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Evaluation of different species of fish for biological control of golden apple snail *Pomacea canaliculata* (Lamarck) in rice

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Abstract

The concept of rice–fish farming was employed to evaluate five species of fish for biological control of golden apple snail in rice. Aquaria trials were initially used to observe the predation potential of the individual fish species, followed by replicated field trials. In the aquaria studies all the fish species preyed upon the hatchlings of the golden apple snail, but at the field level only common carp and African catfish consumed snails significantly more than the other species. Common carp, which attained a recovery rate of 90% was the only fish species suitable for biological control of snail in rice. African catfish was not adaptable to the rice field conditions; the fish suffered a low recovery rate of 17% even when the plots were covered with nets to protect the fish from natural predators. The density of common carp recommended for biological control of snail in rice was 2041 fish/ha. However, it was essential to set up a pond refuge to improve survival rate and to enhance fish production. The study revealed that under direct seeding planting method, the increase in plant density restricted the foraging activities of the fish. Consequently, the number of snail sampled in direct seeded plots was significantly greater than in transplanted plots. Throughout the studies, the fish neither caused a significant increase in rice yields nor a reduction in stem borer, case worm and stink bug infestations. Common carp was however, an effective predator of the golden apple snail in rice.

Keywords: Biological control; Common carp; Golden apple snail; *Pomacea canaliculata*; Rice–fish farming

1. Introduction

The golden apple snail *Pomacea canaliculata* (Lamarck) is native to South America. It was introduced from Argentina into Taiwan in the 1980s for commercial production (Mochida, 1991). From there, it was later distributed to most Asian countries as a protein supplement in the diet and as income earner for the rural poor (Matienzo, 1984; Anderson, 1993). However, the introductions were done in haste with no prior studies on economic benefits and ecological impacts in the new environment (Acosta and Pullin, 1989). When market demand for the snail was poor, many snail-farming projects were abandoned and in many instances the snails escaped and subsequently became a pest of crops. Rice crops were particularly affected (Naylor, 1996). The estimated infested area in Taiwan was 171,425 ha in 1986, 16,196 ha in Japan in 1989 and 400,000 ha in the Philippines in 1989 (Mochida, 1991). When the golden apple snail began to attack the rice crop, information on its ecology, biology and control measures were lacking, so pesticides were selected rather arbitrarily and were applied inappropriately causing environmental pollution and hazard to public health. Farmers suffered a range of health problems (Anderson, 1993). The golden apple snail is now a major rice pest in Asia (Halwart, 1994a). Several control techniques are now available; these include biological (Halwart, 1994b; Teo, 2001), cultural (Teo, 2003) and chemical (Litsinger and Estano, 1993; Palis et al., 1994) controls. However, a non-chemical control approach is preferable, as excessive applications of pesticides are hazardous to the environment. This paper presents the results of a study on the biological control of golden apple snail in rice with fish by employing the concept of rice–fish farming, an integrated agriculture–aquaculture system, which was widely practiced by resource-poor farmers in Asia (Prein, 2002).

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2. Materials and methods

2.1. Aquaria studies to determine the predation potential of the individual fish species

The species of fish used in the studies include hybrid of tilapia (*Oreochromis nilotica* Linnaeus × *Oreochromis mossambica* Peters) known as red tilapia, kerok (*Anabas testudineus* Bloch), jalak (*Ophicephalus striatus* Bloch), African catfish (*Clarias gariepinus* Burchell), and common carp (*Cyprinus carpio* Linnaeus). The main objective of the experiment was to study the predation potential of the individual fish species in the aquarium. Each aquarium measured 75 cm × 60 cm × 75 cm. The mean body weight of common carp, African catfish, red tilapia, kerok and jalak were 31.8, 27.4, 35.0, 32.4, and 11.5 g, respectively. The aquariums were filled with water to a depth of 45 cm and were aerated continuously throughout the trial. The snail hatchlings were placed into the aquariums at 50, 100, 200, 300 and 400 snails/aquarium. The fish was placed at 1 and 3 fish/aquarium. Commercial feed was provided at 5% body weight split in two servings, morning and afternoon. After 24 h, all the snails were siphoned out from the aquarium and the number of snails consumed by fish was calculated by subtracting the remaining snails from the initial number placed in the aquarium. The snails were replenished to the initial quantity after recording. The procedure was repeated until four replicates were obtained.

2.2. Aquaria studies of prey–predator relationship of common carp and African catfish

This part of the study consisted of prey–predator relationship of fish and snails using fish of different sizes. Only common carp and African catfish were tested because of their promising performance in the field. Common carp with a body weight of 110, 220, 380, 580, 1050, 1650 g and African catfish with a body weight of 105, 220, 310, 420, 620, and 1400 g/fish were selected for the studies. The mouth width of the fish was also measured by placing a digital Vernier caliper on the left and the right side of the mouth. Each of the fish was placed in an aquarium and given snails ranging in size from 7.50 to 19.5 mm for common carp, and 7.5 to 21.5 mm for the African catfish. The maximum snail size the fish could consume was determined after 24 h by examining the sizes of the remaining snails in the aquarium. When this was known, 100 snails at the maximum shell size that a fish could consume were placed into the aquarium. The total number of snails the fish consumed was examined again after 24 h. The snails were replenished to the initial quantity after recording. The procedure was repeated five and eight times for common carp and African catfish, respectively. An observation study was also conducted to investigate if the bigger fish could consume snails with a shell height of 25 mm, this was carried out by placing the snails into the aquariums containing African catfish and common carp with a body weight of 1400 and 1650 g, respectively.

2.3. Field trials

2.3.1. General

Experimental trials conducted in the field employed a randomized complete block design consisting of a 7 m × 7 m plot per treatment with four replications. Field trials were enclosed with a net to protect the fish from natural predators. The plots were transplanted with 21-day-old rice seedlings spaced at an equidistance of 25 cm with the water depth maintained at approximately 15 cm. A treatment without fish was included to serve as a control. In the event of insect pest outbreaks, fipronil and α-cypermethrin were used to control the insect pests by spraying at the recommended application rates. Insect pest sampling was carried out by sampling 15 plants/plot at random during the grain filling stage. The crop was fertilized with N:P:K 90:75:75 kg/ha, 1 month after transplanting and during the booting stage. Yield was recorded on a plot basis. The fish were released into the plots about 1 month after transplanting and were fed with commercial feed at 5% body weight split in two servings, at 8:00 am and 3:00 pm. After 1 month the feed was increased to 100% based on initial body weight of the fish. The weight of the fish was recorded before release. Snail hatchlings were prepared by collecting the snail egg masses from the field and allowing them to hatch in the lab. The egg masses were placed on a wire mesh laid on top of a basin filled with 5 cm of water for collecting the hatchlings. The hatchlings, which were less than a week old, were released into the plots at 1000 hatchlings/plot 1 week prior to the release of fish. This procedure was repeated every week until the crop advanced into the ripening phase. The total number of snails released into each plot was 11,000. One week after the last round of snail release, papaya (*Carica papaya* L.) leaves, which are a potent snail attractant (Teo, 1999) were tied in a small bundle of three leaves and placed at the four corners of each plot for snail samplings. The snails were collected early in the morning for 5 consecutive days. The papaya leaves were replaced if they were rotten. In the subsequent week, the fish were harvested from the plots and 5–10 fish/plot were recorded for their weights. The fish were in the rice plots for a period of 79 days on average. A histogram was used to plot the raw data to test for normality, and data that did not show a normal distribution were transformed with log prior to an analysis. The data were analyzed using regression analysis and ANOVA. The standard deviation of individual sample mean was also calculated.

2.3.2. Evaluation of predation potential of the fish species under rice field conditions

The five species of fish studied in the aquarium were tested in the field. The mean weight of common carp, African catfish, jalak, red tilapia, and kerok was 44.0, 56.3, 34.1, 30.6 and 42.3 g, respectively. The fish were released into the plots at 30 fish/plot or 8000 fish/ha. One week after the third round of snails was introduced into the plots,