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Diversity of pest and non-pest insects in an organic paddy field cultivated under the System of Rice Intensification (SRI): A case study in Lubok China, Melaka, Malaysia

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Abstract

Insect diversity studies were conducted in paddy plots planted organically under SRI in Lubok China, Melaka. Eight sampling visits were made starting from the planting of seedlings until flowering stage, milky stage and ripening of the grains. Five sampling methods were used, i.e. light trap, sweeping net, sticky trap, yellow pan trap and pitfall trap. A total of 34 species representing 21 families and 8 orders of insects was recorded comprising Homoptera, Hymenoptera, Coleoptera, Orthoptera, Odonata, Hemiptera, Lepidoptera and Diptera. For the total sampling period, the Shannon-Wiener diversity index (H') is 1.17, Shannon-Weiner evenness index (E') is 0.89 and Margalef richness index (R') is 4.77, respectively. However, no significant differences between the sampling visit ($p > 0.05$). The most abundant insects order were Orthoptera (22.9%; 231 individuals) the lowest was Diptera (2.3%; 23 individuals). The most abundant species was order Lepidoptera (13.8%) and the lowest was from Hemiptera (5.9%). In terms of feeding habits, herbivorous insects were the most abundant (65%), followed by carnivores (27%) and omnivores (8%). Results indicated that SRI has ensured a good balance between the populations of pests, beneficial insects (predators and parasitoids) as well as other insect's community during the various phases of paddy development without any appreciable loss in yield. These show that SRI is an effective way to conserve, use and enhance biodiversity crucial to sustainable food security.

Key words: System of Rice Intensification (SRI), diversity, paddy, insect pests.

Introduction

In terms of national food sufficiency and security, paddy cultivation is an economically important agricultural activity in Malaysia. In order to increase the quality and yield of the rice crop, many modern and scientific techniques are being tested and adopted by the local farmers each year. The organic farming method known as the System of Rice Intensification (SRI), which can increase the paddy yield up to threefold per harvest, was developed 20 years ago in Madagascar by a French agronomist, Father Henri de Laulanié based on 20 years of working with farmers to improve their rice production without dependence on external inputs [1]. Since then, the productivity of the SRI method has been validated in 28 countries worldwide including Malaysia [1]. However, to date, paddy cultivation is still faced with various limitations ranging from climate, soil type and fertility, to irrigation, water supply and pest problems. The paddy field ecosystem is the main habitat for many species of insects that utilize the paddy crop as their food source, from the planted seedlings to the harvested rice grains. The diversity and abundance of insects in the ecosystem vary according to abiotic and biotic factors as well as the growth stages of the paddy plant. Taxonomic and biological studies have been conducted on the various groups of insects found in the paddy field, including pests and non-pests of rice, those predating on the rice crop and weeds as well as their parasites and predators [2]. This study reports on the diversity of the insect fauna in the paddy plots cultivated under the SRI in Lubok China, Melaka. The main objective of this study was to determine the diversity and population abundance of insects during the growing stages of the paddy plants in relation to biological control and sustainable management of the paddy crop. The study site is located at a privately owned paddy field in Lubok China, Melaka, which has been cultivated by the SRI method for two consecutive seasons.

Materials and Methods

Description of the study site: The study site, is a privately owned paddy field in Lubok China situated 2°25'26" N, 102°04'44" E and located in the district of Alor Gajah, Melaka, Malaysia. The paddy plots have been cultivated under the SRI for two consecutive seasons. The surrounding land use comprises rural settlement interspersed with rubber and oil palm plantations, covering an area of about 67,440 hectares (Fig. 1).

Methodology: The procedures used in this study include collecting of insect samples from the paddy field, specimen preservation, preparation and identification at the Universiti Kebangsaan Malaysia (UKM) laboratory in Bangi, Selangor, Malaysia. Eight sampling visits were conducted during the growing phase of the paddy crop, i.e. between 18th June to 1st July October 2009 (active tillering stage); from 18th July to 21st August 2009 (maximum tillering stage); from 28th August to 4th September 2009 (flowering stage); and from 11th September to 1st October 2009 (ripening stage). Five sampling methods were employed, namely the use of light traps, sweeping nets, yellow pan traps,

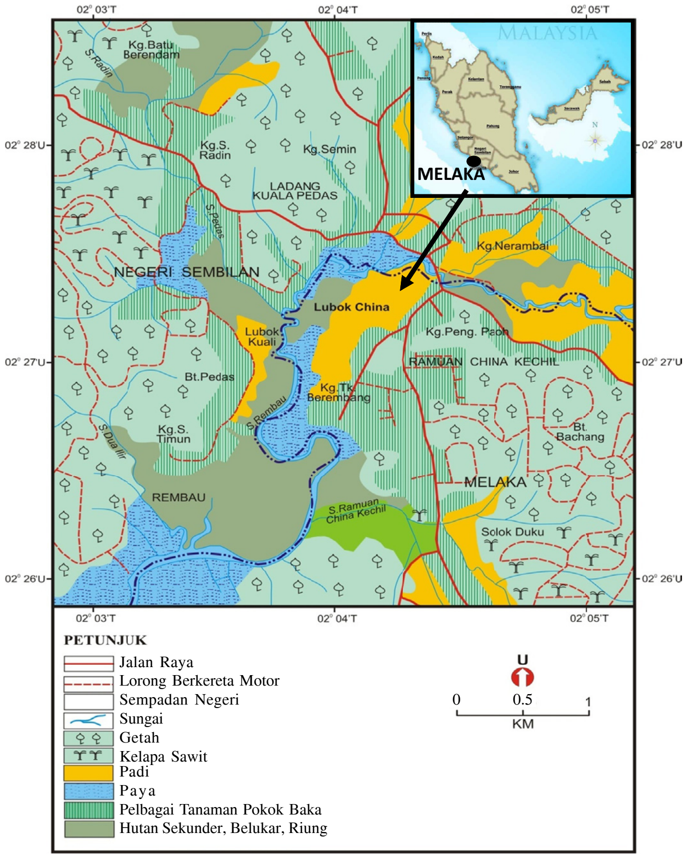

Figure 1. Study site of the paddy field practicing organic farming (SRI) in Lubok China, Melaka.

adhesive traps and pitfall traps [3]. The light trap is the most suitable method for sampling nocturnal insects. It comprises a vertically hung mosquito netting illuminated by a 160 watt mercury vapour bulb and powered by a portable generator, set up between 1900 and 2200 hours. Individual insects that land upon the mosquito netting are collected manually, and killed in a jar containing a wad of cotton wool soaked in ethyl acetate. Specimens are new rapidly taken to the UKM laboratory where they are pinned, oven-dried, identified, labeled and classified. Species identification is done with the aid of standard references [4-6]. Identified type specimens are then kept in the depository of the Centre for Insect Systematics, UKM (CIS-UKM) in Bangi, Selangor.

For the yellow pan trap, five yellow pans (10 x 5 cm) containing an odorless and colorless detergent (Alconoc solution) are placed randomly in the paddy plots to attract flying insects. Many insects are attracted to the yellow colored pan and were subsequently get drowned in the detergent. The insect specimens are collected every 48 h and preserved in 75% alcohol. The pitfall trap is used to trap soil and litter insects. A 8 x 15 cm glass vessel containing Alconoc solution is buried in the ground with its lips flush with the ground surface. The opening is covered with a slightly raised lid to keep out predators and to prevent trapped animals from drowning when it rains. Insects, which are accidently trapped and drowned in the glass vessel, are collected every 48 h [3,7].

The adhesive or sticky trap is made up of a sticky stiff cardboard (10 x10 cm) painted on both sides with a strong glue and pegged onto a short stick placed upright in the paddy plot. Flying insects are attracted to the food bait in the glue and get trapped onto the sticky surface of the cardboard. For the sweeping net method, the paddy plots are randomly swept by a sweeping net in a zig-zag manner for a total of 100 sweeps per plot [3].

Specimens collected in the field are sorted, some being wet-preserved in 75% alcohol, while others such as dragonflies and lepidopterans are preserved as dry specimens, later to be pinned and oven-dried at 40-45°C in the laboratory. Most of the specimens are identified up to the order and family levels while others are identified up to the species level, with the aid of standard references and by cross-referencing with type specimens from the Centre for Insect Systematics, UKM, Bangi, Selangor, Malaysia.

***Data analysis*:** Insect diversity and richness over the sampling period are determined by the Shannon-wiener diversity index (H') and the Margalef richness index (R'), while significant differences between the insect populations in the paddy plots are statistically determined by the one-way ANOVA test.

Results and Discussion

The five sampling methods adopted during the eight sampling visits at the SRI organic paddy field in Lubok China, Melaka yielded a total of 1008 insects, representing 34 species in 21 families and 8 orders (Table 1). The dominant orders were Orthoptera (231), followed by Homoptera (220), Coleoptera (132), Lepidoptera (140), Hymenoptera (122), Hemiptera (85), Odonata (55) and Diptera (23) (Fig. 2 and Table 2). Orthoptera recorded the highest percentage (22.9% of the total catch), while Diptera recorded the lowest percentage (2.3%). Likewise, the family Pentatomidae from order Homoptera recorded the highest number of individuals for the whole study period, followed by Coccinellidae (order Coleoptera) and Tettigoniidae (order Orthoptera), respectively.

Overall insect diversity in the field, during the growing period of the paddy crop as indicated by the Shannon-wiener species

Table 1. List of insects based on order, family and species collected from the SRI paddy field in Lubok China, Melaka.

Order	Family	Number of Species	Number of Insects (%)	Population abundance (mean ± SE)
Orthoptera	Tettigoniidae	3	98	
	Acrididae	1	41	
	Gryllidae	1	83	
	Gryllotalpidae	1	9	
			231 (22.9%)	28.9 ± 2.29
Homoptera	Pentatomidae	2	152	
	Coreidae	2	68	
			220 (21.8%)	27.5 ± 2.66
Lepidoptera	Noctuidae	1	6	
	Nymphalidae	1	1	
	Arctiidae	1	43	
	Pyralidae	4	77	
	Lymantriidae	1	13	
			140 (13.9)	17.5 ± 2.38
Coleoptera	Coccinellidae	2	104	
	Scarabaeidae	2	28	
			132 (13.1%)	16.5 ± 1.58
Hymenoptera	Braconidae	1	27	
	Formicidae	1	10	
	Ichneumonidae	2	85	
			122 (12.1%)	15.3 ± 1.92
Hemiptera	Belostomatidae	2	85	
			85 (8.4%)	10.6 ± 1.05
Odonata	Libellulidae	3	36	
	Agrionidae	1	19	
			55 (5.5%)	6.9 ± 1.62
Diptera	Hesperidae	1	9	
	Muscidae	1	14	
			23 (2.3%)	2.9 ± 0.64

Table 2. Percentage insect species collected from the SRI paddy field in Lubok China, Melaka.

No.	Family	Species	No. of specimens	Percentage (%)
1	Gryllidae	*Metioche vittaticollis*	83	8.23
2	Pentatomidae	*Nezara viridula*	81	8.04
3	Coreidae	*Lepticorisa oratorius*	73	7.24
4	Pentatomidae	*Scotinophara coarctata*	71	7.04
5	Braconidae	*Opius* sp.	67	6.65
6	Coccinellidae	*Micrapis discolor*	57	5.65
7	Coccinellidae	*Lemnia biplagiata*	47	4.66
8	Coreidae	*Riptortus linearis*	47	4.66
9	Arctiidae	*Creatonotus gangis*	43	4.27
10	Tettigoniidae	*Atractomopha crenulata*	42	4.17
11	Acrididae	*Oxyca chinensis*	41	4.07
12	Tettigonidae	*Phaneroptera gracilis*	32	3.17
13	Pyralidae	*Chilo supressalis*	31	3.08
14	Ichneumonidae	*Stenobracon nicevillei*	27	2.68
15	Scarabidae	*Anomala pallida*	26	2.58
16	Tettigonidae	*Conocephalus longipennis*	24	2.08
17	Belostomatidae	*Pachybracius pallicornis*	21	2.08
18	Libellulidae	*Acisoma panorpoides*	20	1.98
19	Agrionidae	*Agriocnemis pygmaea*	19	1.88
20	Ichneumonidae	*Temelucha philippinensis*	18	1.79
21	Pyralidae	*Sesamia inferens*	18	1.79
22	Muscidae	*Musca domestica*	14	1.39
23	Pyralidae	*Herpetograma licarsisalis*	14	1.39
24	Pyralidae	*Scirpophaga incertulas*	14	1.39
25	Lymantriidae	*Laelia suffuse*	13	1.29
26	Belostomatidae	*Lepthocerus indicus*	12	1.19
27	Libellulidae	*Orthetrum sabina*	11	1.09
28	Formicidae	*Componotus* sp.	10	0.99
29	Gryllotalpidae	*Gryllotalpa orientalis*	9	0.89
30	Hesperidae	*Argyrophylax nigrotibialis*	9	0.89
31	Noctuidae	*Spodoptera mauritia*	6	0.60
32	Libellulidae	*Diplacodes trivialis*	5	0.50
33	Scarabidae	*Oryctes rhinoceros*	2	0.20
34	Nymphalidae	*Melanitis leda*	1	0.10

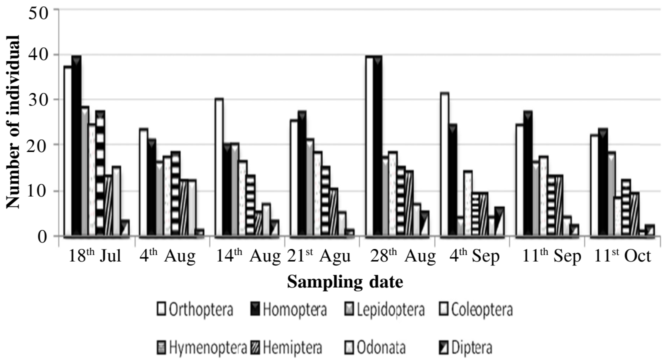

Figure 2. Abundance of insect orders collected from the SRI paddy field in Lubok China, Melaka.

diversity index, gave a value of H' = 1.17, while diversity index for the various stages showed that the highest diversity was at the active tillering stage (H' = 1.17), followed by the flowering (H'= 0.69) and ripening (H'= 0.60) stages, respectively. Likewise, the Shannon-wiener evenness index gave an overall value of E'= 0.89, at decreased in tandem with the growth stage of the paddy plants (Table 3). The Margalef richness index was relatively high for the overall insect population, with the value of R'=4.77. It can be concluded that the overall abundance, evenness and richness of insect population in the SRI paddy plots decreased in relation to the growth stage of the paddy plants from early growth to the ripening stage. Nevertheless, the T-test and one-way ANOVA did not show any significant difference ($p > 0.05$) in insect abundance between the paddy plots and the growth phases of the paddy plants.

Table 3. Shannon-wiener species diversity index (H'), evenness index (E') and Margalef richness index (R') for the insect population during the different growing stages of paddy plants in the SRI plots.

Growth phase of paddy	H'	E'	R'
1. Active tillering stage	1.17	0.89	*Species richness
2. Flowering stage	0.69	0.54	for total sampling
3. Ripening stage	0.60	0.47	is 4.77

From the active tillering stage of paddy plant growth until the flowering stage (18th July to 21st August), the family Pentatomidae showed the highest recorded population, followed by Coccinellidae, Tettigonidae and Ichneumonidae, respectively (Fig. 3). These four families also had the most abundant insect population for the entire growing period of the paddy crop under the SRI method. According to Adalla and Alzona [8], *Scotinophara coarctata* was the dominant pentatomid beetle species found in the paddy area, probably due to the high adaptive capacity of this species. During its 200-day lifespan, *S. coarctata* predated on the paddy plants at the various stages of its development, but it was most predominant at the active tillering stage of the paddy plants [8]. Joshi *et al.* [9] noted in their study of this pest species in the Philippines that the beetle incurred serious damage to the rice crop, inflicting a net yield loss of 15-20%. Adults and larvae of *S. coarctata* usually attack the basal parts of the paddy plant, especially during daytime. Other species from the family Pentatomidae such as *Nezara viridula* have also been identified as dominant pests of paddy, sucking sap from the basal parts and causing growth retardation and yellowing of the stems and leaves. However, these pests only accounted for about 1% infestation of the paddy area in Malaysia [10].

Several species belonging to the family Braconidae and Coccinellidae were found to be dominant predators (i.e. beneficial insects) of paddy pests in the SRI plots of Lubok China, Melaka. These species act as important biological control agents in the paddy field, thus avoiding the need for excessive use of chemical pesticides. Most members of Braconidae are prevalent in the paddy habitat, and a few species are useful parasitoids of the folded-leaf larvae, thus helping in reducing damage to the paddy plants [1, 11]. When plants are under attack by insect herbivores, the plants begin to emit specific odorous volatiles that signal parasitic wasps to locate their host caterpillar larvae [12, 13]. In the current study, *Micrapis discolor* and *Lemnia biplagiata* (Coccinellidae) were

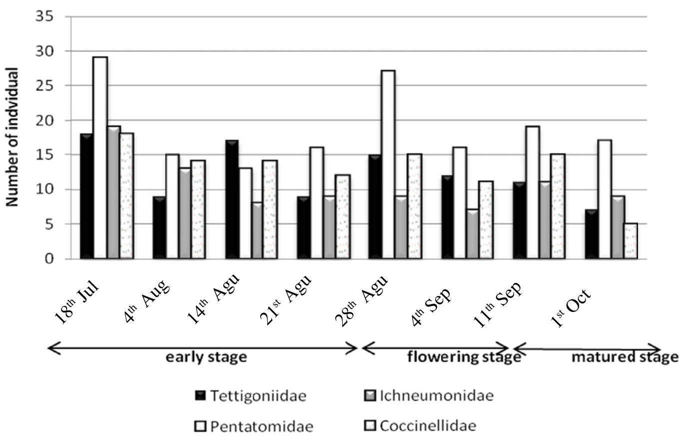

Figure 3. Abundance of four dominant insect families during the different growing stages of the paddy plants.

the most important biological control agents in the SRI plots as predators of the main pest, *Nilaparvata lugens* larvae [14]. *Nilaparvata lugens* or the brown planthopper outbreak is currently prevalent in Thailand, Indonesia and Phillippines. It had caused one of the biggest economic losses in rice production in the last five years. Possible causes could be the excessive use of urea as the nitrogenous fertilizer which increased the fecundity of the brown planthopper and the use of insecticides that reduced the population of the natural predators [15]. In most rice fields of Asia the increase in population of major insect pests such as planthoppers (*Nilaparvata lugens and Sogatella furcifera*), leaffolders (*Cnaphalocrocis medinalis*), and stem borers (*Scirpophaga incertulas, Chilo suppressalis, S. innotata, C. polychrysus* and *Sesamia inferens*) has been related to the long-term excessive use of nitrogenous fertilizers [16]. Since both these practices are non-existent in the organic SRI and with the absence of *N. lugens* in these SRI plots, it can be concluded that the existing predators were highly effective in controlling the brown planthopper pests.

During the sampling visits, the percentage abundance of insects decreased in tandem with the developmental stages of the paddy plants. However, other factors also played a role in affecting the population profile of the pest and non-pest insects, and these included the populations of prey and predator insects and vertebrates (e.g. birds, frogs and fishes), life cycle of each species, vegetation, sampling period, time (day or night), rainfall pattern and other meteorological factors. Furthermore, most orders of insects have close correlations with climate, food, and pathogens that can influence their daily activities and life cycles [17]. Warm climate and active vegetative growth phase of the host plants would stimulate insect development and abundance because of the availability of abundant food and optimum temperature for their proliferation [18]. The proximity of forest vegetation to the paddy area could also influence the distribution pattern of insects, where their diversity would increase due to the abundance of a reservoir of host plants [19]. From the 34 species of insects identified in the study plots some 65% of the insect species were categorized as herbivores, 27% as carnivores and 8% as omnivores (Fig. 4). The carnivorous species, in turn, can be divided into parasitoids and predators, and in the SRI paddy plots of Lubok China, the herbivores comprised the most abundant group of insects. However, the total number of competitors and enemies for the various types of insects is in natural equilibrium, where reduced usage of pesticides and agrochemicals under the SRI paddy cultivation has facilitated the adaptive balance between the herbivorous, carnivorous and omnivorus insect groups and this is crucial in controlling pestilence and pest outbreaks in the agricultural area [1]. The herbivorous insects include members of Homoptera, Orthoptera, Hymenoptera, Lepidoptera, Hemiptera and Coleoptera that constitute the main pests of paddy, particularly the sap feeders, which also act as vectors and carriers of viral diseases of paddy [20, 21]. Table 2 shows that the sap feeders *L. oratoria* and *N. viridula* are the main herbivorous pests of paddy in the vegetative and early flowering stages. The carnivorous insects or natural enemies of paddy pests comprised members of the orders Hymeoptera, Coleoptera and Diptera. However, the ratio of the carnivorous to the pest species indicates that the number of the former was insufficient to control the population of pest insects in the study plots.

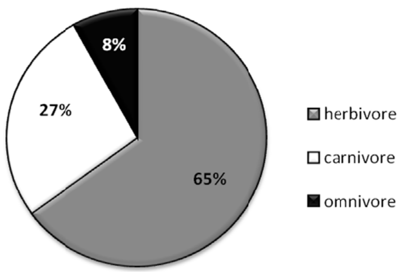

Figure 4. Percentage of herbivorous, carnivorous and omnivorous insects in the SRI plots.

Conclusions

In conclusion, the organic cultivation of paddy under the System of Rice Intensification (SRI) supported a high diversity of insects, represented by 34 species in 21 families and 8 orders in the study plots of Lubok China, and these comprised members of Homoptera, Hymenoptera, Coleoptera, Orthoptera, Odonata, Lepidoptera, Hemiptera and Diptera. The highest population abundance was recorded for the Orthoptera (22.9%), while the highest species diversity was found in the Lepidoptera (13.8%). The overall insect diversity and richness decreased in tandem with the growth phase of the paddy plant, and although the overall population abundance of insects increased with the growth and development of the paddy plants, there were no significant difference recorded between plots and sampling visits ($p > 0.05$).

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