Aboveground arthropod pest and predator diversity in irrigated rice (*Oryza sativa* L.) production systems of the Philippines

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Abstract

Abundance and diversity of pest and predator species at different stages of crop growth were studied in chemical insecticide-treated and untreated irrigated rice production systems of the Philippines in a single season. Immigration of pest and predator species to the rice fields from the adjoining vegetated patches was also monitored for assessing the potential role of the latter group in natural biological control. Dominant pest species during the tillering stage were plant and leafhoppers belonging to the Hemipteran families of Cicadellidae and Delphacidae. Higher pest species diversity was recorded during the milk stage of the crop in both treatments compared to other pheno-phases. Among the predator species, *Micraspis crocea*, *Conocephalus longipennis*, *Metioche vittaticollis*, *Agriocnemis* spp., and *Cyrtorhinus lividipennis* were abundant. Malaise trap catches indicated the movement of pests, namely *Recilia dorsalis*, *Cofona spectra*, *Nephotettix* spp., *Nilaparvata lugens,* and *Eysarcoris* spp. and predator species such as *M. crocea*, *Agriocnemis* spp., and *M. vittaticollis* from the adjoining areas. Diversity and richness indices of pest and predators were higher in the untreated fields compared to the insecticide-treated fields. Highest pest species richness was found during the tillering stage, while predator species richness was highest during the milk stage. Implicit in this is that as the pest species increased, the predator diversity followed.

Keywords*:* Biological control, Immigration, Shannon index, Species richness, Evenness, Dominance.

Introduction

Arthropod pest and predator populations in rice (*Oryza sativa* L.) fields are intimately associated with each other (Settle et al., 1996). A lot of ecological research has been done on this and many scientific publications brought out on the occurrence, abundance, and diversity of arthropods, besides the variations due to topography, geographical conditions, and weather conditions (e.g., Landis et al., 2000; Juen et al., 2003). Yet there have been few studies demonstrating how the abundance and diversity of arthropod pests and predators contribute to the biological control of crop pests at different stages of growth. The tropical rice fields offer a biologically diverse and dynamic environment for invertebrate and vertebrate populations (Settle et al., 1996). The biodiversity in irrigated rice agroecosystem has interested both agroecologists and conservation biologists alike (Bambaradeniya et al., 2004).

The Philippines is one among the chief rice growing and consuming countries in the world. Among the major constraints of Philippine rice production are the high incidence of pests and the consequent over-use of chemical insecticides (Rola and Pingali, 1993), which disrupts the natural balance between insect pests and their natural enemies. In particular, spray formulations of monocrotophos, chloropyrifos, and quinalphos have adversely affected the predators and parasitoids of major rice pests (Patel et al., 1997). However, some workers have argued that Acephate, chloropyriphos, and monocrotophos are relatively safe to the predator species such as *Lycosa pseudoannulata, Tetragnatha javanica* and *Paederus fuscipes* (e.g., Kumar and

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Velusamy, 2000). It thus necessitates further and more systematic efforts to evaluate the effects of insecticidal applications on the pest complex of rice and the natural abundance and diversity of predators. This paper focuses on the diversity and abundance of pests and predators in insecticide-treated and control (no insecticide) fields and correlates the effects of insecticidal application on arthropod species diversity, besides analyzing the immigration pattern of arthropod pests and predators to the rice fields from adjoining patches of natural vegetation. The community structure of the selected taxa and species diversity in different stages of rice growth were also monitored.

Materials and Methods

The study was conducted in the Baybay municipality in Western Leyte, one of the Visayas group islands (124°17' E longitude and between 9°55' and 11°48' N latitude) in the Philippines. Two sampling sites were established: one near the Leyte State University (LSU) campus in the rice fields adjacent to the Agroforestry Demo Farm (AF site) and the second in Barangay Pangasugan about 2.3 km north from the LSU administrative headquarters (BP site). The AF site was near an upland contour demo farming system planted with leguminous hedgerows and alleys planted with annual crops. Stands of *Carica papaya, Mangifera indica, Musa paradisiaca, Ficus* spp., *Ananas comosus, Ipomoea batata, Leucaena leucocephala, Mallotus barbatus* exist in this area. Weed flora including *Pseudoelephantopus spicatus* (Asteraceae), *Ipomoea pescaprae* (Convolvulaceae), *Colocasia esculenta* (Araceae), *Commelina diffusa* (Commelinaceae), *Hyptis capitata* (Lamiaceae), *Wedelia trilobata* (Asteraceae), *Axonopus compressus* (Poaceae), *Mimosa pudica* (Mimosaceae), and *Mikania cordata* (Asteraceae) were found at both sites. The rice sampling areas lay adjacent to the demo farm at the lower slope at an elevation of around 10 to 15 m above sea level. The BP site was situated in a communal farmer's rice field and was not treated with insecticides during the whole duration of the crop. This is part of an organic farm of LSU and was always kept free of insecticides and the surrounding areas are all rice fields compared to the AF site surrounded by an agroforest. The AF site was also treated once in 10 weeks of crop growth with Rador (Chloropyrifos–250 g L^{-1}, Betacyfluthrin–12.5 g L^{-1}, and Solverro150–633.5 g L^{-1} active ingredients). Three plots of size 100 m^2 (10 x 10 m) were selected at both sites during March 2004. Rice (var. RC-18) was planted in both sites at a spacing of 20 x 20 cm.

Aboveground arthropod pest and predator species at different stages of rice growth, which can be easily trapped in sweep nets (32 cm dia) and malaise traps, were monitored. Sampling was done by sweep netting in established plots during various stages of rice growth. Twenty sweeps per plot was used as the standard. Weekly data on the number of individuals of each species obtained by net sweeping from both sites for the whole rice-cropping season was used to calculate the indices of diversity and to describe the community structure of arthropods. The malaise trap was installed at both sites along the border of the rice field to study the immigration of insects from weedy vegetation and agroforest to the rice fields. The trap was kept open only in one direction. Collection jars filled with 70% ethyl alcohol were attached to the traps in the morning (9 a.m.) and maintained until 9 a.m. the next day. Observations were made every 24 h and once every week the samples were identified to its lowest taxonomic category. Shannon's index of diversity (H'), Menhinick index (ES) for species richness, species evenness index (Magurran, 1988), and index of dominance (Odum, 1971) were computed to assess the diversity of arthropods at both sites. ANOVA and regression analysis were done to compare the insecticide effect on pest and predator abundance and diversity.

Results and Discussion

Arthropod pest diversity

Seventeen (AF site) and 14 (BP site) species were recorded by net sweeping (Table 1). They belonged to three major orders (Homoptera, Hemiptera, and Coleoptera) and five major families (Cicadellidae, Delphacidae, Alydidae, Pentatomidae, and Chrysomelidae). In general, the results indicate that

Table 1. Occurrence and abundance of arthropod pest species at treated (AF) and an untreated (BP) site in the Leyte Island of Philippines.

Name of the species, Family, and Order	Weekly catch (no.)									
	AF site					BP site				
	Total (S)	Total (M)	Mean (S)	SE (S)	Range (S)[1]	Total (S)	Total (M)	Mean (S)	SE (S)	Range (S)[1]
Chaetocnema basalis – Chrysomelidae (Coleoptera)	NO	1	-	-	-	1	NO	0.08	0.27	1
Dicladispa armigera – Chrysomelidae (Coleoptera)	NO	NO	-	-	-	NO	NO	-	-	-
Oulema oryzae – Chrysomelidae (Coleoptera)	NO	NO	-	-	-	NO	NO	-	-	-
Monolipta spp. – Chrysomelidae (Coleoptera)	2	2	0.15	0.37	1	3	2	0.23	0.59	2
Leucopholis irrorata – Scarabidae (Coleoptera)	NO	NO	-	-	-	NO	NO	-	-	-
Holotrichia mindanaoana – Scarabidae (Coleoptera)	NO	NO	-	-	-	NO	NO	-	-	-
Phyllophaga spp. – Scarabidae (Coleoptera)	NO	NO	-	-	-	NO	NO	-	-	-
Anomala pallida – Scarabidae (Coleoptera)	1	NO	0.07	0.27	1	NO	NO	-	-	-
Scotinophara coarctata/lurida – Pentatomidae (Hemiptera)	16	2	1.23	2.27	7	1	1	0.07	0.27	1
Nezara viridula – Scarabidae (Hemiptera)	7	NO	0.54	1.94	7	NO	NO	-	-	-
Pygomenida varipennis – Coreidae (Hemiptera)	7	NO	0.54	1.45	5	2	NO	0.15	0.37	1
Eysarcoris spp./*cletus* spp. – Coreidae (Hemiptera)	119	3	9.15	12.4	32	67	1	5.15	11.02	34
Nephotettix spp. – Cicadellidae (Hemiptera)	434	6	33.38	34.31	96	407	17	31.3	43.67	116
Recilia dorsalis – Cicadellidae (Hemiptera)	53	21	4.07	3.7	12	20	22	1.53	2.1	7
Cofona spectra – Cicadellidae (Hemiptera)	12	12	0.92	1.32	4	4	3	0.31	0.63	2
Thaia oryzivora – Cicadellidae (Hemiptera)	NO	NO	-	-	-	NO	NO	-	-	-
Cicaclulina bipunctata – Cicadellidae (Hemiptera)	2	1	0.15	0.55	2	NO	1	-	-	-
Pachybrachius pallicornis – Coreidae (Hemiptera)	1	NO	0.07	0.27	1	1	NO	0.07	0.27	1
Nilaparvata lugens – Delphacidae (Hemiptera)	14	2	1.07	2.43	7	33	39	2.54	5.38	15
Sogatella furcifera – Delphacidae (Hemiptera)	27	3	2.07	3.01	8	36	1	2.76	5.37	18
Laudelphax striatellus – Delphacidae (Hemiptera)	NO	NO	-	-	-	NO	NO	-	-	-
Leptocorisa spp. – Alydidae (Hemiptera)	198	2	15.2	16.89	47	102	2	7.84	13.16	35
Oxya hyla intricate – Acrididae (Orthoptera)	5	1	0.38	0.65	2	7	2	0.53	0.87	3
Ailopus thalassinus – Acrididae (Orthoptera)	NO	NO	-	-	-	NO	2	-	-	-
Heteropternis banian – Acrididae (Orthoptera)	2	1	0.15	0.55	2	1	2	0.07	0.27	1
Atractomorpha spp. – Pyrgomorphidae (Orthoptera)	2	1	0.15	0.55	2	NO	1	-	-	-

SE= standard error, S=sweeping, M=malaise trap, NO=not observed, [1]Range= maximum values indicated (min. = "0"). AF site= Agroforestry Demo Farm; BP site = Barangay Pangasugan

pest incidence started to buildup during the tillering stage (Figs. 1 and 2), which is consistent with the observations of Wilby et al. (2006). This is because sapsuckers and leaf feeding insects (Cicadellids, Delphacids, and Chrysomelids) flourish during the vegetative phase of rice growth. As food availability generally determines the type of dominant phytophages, Delphacidae (*Sogatella furcifera*) became abundant as the crop matured, especially at the BP site. At milk or dough stage, when the rice leaves do not provide particularly attractive feedstuffs to the insects because of its lower succulence, grain suckers belonging to Alydidae and Pentatomidae were abundant. This increasing trend of pest abundance from tillering to maturity is consistent with the diversity indices and species richness (Figs. 1 and 2). However, the low evenness indices indicate the dominance of certain pests mainly *Nephotettix* spp., *Recilia dorsalis,* and *S. furcifera* during the tillering stage of the crop (Figs. 3 and 4). The dominant pests at tillering were mainly plant and leafhoppers of the family Cicadellidae and some belonging to Delphacidae (Table 1).

Higher pest species diversity was recorded during the

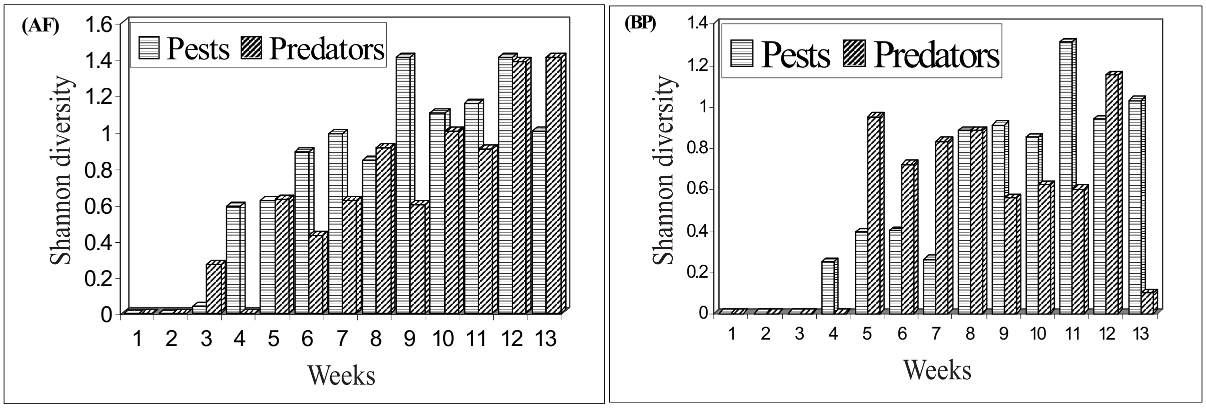

*Figure 1***.** Pest and predator diversity (Shannon index) at different growth stages in an insecticide treated (AF) and an untreated (BP) site in the Leyte Island of Philippines (1, 2, and 3 week correspond to seedling stage after planting; 4 to 8 weeks tillering stage; 9 to 12 weeks milk stage; and maturity stage starting with 13 weeks).

milk stage of the crop regardless of the site (Fig. 1), which correlates well with the observations of Didonet et al. (2001) on Delphacidae and Cicadellidae in the rice fields of Brazil. However, diversity and richness indices of AF site were higher than that of the BP site. During the milk stage, arthropod pest and predator associations were generally even at both sites, indicating that no single species dominated the community. Malaise trap catches showed relatively high abundance of *R. dorsalis, Cofona spectra, Nephotettix* spp., *Nilaparvata lugens*, and *Eysarcoris* spp. indicating that these species might have immigrated from the neighboring rice fields (AF site) and the weedy (ruderal) vegetation at the BP site (Tables 1 and 2). This was especially true for *N. lugens* (5th week), while *R. dorsalis* and *Nephotettix* spp. (4th week) immigrated during the tillering phase at the BP site. Conversely, the weedy vegetation near the agroforests (AF site) managed to keep this species away from the rice plots, although *C. spectra* immigrated in large numbers at this site. *Nephotettix* spp. was abundant at the BP site during tillering (Table 2); both, however, belonged to Cicadellidae.

The high arthropod pest diversity observed at the AF site may be attributed to the proximity to Mt. Pangasugan (1263 m above mean sea level) and the agroforests, which might have served as additional source of pollen, nectar, and honey dew to the arthropod pests as well as the predator populations (Landis et al., 2000). At both sites when the crop reached maturity, there was 2 to 5 times more pests than the predators. However, many species such as *Scotinophara coarctata/lurida*, *Nezara viridula*,

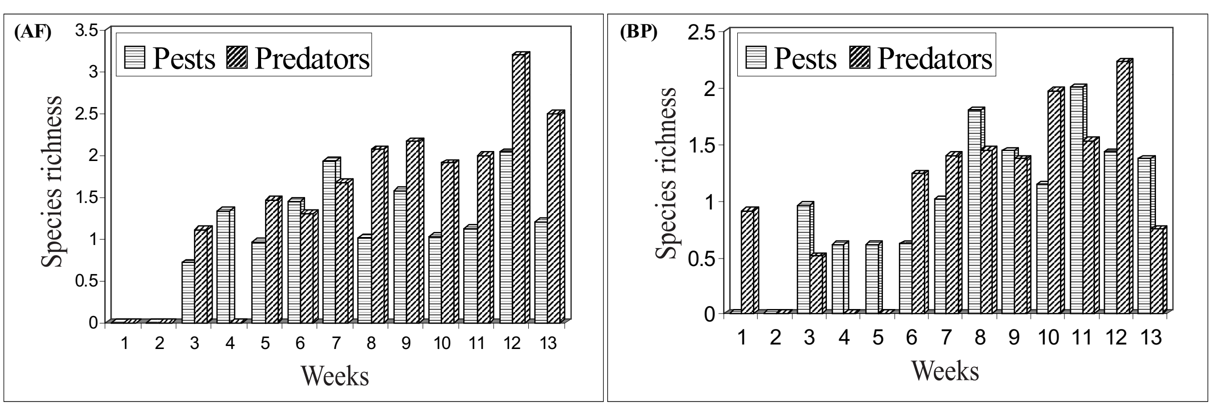

*Figure 2***.** Species richness of insect pests and predators in an insecticide treated (AF) and an untreated (BP) site in the Leyte Island of Philippines (1, 2, and 3 week correspond to seedling stage after planting; 4 to 8 weeks tillering stage; 9 to 12 weeks milk stage; and maturity stage starting with 13 weeks).

Table 2. Abundant migratory pest and predator species in rice fields at insecticide treated (AF) and untreated (BP) site.

Species	Total malaise trap catch in 13 weeks		Max. per week in 13 weeks (min. =“0”)	
	AF site	BP site	AF site	BP site
Recilia dorsalis (P)	21	25	5	10
Cofona spectra (P)	12	3	7	2
Nilaparvata lugens (P)	2	39	2	35
Eysarcoris spp. (P)	3	1	3	1
Nephotettix spp. (P)	10	19	5	8
Micraspis crocea (PR)	3	20	2	5
Agriocnemis spp. (PR)	4	8	2	4
Metioche vittaticollis (PR)	4	2	2	1

P= pest, PR=predator.

Pygomenida varipennis, *Eysarcoris* spp., *Nephotettix* spp., *R. dorsalis*, *C. spectra*, and *Leptocorisa* spp. were more abundant at the AF site (Table 1). Disturbance associated with the Ormoc-Baybay road, which bisects the area (BP site), and its relative distance from the natural forests where abundant sources of arthropod population occur, may have resulted in the lower pest diversity there.

Regression analysis showed that pests belonging to Acrididae, Alydidae, Cicadellidae, Coreidae, and Pentatomidae experienced no profound insecticidal effect (p=0.05). However, the Delphacids (*N. lugens* and *S. furcifera*) populations were significantly (p=0.007) influenced. Delphacidae pests generally appear during the milk and tillering stages of the crop and the insecticide treatment during the 10th week of plant growth (AF site), when the plants almost approached maturity, may be detrimental to their populations.

Arthropod predator diversity

Sixteen (AF site) and 13 (BP site) species were caught by sweep netting and included the families Coccinellidae, Carabidae, Tettigoniidae, Gryllidae, Coenagrionidae, Miridae, and Araneae (Table 3). The most abundant species were *Micraspis crocea*, *Conocephalus longipennis*, *Metioche vittaticollis*, *Agriocnemis* spp., *Cyrtorhinus lividipennis*. Although high diversity was observed starting from the post-seedling phase until crop maturity at the AF site, a severe drop was noted at maturity at the BP site (Fig. 1). The BP site also showed a high dominance index at maturity (Fig. 4) indicating that

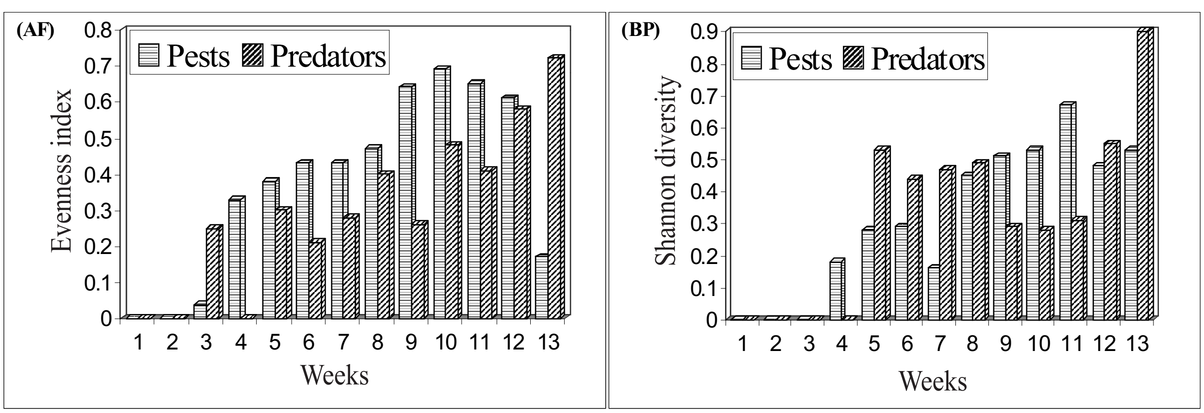

*Figure 3***.** Species evenness of insect pests and predators in an insecticide treated (AF) and an untreated (BP) site in the Leyte Island of Philippines (1, 2, and 3 week correspond to seedling stage after planting; 4 to 8 weeks tillering stage; 9 to 12 weeks milk stage; and maturity stage starting with 13 weeks).

Table 3. Occurrence and abundance of arthropod predator species at treated (AF) and an untreated (BP) site in the Leyte Island of Philippines.

Name of the species, family and order	Weekly catch (no.)									
	AF site					BP site				
	Total (S)	Total (M)	Mean (S)	SE (S)	Range (S)[1]	Total (S)	Total (M)	Mean (S)	SE (S)	Range (S)[1]
Micraspis crocea – Coccinellidae (Coleoptera)	208	3	16	21.3	75	165	20	12.69	17.17	48
Harmonia octomaculata – Coccinellidae (Coleoptera)	NO	NO	-	-	-	NO	NO	-	-	-
Menichilus sexmaculates – Coccinellidae (Coleoptera)	NO	NO	-	-	-	NO	NO	-	-	-
Ophionea nigrofasciata – Carabidae (Coleoptera)	7	NO	0.54	0.77	2	NO	NO	-	-	-
Conocephalus longipennis – Tettigoniidae (Orthoptera)	20	NO	1.46	1.56	5	23	1	1.76	3.03	10
Anaxipha longipennis – Gryllidae (Orthoptera)	4	NO	0.3	0.85	3	1	NO	0.07	0.27	1
Metioche vittaticollis – Gryllidae (Orthoptera)	6	4	0.46	0.77	2	1	2	0.07	0.27	1
Agriocnemis spp. – Coenagrionidae (Odonata)	65	4	4.84	4.61	15	51	7	3.92	4.34	14
Scipinia rapax – Reduviidae (Hemiptera)	3	NO	0.23	0.43	1	NO	NO	-	-	-
Polytoxus fuscovittatus – Reduviidae (Hemiptera)	1	NO	0.07	0.27	1	NO	NO	-	-	-
Cyrtorhinus lividipennis – Miridae (Hemiptera)	43	NO	3.3	5.7	18	50	NO	3.8	6.6	19
Lycosa pseudoannulata – Lycocidae (Araneae)	43	NO	3.3	4.5	17	7	4	0.5	0.96	3
Oxyopus spp. – Oxyopidae- (Araneae)	19	NO	1.46	1.71	4	10	NO	0.76	1.09	3
Phidippus spp. – Salticidae- (Araneae)	NO	NO	-	-	-	NO	NO	-	-	-
Atypena formosana – Linyphiidae (Araneae)	3	NO	0.23	0.43	1	1	NO	0.07	0.27	1
Argiope/Araneus spp. – Araniidae (Araneae)	11	NO	0.84	1.62	6	12	2	0.92	1.11	3
Tetragnatha maxillosa – Tetragnathidae (Araneae)	457	NO	35.15	53.5	173	132	NO	10.15	13.3	38
Misumena vatia – Thomisidae (Araneae)	3	NO	0.23	0.6	2	1	NO	0.07	0.27	1
Runcinia spp. – Thomisidae (Araneae)	1	NO	0.07	0.27	1	2	NO	0.15	0.37	1
Clubiona japonicola – Clubionidae (Araneae)	NO	NO	-	-	-	NO	NO	-	-	-

SE= standard error, S=sweeping, M=malaise trap, NO=not observed, [1]Range=maximum values indicated (min. = "0"); AF site= Agroforestry Demo Farm; BP site = Barangay Pangasugan

the samples were dominated by a single species (*C. longipennis*).

Weekly species richness was higher as the crop approached maturity, which was similar to pest species (Fig. 2). This may be due to the availability of resources for predators due to higher pest abundance. It was observed that the pattern of weekly species richness of predators gradually increased from tillering to maturity. These results correlate well with the previous observations that as soon as the pest population buildup during a particular stage of the crop growth, predators follow that implying some sort of a balance between pests and its natural enemies. van den Berg et al. (1992) reported that Gryllidae, Coccinellidae, Carabidae, and Miridae were voracious feeders of pests which corresponds well with our observations on species richness of these species at the respective growth stages of the crop. At the BP site, higher density of *Cyrtorhinus lividipennis* (Miridae) was encountered around the 4th and 5th weeks (tillering period). Families Cicadellidae and Delphacidae dominated most of the potential preys during this stage. Implicit in this is that Delphacid pests, mainly *N. lugens* (Stål) can be controlled by using the preferential predator species such as Miridae (*C. lividipennis*). This predator was abundant at both sites until tillering (8th week), which is also the stage of high abundance for *N. lugens*.

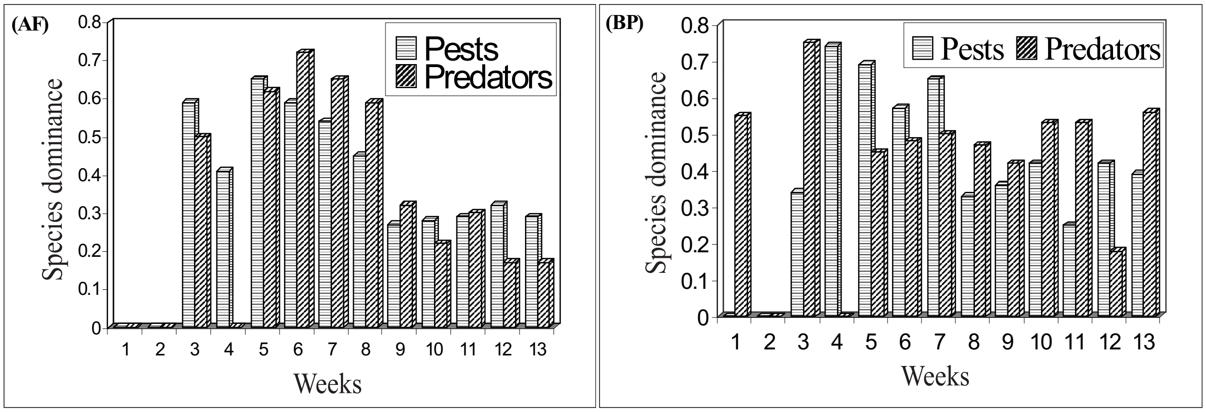

Figure 4. Species dominance of insect pests and predators in an insecticide treated (AF) and an untreated (BP) site in the Leyte Island of Philippines (1, 2, and 3 week correspond to seedling stage after planting; 4 to 8 weeks tillering stage; 9 to 12 weeks milk stage; and maturity stage starting with 13 weeks).

The higher indices of dominance between 5 and 8 weeks (Fig. 4) indicate that the total population of samples collected was dominated by a single predator species *Tetragnatha maxillosa*, particularly at the AF site. *T. maxillosa* is a web spider and *N. lugens* was mostly found trapped in their webs. Spiders feed on larvae and pupae of Coccinellids as well as older instars of the *Chrysopa* spp. (Kuznetsov, 1993 cited by Hodek and Honek, 1996). Both being predators, might have altered the predator abundance and diversity in this study.

Malaise trap observations showed that the coccinellid *M. crocea*, immigrated in large numbers into the BP site at milk stage, while *M. crocea* and *Agriocnemis* spp. together were found in relatively large numbers at the BP site during the whole duration of the crop (Table 2). Regression analysis also showed that spider population with highly significant negative insecticide effect ($p < 0.0001$), as they mainly prefer the Delphacidae pests. Gryllidae, Miridae, and Tettigonidae, however, did not show significant insecticide effect, as these predators do not directly feed on the plants.

On a final note, under undisturbed conditions without insecticides, natural populations of predators may exert some control over the pest populations so that pest outbreak can be prevented and insecticidal application may not be necessary. Predator population usually buildup following pest population increase and there is correlation between pest and predator abundance and diversity. As this study was conducted during a single cropping season, there is scope to replicate this for different cropping seasons.

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