Comparison of Biodiversity Index in Pesticide Treated and Untreated Rice Field in Northeast of Thailand

Supaporn Chaigarun,[1*] Nusaraporn Kessomboon,[2] Pattapong Kessomboon,[3] Sungwarl Somboon,[4] Perayos Khangkhan,[5] and Kong Luen Heong[6]

[1]*The Community Health Program, Faculty of Science, Ubon Ratchathani Rajabhat University, Ubon Ratchathani 34000, Thailand*

[2]*Faculty of Pharmaceutical Science, Khon Kaen University, Khon Kaen 40002, Thailand*

[3]*Faculty of Medicine, Khon Kaen University, Khon Kaen 40002, Thailand*

[4]*Faculty of Agriculture, Ubon Ratchathani Rajabhat University, Ubon Ratchathani 34000, Thailand*

[5]*Faculty of Technology, Mahasarakham University, Mahasarakham 44150, Thailand*

[6]*Entomology Division, International Rice Research Institute, Los Banos, Philippines*

**Corresponding author: E-mail: s_chaigarun@yahoo.com*

ABSTRACT

The biodiversity index could be used in Health Impact Assessment process since it might affect the quantity and quality of human food supply - an important health determinant. This pilot study explored the biodiversity index between treated and untreated pesticide in rice cultivation. A field experimental study was performed in the wet season. A sweep net sampling method was used to collect insects from two rice fields, untreated and treated with pesticide in recommended rate according to the standard manual for testing insecticides on rice fields developed by the International Rice Research Institute. The species richness index (Esn) was computed by EcoSim - A null model software for ecology. Mean difference (MD) between groups with their 95% confident interval was estimated based on linear regression model. The results showed that the proportion of herbivores was similar to beneficial insects. Hence, the beneficial insects could control pests in rice fields and the application of pesticide might not be needed. Next, there were less unsafe handing system and practices of physical health for farmers, less contamination in food chain and less impact to biodiversity as well as less production loss and food security which effects to tension and mental health problems for farmers at finally. However, it was found that pesticides were highly toxic to natural enemies such as spiders and hymenopteran parasitoids, thus, disorganized predator-prey relationships. Moreover, the above-ground arthropod diversity in the rice field with untreated pesticide was significantly of higher degree than in the rice field with treated pesticide.

Keywords: Biodiversity index, Health determinant, Rice field, Pesticide

INTRODUCTION

Pesticides are commonly used in Thai rice field (Vanichanont, 2004). The adverse effects arise from various circumstances, both direct and indirect human contacts. In environment, biodiversity is an important factor of health determinant affecting health that might be used for assessment in the Health Impact Assessment (Health Development, 2000). The continued health of human societies depends upon a natural environment that is productive and contains a wide diversity of plants, animals and microbe species. Biological diversity can be considered on different hierarchical levels of life: gene, population, species, genus, family, order, phylum, ecosystem, etc. and considered in the sense as biodiversity (Groombridge, 1992). For example, conserving pollinators and natural enemies of pests are essential for successful grain, fruit and vegetable production. Improving food production also decreases malnutrition (Scott-Samuel et al., 2001; Healthy Public Policy and Health Impact Assessment Program, 2005a; 2005b). The loss of a key species (e.g., loss of a predator) creates an imbalance among the remaining species, and can sometimes result in the collapse of the entire ecosystem. Biodiversity affects the quantity and quality of human food supply. Yet, at present, the rapidly expanding human population is intensifying the need for increased food supplies (Pimm et al., 1995; Pimental et al., 1998). Hence, this pilot study explored the biodiversity index between treated and untreated pesticide in rice cultivation because it could help to identify and consider the potential health impacts for Thai society.

MATERIALS AND METHODS

Experimental sites

Two separate rice growing areas were selected as experimental sites in Khon Kaen Province, Northeast of Thailand. Detailed descriptions of the experimental sites are presented in Table 1.

Table 1. Summary of experimental sites, Khon Kaen province, Thailand.

Sites	Location, elevation annual rainfall	Rain patterns	Cropping pattern	Sampling dates, plot size
Khon Kaen	17° 30’N, 102° 25’ E 900 m above sea level 1,200 mm rain	Annual rainfall May-September	Rice mixed with vegetables	*May 16-August 7, 2008 *(wet season)* 3,200 m^2

Sampling

following the Manual for Testing Insecticides on Rice by International Rice Research Institute procedure (International Rice Research Institute, 1981) and then insects were kept in vials of 70% ethanol. Sampling was replicated 10 times on each occasion at each site. A total of 600 samples were obtained in the study, taken at weekly intervals. Samples in individual vials were sorted and counted with farmers and in the laboratory with entomologist. The arthropods obtained from the samples were identified to species whenever possible. They were later grouped into guilds as used by Moran and Southwood (1982) and Heong et al. (1991).

Insecticide application

Thiamethoxam 25% WG (Actara®) was used to control insect pests in the sprayed rice field in ratio of 10 grams per 20 litres of water. (Maienfisch, 2006). Application timing was related to brown planthoppers migration as firstly, at vegetative stage in July 5, 2008, and secondly, at reproductive stage in July 25 and July 31, 2008.

Site selection

There were two sites selected in Khon Kaen Province, Thailand. The first site, selected as a control for non pesticide use, stopped using pesticide for seven years and qualified as an organic farm under standard EU2092/91 No. CU 019946 for European countries and OMIC No. 1262 for Japan (2002-present) under which agricultural products are imported from European countries. The second site had used pesticides for more than 10 years.

Quality control

1) Well-trained sweeper with experience in the method to sweep and identify types of insects.

2) The following factors were equally assigned to all groups of experiment

- Soil type: Silt-loam
- Fertilizer 15: 15:15 (N:P:K)
- Fertilizer rate: 154.44 kg. per hectare
- Type of rice cultivation: direct seeding
- Rice variety: KDML105
- Size of experimental area: 3,200 m^2 per 2 plots (1 plot= 1,600 m^2)
- Cultural practice: Land preparation, Seed germination

Data analysis

There are numerous diversity indices available in the literature; Magurran (1988) provided a comprehensive review of indices. Then, Taylor (1978) examined the discriminant ability of eight diversity measures by using analysis of variance to test for between- site variations in the total annual moth samples (replicated over 4 years) from nine environmentally-stable sites in the Rothamsted Insect Survey. Of all the indices he tested, Taylor reported that Rarefaction (Esn) and the transformed Shannon index (exp H') were the best and second discriminator. Next, Kempton (1979) looked at the discriminant ability of the numbers of Hill's family. Once again, the Rothamsted moth data were employed but on this occasion, the sample size was increased to 14 sites, each replicated over 7 years. So he summarized in the same ways as Taylor that the degree of discrimination was greater for the transformed versions of the Shannon indices (exp H') than for its untransformed counterparts. Hence, indices that were used in this study were:

1. Rarefaction

To avoid sample size sensitivity, rarefaction techniques were used to compute species richness and the less sample size sensitive indices with more discriminating abilities were used for comparison. These methods were as, firstly, the calculation involves many factorials and are tedious. Secondly, rarefaction leads to a great loss of information. The formula is

$$Esn = \sum \left\{ 1 - \left[\frac{\binom{N-Ni}{n}}{\binom{N}{n}} \right] \right\}$$

Where E_{sn} = the expected number of species in the rarefied sample
n= standard sample size
N= the total number of individuals recorded in the sample to be rarefied
Ni= the number of individuals in the ith species in the sample to be rarefied

Remark: the term $\binom{N-Ni}{n}$ and $\binom{N}{n}$ are 'combinations' which are as follows:

$$\binom{N}{n} = (N!)/\ [n!*\ (N-n)!]$$

N! is a factorial. For example 4! =4*3*2*1=24

2. Shannon diversity index (H')

The formula for calculating the H' is

$$H' = -\sum pi * \ln pi$$

Where pi, the proportional abundance of the ith species = (ni/N)

In calculating, exp H', the exponential Shannon index, was transformed before comparison because of more discriminating abilities (Magurran, 1988).

The functional biodiversity indices were analyzed, using indices computed by EcoSim version 7.72 (Gotelli and Entsminger, 2005) -null model software for ecology.

Finally, mean differences (MD) between groups with 95% confident intervals were estimated based on linear regression model.

RESULTS

There were 819 arthropods in experimental rice field in wet season. Both pests and benefit arthropods were sorted into 4 guilds as herbivores (38.71%), predators (21.73%), parasitoids (19.9%) and ditritivores (18.44%) (Table 2). During sorting, hoppers were recorded the most pests. Spiders were the most of the predators' species and dipterans were the majority of detritivores species.

Moreover, Table 2 also shows the biodiversity indices of the arthropod guilds of the two sites and the species richness (rarefaction). Arthropod biodiversity and Species richness in untreated field had increased comparing with that of treated. In all guilds, species richness, Esn (rarefaction) and the transformed Shannon-Weiner (exp H') were high when no pesticide was used.

Table 2. Comparison of arthropod biodiversity in untreated and treated rice field in Khon Kaen Province, Thailand.

Guilds	Biodiversity Parameters	Untreated* (Mean±SD)	Treated* (Mean±SD)	MD	95%CI	P
Herbivores	Number	317	146			
	Species richness, E_{sn} (rarefaction)	36.9±0.57	13.1±0.32	23.8	23.70 to 23.89	P<0.001
	Exp Shannon (exp H')	9.34±0.32	7.48±0.53	1.86	1.78 to 1.94	P<0.001
Predators	Number	178	64			
	Species richness, E_{sn} (rarefaction)	53.8±0.42	28.8±0.42	25	24.88 to 25.12	P<0.001
	Exp Shannon (exp H')	10.9±0.41	8.2±0.20	2.7	2.59 to 2.81	P<0.001
Parasitoids	Number	163	16			
	Species richness, E_{sn} (rarefaction)	34±0.48	16.4±0.52	17.6	17.35 to 17.84	P<0.001
	Exp Shannon (exp H')	20.3±0.43	5.2±0.16	15.1	14.88 to 15.32	P<0.001
Detritivores	Number	161	65			
	Species richness, E_{sn} (rarefaction)	23±0.48	7.9±0.32	15.8	15.67 to 15.93	P<0.001
	Exp Shannon (exp H')	9.31±0.26	1.39±0.10	7.92	7.85 to 7.99	P<0.001

**Analyzed by EcoSim (Gotelli and Entsminger, 2005)*

DISCUSSION

From the result, there were several species of herbivores such as thrips, beetles and hoppers present in untreated site and decreased in treated field. Predators' species were enriched by a greater diversity of generalists such as spiders, hemipterans and beetles. There were more hymenopteran species in untreated than in treated site, particularly scelionids. Species richness of detritivores was markly increased in untreated field, especially of dipteran. Although the number of herbivores or pests is the highest among all methods of collecting insects, the total of number of beneficial insects including predators, parasitoids, and detritivores were higher than pests. It represents that the beneficial insects can control pests in these rice fields in Khon Kaen province. Therefore, it is not need to spray pesticide more in rice field. It meant that less unsafe handing system and practices of physical health for farmers, less contamination in food chain and less impact to biodiversity and less production loss and food security which effect to tension and mental health problems for farmers at finally (Healthy Public Policy and Health Impact Assessment Program, 2005a; 2005b). However, after spraying thiamethoxam, rice hoppers such as brown planthoppers, green leafhoppers and white backed planthoppers were killed in a large number. Consequently, the number of herbivores was decrease. Thiamethoxam 25WG @ 25 g a.i./ha was effective against brown planthopper on rice (Hegde and Nidagundi, 2009) as shown in Table 2. This rice field ecosystem was good for the food chain because beneficial insects, especially predators and parasitoids were secondary consumers which ate primary consumers. For example, lady beetle (*Micraspis discolor*) consumed brown planthopper (*Nilaparvata lugens*), and long-jawed spider (*Tetragnatha* spp.) ate both green leafhopper (*Nephotettix virescens*) and white leafhopper (*Cofana spectra*) (Heong et al., 1991). These relationships created a balance among the remaining species. The change in the dominance pattern of primary-secondary consumers proves to be a good indicator of the species diversity reduction and of the ecological imbalance induced by noxious factors (Teodorescu, 2005).

Considering arthropod sorting, both by farmers and counting by entomologist in the laboratory, biodiversity index in the transformed Shannon-Weiner index (exp H’) sorting were also reported to be of the same tendencies, that were 1.728 in untreated site and 1.344 in treated site with recommended rate in wet season, Khon Kaen province; mean difference =0.384 (0.258 to 0.521) with farmers (Chaigarun et al., 2009). When insect sorting in laboratory was compared with farmers in the field, no significant difference were obtained. Biodiversity indices of herbivores, predators, parasitoids, and detritivores were 9.34, 10.9, 20.3 and 9.31 in untreated site, respectively, and 7.48, 8.2, 5.2, and 1.39 in treated site with recommended rate, respectively; mean difference =1.86 (1.78 to 1.94), 2.7 (2.59 to 2.81), 15.1 (14.88 to 15.32) and 7.92 (7.85 to 7.99), respectively (Table 2). Even using rapid or comprehensive sorting, the result also showed the same way. Hence, rapid arthropod sorting is a simpler way to open for farmer’s participation that is important for health impact assessment process.

Focusing on certain indicator taxa might facilitate the task of monitoring human-induced impacts. Duelli (1997) suggested that spiders are good indicator for biodiversity. Moreover, spiders and lady beetles are well known to many people and are still very good quality guides to natural enemy recognition and their use as biological control agents (Williamson, 1998). Moreover, the International Rice Research Institute detailed spiders in a pocket guide entitled Friends of the Rice Farmer (Shepard et al., 1987).

The significant differences between biodiversity index in untreated and treated sites indicated that above ground arthropod diversity can be used as a simple indicator of environmental quality in agrosystems.

In addition, Kam Koon Center, Ubonrat Hospital, Thailand studied *“The Learned Lesson for I-san Healthy Community”* and reported that the increase in numbers and types of species meant good environment and healthy trends which are considered one of eight Gross Domestic Happiness indicators (GDH) (Thai Health Promotion Foundation, 2008).

This study showed that farmers who do not use pesticides in their rice fields can enjoy the healthy impact of having higher arthropod biodiversity index than those who use pesticides with subsequent significant reduction of arthropods.

CONCLUSION

The biodiversity index in untreated rice field was higher than in the treated. It indicated that untreated rice field has more diversity or healthier ecosystem than the one using pesticide. This species diversity data should be collected continuously in Thailand because stakeholders will be able to use these for studying association with chronic health problems in the future. Further research should be focused on relationship of the biodiversity index to rice yields, food supply, other health determinants, i.e., economic security and health status for sustainability.

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