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Species diversity of predators on sucking pest complex in mulberry gardens of West Bengal

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Abstract
Mulberry, the sole food plant of silkworm, *Bombyx mori* (Linnaeus) is invaded by a variety of polyphagous pests, severely hampering sericulture. Present study was conducted to identify natural species diversity and population dynamics of native predators of major sucking pests of mulberry in tropical ecosystem of Eastern India. Seasonal incidence of major sucking pests (thrips, mealybug and whitefly), species diversity and population dynamics of their native predators on unsprayed (n=6) was compared with sprayed (n=6) mulberry gardens during 2014-15. At least eighteen predators that were consistently associated with the sucking pests of mulberry were collected in the unsprayed gardens. Major predators of thrips were *Micraspis discolor* and *Micraspis crocea*. The mealybugs were predated by chrysopid, *Mallada desjardinsi* (Navas) and coccinellid species *Menochilus sexmaculatus*, *Coccinella septempunctata*, *Scymnus sp*, *Scymnus coccivora*, *S. bourdilloni*, *S. nubilus*, *S. pallidicollis*, *S. pyrocheilus*, *Nephus bipunctatus*, *Nephus sp. nr. roepkei* and *Nephus regularis*. Two species of whiteflies, *Dialeuropoda dicempuncta* Quaintaince & Baker and *Aleuroclava pentatuberculata* Sundararaj & David were predated by *Brumoides suturalis*, *Jauravia pallidula*, *Serangium parcetosum* and *Chilocorus* sp. The sprayed mulberry gardens conspicuously indicated non-specific elimination of the insect species with reduced species richness and abundance. Biodiversity indices were calculated for the sprayed and unsprayed gardens and the results emphasized the relevance of conservation biological control to reduce pest burden in mulberry and to promote species diversity.

Keywords: Sucking pest, Mulberry, species diversity

Introduction

Mulberry, the sole food plant of silkworm, *Bombyx mori* (Linnaeus) is invaded by a variety of polyphagous pests, severely hampering sericulture. Thrips, mealy bug and whiteflies are the major sucking pests in mulberry due their perennial occurrence, persistent level of abundance and extent of damage potential. During varying seasons, these pests used to cause qualitative and quantitative leaf yield loss to the tune of 10% - 25%. Due to thrips incidence leaf damage in mulberry was reported to the tune of 22.17% [1]. The leaf yield loss incurred due to pink mealy bug infestation was 69.87 kg/ha/crop [2]. Two species of whiteflies, *Dialeuropoda dicempuncta* Quaintaince & Baker and *Aleuroclava pentatuberculata* Sundararaj & David were reported in mulberry accounting to a leaf yield loss to the tune of 24% [3]. Recently the invasive exotic pest, papaya mealybug, *Paracoccus marginatus* got entry into West Bengal and infestation in mulberry were recorded during 2013-14 [4]. Application of chemical pesticides reduces the pest infestation, on the other hand creates an imbalance by affecting the population dynamics of the associated predators.

The Indo-gangetic plains of West Bengal harbour rich fauna of native arthropod predators. Knowledge of spatial and temporal diversity patterns is a key prerequisite for the development of effective strategies of biodiversity conservation [5]. The control of pest insects is relied heavily on chemical insecticides which are often overused or misused. The beneficial species, such as parasites and predators that check the outbreak of insect pests in the agro ecosystem is being frequently disturbed. To understand the changes that impact the insect population imbalance, studies on species diversity of the affected agroecosystem becomes indispensable. Various measures of species diversity continue to be useful tool in quantifying changes occurring naturally or induced by manipulation [6].

The objective of this work was to evaluate the species diversity, population dynamics of major sucking pests and their associated arthropod predators in sprayed and insecticide free mulberry gardens. The study envisages to explain the influence of insecticide spraying on the composition of insect pests and beneficial arthropods in mulberry.

Materials and methods

Study area

The present study was conducted at Central Sericultural Research and Training Institute, Berhampore and farmers field in Murshidabad district (24.1 °N latitude 88.25°E longitude and 18m above MSL) during 2014-15. Twelve experimental plots of S1 mulberry plantation, 40 X 40m plot each (2'X2' spacing) of same age and sufficient isolation distance of at least 100m between each other were selected to minimise movement of arthropods from one field to other. The mulberry plantation were maintained as per standard agronomic package of practices except insecticidal application either on foliage or in soil [7, 8]. Six plots were maintained with insecticide protection by spraying 0.01% thiomethoxam (Actara ® Syngenta) twice at 15 and 30 days after pruning. Two sprays were recommended [9], after which the crop is allowed to grow up to 75 days and pruned. Another set of six plots were maintained without any insecticide spray. The standard pruning schedules were adopted in all the experimental plots as per the standard sericulture crop recommendations of West Bengal [10].

Sampling method

For monitoring the population trends of the pests and predators, 25 plants from each plot/ replication of each treatment (sprayed and unsprayed) were selected at random by taking five plants each from the four corners and five from the middle of the plot were examined. Sampling of sucking pests and associated predators was conducted at fortnightly intervals. Insect sampling techniques used for the study were dislodgement (sweep net), passive collection (trap) or visual estimation [11]. The major group of predators were found to be coccinellids and chrysopids. Hence, hand picking [12] and aspirator methods [13] were also used for collection. The collected predators were identified. Monthly population fluctuation of the major sucking pests (thrips, mealybug and whitefly) and all the associated arthropod predators were recorded. Thrips incidence was recorded as average number per leaf from top 4^{th}, 5^{th}, 6^{th} and 7^{th} leaf of the primary shoot. Mealybug infestation was scored as average population count per shoot. Whitefly population was recorded as average number per leaf from top, middle and bottom. The arthropod predators were estimated as number per plant. Studies on phenology, population trends of the sucking pest complex and their natural enemies were conducted.

Species diversity estimates

Species diversity was assessed within the habitat (α diversity) using methods described earlier [14, 15, 16]. To measure the species diversity of the insect community, the following measures and indices were calculated.

Abundance (N)

The individual number of insects was estimated using abundance (N), which is the number of individuals of a particular species found in a given unit area or volume [17].

Species Richness (S)

Species richness measuring the number of species found in ecological community, landscape or region is only the count of species and does not take into account the abundances of the species or their relative abundance distributions.

Relative Abundance (Pi)

Relative abundance (Pi) is the measure of the proportion of individuals over abundance (N) of all the species.

$$Pi = Ni/N \quad \text{----------------------------------} \quad (1)$$

where N represents the abundance of the i-th species in the sample in other words the total number of all individuals in the sample and

$$N = \sum_{i=1}^{s} Ni \quad \text{------------------------} \quad (2)$$

where S is the total number of species in the sample

Shannon-Wiener Diversity index (H')

In order to study the proportion of each species within the local community, species diversity was computed based on Shannon-Wiener formula [18]. It is a nonparametric measure of heterogeneity. The Shannon's index accounts for both abundance and evenness of the species present in the ecosystem. The diversity index was calculated by using the formula

$$H' = -\sum_{i=1}^{s} Pi \times In\ Pi \quad \text{-------------------------} \quad (3)$$

where Pi= relative abundance; In = logarithm to base e

$$\text{Or } H' = -\sum_{i=1}^{s} Ni/N \times In\ Ni/N \quad \text{-------------} \quad (4)$$

Pielou's evenness index (J'):

Evenness is a measure of biodiversity which quantifies how equal the community is numerically. The apportionment of individuals within species was measured with the evenness index J' [19].

$$J' = H'/H'_{max} \quad \text{----------------------------} \quad (5)$$

i=1

where H' is the observed Shannon-Wiener diversity index and H' max is the maximum possible diversity for the sample. H' max is numerically equal to loge S, where S is total number of species. J' is constrained between 0 and 1. Lesser the variation in communities between the species with dominant species lower J' is recorded and vice versa.

Simpson's index (D)

Simpson's index was calculated to assess the dominance or rareness of any species in the ecosystem [20].

$$D \quad \sum_{i=1}^{s} = Pi(Pi-1) \quad \text{or} \quad \sum_{i=1}^{s} D = Ni\,(Ni-1)\,/\,N(N-1) \quad \text{----------} \quad (6)$$

The value of D ranges from 0-1. With this index, 0 represents infinite diversity and 1 represents no diversity. Larger the value of D, the lower the diversity. This is neither intuitive nor logical. To overcome the problem of the counter-intuitive nature of Simpson's Index Simpson dominance index $\lambda = 1/D$, Gini-Simpson Index $1- \lambda$ and equitability $\lambda /(1- \lambda_{max})$ were also calculated.

Berger-Parker index of dominance (d)

Berger-Parker index of dominance is defined as:

$$d = N_{max} / N \quad \text{-------------------} \quad (7)$$

where N is the total number of individuals and Nmax is the number of individuals in the most abundant species.

Results and discussion

In the present study, the population dynamics and phenology of sucking pests and its associated arthropod predators as influenced by pesticide treatment was examined. The species diversity estimates were calculated based on the two year study. The region experiences tropical type of climate. The summer season extends from first week of March to June (26-43 ^{0}C) after a short spring. The rainy season stretches from July to the end of September. Autumn is experienced as a short period, from beginning of October to the middle of November. Winter season onset starts in the state from mid-November to February, with January being the coldest month with average minimum temperature ranging from 9 to 16 ^{0}C.

The mulberry crop are pruned five times in a year for rearing 4-5 commercial silkworm crops in West Bengal. During this regular pruning, the pest and predator population migrates from the crop to the border plants and other adjacent crops (data not shown). The decrease in the pest and predator population dynamics during 2nd fortnight of January, March, June, August and October was primarily due to the pruning practices adopted in all the experimental plots (Fig. 1). The pest incidence and the respective predator population graphs plotted against the months at fortnightly intervals for the two year study revealed that both pest and predator population declined in the insecticide sprayed plots as compared to unsprayed plots of mulberry in both the years (Fig.1A,B).

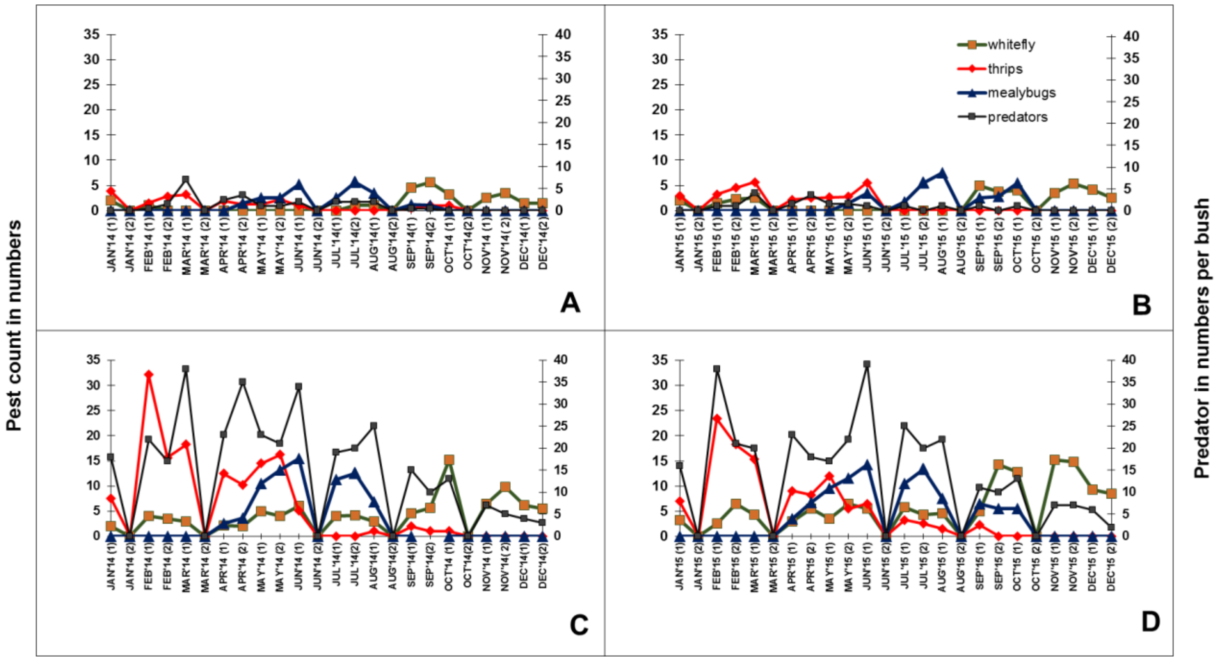

Fig 1: Sucking pests and predator population dynamics in insecticide sprayed gardens in 2014 (A) and 2015(B); unsprayed mulberry gardens 2014 (C) and 2015(D)

The two year study also revealed a specific pattern of sucking pest incidence along the mulberry crop phenology. Present study revealed the presence of thrips in mulberry from 1st fortnight of January to 2nd fortnight of June. After pruning at during 2nd fortnight of June, thrips population reduced and mealybug incidence was higher (Fig.1C and D). Five species of thrips viz., *Pseudodendrothrips mori* (Niwa), *Haplothrips tenuipennis* Bagnall, *Megalurothrips distalis*, *Bathrips melanicornis* Schumsher, *Psuedo dendro thrips ornatissimus* (Shmutz) and *Aelothrips intermedius* Bagnall were prominently found infesting mulberry (Table 1). Earlier findings also revealed these species of thrips in mulberry [21, 22].

Pink hibiscus mealybug, *Maconellicoccus hirsutus* (Green) was prevalent from 2nd fortnight of March to 2nd fortnight of August months in mulberry manifesting tukra symptoms. Papaya mealy bug, *Paracoccus marginatus* was recorded during June- July months of the year. The mealybugs were found to breed abundantly in summer months in the region, resulting in increased infestation of mulberry plants. Two species of whiteflies, *Dialeuropoda dicempuncta* and *Aleuroclava pentatuberculata* were found infesting mulberry throughout year and found severe during August to November months of the year (Fig.1).

The predators associated with the thrips population includes *Micraspis discolor* Fab. *and Micraspis crocea*. Fab. However, *Menochilus sexmaculatus* Fab. and *Coccinella septempunctata* Fab. were also found to check the population build-up of both thrips and psuedococcids. Regular association of a chrysopid, *Mallada desjardinsi* (Navas) and coccinellids *Scymnus sp*, *Scymnus coccivora*, *S. bourdilloni*, *S. nubilus*, *S. pallidicollis*, *S. pyrochielus*, *Nephus bipunctatus*, *Nephus sp. nr. roepkei* and *Nephus regularis*. were observed on mealybug populations infesting mulberry. *Brumoides suturalis*, *Jauravia pallidula*, *Serangium parcetosum*, *Micraspis discolor* and *Chilocorus* sp. were often found predating the egg and nymphal stages of the whiteflies.

Eighteen predators were found associated with the sucking pests of unsprayed mulberry gardens while only six species were collected in few number from the sprayed mulberry plots (Table 1). The percent relative abundance (Pi) of individual predator species indicates how common or rare a species is relative to other species in a given population of a location in unsprayed mulberry gardens the relative abundance varied from 1.44 to 9.78 percent among the eighteen species.

The Berger Parker index (d) explains the species dominance and unequal distribution of abundance between species. An increase in the Berger Parker dominance index value indicates a reduction in dominance. The individual species dominance expressed in Berger parker index (Table 1) shows that the most dominant species among all the predators, were *Brumoides suturalis* (9.78%) followed by *Serangium parcetosum* (9.64%). and *Scymnus* sp. (8.78%) in the insecticide free plots. In sprayed plots only six predators showed sustained existence with low population counts.

The species diversity estimates (Table.2) indicates the depletion of species richness and abundance in the sprayed gardens compared to unsprayed gardens. A significantly greater predator species richness (S=18) and abundance (N=358) was recorded in insecticide free treatments as compared to the sprayed gardens (S=6 and N=26). The differences were significant at $P < 0.05$.The mean predator population recorded from of insecticide free plots was significantly higher, 29.83 and 28.08 per month in a mulberry bush during 2014 and 2015 respectively, as against 1.58 and 2.17 per month in a mulberry bush in insecticide sprayed mulberry gardens.

Table 1: Species diversity estimates of predators of sucking pest complex in insecticide sprayed and unsprayed mulberry.

		Unsprayed			Sprayed		
		Species abundance Ni ± SE#	**Relative abundance (Pi)**	**The Berger-Parker Dominance Index (d)**	**Ni ± SE#**	**Relative abundance (Pi)**	**The Berger-Parker Dominance Index (d)**
Pseudodendrothrips mori (Niwa), *Haplothrips tenuipennis* Bagnall, *Megalurothrips distalis*, *Bathrips melanicornis* Schumsher, *Psuedodendrothrips ornatissimus* (Shmutz) and *Aelothrips intermedius* Bagnall *Maconellicoccus hirsutus* (Green) *Paracoccus marginatus* Williams and Granara de Willink *Dialeuropoda dicempuncta* Quaintaince & Baker *Aleuroclava pentatuberculata* Sundararaj & David	*Micraspis discolor* (Fabricius)	18.00 ± 1.85	0.052	1.89	6.50 ± 0.93	0.289	1.00
	Micraspis crocea (Fabricius)	13.00 ± 1.52	0.037	2.62	3.00 ± 0.58	0.133	2.17
	Menochilus sexmaculatus	10.00 ± 0.75	0.030	3.40	2.50 ± 0.33	0.111	2.60
	Coccinella septempunctata	16.00 ± 1.23	0.029	2.13	-	-	-
	Mallada desjardinsi (Navas)	10.50 ± 0.98	0.046	3.24	-	-	-
	Scymnus sp,	30.50 ± 2.60	0.088	1.11	1.50 ± 0.23	0.067	4.33
	Scymnus coccivora Ayyar	26.00 ± 2.41	0.075	1.31	-	-	-
	S. bourdilloni Kapur	20.00 ± 1.87	0.058	1.70	4.00 ± 0.68	0.178	1.63
	S. nubilus Mulsant	19.00 ± 1.93	0.055	1.79	-	-	-
	S. pallidicollis Mulsant,	22.00 ± 1.64	0.063	1.55	-	-	-
	S.pyrocheilus Mulsant	15.00 ± 1.06	0.043	2.27	-	-	-
	Nephus bipunctatus	14.00 ± 1.03	0.040	2.43	-	-	-
	Nephus sp.nr.roepkei	5.00 ± 0.63	0.014	6.80	-	-	-
	Nephus regularis	10.50 ± 0.74	0.030	3.24	-	-	-
	Brumoides suturalis (Fabricius)	34.00 ± 1.70	0.098	1.00	5.00 ± 0.42	0.222	1.30
	Jauravia pallidula Motschulsky	28.50 ± 1.64	0.082	1.19	-	-	-
	Serangium parcetosum Sicard	33.50 ± 1.83	0.096	1.01	-	-	-
	Chilocorus sp.	22.00 ± 1.40	0.063	1.55	-	-	-

Ni ± SE represents the pooled mean and standard error value of monthly data of 150 replications in each treatment.

Table 2: Diversity indices of the predators of sucking pest complex in mulberry

Diversity indices (^{q}D)	**2014 Unsprayed**	**2015 Unsprayed**	**2014 Sprayed**	**2015 Sprayed**
Abundance (N) No. of predator (Mean/bush/month)	358.00 ^{a} 29.83 ^{a}	337.00 ^{a} 28.08 ^{a}	26.00 ^{b} 1.58 ^{b}	19.00 ^{b} 2.17 ^{b}
Richness(S)	18.00 ^{ab}	18.00 ^{ab}	6.00 ^{bc}	4.00 ^{bc}
Shannon Weiner Diversity index (H')	2.81 ^{ac}	2.77 ^{ac}	1.74 ^{bd}	1.36 ^{bd}
Pielou's Evenness index (J') Hmax/H'	0.97 ^{ad}	0.96 ^{ad}	0.79 ^{be}	0.46 ^{be}
Simpson Dominance λ	0.06 ^{a}	0.07 ^{a}	0.19 ^{a}	0.26 ^{a}
Gini-Simpson Index (1- λ):	0.94 ^{a}	0.93 ^{a}	0.81 ^{a}	0.74 ^{a}
Equitability λ /(1- λ max)	0.99 ^{a}	0.99 ^{a}	0.98 ^{a}	0.98 ^{a}

Means in the same rows followed by the same letters are not significantly different at 0.05 % level of probability by Sidaks multiple comparison test

Comparing the species diversity indices of the treatments according to the Shannon-Wiener index values, unsprayed mulberry plots were distinctly more diverse than sprayed plots in both the study years. The Shannon index (H') increases as both the richness and the evenness of the community increased. Pielou's evenness index (J') values nearing one (0.97 and 0.96) of unsprayed gardens indicated the higher evenness compared to the sprayed gardens. The results revealed the stability of the ecosystem with balanced food web in insecticide free plots. On the other hand, the H' and J' implied that there is a negative influence of insecticides on the species diversity of predators.

Lower Simpson index in insecticide free plots indicated higher diversity when compared to relatively higher values in insecticide sprayed plots indicating the dominance of certain species. However, Simpson's dominance, Gini-Simpson and equitability indices depicting evenness of individuals were not significantly different at $p > 0.05$.

The results emphasise the relevance of conservation biological control to reduce pest burden in mulberry and to promote species diversity. Minimizing the level of disturbance by judicious insecticide use and habitat management in any agricultural ecosystem will determine the successful implementation of biological control [23, 24]. Mono-cropping of mulberry for sericulture practices increases the incidence of pests. On the other hand, the timely scheduled pruning practices reduces the predator coexistence with the pest. Enhancing plant diversity in agro-ecosystems, either through the use of non-crops in undergrowth or field margins can ensure non-prey food resources for the native predator species [25]. In mulberry crop grown for sericulture, predators are forced to emigrate upon pruning, crop senescence or harvesting. The predatory insects that are potential natural enemies in annual crop systems migrate cyclically between neighbouring fields with alternate hosts and surrounding permanent habitats.

Conclusion

The present study indicates a reduction in species richness and abundance in the insecticide sprayed mulberry gardens compared to the insecticide free plots, adversely affecting predator population dynamics of sucking pests of mulberry. Conservation of species diversity is advocated to effectively utilize the strength of native predators for bio control in mulberry gardens.

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