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EFFECTS OF AGROCHEMICAL RESIDUES ON AQUATIC INVERTEBRATES IN SEMI-ORGANIC RICE FIELDS

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ABSTRACT: This study presents a case study for rice farming change from a conventional to semi-organic process. Alterations of aquatic invertebrate composition and diversity between these two rice farming methods were compared. Aquatic invertebrates were collected in flooded rice fields between August and October 2015. Four phyla comprising 12 taxa were identified with average abundances in conventional and semi-organic samples of 5,717 and 10,676 individuals/m^2, respectively, while the Shannon diversity index ranged between 0.45-0.62 and 0.35-0.59, respectively. Evenness index in conventional and semi-organic ranged between 0.26-0.65 and 0.23-0.71 respectively, while the dominant index was highest in semi-organic farming. Water quality parameters as temperature, dissolved oxygen and pH were not significantly different between the two farming methods. Contamination occurred from chemical substances remaining in semi-organic rice fields. Abundant pollution indicator species such as Oligochaeta, Chironomidae and Viviparidae suggested pesticide or herbicide contamination from water sources as agrochemical residues persisted from previous conventional rice farming.

Keywords: Ecotoxicology, Semi-Organic Rice Farming, Aquatic Invertebrate, Soil Ecology

1. INTRODUCTION

Rice is a semi-aquatic annual grass that is globally cultivated in over 100 countries [1]-[2]. Rice fields are temporary wetlands and important habitats for many aquatic organisms such as earthworms, aquatic insects, water birds and fish [3]-[5]. Use of agrochemicals in rice fields indices contamination from pesticides and chemical fertilizers [4]-[7]. In conventional rice cultivation, herbicides and insecticides are applied during vegetative growth through to the reproductive growth stage which causes variations in the benthic community [8]. Benthic invertebrate groups have historically been used as an indicator of freshwater ecology [9]-[10], [21]. The Chironomidae family in rice fields has a statistically significant relationship with dissolved oxygen [11], and soils of flooded rice fields are predominated by aquatic oligochaetes such as the tubificid *Branchiura sowerbyi* [12].

Rice production can be categorized into three groups based on cultivation methods as (1) conventional rice farming, which requires the application of mineral fertilizers and pesticides with irrigation as the water source, (2) semi-organic rice farming, where the farmer applies organic fertilizer and biopesticides but may also use inorganic fertilizers. Some chemical compounds may remain as contamination in the rice paddies after harvest [13], and (3) organic rice cultivation, where no chemical fertilizers or pesticides are used and the water source is spring water or rainfed [14]. Here, the influence of rice field management on abundance and community of benthic animal species was investigated to determine differences between conventional and semi-organic rice farming methods.

2. MATERIAL AND METHODS

2.1 Study Sites and Sampling Methods

Study areas were located in Maha Sarakham Province, Northeast Thailand. Sampling sites cultivated rice crops by both conventional and semi-organic techniques. For conventional rice cultivation, farmers burned straw stubble, applied inorganic fertilizers, herbicides and insecticides and used gravity-fed irrigation water. In semi-organic rice farming, farmers prepared the soil by plowing in the stubble using a tractor and applied inorganic and organic fertilizers, avoiding herbicides or insecticides, and used irrigation water. Invertebrate samples were collected from 3 paddy fields of conventional plots (16° 20' 15" N; 103° 9' 56" E) and 3 paddy fields of semi-organic plots (16° 20' 9" N; 103° 10' 13" E). Three replicates of each paddy field were also sampled using a 12 cm diameter sediment corer between August and October 2015 when the paddies were flooded. The collected invertebrates were sieved through a 0.5 mm mesh net and preserved in 80% ethanol. Water qualities as temperature, pH and dissolved oxygen were investigated using an Oakton (Eutech PCD 650) Multiparameter Meter.

2.2 Aquatic Invertebrates Identification

Aquatic invertebrate samples were sorted under a light microscope, with taxa identified to the lowest possible level according to taxonomic keys [20]. Invertebrates of each taxon were counted and total numbers were recorded.

2.3 Data Analysis

Diversity and evenness indices [15] were calculated following Eq. (1) to Eq. (3) with the dominance index [16] as Eq. (4),

$$H' = -\sum p_i \ln p_i \quad (1)$$

$$p_i = n_i / N \quad (2)$$

$$E_H = H' / \ln S \quad (3)$$

$$D = \sum p_i^2 \quad (4)$$

where H' is the Shannon's diversity index; p_i is the proportion of individuals found in taxon *i*; n_i is the number of individuals in taxon *i*; *N* is the total number of individuals of all taxa; E_H is the evenness index; *S* is the total number of taxa and *D* is the dominance index.

Abundance, diversity, evenness and dominance indices of aquatic invertebrates found in conventional and semi-organic rice farming paddies were compared using Levene's test for equality of variances and the t-test for equality of means. A significant level of p-value was set at less than 0.05.

3. RESULT AND DISCUSSION

3.1 The Composition and Abundance of Aquatic Invertebrates

Freshwater invertebrates from 3 phyla comprising 12 taxa were found in conventional rice fields while 4 phyla made up of 11 taxa were present in semi-organic rice fields. Taxa richness was similar between the two farming methods. Five taxa as Chironomidae, Ephemerellidae, Cyclopoida, Oligochaeta and Viviparidae were found at all plots, while 3 taxa (Odonata, Anisoptera and Hirudinea) were only collected from conventional rice fields and 3 taxa (Nematoda, Tipulidae and Baetidae) were found only in semi-organic plots (Table 1).

Aquatic invertebrates found in conventional and semi-organic rice fields totaled 1,753 and 3,266 individuals, respectively. Aquatic composition in conventional rice fields included Oligochaeta (88%) followed by Gastropoda (10%) and Insecta (2%), whereas semi-organic rice fields were composed of Oligochaeta (91%), Gastropoda (8%) and Arthropoda (1%) (Fig. 1). Oligochaeta was the dominant taxon at all sampling sites.

Average abundances of aquatic invertebrates in conventional and semi-organic rice fields between August and October 2015 were 5,717 and 10,676 individuals/m^2, respectively (Table 2). Average abundance between rice field treatments showed no significant difference with high variability between sampling sites.

3.2 The Diversity, Evenness and Dominant Indices

Diversity indices in conventional and semi-organic rice fields ranged between 0.45-0.62 and 0.35-0.59, respectively, with values for both study sites lower than previous reports from Kalasin Province, Thailand at 0.88 for conventional and 1.36 for organic farming methods [5]. The conventional rice field of Malaysia contaminated by the amount of agrochemicals have diversity index 0.94 [6]. An evenness index close to zero indicated dominant taxa in the area [5].

3.3 Water Quality of Soil Surface Water

Water quality parameters as temperature, dissolved oxygen (DO) and pH ranged between 26.33-33.34°C, 2.93-8.08 mg/L and 6.11-7.50, respectively (Table 3). All parameters were no significant difference between conventional and semi-organic paddy fields (p>0.05). The water quality in rice paddies at Malaysia was reported slightly acidic of pH range from 5.19-6.70 and low level of DO 0.76-3.81 mg/l, they categorized the water quality index (according to the Department of Environment Water Quality Index Classification) under classIII and slightly polluted. [28]

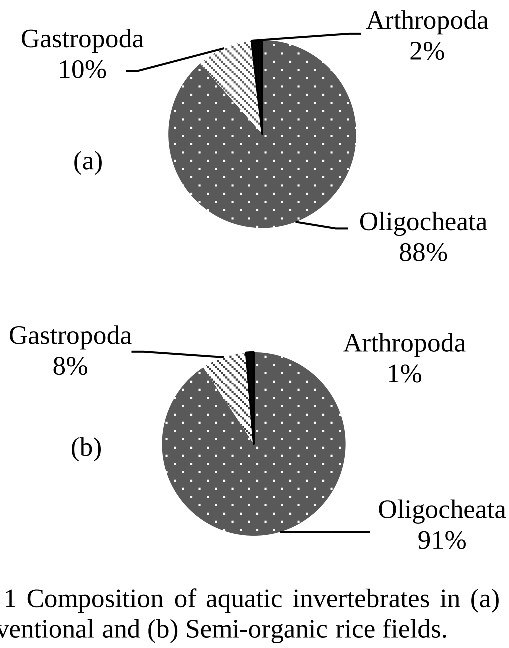

Fig. 1 Composition of aquatic invertebrates in (a) Conventional and (b) Semi-organic rice fields.

Table 1 Total numbers (individuals) of aquatic invertebrates classified to taxa recorded in conventional and semi-organic rice fields during flooding.

Aquatic Invertebrates Taxa	Conventional	Semi-0rganic
ANNELIDA		
Oligochaeta	1550	2964
Hirudinea	1	0
NEMATODA	0	7
MOLLUSCA		
Gastropoda		
Architaenioglossa		
Hydrobiidae	9	12
Viviparidae	161	247
ARTHROPODA		
Insecta		
Odonata	1	0
Anisoptera	1	0
Zygoptera	5	0
Diptera		
Chironomidae	7	11
Tipulidae	0	1
Ephemeroptera		
Ephemerellidae	13	3
Baetidae	0	1
Copepoda		
Cyclopoida	2	16
Entognatha		
Collembola	1	0
Branchiopoda		
Cladocera	1	0
Crustacea		
Decapoda	1	3
Ostracoda	0	1
Total number	1753	3266

Table 2 Abundance (individuals/m^2), diversity, evenness and dominance indices of aquatic invertebrates in conventional and semi-organic rice fields during flooding.

Index	Conventional			Semi-Organic		
	Aug	Sep	Oct	Aug	Sep	Oct
Abundance	1,990	8,328	6,833	2,510	21,843	7,676
Diversity	0.62	0.45	0.58	0.59	0.35	0.42
Evenness	0.65	0.26	0.39	0.71	0.23	0.28
Dominant	0.63	0.78	0.69	0.63	0.81	0.78

Table 3 Water quality parameters in conventional and semi-organic rice fields.

Rice fields	Parameters	Aug	Sep	Oct
Conventional	Temperature (°C)	33.33	29.43	26.33
	DO (mg/l)	8.08	3.04	2.93
	pH	7.14	6.31	6.64
Semi-Organic	Temperature (°C)	33.43	30.33	26.83
	DO (mg/l)	6.97	4.83	4.53
	pH	7.50	6.53	6.65

Rice field management techniques resulted in no significant differences in taxa richness, abundance, diversity, evenness and dominance indices ($p>0.05$). The high variation of abundance was observed. By contrast, apparent of some taxa possibly resulted from agrochemical applications in rice field areas. Cyclopoida was highly in semi-organic rice fields and can be used as an indicator of non-polluted areas [17]-[18]. Chironomidae have also been utilized as indicators of nutrient enrichment in water and sediment [6], [27], and were more abundant in semi-organic rice fields than in conventional plots. Oligochaeta, as an indicator of herbicide application, positively correlated with pH values in rice fields [4], [19]. Oligochaetes were more prevalent in semi-organic than conventional rice fields. Here, semi-organic rice fields were irrigated by water from canals which may have resulted in chemical substance contamination and similar benthic communities between the two sites Moreover, farmers often change rice cultivation methods from conventional to semi-organic and chemical contaminants may remain in the soil. At a result, low diversity of benthic community and abundance of oligochaetes were found at both sites. Abamectin insecticide and Niclosamide has been widely used to eradicate golden apple snails in Thailand rice farming [22]. This chemical substance has an impact to an aquatic animal that living in rice filed such as fairy shrimps (*Streptocephalus sirindhornae* and, Branchinella *thailandensis*), sliver barb (*Barbodes gonionotus*) and tadpole (*Hoplobatrachus rugulosus*) [22]-[23]. The present study, all of the species aforementioned have not found between the two sites. The low level of DO occurred in conventional rice fields from September to October may affect to sensitive species [24] and disappear from rice fields. The density of Gastropods in conventional and semi-organic rice fields showed no significant difference. Gastropod generally related to agricultural sewage with high density in polluted water [25], thus runoff during the rainy season from rice fields flow through canal and river may cause of eutrophic in the aquatic ecosystem. The density of Arthropods was low after pesticide applications [26], this indicates that in conventional and semi-organic rice fields were contaminated by agrochemical residues such as pesticide, herbicide or chemical fertilizer.

4. CONCLUSIONS

Effect of agrochemical residues was shown in semi-organic rice fields. Contamination from chemical substances was found in semi-organic farming systems. The abundance of pollution indicator species such as Oligochaeta and Chironomidae in semi-organic systems suggested pesticide or herbicide contamination from water sources as agrochemical residues from a former conventional rice farming system.

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