Effects of Pesticide Application on Chironomid Larvae and Ostracods in Rice Fields

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Benthic macroinvertebrates were surveyed in rice fields in which three pesticide applications were adopted; no pesticide, herbicide only, and herbicide + insecticide + fungicide. Abundant taxa were chironomids and ostracods. The populations of these animals fluctuated widely in the pesticide-treated rice fields. Larval populations of odonates and dytiscids which prey on chironomid larvae and ostracods, were depressed according as various pesticides were applied. The low density of predators presumably allowed the large increase in the populations of chironomids and ostracods. However, competition between chironomids and ostracods, as well as the direct toxic effect of pesticides, may have suppressed the increase of their numbers in some degree. Benthic algae decreased with most applications of herbicide. The algae showed a slight increase probably due to heavy grazing by chironomids and ostracods and to herbicide toxicity in the pesticide-treated fields.

INTRODUCTION

Pesticides are repeatedly applied to rice fields to control various rice plant pests, and the applications may affect on various aquatic organisms appearing in rice field floodwaters. However, only a few studies on the effects of pesticide have been made on these aquatic organisms. Ikeshoji (1980) observed the chironomid population in rice fields with different fertilizer treatments, but no appreciable effect of pesticide application was found on animals. Satō and Yasuno (1979) practiced acute toxicity tests of eight insecticides on larvae of five chironomid species. Their results indicate that the effective concentration of some pesticides is lower than the actual concentration detected in the rice fields. Application of fenitrothion by helicopter heavily reduced the abundance of a zooplankter Moina sp. in the floodwater of rice fields (Takaku et al., 1979). Gamma-BHC application also decreased ostracod abundance in the floodwater (Raghun and MacRae, 1967). In these studies, the decrease of crustaceans was accompanied by increased algal biomass. Therefore, not only primary, but also secondary effects (Hurlbert, 1975) on aquatic ecosystem can be expected by pesticide applications in rice fields.

The present investigators conducted an experiment to clarify how the pesticide applications in rice fields determine the community composition of aquatic organisms. This report described benthic macroinvertebrates in the experimental rice fields which were used for different pesticide applications and discussed the effects of pesticides on animals.
MATERIALS AND METHODS

Rice fields. The three fields used were located in the National Institute of Agricultural Sciences farm in late May through September, 1983. Field A was 10 m × 10 m in area and treated with no pesticides. Field B was 10 m × 40 m and treated with herbicide only. Both Fields A and B were treated with 4 kg inorganic fertilizer (0.56 kg N, 0.24 kg P, 0.46 kg K) per are. Field C (10 m × 50 m) was treated with 7.2 kg inorganic fertilizer (1.0 kg N, 0.44 kg P, 0.84 kg K) and 80 kg compost (decayed rice straw enriched with nitrogen) per are and then with insecticides, herbicides and fungicides. The rice cultivation scheme is summarized in Table 1. Fields A and B were flooded on 25 May and Field C on 1 June. When flooded, soil was plowed and mixed with fertilizer. Seedlings of rice were transplanted after a week. Water level was kept at about 5 cm in the three fields until the drainage began in August.

In Fields B and C, a herbicide, oxadiazone, was applied on the same day when the fields were flooded and plowed. Another herbicide, bentazon, was applied in Field B on 20 June and 12 August. Insecticides applied in Field C were propoxur on 29 June, together with a mixture of herbicides, thiobencarb and simetryne; fenitrothion on 29 July, 5 and 26 August; and methomyl on 19 August. The latter two insecticides were used with fungicides, kasugamycin-hydrochloride and neo-asozin; in addition, thiram and benomyl were employed on 19 and 26 August. The three formulations of fungicides were also applied on 12 August. Pesticide concentrations in water and soil were measured one or several days after application. Gas chromatography (ECD or N-P FID) was used for the analysis after extraction with acetone.

Temperature, pH and dissolved oxygen in the floodwater and oxidation-reduction potential in the surface soil were measured during 9:00–10:00 a.m. in each field. No consistent differences of these measurements were observed among the three fields during the study period. Water temperature fluctuated in the range of 16–30°C from late May through June. It cooled to less than 25°C in early July. Thereafter it rose to the range of 24–33°C except in late August. The pH was around 8 in June and gradually decreased to near 7 in August. Oxygen deficiency in water was not observed, and the surface soil had been oxidized throughout the study.

Benthic animals. Benthic animals as well as benthic algae were sampled every other day from late May until the end of July and two or three times a week in August. In collection, a square tube (15 cm × 15 cm × 40 cm) made of acrylic acid resin was embedded in the bottom mud of the fields and the surface soil of approximately 3 cm in depth inside the tube was scooped off using a nylon hand net (94 μm mesh). Animals were washed onto a 177 μm mesh stainless steel sieve, sorted out under a binocular

<table>
<thead>
<tr>
<th>Field</th>
<th>Pesticide</th>
<th>Flood and plowing</th>
<th>Transplantation</th>
<th>Drainage</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>None</td>
<td>25 May</td>
<td>1 June</td>
<td>27 Aug.–</td>
</tr>
<tr>
<td>B</td>
<td>Herbicide</td>
<td>25 May</td>
<td>1 June</td>
<td>27 Aug.–</td>
</tr>
<tr>
<td>C</td>
<td>Herbicide</td>
<td>1 June</td>
<td>9 June</td>
<td>31 July–10 Aug.</td>
</tr>
<tr>
<td></td>
<td>Insecticide</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fungicide</td>
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</tbody>
</table>

Table 1. Cultivation regime in the experimental rice fields
microscope (<40 folds magnification), and preserved in 3% neutralized formaldehyde. Five collections were made from each field on each sampling day, of which four served for counting animals.

Benthic algae. Abundance of benthic algae was measured as chlorophyll \( a \) content in the soil. Surface soil of 1 cm thick was collected with a vessel (5 cm \( \times \) 5 cm in opening) furnished with holes of 2 mm in diameter which allowed the water to overflow from the vessel during collection. The soil was half-dried at room temperature, ground with an electric grinder and weighed. Chlorophyll \( a \) was extracted from some 600 mg of the ground soil with 90% acetone solution and measured with a photospectrometer (HITACHI 220A) according to UNESCO/SCOR (1966). Some 3 g of the ground soil was dried at 105°C over 24 hr to measure the water content of half-dried ground soil, which gave chlorophyll \( a \) concentration in soil on dry weight basis.

RESULTS

Chironomid larvae and ostracods

Many species of invertebrates were found on the bottom of the rice fields. But most of them were in low densities as not more than ten individuals in a 15 cm \( \times \) 15 cm bottom sampler. Chironomid larvae and ostracods were usually abundant (Fig. 1). Chironomids comprised 12 species and ostracods 7 species (Table 2). The two inver-

Fig. 1. Changes in the density of chironomid larvae and ostracods in the experimental rice fields. Vertical bars represent 95% confidence intervals. Arrows indicate pesticide applications. No collections could be made in Field C during the draining period (31 July-10 Aug.).
Chironomids and Ostracods in Rice Fields

Table 2. Fauna of chironomids and ostracods in the experimental rice fields

<table>
<thead>
<tr>
<th>Chironomidae</th>
<th>Cypridae (Ostracoda)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chironominae</td>
<td>Cyprinae</td>
</tr>
<tr>
<td><em>Chironomus kiiensis</em></td>
<td><em>Cypretta sp.</em></td>
</tr>
<tr>
<td><em>Cryptochironomus sp.</em></td>
<td><em>Cyprinotus senoi</em></td>
</tr>
<tr>
<td><em>Glyptotendipes tokunagai</em></td>
<td><em>Dolerocypris sp.</em></td>
</tr>
<tr>
<td><em>Harnischia sp.</em></td>
<td><em>Potamocypris sp.</em></td>
</tr>
<tr>
<td><em>Microchironomus sp.</em></td>
<td><em>Stenocypris sp.</em></td>
</tr>
<tr>
<td><em>Polypedilum nubifer</em></td>
<td><em>Unidentified sp.</em></td>
</tr>
<tr>
<td><em>Tanypodus oyamae</em></td>
<td><em>Ilyocyprinae</em></td>
</tr>
<tr>
<td>Orthocladiinae</td>
<td></td>
</tr>
<tr>
<td><em>Cricotopus sylvestris</em></td>
<td><em>Ilyocypris sp.</em></td>
</tr>
<tr>
<td><em>Pectrocladius sp.</em></td>
<td></td>
</tr>
<tr>
<td><em>Smitia sp.</em></td>
<td></td>
</tr>
<tr>
<td>Tanytarsinidae</td>
<td></td>
</tr>
<tr>
<td><em>Ablabesmyia monilis</em></td>
<td></td>
</tr>
<tr>
<td><em>Procladius sagittalis</em></td>
<td></td>
</tr>
</tbody>
</table>

The bimodal taxa were similar in density in Field A except in August. Both animals showed a bimodal change of density in this field. Their peak density in June was about 10,000/m². Ostracods gradually increased up to about 15,000/m² from mid July to late August, while chironomids decreased in August after the maximum (8,300/m²) in late July.

Much more chironomids and ostracods were found in Fields B and C (Fig. 1). In June, chironomids increased to a higher density in these fields than in Field A. The highest density of chironomids was in Field C (>30,000/m²). The larvae decreased to less than 5,000/m² in July and never increased again as in Field A. Ostracods showed a bimodal change in density in Fields B and C. The animals had the highest density in Field B. The density of ostracods in June was similar in Fields A and C on average, though fluctuating more widely in Field C. The density of ostracods in late July was much higher in Field C than in Field A.

Ostracods decreased significantly by treatment with the mixture of propoxur, thiofencarb and simetryne on 20 June in Field C (Fig. 1). Ostracods also decreased with bentazon applications on 12 August in Field B and with the mixture of methomyl, kasugamycin-hydrochloride, neo-asozin, thiram and benomyl on 19 August in Field C, though not significantly. Chironomids decreased with the mixture of propoxur, thiofencarb and simetryne on 20 June in Field C as well. Effects of the three applications of fenitrothion and fungicides in Field C could not be assessed because no floodwater was in the field at these times.

**Benthic algae**

Chlorophyll *a* concentrations in the surface soil were below 15 μg/g in the three fields a few days after the flooding (Fig. 2). Chlorophyll *a* began to increase in Field B after transplanting, whereas it remained at the initial level in June in Fields A and C. The concentration in Field B fluctuated around 20 μg/g during the study period. Chlorophyll *a* in Field A increased in July and August with a wide fluctuation and exceeded 60 μg/g on 15 August. Chlorophyll *a* in Field C increased gradually in July but mostly remained less than 30 μg/g.

Chlorophyll *a* decreased markedly from the herbicide application on 20 June and...
12 August in Field B. A lower initial concentration of chlorophyll $a$ was observed in Fields B and C where a herbicide, oxadiazone, was initially applied. The herbicide applications damaged benthic algae.

**Larvae of odonate and dytiscid**

No fish were introduced in the rice fields. Major predacious animals in the floodwater of these fields were larvae of odonate (*Sympeptrum frequens, Orthetrum albistylum speciosum, Pantala flavescens, Cercion sieboldii*) and dytiscid (*Bidessus japonicus*). These predators had a lower density in the pesticide-treated fields.

Odonates were most abundant in Field A (Fig. 3). Some 50/m$^2$ of odonates were found in mid-June and more larvae in August reaching 100/m$^2$. Odonates in Field B were also most abundant in August, but the density was mostly less than 50/m$^2$. Odonates scarcely appeared in Field C. A few larvae were collected in late July and mid-August.

Fields A and B were similar in the density of dytiscids. About 20 larvae were found per square meter in mid-June. The density decreased with time, and few were collected in August. Dytiscid rarely occurred in Field C.

**Chironomid larvae and ostracods in relation to benthic algae and predacious insects**

The density of chironmids and ostracods was low in the rice fields in early July. In the same period, benthic algae increased in Fields A and C, while the algae in Field B did not increase.

Since mid-July, the chironomid population increased gradually in Field A, while the populations remained in the previous size in Fields B and C. Ostracods were much more abundant in Field B than in the other fields since mid-July. The ostracod population in Field C was much larger than in Field A in late July before the drainage. The algal abundance was the highest in Field A where the population of the benthic animals was smaller than in Fields B and C.
Chironomids and Ostracods in Rice Fields

Although similar relationships between the populations of the benthic animals and the benthic algae were not observed in June, it seemed that benthic algae increased when the benthic animals remained in the lower density.

The populations of chironomids and ostracods fluctuated widely in the rice fields where the predacious aquatic insects had a lower density. The fluctuation of the chironomid population was the largest in Field C, but the fluctuation of the ostracod population was the largest in Field B.

DISCUSSION

The populations of chironomids and ostracods exhibited a wide fluctuation in the pesticide-treated rice fields where the density of odonates and dytiscids was lower. Chironomid larvae and ostracods are major food items of odonate larvae (Bay, 1974; Benke, 1978; Pritchard, 1964). Benke (1978) manipulated larval dragonfly populations in the experimental pens in the littoral zone of a pond. He showed that larvae of the odonates which emerged early in the summer lowered the abundance of chironomid larvae. Morin (1984) found that ostracods were fewer in his fish-exclusion pens where odonate larvae were in larger number as compared with his open pens. Odonates probably control the populations of chironomids and ostracods in the pesticide-untreated rice field as in Field A. Ostracods continued to increase from mid-July to late August, whereas chironomids decreased in August in Field A. This fact might suggest that odonates suppress the chironomid population more effectively than the ostracod population, but more evidence is needed to verify this conjecture. Dytiscid larvae also prey on chironomid larvae and ostracods (Veneski and Washino, 1970). Dytiscids may also serve to control the populations of chironomids and ostracods, while they appeared in a low density during the early flooded period.

However, the ostracod population fluctuated to a smaller extent in Field C, where the predators were rare, than in Field B. Furthermore, chironomids did not increase despite the lower density of predators in Fields B and C in July and August. It is possible that pesticide application decreased the prey populations themselves. Meanwhile, chironomids greatly increased in Fields C in June. Ostracods also much increased in Field B and C in July and August. Most chironomids in the rice fields take benthic algae as a major food, though predacious Tanypodinae and Cryptochironomus also appeared (Table 2), and ostracods also feed on benthic algae. It is likely that chironomids and ostracods are in a competitive relationship, which eventually determines their numbers (which their predators fail to control).

Benthic algae did not increase in Fields B and C as much as in Field A. The growth of algae is inhibited by some herbicides (Butler, 1977). Indeed, the abundance of benthic algae in the rice fields was suppressed by the applications of bentazone and oxadiazon. The herbicide toxicity on benthic algae may have been appreciable. Meanwhile, benthic algae increased when chironomids and ostracods remained in a low density. Raghu and Macrae (1967) also reported that algae increased in the rice field after gamma-BHC had killed ostracods. The algal increase may have been suppressed by heavy grazing by chironomids and ostracods, which the predators could not control, in Fields B and C. Pesticide application in the rice field results in a slight increase in the abundance of benthic algae, probably through heavy grazing as well as herbicide toxicity.
We wish to express our thanks to Dr. K. Kiritani and Dr. S. Miyai of the National Institute of Agro-Environmental Sciences, who allowed us to work in the rice fields of their institute. Thanks are also due to Dr. M. Sasa, Toyama University of Medicine and Pharmacology, who gave us valuable suggestions on the identification of chironomid species, and to Dr. I. Okubo, Shujitsu Joshi University, who kindly identified most of the ostracod genera.

REFERENCES


