Bio-Ecology of Predatory Coccinellid Beetle, *Coccinella septempunctata* (Coleoptera: Coccinellidae) and its Dynamics in Rice Field of Terai Region of West Bengal, India

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Abstract

Incidence of predatory coccinellid beetle, *Coccinella septempunctata* population in rice crop (*Oryza sativa* L.) was assessed by light trapping during four consecutive *kharif* crop seasons (2005-2008) at Cooch Behar, West Bengal. Mean duration of 1st, 2nd, 3rd and 4th larval instars *C. septempunctata* were 3.10±0.47, 4.20±0.48, 5.20±0.69 and 7.9±0.85 days respectively. Duration of total larval period was 20.4±0.73. While that of the pupal period was 5.10±0.53 days. Mean male and female emergence rate was 36.6±2.98% and 57.6±4.21%, respectively. Male to female sex ratio was 1:1.7±0.19. The food consumption of ladybirds was significantly higher in 4th instar grubs. Searching distance by ladybird beetle was significantly higher in case of 4th instar grubs. Grossly, *C. septempunctata* population was initiated at about 25 standard meteorological weeks (SMW), improved at first slowly up to 27 SMW then steadily up to 32 SMW attaining the maximum at about 34 SMW which was maintained up to about 37 SMW. The population then subsumed at first slowly up to 40 SMW then abruptly. Abiotic conditions such as minimum temperature, temperature gradient, maximum relative humidity and average relative humidity had significant positive influence on *C. septempunctata* population. In case of minimum relative humidity and sunshine hours, a negative influence was observed. In addition, other factors such as rainfall imparted insignificant positive effect on population development.

1. Introduction

Biodiversity both theoretically and practically has relevance in addressing many problems of contemporary agriculture and allows the formation of functional groups that drive key ecosystem processes (Mew et al., 2001). One of the most significant processes in rice agro-ecosystems is pest regulation, because biodiversity is related closely to host-plant resistance, pest supervision attributes, natural biological control agents and their impacts, and constancy as the ecological basis for pest management. Natural biological control in irrigated rice at the early crop stages can mainly be attributed to spiders. Orb-weaving spiders are the most abundant spiders assessed across the cropping season, with *Tetragnatha* spp. being the single most common genus in South East Asian countries, except the Philippines where *Pardosa pseudoannulata* is the more common species.

To protect the plants and environment, biological control is a good replacement of highly toxic insecticides which is a common practice for pest control (Bellows, 2001). Biological control provides a helpful alternate to pesticides in managing a variety of arthropod pests (Opit et al., 2005). The spatial distribution of an insect can be employed in investigating population dispersion behavior, establishing a precise sampling system and sequential sampling (Margolis et al., 1984) and assessing crop loss (Hughes, 1996).

Natural enemies of insect pests play a key role in reducing the levels of pest populations below those causing economic injury. It belongs to family Coccinellidae which comprise 4500 species world over. *C. septempunctata* is an extensive ladybird beetle in the Palearctic, Nearctic and oriental regions.

Coccinella septempunctata L. is one of the possible predators in paddy. Being a significant biological control agent, it predates also on other soft bodied arthropods in addition to aphids (Debaraj and Singh, 1990). It is the most important beneficial insect of cotton pests, with its immature and mature stages as voracious feeder of all the species of aphids

(Karpacheva, 1991). Biological control of aphids and other small soft bodied pests in some system appears to be benefiting from various appetite of multicolored Asian lady beetle (Koch, 2003). Among the northern parts of West Bengal, India, Cooch Behar district offers a congenial environment for paddy cultivation. Grossly, there are three specific objectives of this study. (i) to define the basic population system of *C. septempunctata* during the *kharif* crop seasons at Cooch Behar, West Bengal (ii) to consider the role of weather parameters on the incidence of *C. septempunctata* population and (iii) to apply the generated information relating to *C. septempunctata* population dynamics in integrated pest management decision-making.

2. Materials and Methods

Field study was conducted during four consecutive *kharif* crop years (2005-2008) in untreated field of paddy cultivar Swarna mashuri (MTU 7029). Transplantation to main field was done with 35-day old seedlings at 10×15 cm^2 spacing on 20-22 standard meteorological weeks (SMW). Cultivation was done with recommended fertilizer doses of 150:60:60 kg ha^{-1} NPK.

Assessment of adult *C. septempunctata* population was done weekly by light trapping. Inexpensive kerosene light traps designed by the entomological department, IRRI with befitting modifications were used for *C. septempunctata* assessment. Such 4 light traps were equidistantly placed in the mono-cultural paddy field (150×150 m^2), 6 m above the ground level with a collection pan (r=35 cm) below each of the light trap, from early vegetative stage till to the maturation stage of paddy, in every week throughout the *kharif* crop season. The traps were operated from 18:00 to 06:00 hours .Collection from 5 traps was averaged. There were five replications in each year for the five successive years.

The adults of *C. septempunctata,* were collected from the rice field. Then it was propagated in laboratory under room controlled ambient conditions (24±2ºC and 65±5% R.H.) in five replications. Newly emerged virgin adults of *C. septempunctata* were placed in a glass jars in single pair. They were fed with counted number of mustard aphids. The open end of the glass jar was tightly enclosed with muslin cloth. Aqueous solution of 10% honey as a food source was also placed in jars. Eggs laid by female on the walls of glass jar were counted and then transferred in petri dishes (8 cm diameter). In each occasion, fifty eggs were observed with six replications, egg hatching in percent and incubation period was recorded. The larvae, after hatching from eggs, were collected and placed in glass jars. There are six replications and in each replication 25 larvae were observed for the assessment of larval and pupal duration. Mortality of larva and pupa in consideration of each developmental stage was calculated. Each larval instar was provided with a known number of aphids (nymphs, adults) as food. The feeding potential was recorded by counting the number of aphids, fed by 1st, 2nd, 3rd and 4th instars of *C. septempunctata* up to pupation. 25 pupae replicate^{-1} in six replications were considered to estimate the percent male and female emergence and sex ratio. Searching efficiency of *C. septempunctata* on rice crop (var. Swarna mashuri) was noted during *kharif* season. Observation was done from randomly selected 20 rice hill. The selected rice hills were initially tagged and grubs such as 1st, 2nd, 3rd and 4th instar and adults of *C. septempunctata* duly reared in laboratory, were released on the rice hills separately. To estimate searching efficiency of *C. septemunctata* morphs, 20 minute was allowed and within that specific time distance covered by the morphs was recorded.

Weekly noted *C. septempunctata* population were correlated with the prevailing weather parameters such as temperature, relative humidity, sunshine hour (Shr) and rainfall (Rfall). Further inter relationship of the weather factors was also worked out and then tabulated in matrix pattern.

3. Results and Discussion

3.1. Natural enemies and their interactions

A number of natural enemies, principally ladybird beetles, *Coccinella septempunctata* (L.) (Coleoptera: Coccinellidae), Syrphid flies, *Episyrphus balteatus* flies (Diptera: Syrphidae), lacewings, *Chrysoperla carnea* (Stephens) (Neuroptera: mainly Chrysopidae) and Braconid wasp, (Hymenoptera: Braconidae), have been noted (Table 1).

3.2. Observation on bio-ecology

Female ladybird beetle, *C. septempunctata* Linn. lays clusters of bright coloured eggs. Incubation period for eggs was 4.7±0.89 days and the extent of egg hatchability was 97.10±2.80% (31.50±0.87). Range of non-viable eggs at this stage was 0.70±0.82% (4.7±0.89). Mean duration of 1st, 2nd, 3rd and 4th larval instars were 3.10±0.47, 4.20±0.48, 5.20±0.69 and 7.9±0.85 days respectively. Duration of total larval period was 20.4±0.73 and the duration of pupal period was 5.10±0.53 days. Total duration of larval and pupal stage is 25.15±1.83. Mean percent of pupation, and pupal mortality was, 83.2±6.20%, and 16.5±6.4%, respectively. Mean male and female emergence was 36.6±2.98% and 57.6±4.21% respectively. Mean pupal mortality was 17.7±6.2%. Male to female sex ratio was 1:1.7±0.19.

The searching distance covered by ladybird beetle in field condition was significantly higher in case of 4th instar grubs as compared to 1st, 2nd and 3rd instars. Hence, the beetles have to cover more distance to meet their food requirement. *Harmonia axyridis* appears to have a high ability to follow

Table 1: Predators of paddy insect pests in the tarai zone of West Bengal

Common english name	Scientific name	Family	Order
Lady bird beetle*	*Menochilus sexmaculatus* (Fabricius)	Coccinellidae	Coleoptera
Lady bird beetle*	*Micraspis* sp. (Mulstant)	Coccinellidae	Coleoptera
Ground beetle (Carabid)	*Ophionea nigrofasciata* (Schmidt-Goebel)	Carabidae	Coleoptera
Crickets	*Anaxipha longipennis* (Serville)	Gryllidae	Orthoptera
Water bugs	*Mesovelia* spp. (Horvath)	Veliidae	Hemiptera
Plant bugs	*Cyrtorhinus lividipennis* (Reuter)	Miridae	Hemiptera
Damselfly*	*Agriocnemis pygmaea* (Rambur)	Coenagrionidae	Odonata
Damselfly	*Agriocnemis femina* (Brauer)	Coenagrionidae	Odonata
Damselfly	*Ceriagrion* sp.	Coenagrionidae	Odonata
Damselfly	*Ischnura aurora aurora* (Brauer)	Coenagrionidae	Odonata
Damselfly	*Ischnura senegalensis* (Rambur)	Coenagrionidae	Odonata
Earwigs	*Euborellia stali* (Dohrn)	Carcinophoridae	Dermaptera
Wolf spider*	*Lycosa pseudoannulata* (Boesenberg and Strand)	Lycosidae	Araneae
Lynx spiders	*Oxypes javanus* (Thorell)	Oxyopidae	Araneae
Dwarf spiders	*Atypena* (=*Cailitrichia*) *formosana* (Oi)	Linyphiidae	Araneae
Orb spiders*	*Argiope pulchella* (Thorell)	Araneidae	Araneae
Orb spiders	*Cyclosa insulate* (Costa)	Araneidae	Araneae
Long jawed spiders*	*Tetragnatha maxillosa* (Thorell)	Tetragnathidae	Araneae
Long jawed spiders*	*Tetragnatha javana (*Thorell)	Tetragnathidae	Araneae

*Most important predators

Table 2: Average weather parameters and the incidence of *Coccinella septempunctata* population during the period of study

SMW	Temperature (ºC)				Relative humidity (%)				Avg. sunshine hour (hr day^{-1})	RF (mm)	Individuals trap^{-1}
	Tmax	Tmin	Tgr	Tavg	RHmax	RHmin	RHgr	RHavg			
25	32.21	24.24	7.97	28.23	96.17	67.71	28.46	81.94	5.74	0.00	1.17±0.42
26	33.11	24.16	8.95	28.64	98.12	47.25	50.87	72.69	5.78	0.00	3.20±0.54
27	33.65	24.81	8.84	29.23	95.47	46.38	49.09	70.93	1.84	9.87	5.26±0.67
28	33.61	24.13	9.48	28.87	94.83	47.14	47.69	70.99	5.17	0.00	8.29±2.15
29	34.89	24.56	10.33	29.73	96.53	47.12	49.41	71.83	8.47	2.03	19.37±3.14
30	34.42	23.21	11.21	28.82	96.22	65.01	31.21	80.62	2.29	2.17	28.58±3.11
31	34.82	24.65	10.17	29.74	95.53	56.27	39.26	75.90	2.04	1.09	34.98±3.13
32	33.72	24.13	9.59	28.93	95.11	44.53	50.58	69.82	3.48	65.32	39.33±4.51
33	32.72	25.35	7.37	29.04	95.84	46.12	49.72	70.98	6.47	47.32	53.21±4.47
34	32.31	25.25	7.06	28.78	94.25	40.12	54.13	67.19	6.94	11.98	69.45±5.03
35	32.35	25.89	6.46	29.12	94.76	41.79	52.97	68.28	8.69	56.87	61.37±3.08
36	32.23	25.85	6.38	29.04	94.28	48.41	45.87	71.35	7.35	62.12	59.45±4.61
37	32.81	25.34	7.47	29.08	96.01	41.59	54.42	68.80	8.51	12.11	53.78±4.75
38	32.15	24.72	7.43	28.44	84.12	39.25	44.87	61.69	5.61	7.12	25.14±3.97
39	30.69	24.92	5.77	27.81	85.01	47.41	37.6	66.21	8.53	2.09	37.93±2.21
40	29.97	21.39	8.58	25.68	87.89	53.53	34.36	70.71	8.73	0.00	19.97±2.19
41	29.48	20.39	9.09	24.94	88.21	57.12	31.09	72.67	6.12	0.00	41.51±2.13
42	29.98	19.83	10.15	24.91	86.71	53.24	33.47	69.98	4.08	0.00	15.37±2.12
43	28.94	18.68	10.26	23.81	90.89	57.13	33.76	74.01	6.27	0.00	12.22±1.08
44	28.73	17.39	11.34	23.06	92.79	69.78	23.01	81.29	6.45	0.00	12.54±1.02
45	27.65	16.03	11.62	21.84	95.73	57.58	38.15	76.66	3.48	0.00	2.21±1.21

Table 3: Correlation coefficient of incidence of *Coccinella septempunctata* population with the weather factors

Weather parameters	Years of observation			
	2005	2006	2007	2008
Maximum temperature (Tmax)	0.202	0.345	0.401	0.311
Minimum temperature (Tmin)	0.567*	0.511*	0.425	0.651*
Temperature gradient (Tgr)	0.508*	0.578*	0.420	0.721*
Average temperature (Tavg)	0.518*	0.358	0.375	0.265
Maximum humidity(RHmax)	0.575*	0.525*	0.501*	0.534*
Minimum humidity (RHmin)	-0.795*	-0.891*	-0.748*	-0.605*
Humidity gradient (RHgr)	0.379	0.528*	0.623*	0.828*
Average humidity (RHavg)	0.701*	0.556*	0.887*	0.519*
Sunshine hours day^{-1} (Shr)	-0.435	-0.752*	-0.778*	-0.831*
Rainfall (Rfall)	0.329	0.345	0.267	0.415

Significant at (p=0.05)

aphid occurance in space and time (Osawa, 2000, With et al., 2002). While searching for prey, larvae are reported to use random movements (Kawai, 1976). Distance covered by ladybird beetles under field conditions was significantly greater as compared to those under laboratory conditions.

3.3. *Observation on population dynamics in field condition*

Dynamics of *C. septempunctata* population in relation to SMW was noted by light trapping. During *kharif* season, initially, at 25 SMW the population was very low. It then increased gradually from about 28 SMW. Moderate number of adult population was noted at about 30-31 SMW which was maintained nearly up to 32 SMW. The appearance of first peak of adult *C. septempunctata* population was noted at about 34 SMW. High level of *C. septempunctata* population persisted up to 37 SMW.

3.4. *Correlation between C. septempunctata population and weather parameters*

In all the years except in 2007, the *C. septempunctata* population showed an insignificant positive relation with the Tmax (Table 2 and 3). While Tmin had imparted a significant positive effect on the incidence of *C. septempunctata* in all the years except in 2007. Except in 2007, the incidence of *C. septempunctata* population showed significantly positive relation with Tgr. Insignificantly positive relation was also found with the Tavg in 2006, 2007 and 2008, but in 2005 relations was significantly positive. Persistent RHmax (85-94%) exerted a significantly positive impact on the abundance of *C. septempunctata* population in all the years, especially at the late tillering stage. A significantly negative relation between RHmin and the field aphid population was found in all the years. Incidence was positively influenced by RHavg almost in all the years. Bright sunshine hour for an average of 8.23 hrs/day had a significant negative effect on the *C. septempunctata* population with the exception of 2005 where the relation though negative, was non-significant. Drizzling Rfall had an insignificant positive effect on the pest structure.

Matrix analysis of important weather parameters leads to determine the relative dynamic of the aphid population (Table 4). However, impact of temperature was more profound. According to Thompson (1975) the attack of beetle to its source food organism has increased when the temperature ranges between 5ºC and 27.5ºC. But it again decreased logarithmically

Table 4: Matrix combination showing linear correlation coefficient (r) of important climatic factors in relation to *Coccinella septempunctata* incidence

Interaction	Tmax	Tmin	Tgr	Tavg	RHmax	RHmin	RHgr	RHavg	Shr	Rfall	Rdays
Tmax	1.0000										
Tmin	0.8031*	1.0000									
Tgr	0.5457*	-0.0270	1.0000								
Tavg	1.0000	0.8070*	0.5733*	1.0000							
RHmax	-0.5759*	-0.5384*	-0.2168	-0.5756*	1.0000						
RHmin	-0.1769	0.1938	-0.5547*	-0.1740	0.1765	1.0000					
RHgr	-0.0548*	-0.4012	0.4578	-0.0556	0.2164	-0.9258*	1.0000				
RHavg	-0.3520	-0.0176	-0.5623*	-0.3530	0.5001*	0.9327*	-0.7334*	1.0000			
Shr	0.4858	0.1635	0.4964	0.4373	-0.2288	-0.0784	-0.0127	-0.1444	1.0000		
Rfall	0.5269*	0.7558*	-0.1566	0.5235*	-0.2857	0.3036	-0.4154	0.1620	-0.1817	1.0000	
Rdays	0.8046*	0.8579*	-0.1768	0.8063*	-0.5265*	0.1160	-0.3161	-0.0818*	0.0343	0.8652*	1.0000

Each correlation coefficient (r) is calculated independently without considering other variables from 5ºC to 16ºC. The maximum rate of predation during this study occurred at 24±2ºC, thus it could be expected that the maximum development of the beetles would occur at the temperature slightly above it.

4. Conclusion

C. septempunctata population was initiated at about 25 standard meteorological weeks (SMW), improved at first slowly up to 27 SMW then steadily up to 32 SMW attaining the maximum at about 34 SMW which was maintained up to about 37 SMW. Abiotic conditions such as minimum temperature, temperature gradient, maximum relative humidity and average relative humidity had significant positive influence on *C. septempunctata* population. In case of minimum relative humidity and sunshine hours, a negative influence was observed. The food consumption of ladybirds was significantly higher in 4th instar grubs as compared to 1st, 2nd and 3rd instars.

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