecosystem is very much scanty particularly from hill zone of West Bengal. Keeping this point in view, the present investigation was undertaken to study the species diversity and community composition of aboveground plant-dwelling arthropod pests and predators in flax under agro-climatic conditions of Darjeeling hills.

MATERIALS AND METHODS

Study area

The experiment was carried out at Kalimpong (27° 04' N latitude and 88° 35' E longitude at an elevation of 1250 meter above the MSL) that lies in the northern part of West Bengal (India) in the mid-hills of eastern Himalayas. The average maximum and minimum temperature round the year recorded 20° C and 2° C respectively. The relative humidity varies from 70 to 80% depending upon the season. The average rainfall varies from 2500 to 3000 mm, of which 80% is received during June to September. The farm where the experiment was conducted is situated in the hilly terraces with a comparatively heterogeneous landscape pattern. More heterogeneous

landscapes contain many different production cover types (e.g. different field crops, intensively grazed lands, orchards) which are distributed in a complex pattern and interspersed with other, more 'natural', cover types (e.g. extensively grazed or non-grazed woodlands, wetlands, field margins). Such patterns are characteristic of traditional farming systems, in contrast with intensive agricultural systems which typically contain only a few sown crop types distributed in large uniform fields [10].

Sampling technique and data collection

The number of species was the simplest measure of species diversity. The counting of aboveground arthropod pests and predators were done by one absolute method viz., visual searching and one relative method viz., using sweep net. The jassid, aphid and thrips population were counted from a random sample of 5 plants taken from each plot. Three leaves were chosen randomly on each plant, selecting one leaf each from top, middle and bottom portion of plant. The lower surface of leaf was thoroughly examined for the presence of any insect [3,11,12]. The data were pooled over the season and season's average was combined to provide an overall average density per plot. The population of beetles, large sized bugs, grasshoppers and spiders were counted from 3 branches selected randomly from 5 plants each plot. Sweeping method was used for counting flying insects. Five times sweeping was done in each plot to make a composite sample. Each sample was examined separately without killing the insects and released them in the same plot immediately after counting.

Identification

The coreid and pentatomid bugs were identified by Dr. Animesh Bal, Hemiptera section, ZSI, Kolkata. Thanks are due to the In-charge, C.E.L. section for identifying the coccinellid beetles.

Statistical Analysis

The Gini-Simpson index [13] and Effective number of species [5] were applied to understand the community composition of pests and predators.

So, Gini-Simpson index (x) = $1 - \sum_{i=1}^s p_i^2$

Where, p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), \sum is the sum of the calculations and s is the total number of insect species found in the community (i.e., the richness).

But, Gini-Simpson index is not itself diversity, it has to be converted to effective numbers of species before it can be treated as true diversity [5]. The number of equally-common species required to give a particular value of an index is called the "effective number of species".

i.e. Effective number of species = $1/(1-x)$

Where, x is the Gini-Simpson index.

RESULTS

Herbivores community

Twenty five species of herbivores belonging to 13 different families under 6 orders were recorded from the flax ecosystem (Table 1). Nine species of insect pests were found to infest the reproductive parts of plants (flower buds and fruits), nine species were recorded on the stem, and twenty four insect pests were found to damage the foliage. Most of the insect pests belonged to three orders such as Hemiptera,

Lepidoptera and Coleoptera. In terms of species composition Hemiptera and Lepidoptera occupied top position (9 species) while Coleoptera ranked second position (5 species).

Table 1: List of insect pests observed in the flax ecosystem and their relative abundance

Order	Family	Common name	Scientific name	Plant part harboured	Population Frequency (%)
Hemiptera	Aphididae	Green peach aphid	<i>Myzus persicae</i> Sulzer	Leaf, stem and flower bud	15.77
	Cicadellidae	Green leaf hopper	<i>Empoasca kerri</i> Pruthi	Leaf	0.77
	Tingidae	Lace wing bug	Unspecified	Leaf and stem	2.31
	Pentatomidae	Shield bug	<i>Plautia fimbriata</i> (Fabricius)	Leaf, stem and capsule	15.38
	Pentatomidae	Green stink bug	<i>Nezara viridula</i> (Linnaeus)	Leaf, stem and capsule	1.54
	Pentatomidae	Shield bug	<i>Dolychoris baccarum</i> Linnaeus	Leaf, stem and capsule	1.15
	Pentatomidae	Shield bug	<i>Dolychoris</i> sp.	Leaf, stem and capsule	3.46
	Coreidae	Coreid bug	<i>Cletus punctulatus</i>	Leaf, stem and capsule	0.38
	Coreidae	Coreid bug	<i>Cletus</i> sp.	Leaf, stem and capsule	0.38
Coleoptera	Chrysomelidae	Steel blue beetle	<i>Altica</i> sp.	Leaf	1.54
	Chrysomelidae	Flea beetle	<i>Phyllotreta cruciferae</i> (Goeze)	Leaf	5.00
	Chrysomelidae	Flea beetle	<i>Phyllotreta striolata</i> (Fabricius)	Leaf	8.85
	Chrysomelidae	White spotted flea beetle	<i>Monolepta signata</i> Oliver	Leaf	1.15
	Chrysomelidae	Red pumpkin beetle	<i>Aulacophora foveicollis</i> (Lucas)	Leaf	0.38
Lepidoptera	Pyralidae	Leaf webber	<i>Nacoleia</i> sp.	Leaf	10.38
	Noctuidae	Green semilooper	<i>Plusia orichalcea</i> (Fabricius)	Leaf	4.62
	Noctuidae	Black semilooper	<i>Grammodes stolidus</i> Fabricius	Leaf	5.38
	Lymantriidae	Hairy caterpillar	<i>Euproctis scintillans</i> Walker	Leaf	0.38
	Noctuidae	Gram pod borer	<i>Helicoverpa armigera</i> (Hubner)	Capsule	2.31
	Noctuidae	Tobacco caterpillar	<i>Spodoptera litura</i> (Fabricius)	Leaf	0.38
	Noctuidae	Cutworm	<i>Agrotis</i> sp.	Stem	0.38
Diptera	Agromyzidae	Pea leaf miner	<i>Phytomyza horticola</i> Goureaux	Leaf	5.00
	Cecidomyiidae	Bud fly	<i>Dasineura lini</i> Barnes	Flower bud	0.77
Orthoptera	Acrididae	Surface grasshopper	<i>Atractomorpha</i> sp.	Leaf	7.69
Thysanoptera	Thripidae	Thrips	Unspecified	Leaf	4.62

The data (Table 1) also revealed the relative abundance of different insect pests in flax agroecosystem. It was recorded that the relative abundance (herbivores) of hemiptera, lepidoptera, coleoptera, orthoptera, diptera and thysanoptera were 41.14, 23.83, 16.92, 7.69, 5.77 and 4.62 per cent respectively (Figure 1). Aphid (*Myzus persicae* Sulzer) was ranked first with respect to the frequency followed by shield bug (*Plautia fimbriata* Fabricius), leaf webber (*Nacoleia* sp.) and flea beetle (*Phyllotreta striolata* Fabricius). The aphid (*Myzus persicae* Sulzer) and shield bug (*Plautia fimbriata* Fabricius) consisted of 15.77 and 15.38 per cent of the total population in the flax aboveground herbivores community. Therefore, by number, the sucking insects such as aphid and shield bug occupied the top position in the flax agroecosystem. The population frequency of leaf webber (*Nacoleia* sp.) and flea beetle (*Phyllotreta striolata* Fabricius) was 10.38 and 8.85 per cent, respectively. Although the frequency of adult gram pod borer (*Helicoverpa armigera* Hubner) was very low (2.31 %) in the field, it was the major pest of flax in respect of capsule damage. The number of adult gram pod borer was very low due to nocturnal in habit and no trap was used to collect the adult at night. Next to gram pod borer, aphid, shield bug and leaf webber were the important pests of flax.

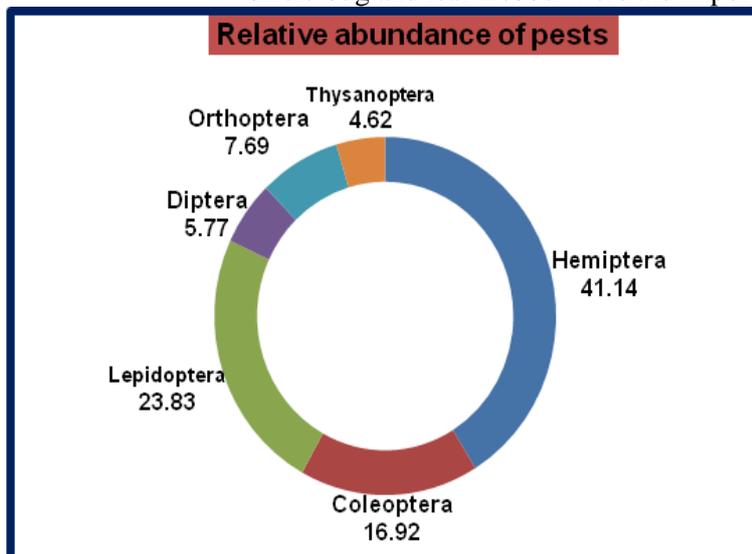


Figure 1: Relative abundance (%) of herbivorous arthropods in the flax ecosystem

Predaceous community

The predaceous arthropods in the flax ecosystem were grouped in 9 families under 7 taxonomical orders (Table 2). In total sixteen species of aboveground predatory arthropods were observed in the flax ecosystem. The relative abundance of different predators has been presented in the figure 2. Mainly spiders (37.92 %) and lady bird beetles (37.91 %) constituted the aboveground predatory fauna in the flax ecosystem. The lynx spider, *Oxyopes* sp. (17.24 %) dominated the flax ecosystem when population frequency is considered followed by the 7-spotted lady beetle, *Coccinella septempunctata* (15.52 %). The rest of the predaceous insects belonged to the order Orthoptera, Dictyoptera, Hymenoptera, Hemiptera and Odonata.

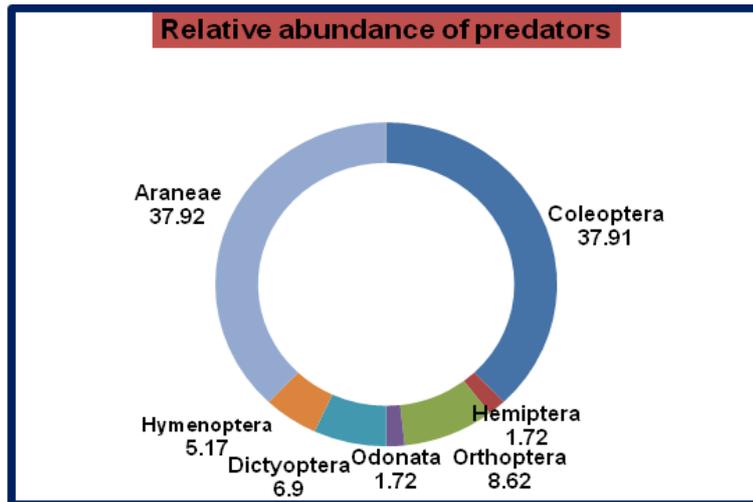


Figure 2: Relative abundance (%) of predaceous arthropods in the flax ecosystem

Table 2: List of predaceous arthropods observed in the flax ecosystem and their relative abundance

Order	Family	Common name	Scientific name	Stage observed	Population Frequency (%)
Coleoptera	Coccinellidae	Lady beetle	<i>Coelophora sexareata</i> Mulsant	Adult	5.17
	Coccinellidae	Lady beetle	<i>Coccinella transversalis</i> Fabricius	Larva and adult	1.72
	Coccinellidae	Lady beetle	<i>Coccinella septempunctata</i> Linnaeus	Larva and adult	15.52
	Coccinellidae	Lady beetle	<i>Oenopia kirbyi</i> Mulsant	Adult	8.62
	Coccinellidae	Lady beetle	<i>Oenopia sauzeti</i> Mulsant	Adult	1.72
	Coccinellidae	Lady beetle	<i>Coelophora unicolor</i> (Fabricius)	Adult	1.72
	Coccinellidae	Lady beetle	<i>Micraspis discolor</i> (Fabricius)	Larva and adult	1.72
	Coccinellidae	Lady beetle	<i>Illeis</i> sp. (Fabricius)	Adult	1.72
	Hemiptera	Pentatomidae	Brown stink bug	<i>Andrallus spinidens</i> Fabricius	Adult
Orthoptera	Tettigonidae	Long horned grasshopper	<i>Conocephalus longipennis</i> (de Haan)	Adult	8.62
Odonata	Libellulidae	Dragonfly	<i>Crocothemis</i> sp.	Adult	1.72
Dictyoptera	Mantidae	Praying mantis	<i>Mantis</i> sp.	Adult	6.90
Hymenoptera	Formicidae	Fire ant	<i>Solenopsis geminata</i> Fabricius	Adult	5.17
			<i>Pardosa</i> sp.	Adult	10.34
Araneae	Oxyopidae	Lynx spider	<i>Oxyopes</i> sp.	Adult	17.24
	Tetragnathidae	Long jawed spider	<i>Tetragnatha</i> sp.	Adult	10.34
	Lycosidae	Wolf spider	<i>Pardosa</i> sp.	Adult	10.34

Diversity index

The Gini-Simpson index and Effective number of species for the pest faunal complex of flax was calculated as 0.914 and 11.628, respectively. This means that, according to the Gini-Simpson index, the herbivorous arthropod community of flax ecosystem has the same diversity as a community with $11.628 \approx 12$ equally-common species. Similarly, the Gini-Simpson index and Effective number of species for the predatory fauna was derived as 0.898 and 9.804, respectively. This interprets that the predatory arthropod community of flax has the same diversity as a community with $9.804 \approx 10$ equally-common species. So, the aboveground plant-dwelling pest and predator community of flax have more or less same diversity pattern as a community with 12 and 10 equally-common species, respectively.

DISCUSSION

Biodiversity is one of the primary interests of ecologists, but quantifying the species diversity of ecological communities is complicated. In addition to issues of statistical sampling, the rather arbitrary nature of delineating an ecological community and the difficulty of positively identifying all of the species present make it a challenging job to have a clear understanding of tritrophic interactions taking place in a specific agroecosystem. In the present study, there has been an attempt to have a clear understanding of the community structure of the pests and predators of flax ecosystem. In total, twenty five species of insect pests and sixteen species of predators have been found to occur on flax. Earlier, a number of researchers have tried to study the arthropod diversity in flax under varied agroclimatic conditions. Flax is cultivated for both seed (oilseed flax) and fibre (linen flax) [14]. The cultivars grown and the production practices used differ depending on the intended use of the flax crop. But there exists no difference in insect diversity between flax grown for seed or for fibre [15]. Twenty eight insect pests have been recorded in an overlapping manner on linseed under the agroclimatic condition of central Uttar Pradesh, India [7]. But Prasad and Prasad [8] could record only twelve insect species to infest linseed in Jharkhand, India. Among the natural enemies of insect pests, spiders, black ants and rove beetle were noticed to be associated with the linseed agroecosystem. Deshmukh et al., [6] recorded twenty one insect pests and one mite pest along with five natural enemies associated with insect pests of linseed at Delhi. Gavloski et al. [16] tabulated twelve insect pests including root feeders, foliage and seed feeders and sap feeders to be most common insect species infesting flax in the Canadian prairies. These variations in the arthropod species diversity from the observations of our present study might be due to varied agroclimatic conditions as well as agroecological habitats of the locality in which the crop was grown.

The capsule borer, *Helicoverpa armigera* (Hubner) was observed as a major pest of flax during the present investigation. This observation draws support from the findings of Gavloski et al. [16], Klein Koch and Waterhouse [17], Prasad and Prasad [18] and Deshmukh et al. [6] who all recorded *Helicoverpa* spp. as an important pest of flax occurring in the different agroclimatic and ecological habitats all over the world. The shield bug, *Plautia fimbriata* (Fabricius) has been recorded for the first time as a major pest of flax from India. Earlier, it has been reported as a minor pest of pigeonpea, field bean, cowpea, cotton, and several other plants [19]. Linseed bud fly, *Dasyneura lini* (Barnes) has been reported as a key pest of flax from different parts of India [7,9,18]. But these observations are in contradiction with our present findings where it has been recorded as a minor pest in the hilly region of Eastern Himalaya of West Bengal, India. However, the results obtained conformed to the

findings of Pathak [²⁰] who reported bud fly as a minor pest of linseed in all the states of North East India.

During the course of present study the spiders and lady bird beetles were emerged as the most dominant group of generalized predators in the flax ecosystems. These observations corroborate with the reports of Prasad and Prasad [⁸] and Patel and Thakur [²¹] who witnessed significant role of spiders (unidentified) and rove beetles (*Paederus* spp.) in reducing and checking the pest population build up in linseed. But contrary to these reports rove beetles could not be recovered from the flax ecosystem of Darjeeling hills during the present course of study.

CONCLUSION

The arthropod diversity was found to be quite rich in the flax agroecosystem under hilly terrain of Eastern Himalayas of Darjeeling, India. The diversity of herbivorous community marginally surpassed that of predatory community both in terms of Gini-Simpson index and Effective number of species occurring in the flax ecosystem.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this paper.

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