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ARTHROPOD BIODIVERSITY AND COMMUNITY STRUCTURES OF ORGANIC RICE ECOSYSTEMS IN GUANGDONG PROVINCE, CHINA

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Abstract

The diversity and community structure of arthropods in an organic double-cropped rice ecosystem in Guangdong Province, China was studied. We compared the arthropod communities in the early season (Apr-Jul) crop to those in the late season (Aug-Nov) crop in 2009. The comparisons were undertaken using a combination of community assessment approaches, including morphospecies richness, the Shannon-Weaver diversity index, H', the Pielou-evenness index, J, the Simpson dominance index C, the Jaccard similarity index q and the compositions of the sub communities. We collected 114 species of arthropods, which consisted of including 58 species of spiders, 16 species of predatory insects, 25 species of phytophagous insects, 15 species of neutral/other insects, in early season crop. Subsequently we collected 109 species of arthropods, which consisted of 50 species of spiders, 19 species of predatory insects, 24 species of phytophagous insects, and 16 species of neutral/other insects, in the late season crop. There were no significant differences ($P < 0.05$) between the arthropod communities of the early and late season rice crops with respect to the Shannon-Weaver diversity index, the Pielou evenness index and the Simpson dominance index. Moreover the Jaccard similarity index in early and late season rice was as high, i.e., 0.70. The spider sub community had the greatest number of species in both rice crops, but the phytophagous insect sub community had the largest number of individuals in both rice crops. The dominance of predatory insects in the early season rice crop was significantly lower ($P < 0.05$) than in late season crop, but there was no significant difference in the composition of the neutral/other subcommunity between the early and late season rice crops.

Key Words: Arthropod biodiversity, community dynamics, abundance, organic rice ecosystems

Resumen

Se realizo un trabajo para estudiar la diversidad y la estructura de la comunidad de artrópodos en los ecosistemas de arroz orgánico en la provincia de Guangdong, China. Se comparó la comunidad de artrópodos en los ecosistemas de arroz del principio y el final de la temporada entre abril y noviembre del 2009. Estas comparisiones se llevaron a cabo utilizando una combinación de enfoques de evaluación de la comunidad, incluyendo la riqueza de morfoespecies, el indice H de diversidad de Shannon-Weaver', el indice J de Pielou-evennes, el índice C de dominancia de Simpson, el índice q de similitud de Jaccard y la composición de la comunidad. Se recolectaron 114 especies de artrópodos (incluyendo 58 especies de arañas, 16 especies de insectos depredadores, 25 especies de insectos fitófagos, 15 especies de insectos neutrales y otros) en arroz de la temporada temprana y 109 especies de artrópodos (incluyendo 50 especies de arañas, 19 especies de insectos depredadores, 24 especies de insectos fitófagos, 16 especies de insectos neutrales y otros) en el arroz del final de temporada. No hubo diferencias significativas (P < 0.05) en el índice de diversidad de Shannon-Weaver, el índice de uniformidad de Pielou y el índice de dominancia de Simpson entre el arroz de la temporada temprana y la temporada tardía. El máximo del índice de similitud de Jaccard en el arroz de la temporada temprana y tardía fue 0.70. Los insectos fitófagos fueron predominantes y las arañas tenían el mayor número de miembros en arroz de la temporada temprana y tardía. El predominio de insectos depredadores en arroz de la temporada temprana fue significativamente menor (P < 0.05) que en arroz de la temporada tardia, pero no hubo una diferencia significativa en las composiciones de otros subcomunidades entre arroz de la temporada temprana y de la temporada tardía.

Palabras Clave: biodiversidad de artrópodos, dinámica de la comunidad, abundancia, ecosistemas de arroz orgánico

Rice (*Oryza sativa* L.; Poales: Poaceae) is a major food crop of the world and its cultivation has been carried out in all regions with warm and abundant moisture weather conditions, mainly subtropical regions. Conventional rice cultivation has often accomplished high yields and stable crop production, but has been heavily dependent on continuous and excessive inputs of chemical pesticides, which lead to pest resistance, resurgence, pesticide residue, ground water contamination, and risks to human health and animal habitats (Nagata 1982; Hirai 1993). Organic cultivation of rice has been regarded as a sustainable system because it avoids the problems such as "3Rs" (pest resistance, resurgence, pesticide residue) and other problems of culture heavily dependent on various chemical inputs (Regannold et al. 1990). For example, Kajimura et al. (1993) reported that the population densities of the rice brown planthopper, *Nilaparvata lugens* (Stål) (Hemiptera: Delphacidae), and the white-backed planthopper, *Sogatella furcifera* (Horvath) (Hemiptera: Delphacidae), were much lower in an organically farmed than in chemically fertilized rice fields. The maintenance of biodiversity within agricultural environments is widely recognized as being essential for their agronomic sustainability (Swift & Anderson 1994; Matson et al. 1997). An important principle of integrated pest management is to maximize natural control, and, therefore, the temporal changes in arthropod abundance, diversity, species richness and community structures are important considerations in designing pest management strategies. After rice establishment, arthropod species colonize and over time progressively increase in diversity. In rice fields, predators, pollinators and soil microorganisms are all key components of biodiversity (Altieri & Nicholls 1999). Their communities may vary with the environment, varieties, cropping patterns, and cultivation practices. Rice fields often support high levels of biodiversity, which play an important role in the agricultural productivity of these systems (Cohen et al. 1994; Schoenly et al. 1998; O'Malley 1999). Organically grown rice fields reportedly have significantly higher morphospecies richness and diversity than the conventional rice fields (Wilson et al. 2008) and other organic agroecosystems also have a greater richness of arthropod species than their conventional counterparts (Dritschilo & Wanner 1980; Brown & Adler 1989; Goh & Lange 1989; Kromp 1989, 1990). Extensive studies in Asian rice fields have demonstrated that when predator communities are conserved through minimizing pesticide use, the impact of pests such as the *N. lugens* is often reduced to negligible levels (Way & Heong 1994; Schoenly et al. 1996; Settle et al. 1996).

So far, there has been no relevant study of double-cropped organic rice in Guangdong, China. The objective of this study was to identify arthropod species, describe the structure of arthropod community, examine arthropod abundances of early and late season organic rice, in order to provide theoretical basis for the sustainable control of organic rice pests.

Materials and Methods

Study Sites

Three separate rice plots were selected each 30 × 45 m and at least 500m distant from each other, and each plot was bordered on all sides by an unplanted walkway 40 cm wide. These experimental sites were located at Huizhou city (N 23°09'50" E 114°29'10"), Guangdong province of China, which receives ~ 1,630 mm of annual rainfall, with 20-22 °C annual average temperature, red soil and in 2009 the dominant natural vegetation was barnyard grass (*Echinochloa* sp.). The first early-season rice crop was grown during Apr through Jul followed in the same fields by the late season crop during Aug through Nov.

At all sites the rice cultivar, 'Haina' was planted and cultured with organic methods. No synthetic agrochemicals had been used on the land for at least 5 years, and none were applied before or during the production of the organic rice crop at any stage. Agronomic practices such as irrigation for growing rice were the same as followed by local farmers.

Sampling

AT 15 d after transplanting (DAT), the arthropod community was sampled in both the early and late season rice crops at two weeks intervals. Five samples were taken at random in each rice plot. All samples were collected near the center of the plot, at least 5m from the edge in order to reduce edge effects. Arthropods inhabiting the rice field and those on the water surface were sampled using a portable vacuum-suction machine, modified according to Carino et al. (1979). This apparatus collects arthropods through a pyramid-shaped, mylar-covered enclosure (0.5 × 0.5 × 0.9 m high, and 0.25 m^2 planar area) fitted with a collecting bag. The enclosure usually covered 4-5 stalks of rice plant after transplanting but only 2-3 after the rice plant had reached maximum tillering. Arthropods inside the enclosure were drawn through a rubber collection hose into a plastic reservoir with a nylon mesh retainer. Sampling duration was fixed at 1 to 2 min depending on the growth stage of the rice. All arthropods (with the exception of parasitoids) inside the enclosure were collected, and then transferred to sample jars containing 70% ethanol, which were returned to the laboratory for identification.

Sampling at each sampling time was repeated 3 times on each of the 3 separate rice plots, and 5 samples were taken each repetition in each area for a total of 15 samples per plot per each sampling time. From Apr 2009 to Nov 2009, the sampling dates were regularly spaced every 2 wk and a total of 180 samples were obtained. All sampled arthropods were examined at low magnification (6.5X) and identified to species.

Data Analysis

The arthropods were separated into 4 functional groups: spiders, predatory insects, phytophagous insects, and neutral and other insects. Neutral insects in this report are a category that consists of insects which do not harm to rice either directly or indirectly.

Alpha species diversity was calculated using the Shannon-Weaver diversity index H', the Pielou-eveness index J, the Simpson dominance index C, and the Jaccard similarity index q (Gianni et al. 2011; Ricardo & Francisco 2011).

Differences between the diversity indices and composition of the arthropod guilds or functional groups in the 2 seasons in the organic rice plots were evaluated with the Tukey test. Species abundance and composition were analyzed using analysis of variance (ANOVA of arcsine, logarithmic and, square root transformed percentages), and means were separated with the Tukey-test as calculated by SPSS 16.0 software. Throughout the text, results are shown as means ± SE.

Results

Abundance of Arthropods

A total of 16,902 individuals were identified as belonging to 135 species of arthropods in 2 classes, 10 orders and 47 families. The morphospecies collected and corresponding taxa of the voucher specimens are shown in Table 1.

The species richness and total number of arthropods in early season rice crop were a little higher than those in the late season crop. There were 114 species of arthropods with 3,177 individuals (the mean number) in the early season crop, and 109 species of arthropods with 2,457 individuals (the mean number) in the late season crop.

Species Richness and Diversity

Some common community indices, specifically the Shannon-Weaver H', the Simpson Dominance C, the Pielou evenness J and the Jaccard Similarity q indices, were calculated for the early and late season rice crops, and are shown in Table 2. There were no significant differences (H': $F_{(2,6)}$ = 2.62, $P > 0.05$; C: $F_{(2,6)}$ = 4.99, $P > 0.05$; J: $F_{(2,6)}$ = 0.78, $P > 0.05$) of these indices between the early and late season crops.

The temporal dynamics of the main indices of arthropod community diversity in the early rice crop and the late rice crop are shown in Fig. 1. The Shannon-Weaver diversity index and the Pielou evenness index of the arthropod community did not differ significantly between the early and late crops at 15, 29, 57 and 85 DAT. However at 43 DAT, the 2 indices of arthropod community in the early crop were significantly lower ($P < 0.05$) than the community in the late crop, but at 71 DAT, the reverse was true. The Simpson dominance index of the arthropod community in the early crop was higher than in the late crop at 15, 29, 43, 57 and 85 DAT, however, it was significantly lower ($P < 0.05$) for this community in the late crop than in the early crop at 71 DAT. The Jaccard similarity index q was high between the early and late season rice.

Dominance Distribution

Overall, 114 species of arthropods (58 species of spiders, 16 species of predatory insects, 25 species of phytophagous insects, 15 species of neutral or other insects) and 109 species of arthropods (50 species of spiders, 19 species of predatory insects, 24 species of phytophagous insects, 16 species of neutral or other insects) were observed in the early and late crops, respectively (Table 3).

There was almost significant dominance of the phytophagous insect functional groups in both early and late season rice (Fig. 2). Spiders and predatory insects displayed the second highest level of dominance among the 4 functional groups. The dominance of predatory insects in the early crop was significantly lower than in the late crop ($F_{(2,6)}$ = 1.25, $P < 0.05$), but there was no significant difference in the other arthropod functional groups between the early and late crops ($F_{(2,6)}$ = 2.47, $P > 0.05$) (Table 4; Fig. 2).

Discussion

A total of 135 species of arthropods was collected in the present study. The number of arthropod species found in this study was higher than those found by Li et al. (2007) in Hangzhou, Fuyang, but obviously lower than those from tropical areas (Settle et al. 1996; Schoenly et al. 1998). These differences was probably are a function of the different study locations, management regimes and sampling strategies. Our study area at Huizhou was located in the southern part of subtropical China (N 23° 09'50" E 114° 29'10"), which receives about 2,000 mm of rainfall annually and has an average annual temperature of 22 °C.

With respect to the arthropod community in the present study, we found no significant difference in diversity of between the early and late season rice crops, dominance distribution or evenness of arthropods. Clearly the similarity of the arthro-

Table 1. List of the arthropod Morphospecies and the higher taxonomic ranks of the voucher specimens collected in plots of organically grown rice at huizhou, Guangdong Province, China.

ORDER	FAMILY	MORPHOSPECIES	ORDER	FAMILY	MORPHOSPECIES
Araneida	Araneidae	*Neoscona theisi* (Walckenaer)			Miridae sp.
		Araneus sp.		Reduviidae	*Coranus* sp.
		Neoscone doenitzi (Boes. et Str.)		Veliidae	*Microvelia horvathi* Lundblad
		Singa pygmaea (Sundevall)	Coleoptera	Staphylinidae	*Paederus fuscipes* Curtis
		Neoscona subpullatus (Boes. et Str., 1906)			*Stenusmacies Sharp*
		Neoscona punctigera(Doleschall)		Coccinellidae	*Menochilus sexmaculata* Fabricius,1781
		Neoscona elliptica Tikader et Bal			*Synharmonia octomaculata* Fabricius
		Araneus ejusmodi Boes. et Str., 1906			*Henosepilachna vigintioctopunctata*(Fabricius)
		Araniella displicata (Hentz)			*Adalia bipunctata* (Linnaeus)
		Neoscona nautica (L. Koch)			*Alesia discolor* Fabricius
		Argiope sp.			*Propylea japonica* (Thunberg 1781)
		Argiope bruennichi (Scopoli,1772)			*Coccinella* sp.
	Tetragnathidae	*Tetragnatha nitens* (Auidouin, 1872)		Carabidae	*Chlaenius bioculatus* Motsch
		Tetragnatha squamata Karsch			*Agonum japonicum* Mostch
		Tetragnatha praedonia L.Koch			Carabinae sp.1
		Dyschiriognatha quabrimaculata (Bose. et Str.)			Carabinae sp.2
		Tetragnatha shikokiana Yaginuma		Cicindelidae	*Cicindela* sp.
		Tetragnatha mandibulata (Walckenaer)	Hymenoptera	Formicidae	Formicidae sp.
		Tetragnatha maxillosa (Thoren, 1895)	Odonata	Libellulidae	Libellulidae sp.
		Tetragnatha jwvana (Thorell, 1890)	Coleoptera	Curculionidae	*Echinocnemus squameus* Billberg
		Tetragnatha nigrita Lendle, 1886		Hispidae	*Dicladispa armigera* (Olivier)
		Leucauge blanda (L. Koch)	Hemiptera	Delphacidae	*Sogatella furcifera* (Horváth)
		Tetragnatha caudicula (Karsch, 1879)			*Nilaparvata lugens*(Stal)
		Tetragnatha sp.		Aphididae	Aphididae sp.
		Leucauge sp.		Cicadellidae	*Inazuma dorsalis* (Motschulsky)
		Dyschiriognatha sp.			*Deltocephalus oryzae* (Matsumura)
	Theridiidae	*Theridion octomaculatum* Boes. et Str.			*Empoascanara maculifrons* (Motschulsky)
		Enoplognatha dorsinotata Boes. et Str., 1906			*Nephotettix impicticeps*
		Theridion pinastri			*Nephotettix bipunctatus* (Fabricius)
		Theridion sp.			*Empoasca subrufa* Melichar
	Linyphiidae	*Hylyphantes graminicola*			Cicadellidae sp.
		Erigone prominens Boes. et Sir., 1906			Cicadellidae sp.
		Ummeliata insecticeps Boes. et Str.		Pentatomidae	*Eysarcoris guttiger* (Thunberg)

TABLE 1. (CONTINUED) LIST OF THE ARTHROPOD MORPHOSPECIES AND THE HIGHER TAXONOMIC RANKS OF THE VOUCHER SPECIMENS COLLECTED IN PLOTS OF ORGANICALLY GROWN RICE AT HUIZHOU, GUANGDONG PROVINCE, CHINA.

ORDER	FAMILY	MORPHOSPECIES	ORDER	FAMILY	MORPHOSPECIES
		Neriene japonica (Oi, 1960)			*Nezara viridula* Linnaeus
		Gnathonarium gibberum Oi, 1960			*Scotinophara lurida*(Burmeister)
		Gnathonarium dentatum (Wider, 1934)			*Piezodorus hybneri* (Gmelin)
		Neriene sp.			*Eysarcoris ventralis* (Westwood)
		Erigone sp.		Cydnidae	*Fromundus* sp.
		Linyphiidae sp.		Scutelleridae	*Poecilocoris druraei* (Linnaeus)
	Lycosidae	*Pirata subpiraticus* Boes.et str.		Coreidae	*Cletus punctiger* Dallas
		Pardosa pseudoannulata			*Cletus trigonus* (Thunberg)
		Pirata piraticus		Lygaeidae	*Pseudopachybrachius guttus* (Dallas)
		Pardosa laura Karsch, 1879	Lepidoptera	Pyralididae	*Tryporyza incertulas* (walker)
		Pardosa tschekiangensis Schenkel			*Cnaphalocrocis medialis* Guenee
		Pirata piraticus		Noctuidae	*Mythimna separata*(Walker)
		Lycosa sp.			*Naranga aenescens* Moore
	Dolomedidae	*Dolomedes pallitarsis* Boes. et Str., 1906	Orthoptera	Catantopidae	*Oxya chinensis*
	Salticidae	*Salticus potanini* Schenkel, 1963		Pyrgomorphidae	*Atractomorpha sinensis* Bol var
		Bianor hotingchiechi (Schenkel)	Diptera	Chironomidae	Chironomidae sp.
		Harmochirus brachiatus(Thorell, 1877)		Tipulidae	Tipulidae sp.
		Marpissa magister (Karsch, 1879)		Stratiomyidae	Stratiomyidae sp.
		Bianor aenescens (Simon, 1868)		Muscidae	Muscidae sp.
		Myrmarachne gisti Fox, 1936	Dermaptera	Labiduridae	*Euborellia pallipes* Shiraki
		Plexippus paykulli (Audouin, 1827)	Coleoptera	Dermestidae	Dermestidae sp.
		Salticidae sp.		Crioceridae	Crioceridae sp.1
		Phintella sp.			Crioceridae sp.2
	Agelenidae	*Agelena difficlis* Fox,1936		Chrysomelidae	Chrysomelidae sp.
	Thomisidae	*Xysticus saganus* Boes. et Str., 1906		Dascillidae	Dascillidae sp.
		Xysticus ephippiatus Simon, 1880		Dytiscidae	Dytiscidae sp.
		Misumenops tricuspidatus F.,1775		Collembola	Poduridae sp.
	Clubionidae	*Clubiona japonicola* Boes. et Str.	Hemiptera	Lygaeidae	*Nysius ericae* (Schilling)
		Clubiona corrugata Boes. et Str., 1960			*Dimorphopterus* sp.
		Clubiona hedina Scnenkel, 1963			Geocoris sp.
		Clubiona sp.			*Entisberus* sp.

TABLE 1. (CONTINUED) LIST OF THE ARTHROPOD MORPHOSPECIES AND THE HIGHER TAXONOMIC RANKS OF THE VOUCHER SPECIMENS COLLECTED IN PLOTS OF ORGANICALLY GROWN RICE AT HUIZHOU, GUANGDONG PROVINCE, CHINA.

ORDER	FAMILY	MORPHOSPECIES	ORDER	FAMILY	MORPHOSPECIES
	Oxyopidae	*Oxyopes sertatus* L. Koch *Oxyopes javanus* Thorell, 1877		Tingidae Miridae	Tingidae sp. Miridae sp.
Hemiptera	Miridae	*Cyrtorrhinus livdipennis* Reuter	Orthoptera	Gryllidae	Gryllidae sp.

pod communities in the early and late rice crops was high. Samples taken from both early and late season organic rice yielded faunal assemblages in our study, showed greater morphospecies richness and higher Shannon diversity indices were found compared with those collected from the conventional rice fields (Tao et al. 1996; Li et al. 2007). This is consistent with the researches in Australian (Wilson et al. 2008) and Jiangmen organic rice fields (Zhong et al. 2005).

Diversity of arthropod community varies widely in different seasons and rice growth stages, and the general trend toward arthropod diversity and evenness in early season rice are less than in late season rice (You & Wu 1989). Results in the present study are consistent with this point. The diversity index and evenness index in early season rice were 1.01 and 0.63, respectively, and 1.14 and 0.71, respectively in late season rice.

In the present study, the majority of arthropods were phytophages in both early and late season rice. Taxonomically, the phytophagous insects in the two season rice were dominated by hemipterans. Planthoppers and leafhoppers were the most important components of the phytophagous fauna, and they were high percentages of the phytophages. Some important hemipteran pests such as the *N. lugens* have been known to cause huge losses to rice production (Heong et al. 1992; Qiu et al. 2004; Backus et al. 2005; Wang & Wang 2007) at 43 DAT, and the dominance index of the arthropod community in early rice was significantly higher than in late rice. This result might have been caused by the high *N. lugens* population densities in the above mentioned studies, but in our study, the levels of *N. lugens* remained below the treatment threshold.

Spider populations (including Linyphiidae, Tetragnathidae and Lycosidae) showed positive responses in both early and late season rice. The dominant species of spiders in early season rice were *Tetragnatha shikokiana* Yaginuma and *Hylyphantes graminicola*,; whereas the dominant species in the late season rice were *Ummeliata insecticeps* Boes. et Str. and *Pirata subpiraticus* Boes. et Str. These spider species were important factors in controlling planthopper and leafhopper populations. Similar responses were also observed in other studies. Such positive response of spider populations have direct impacts on hopper survival and spiders are the key factor in population control of hoppers (Kenmore et al. 1984). Since spiders constitute more than 20% of arthropods in the present study, their impacts would be underestimated by merely comparing numerical relationships.

In this study, predatory insects were mainly composed of the Hemiptera and Coleoptera. *Cyrtorrhinus livdipennis* Reuter (Hemiptera: Mi-

TABLE 2. DIVERSITY INDICES OF THE ARTHROPOD COMMUNITY IN THE EARLY SEASON (APR-JUL) AND LATE SEASON (AUG-NOV) CROPS OF DOUBLE-CROPPED ORGANICALLY GROWN RICE AT HUIZHOU, GUANGDONG PROVINCE, CHINA.

Diversity index	Early season rice	Late season rice
Shannon-Weaver, H´	1.01 ± 0.14 a	1.14 ± 0.08 a
Simpson Dominance, *C*	0.26 ± 0.09 a	0.15 ± 0.03 a
Pielou Evenness, *J*	0.63 ± 0.09 a	0.71 ± 0.05 a
Jaccard Similarity, *q*	0.70 ± 0.06	

Mean ± SE is the mean of three replicates and standard error. Values in the same row with different letters show significant difference (Tukey-test, $P < 0.05$). *H´*: Shannon-Weaver diversity index; *C*: Simpson Dominance index; *J*: Pielou Evenness index; *q*: Jaccard similarity index.

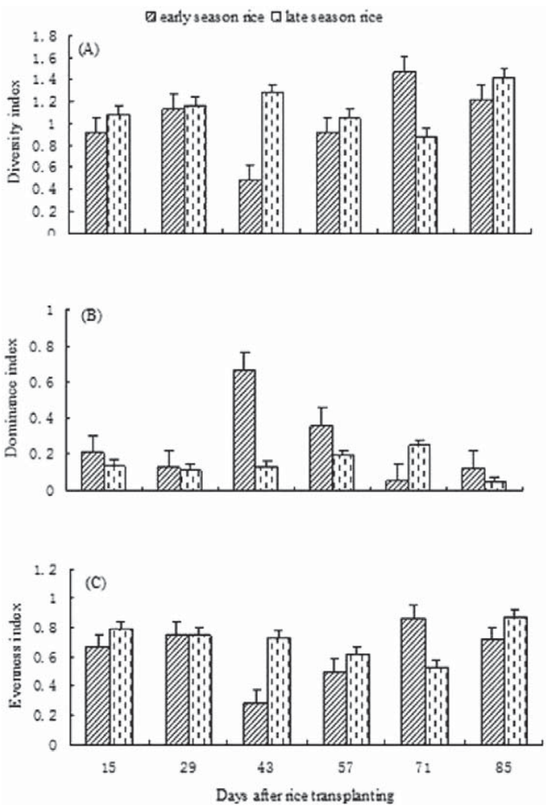

Fig. 1. Temporal dynamics (± SE) of main indices [diversity index (A), dominant index (B) and evenness index (C)] of arthropod community diversity in the early season (Apr-Jul) and late season (Aug-Nov) crops of double-cropped organically grown rice at Huizhou, Guangdong Province, China.

ridae) and *Paederus fuscipes* Curtis (Coleoptera: Staphylinidae) were the dominant species in both early and late season rice. Although predatory insects represented a lower percentage than spiders in early season rice, they still played an important role in the control of the pests.

The regulation effects of the neutral insects on pest abundance were mainly realized by natural enemies (Wu et al. 1994). The functional group of natural enemies grew faster than that of pest insects at the earlier rice stages mainly by using neutral insects as prey. The results showed that extremely large populations of Poduridae species and Chironomidae species dominated faunal assemblages in both early and late season rice fields. Although the percentages of neutral and other insects represented a low level in the study, they played an important role in the community food web in paddy fields.

Based on analysis of the arthropod biodiversity and community structure of early and late season organic rice ecosystems, we thus drew the following conclusions: (1) The Shannon-Weaver diversity and Pielou evenness indices in late season rice were a little higher than those of the early season rice; the Simpson dominance index in late season rice was a little lower than that of the early season rice; the Jaccard similarity index between early and late season rice was high up to 0.70; (2) the preponderance of spiders (as having the largest guild membership) was found in both early and late season rice, followed by phytophagous insects, predatory insects, and neutral and other insects; (3) the numerical dominance of phytophagous insect individuals was found in both

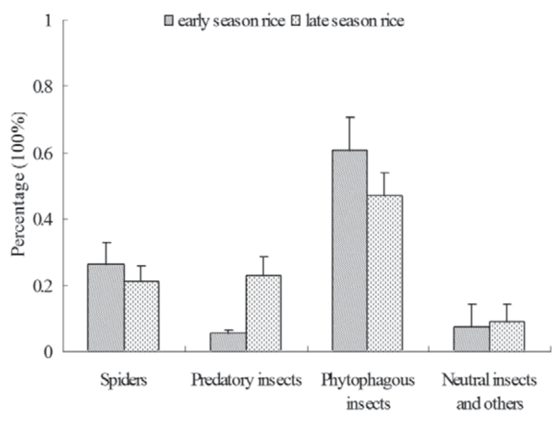

Fig. 2. Dominance distribution (± SE) of functional groups of arthropods in the early season (Apr-Jul) and late season (Aug-Nov) crops of double-cropped organically grown rice at Huizhou, Guangdong Province, China.

TABLE 3. NUMBER OF SPECIES AND INDIVIDUALS FOR EACH SUB-COMMUNITY SAMPLED IN THE EARLY SEASON (APR-JUL) AND LATE SEASON (AUG-NOV) CROPS OF DOUBLE-CROPPED ORGANICALLY GROWN RICE AT HUIZHOU, GUANGDONG PROVINCE, CHINA.

		Spiders	Predatory insects	Phytophagous insects	Neutral insects and others
Species abundance	E	58 ± 0.58 a	16 ± 1.15 a	25 ± 0.00 a	15 ± 0 .58 a
	L	50 ± 1.53 b	19 ± 0.00 b	24 ± 0.00 b	16 ± 1.15 a
Number of individuals	E	840 ± 22.60 a	173 ± 15.13 a	1928 ± 11.15 a	236 ± 9.29 a
	L	516 ± 11.93 b	560 ± 16.16 b	1159 ± 19.08 b	222 ± 7.09 b

Mean ± SE is the mean of three replicates and standard error. Values in the same row with different letters show significant differences based on ANOVA (Tukey-test, $P < 0.05$). E - Early season rice; L - Late season rice.

TABLE 4. COMPOSITION OF THE ARTHROPOD SUB-COMMUNITIES IN THE EARLY SEASON (APR-JUL) AND LATE SEASON (AUG-NOV) CROPS OF DOUBLE-CROPPED ORGANICALLY GROWN RICE AT HUIZHOU, GUANGDONG PROVINCE, CHINA.

	Spiders	Predatory insects	Phytophagous insects	Neutral insects and others
Early season rice	26.44 ± 6.25 a	5.45 ± 1.04 a	60.69 ± 9.88 a	7.43 ± 6.64 a
Late season rice	21.00 ± 4.74 a	22.79 ± 5.48 b	47.17 ± 6.82 a	9.04 ± 5.36 a

Mean ± SE is the mean of three replicates and standard error. Means within columns not followed by the same letter are significantly different (Tukey-test, $P < 0.05$).

early and late season rice, followed by numerical dominance of spider individuals.

Our results clearly revealed the early and late rice crop arthropod community structures and the dynamics of phytophagous insects, spiders, predatory insects, neutral and other insects in a Guangdong organically grown double-cropped rice ecosystem. These results may provide useful foundation for exploring integrated pest management strategies appropriate for organically grown rice.

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