Research Article

BIODIVERSITY AND BIOCONTROL PROSPECTS IN MULBERRY GARDENS OF WEST BENGAL WITH SPECIAL REFERENCE TO NEW PREDATOR *SCYMNUS LATIFOLIUS*. SP. NOV ON MEALYBUGS INFESTING MULBERRY

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ABSTRACT

Mulberry, the sole food plant of silkworm, *Bombyx mori* (Linnaeus) is invaded by various polyphagous pests, causing economic loss in sericulture. Native predators in the plant ecosystem play a vital role in checking the pest infestation. In the present study, population dynamics, phenology of the arthropod predators of *Paracoccus marginatus* Williams and Granara de Willink and *Maconellicoccus hirsutus* (Green) infesting mulberry in four sericulture practicing districts (Murshidabad, Nadia, Birbhum and Malda) of West Bengal was studied. A diverse assemblage of alternate hosts and arthropod natural enemies were found associated with mealybugs infesting mulberry in the Indo gangetic plains of West Bengal. About 53 plant species acted as alternate hosts in the adjoining plots of mulberry gardens and profoundly influenced the population dynamics of mealybug pests and its associated predators and allowed migration rapidly from alternate hosts to mulberry as soon as the new flushes appeared after pruning. Sixteen predator species, were found consistently associated with mealybugs during the study. They are *Brumoides suturalis* (F), *Coccinella septempunctata* L., *Jauravia pallidula* Motschulsky, *Menochilus sexmaculatus* (F), *Nephus regularis* Sicard, *Nephus sp. nr. roepkei* de Fluiter., *Nephus bipunctatus* Kugelann, *Scymnus bourdilloni* Kapur, *Scymnus coccivora* Ayyar, *Scymnus nubilus* Mulsant, *Scymnus pallidicollis* Mulsant, *Scymnus pyrocheilus* Mulsant, *Spalgis epius* (Westwood), *Mallada desjardinsi* (Navas) and one anthocorid bug. Apart from these arthropods, one new species of *Scymnus* Kugelann, *Scymnus (Pullus) latifolius* Poorani sp. nov, was collected and reported for the first time. The predatory potential of the new predator was studied and amenability of the predator for mass multiplication in laboratory conditions opened avenues for its use as a potential biocontrol agent for checking mealybug pests in various agroecosystems.

INTRODUCTION

Mulberry sericulture is practised extensively in Indo-gangetic plains of West Bengal. The major pests of mulberry are thrips, mealybug, whitefly, root mealy bug and leaf webber. The mealybug attack in mulberry poses a serious threat to sericulture industry by reducing the availability of quality leaves for silkworm rearing. The pink hibiscus mealybug, *Maconellicoccus hirsutus* (Green) and papaya mealybug, *Paracoccus marginatus* causes severe qualitative and quantitative yield losses in mulberry gardens of West Bengal (Lalitha *et al.*, 2015a). Further, feeding the silkworms with the mealy bug infested leaves proved detrimental as it affected the growth and development of the silkworms and also the quality parameters of the cocoon (Sakthivel *et al.*, 2012).

In West Bengal, the first report of *P. marginatus* infestation was recorded during 2013 infesting papaya (Seni and Sahoo, 2013) and mulberry (Lalitha *et al.*, 2015b). The pest gradually spread to a greater extent in many alternate hosts. This suggests requirement of multitude control measures in

neighbouring host gardens to alleviate mealybug infestation and reduce economic losses in mulberry.

Biological control is an eco-friendly approach that provides feasible and long lasting solution to mealybug infestation. The biocontrol agents are self-perpetuating and persist even when the mealybug is at low population densities. Earlier survey conducted in West Bengal revealed several natural enemies associated with pests of mulberry. However, the inventory of natural enemies associated with mealybugs were changing year after year due to climatic variation, adaptation, availability of food during non-availability of hosts and other factors.

This study presents the diverse assemblage of alternate hosts and arthropod natural enemies that were found associated with mealybugs infesting mulberry in the Indo gangetic plains of West Bengal.

MATERIALS AND METHODS

The study was carried out in the mulberry fields of four sericulture districts namely Murshidabad (24.1 °N latitude 88.25°E longitude and 18m above MSL) and , Nadia (23.97° N, latitude 88.62° E longitude and 15m above MSL), Birbhum (24° 35' 0" N latitude 87° 5' 25" and 88° 1' 40" E longitude and 42m above MSL) and Malda (24°40'20" N latitude 87°45'50" E longitude and 31m above MSL) during 2014 and 2015.

The surveillance studies were done on a fixed plot survey in each location at Murshidabad, Nadia, Birbhum and Malda at fortnightly intervals. From each location three mulberry gardens of 0.5 acre area each were selected as one replication unit. The S_1 cultivar mulberry plantation was considered for data collection. The mulberry crops were pruned five times in a year for rearing 4-5 scheduled commercial silkworm crops. The selected sample plots of mulberry plantation were maintained as per standard agronomic package of practices (Krishnaswami, 1986; Choudhury and Giridhar, 1987) without insecticidal application either on foliage or in soil (Patnaik *et al.*, 2011).The standard pruning schedules were adopted in all the experimental plots as per the sericulture crop recommendations of West Bengal (Choudhury *et al.*, 1991). During the study period, the inventory of all alternate host plant species that were grown in the neighbouring plots of mulberry gardens were recorded.

Sampling of mealybugs and its associated arthropod predators was conducted at fortnightly intervals. For monitoring the population trends of the mealybug infestation and associated predators, 25 plants from each plot/ replication (N=3) were selected and examined at random by taking five plants each from the four corners and one from the middle of the plot in every location (Mukhopadhyay, 2006). Five infested mulberry shoots (one sample unit) were collected from each field (N=3) from four locations. The mealybug infested shoot portions of mulberry (15 cm length from the top) were cut along with the host population and all predator stages intact was reared in the laboratory until the adult predators emerged. The absolute counts of mealybugs and all arthropod predators associated with mealybugs in each sampling unit were recorded. The predators were sorted out and duly identified. Individuals which could not be identified to species were initially grouped at genus level and send to experts at NBAIR, ICAR, Bangaluru for further species level identification.

Species diversity was assessed within the habitat (α diversity) using methods suggested by Magurran, 2004 and Begon *et al*., 2006. Species abundance (Ni) was recorded, relative abundance (Pi), proportional abundance, Berger parker dominance and dispersion indices by variance mean ratio (VMR) were calculated.

RESULTS AND DISCUSSION

Population dynamics and phenology data indicated the highest record of predators during April to August months of the year, coinciding with the peak incidence of mealybugs in mulberry (Fig. 1). During 2015, the pest incidence extended even up to October month. The climate changes in the region changes the trend in favour of the pest. Susceptibility of the crop to mealybug infestation is increasing year after year due to shift in seasons due to climate change.

A diverse assemblage of alternate hosts and arthropod natural enemies were found associated with mealybugs infesting mulberry in the Indo gangetic plains of West Bengal. About 53 plant species acted as alternate hosts in the adjoining plots of mulberry gardens and profoundly influenced the population dynamics of mealybug pests and its associated predators and allowed migration rapidly from alternate hosts to mulberry as soon as the new flushes appeared after pruning.

The alternate host plant inventory (Table1) included a total of 53 plant species, of which seven belonged to family Malvaceae, eight belonged to family Solanaceae, four belonged to family Euphorbiaceae, three each, belonged to Amaranthaceae and Apocyanaceae, seven belonged to family Fabaceae, six belonged to family Cucurbitaceae, two plant species each, belonging to the families Rutaceae, and Asteraceae. One species each from Caricaceae, Simarubaceae, Annonaceae, Convolvulaceae, Anacardiaceae, Lauraceae, Myrtaceae, Lythraceae, Aizoceae, Moraceae and Lamiaceae.

Table 1: Inventory of alternate host plants of mealybugs in and around mulberry gardens from January 2014-December 2015 in four districts of West Bengal

Sl. No	Botanical Name	Family	Common name	Economic importance	Murshidabad	Nadia	Birbhum	Malda
1	*Abelmoshus esculentus*	Malvaceae	Bhendi/okra	Vegetable		+	+	+
2	*Abutilon indicum*	Malvaceae	Indian Mallow	Medicinal	+		+	
3	*Acalypha indica*	Euphorbiaceae	Acalypha	Ornamental		+	+	
4	*Acalypha wilkesiana*	Euphorbiaceae	Copper leaf	Ornamental	+		+	
5	*Ailanthus excelsa*	Simarubaceae	Ghoda neem	Medicinal	+	+	+	+
6	*Amaranthus cruentus*	Amaranthaceae	Spiny amaranth	Vegetable	+	+	+	+
7	*Amaranthus spinosus*	Amaranthaceae	Spiny amaranth	Vegetable	+	+	+	+
8	*Annona squamosa*	Annonaceae	Custard apple	Fruit Crop		+	+	
9	*Artocarpus heterophyllus*	Moraceae	Jack	Fruit Crop	+	+		+
10	*Cajanus cajan*	Fabaceae	Pigean pea	Pulses/Gram	+	+		+
11	*Capsicum annuum*	Solanaceae	Chilli	Vegetable		+		+
12	*Carica papaya*	Caricaceae	Papaya	Fruit Crop	+	+	+	+
13	*Ceiba pentandra*	Malvaceae	Kapok	Fibre		+	+	
14	*Celosia argentea*	Amaranthaceae	Cocks comb	Vegetable		+	+	
15	*Citrus maxima*	Rutaceae	Pomelo	Fruit Crop		+	+	
16	*Citrus. aurantifolia*	Rutaceae	Lime	Fruit Crop		+	+	
17	*Codiaeum variegatum*	Euphorbiaceae	garden croton	Ornamental	+	+		+
18	*Crotolaria juncea*	Fabaceae	Sunn hemp	Green Manure		+	+	
19	*Crotolaria retusa*	Fabaceae	Rattle weed	Weed		+	+	
20	*Cucurbita pepo*	Cucurbitaceae	Pumpkin	Vegetable	+	+	+	+
21	*Dolichos lablab*	Fabaceae	Field bean	Vegetable		+	+	+
22	*Hibiscus canabinus*	Malvaceae	Deccan Hemp	Medicinal	+		+	
23	*Hibiscus mutabilis*	Malvaceae	Changeable Rose	Ornamental	+		+	
24	*Hibiscus rosasinensis*	Malvaceae	China rose	Ornamental	+	+	+	+
25	*Hibiscus subdariffa*	Malvaceae	Roselle	Medicinal	+		+	+
26	*Ipomoea carnea*	Convolvulaceae	Morning glory	Medicinal	+	+		+
27	*Luffa acutangula*	Cucurbitaceae	ridged gourd	Vegetable		+	+	
28	*Luffa aegytiaca*	Cucurbitaceae	Sponge gourd	Vegetable	+	+		
29	*Lycopersicon esculentum*	Solanaceae	Tomato	Vegetable	+	+		+
30	*Mangifera indica*	Anacardiaceae	Mango	Fruit Crop		+	+	+
31	*Manihot esculenta*	Euphorbiaceae	Sweet potato	Vegetable	+	+	+	+
32	*Momardica charantia*	Cucurbitaceae	bitter gourd	Vegetable	+	+	+	+
33	*Nerium oleander*	Apocynaceae	Oleander	Ornamental	+	+	+	+
34	*Parthenium hysterophorus*	Asteraceae	Congress weed	Weed	+	+	+	+
35	*Persea americana*	Lauraceae	Avacado	Fruit Crop		+		
36	*Plumeria abtusa*	Apocynaceae	Indian chamba	Ornamental	+	+	+	+
37	*Plumeria rubra*	Apocynaceae	Red Frangipani	Ornamental	+	+	+	+
38	*Psidium guajava**	Myrtaceae	Guava	Fruit Crop		+	+	+
39	*Punica granatum*	Lythraceae	Pomegranate	Fruit Crop	+	+	+	+
40	*Solanum melongena*	Solanaceae	Brinjal	Vegetable	+	+	+	+
41	*Solanum nigrum*	Solanaceae	black nightshade	Vegetable	+	+	+	+

Sl. No	Botanical Name	Family	Common name	Economic importance	Murshidabad	Nadia	Birbhum	Malda
42	*Solanum torvum*	Solanaceae	Turkey berry	Vegetable	+	+	+	+
43	*Solanum trilobatum*	Solanaceae	Pea egg plant	Vegetable		+	+	
44	*Solanum tuberosum*	Solanaceae	Potato	Vegetable		+		+
45	*Solanum virginianum*	Solanaceae	Yellow night shade	Vegetable		+	+	
46	*Tectona grandis*	Lamiaceae	Teak	Timber	+	+		+
47	*Tephrosia purpurea*	Fabaceae	Indigo	Medicinal	+	+	+	+
48	*Trianthema portulacastrum*	Aizoaceae	Pig weed	Weed	+	+	+	+
49	*Trichosanthes cucumerina*	Cucurbitaceae	Snake Gourd	Vegetable		+		
50	*Trichosanthes dioica*	Cucurbitaceae	Pointed gourd	Vegetable	+	+	+	
51	*Tridax procumbens*	Asteraceae	Mexican daisy	Weed	+	+	+	+
52	*Vigna mungo*	Fabaceae	Black gram	Pulses		+	+	+
53	*Vigna radiata*	Fabaceae	Green gram	Pulses		+		+
Total Number					**32**	**48**	**41**	**34**

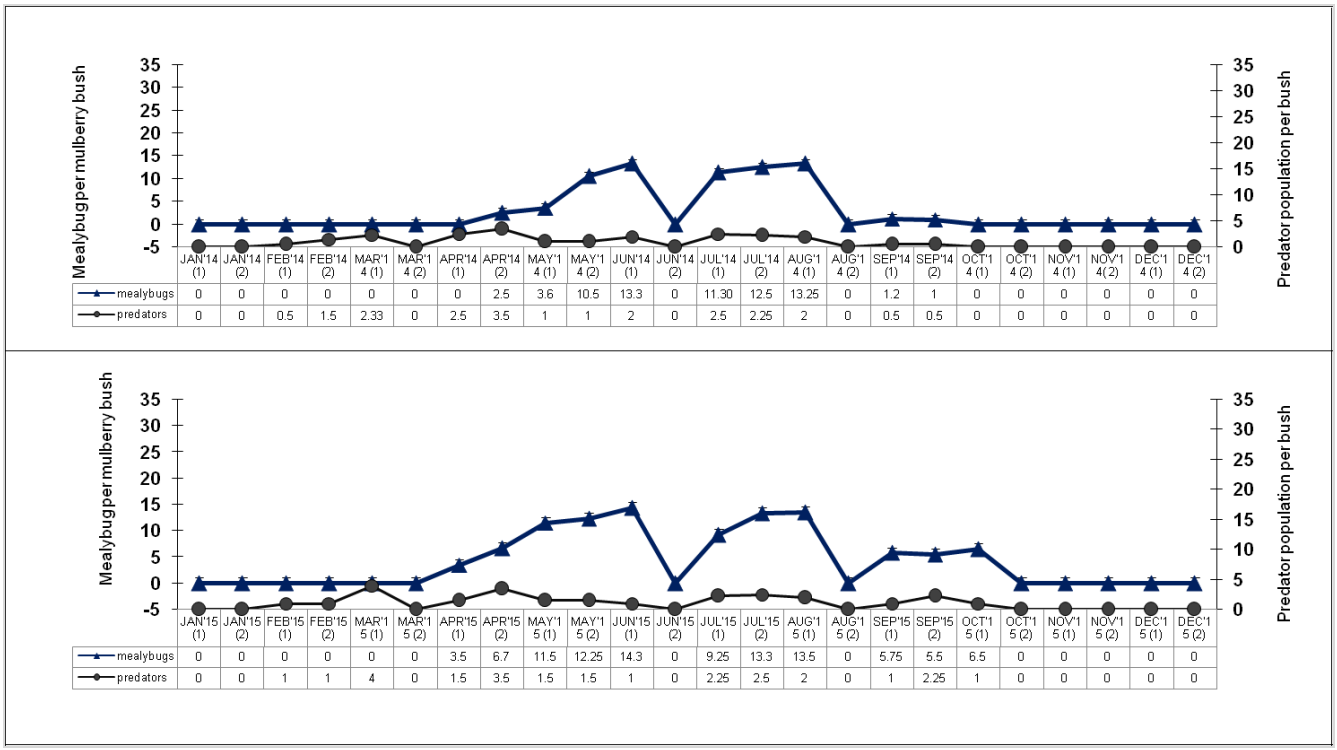

Figure 1: The population dynamics of mealybug pests and its associated predators during 2014(A) and 2015(B) in West Bengal

Among the four districts studied, maximum of 49 plant species was recorded in Nadia district as alternate hosts of mealybugs in the adjoining plots of mulberry gardens. In Birbhum district 41 alternate hosts were recorded while in Murshidabad and Malda district the number of alternate hosts recorded were 30 and 33 respectively. Murshidabad and Malda districts recorded lower plant diversity in sericulture tracts due to the mono cropping patterns of mulberry followed in earlier years. Among these hosts papaya and *Hibiscus rosa sinensis* recorded severe infestation of *P. marginatus* and *M. hirsutus*, while other alternate hosts recorded moderate infestation. Diversity of plant species in adjoining plots of mulberry gardens tend to profoundly influence the population dynamics of mealybugs

and its associated predators in mulberry. During pruning in mulberry, the pest and its predators remains in the alternate hosts. As soon as the new flushes appear after pruning in mulberry, the pest and its predators migrated rapidly from alternate hosts to mulberry. The results of present study confirms the earlier observations (Carrière *et al.*, 2012) that the population dynamics of many polyphagous pests depends on the characteristics of the surrounding landscape and crop management practices followed.

Sixteen predator species, were found consistently associated with mealybugs during the study. They are *Brumoides suturalis* (F), *Coccinella septempunctata* L., *Jauravia pallidula* Motschulsky, *Menochilus sexmaculatus* (F), *Nephus regularis* Sicard, *Nephus sp. nr. roepkei* de Fluiter., *Nephus bipunctatus* Kugelann, *Scymnus bourdilloni* Kapur, *Scymnus coccivora* Ayyar, *Scymnus nubilus* Mulsant, *Scymnus pallidicollis* Mulsant, *Scymnus pyrocheilus* Mulsant, *Spalgis epius* (Westwood), *Mallada desjardinsi* (Navas) and one anthocorid bug. Apart from these arthropods, one new species of *Scymnus* kugelann, *Scymnus (Pullus) latifolius* Poorani sp. Nov, was collected, described and reported for the first time (Poorani and Lalitha, 2018). This was earlier misidentified and accounted as *S. pallidicollis or S. apiciflavus.* Owing to the small size and difficulty in examination of male genitalia, classification of accurate species and identification of Scymnini tribe is often difficult (Wilson 1927; Pang and Gordon, 1986).

In Murshidabad district, the dominant species among all the predators, in descending order of abundance, were *S. latifolius* sp. nov. (13.52 %) followed by *S. coccivora* (12.85%) and *S. pyrocheilus* (9.68%) (Table 2). During 2014 seven species viz., *S. coccivora, S. latifolius* sp. nov., *S. nubilus, S.pallidicollis, S. pyrocheilus, J. pallidula* and *B. suturalis* were recorded 10-15 nos persample unit of five infested mulberry shoots. On the contrary, during 2015, only two species (*S. latifolius* sp. nov., *S. coccivora*) were recorded 10-15nos per sample unit. Only 14 predator species were recorded in this location.

Table 2: Species diversity estimates of predators feeding on mealybugs in mulberry at Murshidabad

Species	Species abundance (Ni)		Relative abundance (Pi)		Proportional abundance (%)	Berger parker dominance index	Dispersion Index (VMR)	Species ranking
	2014	2015	2014	2015				
Anthocorid bug	0.00	1.00	0.000	0.012	0.50	27.00	0.97	14
Brumoides suturalis (F)	10.00	8.33	0.089	0.096	9.18	1.47	0.86	5
Coccinella septempunctata	1.00	2.00	0.009	0.023	1.50	9.00	0.88	13
Jauravia pallidula Mots	12.33	8.67	0.110	0.100	10.52	1.29	1.31	3
Mallada desjardinsi (Navas)	2.67	1.33	0.024	0.015	2.00	6.75	1.01	12
Menochilus sexmaculatus (F)	5.67	5.00	0.050	0.058	5.34	2.53	0.88	9
Nephus regularis	6.67	3.00	0.059	0.035	4.84	2.79	1.30	10
Nephus bipunctatus	5.00	4.67	0.045	0.054	4.84	2.79	1.16	10
Scymnus bourdilloni Kapur	7.67	7.33	0.068	0.085	7.51	1.80	1.19	8
Scymnus coccivora Ayyar	13.00	12.67	0.116	0.146	12.85	1.05	1.50	2
*Scymnus latifolius*Poorani sp. nov.	14.33	12.67	0.128	0.146	13.52	1.00	1.70	1
Scymnus nubilus Mulsant	10.00	7.67	0.089	0.088	8.85	1.53	1.68	6
Scymnus pallidicollis Mulsant	11.67	6.00	0.104	0.069	8.85	1.53	1.68	6
Scymnus pyrocheilus Mulsant	13.00	6.33	0.116	0.073	9.68	1.40	1.98	4

In Nadia district, the dominant species among all the predators, in descending order of abundance, were *S. latifolius* sp. nov. (11.46 %) followed by *S. coccivora* (10.76 %), *S. bourdilloni* (9.88%) and *B. suturalis* (9.88%) (Table 3). During 2014 in Nadia district, *S. latifolius* sp. nov. And *S. coccivora* recorded 10-15 nos/ sample unit. Nine species were in 5-10 nos. and five species were recorded <5 nos per sample unit. However, in 2015 the predator species population increased and four species *S. bourdilloni, S.coccivora, S. latifolius* sp. nov., and *B. suturalis* recorded in the range of 10-15 nos per sample unit. The increase in the predator population in Nadia in the consecutive year could be attributed to the crop diversity compared to other districts where mono-cropping of mulberry were practised. Multiple cropping patterns followed in the region influenced the species diversity.

In Birbhum district, no predator species were recorded in the range of 10-15 nos per sample during both the years. Nine and seven species were recorded in frequency of 5-10 nos per sample unit during 2014 and 2015 respectively (Table-4). *M. desjardinsi* and *S. epius* were not recorded in this location. Mono-cropping of mulberry were common in this district.

Table 3: Species diversity estimates of predators feeding on *P. marginatus* in mulberry at Nadia

Species	Species abundance (Ni)		Relative abundance (Pi)		Proportional abundance (%)	Berger parker dominance index	Dispersion Index (VMR)	Species ranking
	2014	2015	2014	2015				
Anthocorid bug	1.00	1.00	0.011	0.010	1.06	10.83	0.92	16
Brumoides suturalis (F)	8.00	10.67	0.087	0.110	9.88	1.16	0.94	3
Coccinella septempunctata	2.33	1.67	0.025	0.017	2.12	5.42	0.84	14
Jauravia pallidula Mots	8.00	6.33	0.087	0.065	7.58	1.51	0.97	6
Mallada desjardinsi (Navas)	2.33	1.67	0.025	0.017	2.12	5.42	1.18	14
Menochilus sexmaculatus (F)	5.67	5.67	0.062	0.058	6.00	1.91	0.77	8
Nephus regularis	5.33	5.33	0.058	0.055	5.64	2.03	1.13	10
Nephus sp. nr. roepkei de Fluiter	2.67	2.00	0.029	0.021	2.47	4.64	1.10	13
Nephus bipunctatus	5.67	5.00	0.062	0.052	5.64	2.03	0.94	10
Scymnus bourdilloni Kapur	7.33	11.33	0.080	0.117	9.88	1.16	1.67	3
Scymnus coccivora Ayyar	10.00	10.33	0.109	0.107	10.76	1.07	1.58	2
Scymnus latifolius Poorani sp. nov.	11.00	10.67	0.120	0.110	11.46	1.00	1.50	1
Scymnus nubilus Mulsant	7.67	9.67	0.083	0.100	9.17	1.25	1.37	5
Scymnus pallidicollis Mulsant	5.67	5.67	0.062	0.058	6.00	1.91	1.31	8
Scymnus pyrocheilus Mulsant	6.33	6.00	0.069	0.062	6.53	1.76	1.15	7
Spalgis epius	3.00	4.00	0.033	0.041	3.70	3.10	0.91	12

Table 4: Species diversity estimates of predators feeding on *P. marginatus* in mulberry at Birbhum

Species	Species abundance (Ni)		Relative abundance (Pi)		Proportional abundance (%)	Berger parker dominance index	Dispersion Index (VMR)	Species ranking
	2014	2015	2014	2015				
Anthocorid bug	2.00	1.00	0.026	0.016	2.16	5.33	0.88	13
Brumoides suturalis (F)	7.00	6.33	0.091	0.103	9.62	1.20	0.65	3
Coccinella septempunctata	4.00	2.67	0.052	0.043	4.81	2.40	0.93	11
Jauravia pallidula Mots	5.67	5.33	0.073	0.087	7.93	1.45	0.85	7
Menochilus sexmaculatus (F)	6.33	3.67	0.082	0.060	7.21	1.60	0.72	9
Nephus regularis	4.67	2.67	0.060	0.043	5.29	2.18	1.17	10
Nephus sp. nr. roepkei de Fluiter	0.00	1.67	0.000	0.027	1.20	9.60	0.94	14
Nephus bipunctatus	3.00	3.33	0.039	0.054	4.57	2.53	0.96	12
Scymnus bourdilloni Kapur	8.67	7.33	0.112	0.120	11.54	1.00	1.35	1
Scymnus coccivora Ayyar	8.00	5.33	0.103	0.087	9.62	1.20	1.11	3
Scymnus latifolius Poorani sp. nov.	6.67	7.00	0.086	0.114	9.86	1.17	1.10	2
Scymnus nubilus Mulsant	8.67	4.67	0.112	0.076	9.62	1.20	1.41	3
Scymnus pallidicollis Mulsant	6.00	5.00	0.078	0.082	7.93	1.45	1.16	7
Scymnus pyrocheilus Mulsant	6.67	5.33	0.086	0.087	8.65	1.33	1.23	6

During 2014 in Malda district, only two species counted 10-15 nos/sample unit while, nine species were recorded in the frequency range of 5-10 nos/sample unit. In 2015, three predator species were recorded in the frequency range of 10-15 nos while, five predator species were recorded in the frequency range of 5-10 nos per sample unit (Table 5). The new species *S. latifolius* sp. nov. showed an increasing trend of species abundance from 2014 to 2015.

Berger-Parker Index is calculated to determine the dominance of species in a population (Berger and Parker, 1970). In all the four locations studied, the Berger Parker index values were ranging from 1-1.5 for all species of *Scymnus* (*S. bourdilloni*, *S. coccivora*, *S. latifolius*, *S. nubilus*, *S. pallidicollis*, *S. pyrocheilus*) and Nephus (*N. regularis*, *N.* sp. *nr. roepkei* and *N. bipunctatus* indicating their predominance over other predators.

Table 5: Species diversity estimates of predators feeding on *P. marginatus* in mulberry at Malda

Species	Species abundance (Ni)		Relative abundance (Pi)		Proportional abundance (%)	Berger parker dominance index	Dispersion Index (VMR)	Species ranking
	2014	2015	2014	2015				
Brumoides suturalis (F)	8.33	10.00	0.088	0.112	9.98	1.18	0.76	5
Coccinella septempunctata	3.33	4.67	0.035	0.052	4.36	2.71	0.67	12
Jauravia pallidula Mots	10.33	9.00	0.110	0.101	10.53	1.12	1.07	3
Mallada desjardinsi (Navas)	2.67	1.67	0.028	0.019	2.36	5.00	0.98	13
Menochilus sexmaculatus (F)	5.00	6.00	0.053	0.067	5.99	1.97	0.67	9
Nephus regularis	5.67	3.00	0.060	0.034	4.72	2.50	1.19	11
Nephus bipunctatus	5.67	4.67	0.060	0.052	5.63	2.10	1.16	10
Scymnus bourdilloni Kapur	10.67	8.33	0.113	0.093	10.34	1.14	1.52	4
Scymnus coccivora Ayyar	9.33	12.33	0.099	0.138	11.80	1.00	1.34	1
Scymnus latifolius Poorani sp. nov.	9.33	12.00	0.099	0.134	11.62	1.02	1.28	2
Scymnus nubilus Mulsant	7.00	6.33	0.074	0.071	7.26	1.63	1.31	7
Scymnus pallidicollis Mulsant	8.00	6.00	0.085	0.067	7.62	1.55	1.34	6
Scymnus pyrocheilus Mulsant	8.00	4.67	0.085	0.052	6.90	1.71	1.22	8
Spalgius epius	1.00	0.67	0.011	0.007	0.91	13.00	0.94	14

Besides, *Scymnus* spp. *B. suturalis* and *J. pallidula* also recorded lower Berger Parker index values indicating their dominance. Apart from feeding mealybugs, they were often found predating the egg and nymphal stages of the whiteflies infesting mulberry. *Menochilus sexmaculatus* and *Coccinella septempunctata* were also found to check the population build-up of thrips in mulberry (Lalitha *et al*., 2018). Hence, these generalist predators were found distributed all through the year. The chrysopid, *Mallada desjardinsi* (Navas) (Neuroptera: Chrysopidae) was recorded as eggs or nymphs in very few samples. Adults are not predatory in habit. The carnivorous lycaenid butterfly, *Spalgis epius* (Lepidoptera: Lycaenidae) was recorded, in very few samples.

Species ranking based on the proportional abundance suggest that that all the *Scymnus* spp were dominant coccidophagous taxa that successfully multiplied and reproduced amidst mealybug hosts. Their population increased and decreased with respect to the mealybug population indicating their close association with the host.

Dispersion index is the coefficient of dispersion indicating the spatial distribution such as uniformity, randomness or aggregation. The dispersion index for the predator collection in four locations are shown in Table 2-5.Based on the dispersion index values calculated using variance mean ratio (VMR) of individual species it was found that all the six *Scymnus* spp., two *Nephus* spp. *J. pallidula* and *M. desjardinsi* showed aggregated dispersion with dispersion index value greater than unity. The other predators exhibited random uniform dispersion with VMR values lesser than one. The spatial distribution of these predators are governed by their hosts/preys availability, environmental conditions and intra-interspecific competitions (Sreedevi and Verghese, 2007). In the present study, the predators that showed aggregate distribution was mainly due to the availability of excess prey/ host population without limitation.

Although earlier workers (Santhakumar *et al*., 1995; Santhakumar and Chakraborty, 1997 and 1999; Chakraborty *et al*., 1999) reported several native predators of mulberry pests from Indo gangetic plains of West Bengal, some of those predators were not traceable in the present study. Previous workers, collected *Stethorus indira* Kapur, *Stethorus tetranychi* Kapur (Poorani, 2002) from this location. But these were not found in the present study. Instead, a few new ones were added to the predator inventory.

The predatory potential of the new predator *Scymnus latifolius* Poorani sp.nov. was studied and found promising for biocontrol of mealybugs. Mass multiplication of the predator in laboratory conditions was found amenable (Lalitha, 2019). Being native to the Eastern zone of India the predator survives the adverse climatic conditions especially high temperature and high humid conditions. Hence, there is enough scope to utilise this predator in biocontrol programmes of different agro ecosystems.

CONCLUSION

In mulberry crop grown for sericulture, predators were forced to emigrate upon pruning, crop senescence or leaf harvesting. Avoiding insecticide use and habitat management will determine the sustenance and survivability of these listed native predators in the

forthcoming years. To ensure the sustenance of the predator population a pest refugia and alternate food resources are essential. In any agricultural ecosystem, to promote species diversity, minimizing the level of disturbance by judicious insecticide use and habitat management is recommended (Landis *et al.*, 2000; Barbosa, 1998). Mono-cropping of mulberry for sericulture practices increases the pest incidence. On the other hand, timely scheduled pruning practices can reduce 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 (Gurr *et al*., 2005). Nevertheless, the alternate hosts of mealybugs grown in adjoining plots of mulberry gardens maintains the pest refugia and ensures the survival of native predators. The predatory insects that are potential natural enemies in annual crop systems migrate cyclically between neighbouring fields with alternate hosts and surrounding permanent habitats. Hence, to translate the strength of native predators of the mulberry gardens to effective bio control, conservation and augmentation of promising predator is advocated.

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