Impacts of fish and pesticide in lowland irrigated rice fields

ARSENIA G. CAGAUAN*, FELIPE FLORBLANCO, ELLA M. CRUZ AND RUBEN C. SEVILLEJA
Freshwater Aquaculture Center, Central Luzon State University, Science City of Muñoz, Nueva Ecija 3120 Philippines (p-fishgn@moscom.com)

KEYWORDS: rice-cum-fish farming, pesticide, aquatic oligochaetes

ABSTRACT

This study examined the effects of fish and pesticide on selected components of the rice-cum-fish farming system using treatments without and with fish and pesticide conducted in two trials (wet and dry seasons). Polyculture of Nile tilapia Oreochromis niloticus and common carp Cyprinus carpio at 104 kg/ha (1:1 ratio by weight) was employed.

Results revealed some positive and negative impacts of fish and pesticide. Fish polyculture in rice field increased rice grain yield (10%) ($P>0.05$) in one out of two trials (trial 2). Based on the mean of two trials, the presence of fish decreased oligochaete abundance by 82% ($P<0.01$) while pesticide effect was positively manifested in increased rice grain yield but reduced oligochaetes (44%) ($P<0.05$). Fish growth and yield were not significantly affected by pesticide. No significant interaction effect of fish and pesticide were found for rice grain yield and aquatic oligochaetes. Findings on gross primary productivity (GPP) seemed to indicate the stimulating effects of fish and pesticide. Mean GPP from two trials was ten times higher in the pond refuge (2.74-3.42 g carbon m$^{-2}$ day$^{-1}$) than in the rice field (0.27-0.34 g carbon m$^{-2}$ day$^{-1}$). This suggests the advantage of pond refuge, a contiguous part of rice field, for fish culture in rice-cum-fish system.

INTRODUCTION

Fish farming in rice fields has a long history as a traditional practice in rice-growing areas of Southeast Asia like China, Vietnam, Indonesia, Thailand and the Philippines. Integration of fish farming into rice agriculture or commonly referred to as rice-cum-fish farming is a type of natural resources management that may sustain food supply and a source of employment in the rural areas. Fish integration with rice can be beneficial as it increases rice grain yield (1). This may be attributed to the roles of fish on pest and disease control and nutrient management in rice field (2).

Rice field ecosystem is a man-made environment that is influenced by agronomic practices. In rice-cum-fish farming, one of the major constraints is the use of pesticides that may affect non-target organisms particularly fish and other aquatic biota in the rice ecosystem. The aquatic oligochaetes are not only considered beneficial to the rice ecosystem as they contribute to soil fertility conservation but also serve as live food for fishes, particularly benthic feeders. As rice growth progresses, primary productivity in the rice ecosystem may decrease due to the development of heavy rice canopy, hence, this condition has implication to availability of natural food for fish culture.

Most of the past research efforts have been focused on the production and economics of rice-cum-fish farming. Definitive investigations to show the impacts of agronomic practices on rice field ecology and fish culture are, however, limited. Elucidating these impacts may lead to a better understanding of rice-cum-fish farming system leading to improved management. Hence, this research examined the effects of fish and pesticide on selected components of the rice-cum-fish ecosystem such as rice yield; fish growth, recovery and yield; aquatic oligochaetes and gross primary productivity.

METHODOLOGY

This study was conducted in two trials: I=wet season 1991 and II=dry season 1992. Twenty 300-m$^2$ plots were used for four treatments consisting of without and with fish and pesticide: 1 = -Pesticide-Fish, 2 = +Pesticide-Fish, 3 = -Pesticide+Fish, and 4 = +Pesticide+Fish. Each treatment was replicated five times. Every plot was provided with 1-m deep pond refuge occupying 12% of the plot area.

Recommended cultural and management practices for lowland irrigated rice using the variety PSBRC2 (Philippine Seedboard Rice Cultivar) were followed. Treatments with pesticide were applied using recommended rates of carbofuran insecticide applied
at rice transplanting; and organostannous molluscicide and butachlor herbicide applied at 4-5 days after transplanting (DAT).

Polyculture of Nile tilapia *Oreochromis niloticus* and common carp *Cyprinus carpio* at 104 kg/ha (1:1 ratio) was employed. Fish culture periods were 90 and 105 days in trials I and II, respectively. Initial fish sizes used were: 6-14 g for Nile tilapia in both trials; and 4 g and 75-79 g for common carp in trials 1 and 2, respectively.

Parameters gathered were rice yield; fish growth, recovery at harvest and yield; aquatic oligochaetes; and gross primary productivity (GPP). Sampling and quantitative assessment of oligochaetes were based on Simpson *et al*. Oligochaetes were sampled at 31, 59 and 87 DAT rice. GPP was estimated by direct measurement of dissolved oxygen for a period of 24 hours at 2-hour interval (4). GPP was converted to carbon using the factor 0.375. Water depth measurement was done using calibrated water gauge placed in each plot.

Analysis of variance in 2 x 2 factorial and randomized complete block design was employed to determine the impacts of fish and pesticide and their interaction on the various parameters gathered (5). Oligochaete counts were transformed using the equation: \( Y = X \left(1 - \frac{1.7}{2}\right) \) (3). Means were compared using least significant difference test.

RESULTS AND DISCUSSION

**Rice.** Observed values of mean rice grain yield from two trials in treatments without fish (-fish) and with fish (+fish) were 3,452 kg/ha and 3532 kg/ha, respectively (Table 1). In both trials, observed mean rice grain yield increased by 4.63% in the presence of pesticide. Analysis of variance showed, however, that differences in rice grain yields were not contributed by the main effects of fish and pesticide nor their interaction.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rice grain yield (kg/ha)</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>+Pesticide-Fish</td>
<td>3578.68</td>
<td>3079.67</td>
<td>3529.18</td>
<td></td>
</tr>
<tr>
<td>+Pesticide-Fish</td>
<td>3701.33</td>
<td>3448.00</td>
<td>3574.67</td>
<td></td>
</tr>
<tr>
<td>+Pesticide-Fish</td>
<td>3349.00</td>
<td>3644.00</td>
<td>3496.50</td>
<td></td>
</tr>
<tr>
<td>+Pesticide-Fish</td>
<td>3598.33</td>
<td>3536.33</td>
<td>3567.33</td>
<td></td>
</tr>
</tbody>
</table>

Based from the observed values of rice grain yield, one out of two trials showed a 10% increase (trial II) in the treatments with fish. This collaborates with previous reports indicating a 4-10% increase in rice grain yield (1). This increase may be attributed to the fish perturbation of the soil, particularly the bottom feeding activity of common carp, which causes the release of soil nutrients to the floodwater and also make the soil more porous bringing about oxygenation. Non-evident increase in grain yield in trial I may be due to the less nutrient status of the soil during this period. Although fish may increase the nutrient status through perturbation, nutrients may be lost from the ecosystem through flooding from heavy rains during the wet season. Moreover, most of the nutrients were used for rice vegetative growth and less grain formation during the wet season. In Philippine rice field soil, the response of grain production to N application is higher during the dry season than in the wet season indicating that more N goes to the straw and less in grains during the wet season (6).

Rice yield increases in treatments +pesticide in both trials were more consistent that in treatments + fish. This may be attributed to the different modes of action of the two factors. The fish perturbation of the soil leading to higher nutrient status of the rice field is an indirect effect of fish on rice. Pesticide effect has a more direct effect as it protects the rice plant against pest attack (insects, weeds and snails).

**Fish.** Table 2 summarizes fish growth, yield and recovery in two trials. Mean growth rates of Nile tilapia in treatments without pesticide (-pesticide) and with pesticide (+pesticide) were 0.22-0.42 g day and 0.23-0.45 g day, respectively, while common carp growth rates were similar ranging from 0.20-1.8 g/day. Growth rates of both fishes were not affected significantly by pesticide (P>0.05). Mean gross yields of both fishes ranged from 292 to 315 kg ha while Nile yield ranged from 129-165 kg ha while common carp gave 140-149 kg ha. Per cent recoveries in Nile tilapia (57-98%) and common carp (52-98%) in treatments without and with pesticide in both trials were comparable. Analysis of variance showed that pesticide effect did not contribute significantly to the variations in mean growth, yields and recoveries of both fishes (P>0.05).

Since fish were stocked 7-10 days after pesticide application, the pesticide toxicity may have dissipated causing no harm to the fish. Field toxicity trials showed that pesticide application at least seven days before fish stocking ensured high survival but not subsequent application after fish stocking (7). Past study showed that residues of carbofuran insecticide
using recommended rate were not found in the tissues of *O. niloticus* at harvest time in rice-fish culture experiment (8).

**Table 2.** Fish growth, yield and recovery from treatments without (-) and with (+) pesticide in rice fields in two trials.

<table>
<thead>
<tr>
<th></th>
<th>Trial 1</th>
<th>Trial 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P</td>
<td>+P</td>
</tr>
<tr>
<td>1. Ave. initial weight (g)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common carp</td>
<td>7548</td>
<td>7863</td>
</tr>
<tr>
<td>Nile tilapia</td>
<td>1305</td>
<td>1359</td>
</tr>
<tr>
<td>2. Ave. final weight (g)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common carp</td>
<td>23775</td>
<td>24429</td>
</tr>
<tr>
<td>Nile tilapia</td>
<td>5048</td>
<td>5432</td>
</tr>
<tr>
<td>3. Total Yield (kg/ha)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common carp</td>
<td>16533</td>
<td>15623</td>
</tr>
<tr>
<td>Nile tilapia</td>
<td>14933</td>
<td>14232</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>31466</td>
</tr>
<tr>
<td>4. Ave. weight gain (g)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common carp</td>
<td>16227</td>
<td>16564</td>
</tr>
<tr>
<td>Nile tilapia</td>
<td>3743</td>
<td>4072</td>
</tr>
<tr>
<td>5. Daily gain in ws. (g)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common carp</td>
<td>1.8</td>
<td>1.84</td>
</tr>
<tr>
<td>Nile tilapia</td>
<td>0.42</td>
<td>0.45</td>
</tr>
<tr>
<td>6. Recovery (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common carp</td>
<td>97.2</td>
<td>97.78</td>
</tr>
<tr>
<td>Nile tilapia</td>
<td>7603</td>
<td>82.4</td>
</tr>
</tbody>
</table>

Legend: -P = without pesticide, +P = with pesticide.

**Aquatic oligochaetes.** Aquatic oligochaetes observed belonged to the families *Naenidae*, *Tubificidae* and *Lumbricidae*. Generally, oligochaete counts were lower in treatments with fish and pesticide (Figure 1). In trial I, mean oligochaetes were 5,027 organisms m\(^{-2}\) in treatments -fish and decreased by about 80% in treatments +fish. Similar results were obtained in trial II where 6,548 organisms m\(^{-2}\) in -fish treatments decreased by about 89% in +fish treatments. Based from the mean of two trials, oligochaete counts were reduced by 82% in the presence of fish and 44% in the presence of pesticide. These reductions were significantly contributed by the main effects of fish (*P* < 0.05) and pesticide (*P* < 0.05) but not their interaction effect. Fish reduction of oligochaetes was evident starting the first sampling period around one month after transplanting rice or 20 days after fish stocking till near harvest.

Fish reduction of oligochaetes at the rate greater than 80% in two trials indicates the utilization by fish of these organisms as food. This may be a negative impact on the rice ecosystem since the reduction of oligochaete densities may limit the beneficial effects of these organisms on soil fertility. Among the reported benefits of oligochaetes in rice fields are: soil aeration and mixing (9); weed suppression as they bury weed seeds and disturb early germination (10); and nitrification by changing the oxidation-reduction condition in the submerged field soil (10).

**Gross primary productivity (GPP).** Generally, GPP in both rice fields and pond refuge declined as culture period progressed. For both trials, pond refuge supported a higher mean GPP (2.74-3.42 g carbon m\(^{-2}\) day) ten times higher than rice fields (0.27 – 0.34 g carbon m\(^{-2}\) day).

Mean GPP from two trials was higher in the treatments with fish and pesticide. Rice field GPP in treatments -fish and -pesticide were similar (0.28 g carbon m\(^{-2}\) day) compared to 0.31 g carbon m\(^{-2}\) day in treatments +fish and +pesticide. Pond refuge GPP was about 0.3 g carbon m\(^{-2}\) day in the absence of fish and pesticide and increased a by 0.3 to 0.4 g carbon m\(^{-2}\) day in the presence of fish and pesticide. Higher GPP in the pond refuge than in the rice field indicates a better environment for supporting fish culture. Limitation for higher productivity in the rice field is brought about by the development of heavy rice canopy that restricts light penetration between plants to the floodwater resulting in the decline of photosynthetic production. Under transplanted rice, the light can be reduced by 50% after 15 days, 85% after 30 days and 95% after 60 days (11). The ensuing changes in light intensity affect the growth of photodependent organisms (12).

Values of pond refuge productivity estimated from our experiment approximate some of the reported values for typical fishponds (13). Fishponds receiving higher fertilizer inputs were reported to have higher productivity such as those from Israel ponds (14). The decline in the pond refuge productivity may be the...
result of the absence of no regular fertilization unlike in a normal fishpond.

Higher productivity in the presence of fish and pesticide imply the stimulating effect of the two factors. Fish movement may have aided in the cycling and distribution of nutrients in the ecosystem resulting to higher productivity. The transfer of P from soil to floodwater may involve three major mechanisms: mechanical disturbances of the soil; diffusion from the soil; and activity of the plankton and the fauna (9). Fish grazing may reduce photosynthetic aquatic biomass but succession rates of these organisms are faster that fish reduction. Moreover, fish grazing on the various phytoplankters could be selective. There are evidences that blue-green algae have a better grazing value because of its nutritive value to the fish as it can be digested easily by Nile tilapia (15). Nile tilapia is capable of lysis of blue-green algae by its gastric juice (16). There are claims of the fertilizing effect of fish feces that may add up to the organic matter pool of the rice ecosystem. Whether this amount of organic matter from fish feces would significantly influence the nutrient status of the rice ecosystem needs more definitive investigation.

The stimulating effect of pesticide on aquatic photosynthetic production is due to the inhibiting effect of pesticide on invertebrates that feed on algae, thus, promoting photodependent organisms (17). Carbofuran insecticide inhibits invertebrates that feed on algae (grazers), thus, promoting blue green algae and biological N2 fixation (18).

REFERENCES