Tropical Agricultural Research Vol. 19: 290 - 300 (2007)

Integration of Goldfish (*Carassius auratus*) Culture with Organic Rice Farming

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ABSTRACT. *The study was conducted to develop suitable culture systems for goldfish (Carassius auratus) fry in organic paddy cultivation. Experiments were conducted in six paddy plots using chicken manure and paddy straw and paddy husk charcoal as organic fertiliser. Performance of goldfish post larvae and fry for eight week and 12 week grow out systems in paddy plots was compared with that of the fish grown in an indoor system. Economics of the paddy production and fish production under organic fertilizers were evaluated and methods to increase productivity and recycling of paddy by-products in the rice–fish system were studied.*

Fry cultured in paddy plots recorded a higher mean total length and a lower survival rate which were significantly different ($p<0.05$) in twelve week culture period compared to the control. Fry stocked at four-weeks and six-week of age at a stocking density of 16000 fry/ha recorded total lengths of 8.3 ± 0.7 cm and 9.4 ± 0.9 cm and survival rates of 58 ± 2.8% and 63 ± 3.8% respectively at the end of 12 week culture cycle. Four-weeks and six weeks old fry at higher stocking rate recorded a total length of 7.5 ± 0.6 cm and 7.7 ± 0.7cm and percentage survival of 55 ± 2.7% and 66 ± 4.5% in eight-week culture cycle in paddy plots. Significantly higher total lengths, higher growth rates and lower survival rates were observed in the fish in paddy plots than in those in indoor system. Higher mortality rates were recorded in the first two week of fish stocking. The percentage of bright coloured fish in paddy plots was 71 ± 1.4 while it was 46 ± 0.7 in the indoor system. All the quality parameters of the fish were high in the fish produced in paddy plots.

Paddy yields in the plots with the fish net cover and fish culture were significantly higher compared to the control. Paddy straw application at 3000 kg/ha and paddy husk charcoal application at 2000 kg/ha with fish integration resulted in significantly higher yields of 3891 ± 155 kg/ha in paddy variety BG 2/379 compared to a yield of 3457 ± 111 kg/ha with application of paddy husk charcoal only.

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INTRODUCTION

The world-wide irrigation efficiency is as low as 37% (Postel, 1996) and there is a need for more integrated approaches to water management which take into account its multiple uses for purposes besides irrigation. Productivity of irrigation water is very low in paddy cultivation and 1.5 - 2 m^3 of water is consumed in the production of 1 kg of paddy (IRRI, 2005). Since agriculture is responsible for some 70% of global water use (FAO, 1995), the potential for water savings through multiple use, including aquatic production is enormous and increasing water use efficiency is a felt need in Sri Lanka.

Although there is a vast potential, paddy farming is becoming a non-lucrative agricultural venture in Sri Lanka. National average yield of paddy in Sri Lanka increased from 2 t/ha in the 1970's to 3.5 t/ha by the early 1990's. Since then, it has remained stagnant. Though, yields higher than the national average were recorded in major irrigation systems where water supply is assured, in minor irrigation and rain fed systems, a lower grain yield was recorded due to various stresses and risk factors involved in crop management (Adhikarinayake, 2005).

Diversification of paddy lands to include upland crop cultivation has marginally resolved the low income issue but has affected the paddy production. Rice-fish integration can be a remedy to increase paddy production, improve productivity of irrigation water and secure satisfactory income to the farmer.

Rice fish integration leads to productive use of agricultural by-products (Nagabovanalli *et al*., 2002). Rice table fish integration increases the amount of animal proteins in the diet of the rural inhabitants thereby improving their nutrition and increases the returns per unit of land area giving farmer a high disposable income (Edirisinghe *et al*., 1992). It also lowers the risk of production failure since the farmer has diversified the production activities which do not confront covariant risks (De Silva and Amarasinghe, 1992). Organic manure serves dual role as the major source of cheap feedstuffs for fish and fertilizer for the rice field, thereby reducing the cost and need for providing compounded fish feeds and also chemical fertilizers for rice. Rice-fish integration has increased the productivity of rice fields by 11%, the overall income by 28% (Nilsson and Blariause, 1994). Profits are increased by reducing the cost of fertilizers and feedstuffs cost of fish production (Edirisinghe *et al*., 1992).

Table fish production under rice-fish integration is not productive because paddy varieties cultivated in Sri Lanka have a short cultivation cycle. The period for fish grow out cycles will be limited to two or three months and the fish that are produced will be small. Since small-sized fresh water fish are not preferred by Sri Lankans, rice-fish integration should not be intended for table fish production (Edirisinghe, 1989) and a system has to be developed to culture high priced ornamental fish species which have a good market (Edirisinghe, 1994).

Therefore this experiment was conducted to study the possibilities of growing different stages of export oriented ornamental fish species such as goldfish in paddy fields with organic manure. The primary objective of this experiment is to study the performance of goldfish *(Carassius auratus)* fry in rice fields fertilized with organic manure and to compare the quality parameters of the goldfish produced in rice fields with intensively farmed goldfish. The second objective is to identify methods to improve paddy yield and farmers profits through rice ornamental fish integration.

MATERIALS AND METHODS

Experiments were conducted at University of Peradeniya (Mid Country, Wet Zone WM2B) during four consecutive seasons from 2003 to 2005. Six paddy plots of 49 m^2 each including a pond refuge of 1 m^2 at the centre were used for the experiment. Air dried poultry manure was applied at the rate of 1000 kg/ha as basal fertilizer at the land preparation. Paddy varieties BG 379\2 and BG 300 were cultivated to get 12 week and 8 week fish grow out cycle respectively. Paddy seedlings were transplanted at 8 X 8 cm spacing between and within rows.

Complete net cover was maintained around the paddy plots from the time of transplanting to the end (Jayaweera, 2004). “Comet” goldfish breeding was undertaken to get required fish post larvae and fry. Rice plots were irrigated and inflow of water was diverted through a mesh (2 mm) type water filter to prevent entry of predatory fish. In the first exprelots were stocked with four weeks old goldfish fry which were 1.4 cm (SD 0.05) in length at the rate of 80 fry per plot (16000 fry/ha) two weeks after transplanting the paddy plants of the paddy variety 2/379 in the second experiment, same four plots were stocked with six weeks old fry at the rate of 80 per plot (16000 fry/ha) two weeks after transplanting the paddy plants of the paddy variety 2/379. Two plots were taken as control without fish. These experiments were repeated with burying paddy straw at 3000 kg/ha at first land preparation and paddy husk as at 2000 kg/ha at the final land preparation. The fish in the rice plots were not fed with formulated ornamental fish feed.

Aerated indoor glass tanks with a capacity of 250 L were used for the comparison. Selected indoor tanks were stocked with 20 fry of 4 week and 6 week of age for the experiments. Fish in glass tanks were daily fed with a formulated ornamental fish feed with 37% crude protein and 3000 kcal/kg of energy.

Poultry manure was applied to the rice plots at 400 kg/ha at fortnight intervals as a top dressing starting from two weeks after transplanting. Hand weeding was practised at four weeks after crop establishment. Water level was maintained at 2.5 cm in rice plots during culture period and completely drained two weeks before intended harvesting day.

Water samples were tested weekly for pH, temperature and plankton content was estimated using a Sedgewick-Rafter cell. The Secchi disc visibility in pond refuges was measured daily. Samples of fish were caught from each pond refuge and each glass tank at weekly intervals for measurement of length. Fourteen days prior to paddy harvesting, fish were collected and total number was counted. Collected fish were separated into 3 classes of red metallic, orange, and yellow body colour. Percentage survival was calculated. Paddy harvest in each plot was measured. Data on paddy harvest, fish production and total income were calculated. Data on length of fish were statistically analysed by pooled T-test. Percentage of fish colour categories were analysed using F test and survival rate was analyzed with Probit procedure.

RESULTS AND DISCUSSION

Before starting the experiment crabs, snails and frogs were found in all paddy plots in addition to wild fish species. Mean soil pH was 5.7 ± 0.4 in the experimental site with a range of 5.2 - 6.2. Water temperature of the pond refuges ranged from 23 to 28°C with a mean of 26.5°C ± 0.41. Goldfish thrive well at any temperature above 5°C and are well adapted to changes in temperature even up to 31°C in tropical waters (Andrews, 1987; Street, 2002). According to Riede (2004) goldfish in their natural habitat can live within the extreme temperature range of 0 - 41°C. Botlinger (2000) reported that the higher temperatures above 26°C favour colour development of goldfish.

The Secchi disc visibility in pond refuges varied from 23 cm to 50 cm with a mean of 31.3 ± 2.87 cm. The lowest Secchi disc values were recorded in ponds before introduction of fish at 13 days after fertilizing the plot with poultry manure at 1000 kg/ha as the basal application. Secchi disc visibility is inversely related to the plankton content in a pond and Secchi disc visibility is accepted as a reliable tool in estimating the abundance of the plankton in fish ponds (Almazen and Boyd, 1978).

Water quality parameters in the straw and paddy husk charcoal treated plots were significantly different in relation to abundance of live food organisms from the control at the time of fish stocking ($p<0.05$). Higher plankton counts were always observed in paddy plots supplemented with straw and paddy husk charcoal in addition to poultry manure. The total phytoplankton number ranged from 8 - 123 million/L with a mean of 41.5 ± 9.23 million/L in pond refuges of the control and 69.1 ± 12.23 million/L in the plots fertilized with straw. The zooplankton count of the pond refuges ranged from 360 - 4851 million/L with a mean of 1663 ± 702 million/L in the control while it was 1968 ± 763 million/L in the plots fertilized with straw. Ramanath *et al.* (2005) found that paddy straw improved the growth and survival in pond culture of *Labeo rohita* (Hamilton). The biological productivity of any aquatic body is generally judged through the qualitative estimation of plankton, which forms the natural feed of fish (Ahmed and Singh, 1989). Kumara *et al.* (2004) found that higher performances of goldfish larvae and fry can be achieved in ponds fertilized with chicken manure at a rate of 100 kg/ha/wk.

Performance of goldfish fry

There was a significant difference ($p< 0.05$) in the total length between fish in paddy plots and those in the indoor tanks starting from six weeks of stocking up to the end (Figure 1) total lengths were significantly different between the two age groups (four-week and six- week old fry) from six weeks after stocking. However, the total length of four-week and six-week old fry in indoor tanks were not significantly different throughout the culture period. Fish in paddy plots have reached average total length of 8.3 cm and 9.4 cm which are above the standard (7.5) for export (Bristol Aquarists' Society, 2005) within ten weeks of stocking. Kumara (2004) reported that goldfish (*Carassius auratus*) grown in the outdoor environment fertilized with chicken manure had a relatively higher body length compared to those in indoor tanks with supplemented feed. Chakrabarty and Hettiarachchi (1982) found that the performance of goldfish was high when grown in mud ponds with combined feeding. The standard length of the fish in the two environments were significantly different ($p<0.05$) starting from six weeks after stocking (Figure 2).

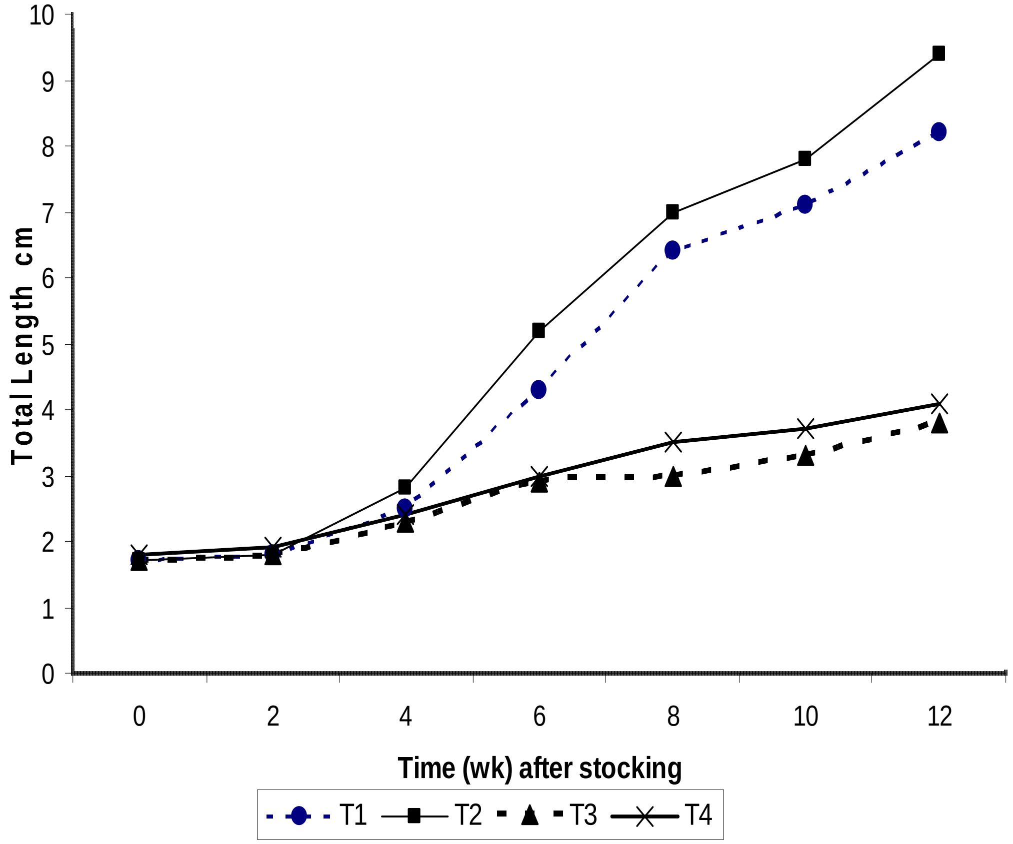

Figure 1. **Increase in total length (TL) of fish fry in paddy plots and in the indoor tanks with time after standing.**

Note: T1: 4 weeks old fry in paddy plots; T2: 6 weeks old fry in paddy plots; T3: 4 weeks old fry in indoor tanks; T4: 6 weeks old fry in indoor tanks.

Both groups of fry in paddy plots have reached 4 cm in standard length within eight to ten weeks of stocking. Standards of export quality for comet goldfish require that standard length of the fish to be minimum 3.5 cm and ratio between standard length and total length to be greater than 3:7 (Bristol Aquarists' Society, 2005). Fish in paddy plots have reached the above standard. Therefore, eight to ten week grow out cycle for fry in paddy plots would be sufficient to obtain the required length for export. If the marketable total length and standard length could be achieved within an 8 - 10 week culture cycle, it is very useful because most of the improved paddy varieties cultivated in Sri Lanka have a short cropping cycle of 12 -16 weeks.

Table 1. Performance of goldfish fry grown in paddy plots and in the indoor environment during twelve-week culture period.

Parameter [i]	Fish in paddy plots (Mean ± SD)		Fish in indoor tanks (Mean ± SD)	
At stocking				
Age (weeks)	4	6	4	6
MTL (cm)	1.7 ± 0.13	1.8 ± 0.01	1.7 ± 0.11	1.8 ± 0.01
MSL (cm)	1.3 ± 0.05	1.3 ± 0.10	1.4 ± 0.05	1.2 ± 0.10
MBD (cm)	0.7 ± 0.06	0.9 ± 0.07	0.7 ± 0.08	0.8 ± 0.07
MLW (g)	0.11 ± 0.01	0.40 ± 0.07	0.12 ± 0.01	0.40 ± 0.07
At harvesting [ii]				
Age (weeks)	16	18	16	18
MTL (cm)	$8.3^{a} \pm 0.73$	$9.4^{a} \pm 0.90$	$3.3^{b} \pm 0.24$	$4.8^{b} \pm 0.73$
MSL (cm)	$4.9^{a} \pm 0.47$	$5.6^{a} \pm 0.50$	$2.2^{b} \pm 0.23$	$3.2^{b} \pm 0.21$
MBD (cm)	$2.0^{a} \pm 0.20$	$2.1^{a} \pm 0.20$	$1.2^{b} \pm 0.10$	$1.5^{b} \pm 0.08$
MLW (g)	$10.5^{a} \pm 1.8$	$16.0^{b} \pm 3.8$	$0.72^{c} \pm 0.21$	$2.07^{d} \pm 0.26$
GR (g/day)	$0.12^{a} \pm 0.06$	$0.19^{b} \pm 0.10$	$0.007^{c} \pm 0.00$	$0.019^{d} \pm 0.00$
CF	$8.9^{a} \pm 4.8$	$9.1^{a} \pm 3.1$	$6.76^{b} \pm 0.3$	$6.31^{b} \pm 0.07$
MSL/MTL	$0.59^{a} \pm 0.20$	$0.59^{a} \pm 0.13$	$0.66^{b} \pm 0.09$	$0.66^{b} \pm 0.10$
Survival (%)	$58^{a} \pm 2.87$	$63^{a} \pm 3.8$	$75^{b} \pm 4.5$	$78^{b} \pm 1.9$

Note: i. MTL: mean total length, MSL: mean standard length, MBD: mean body depth, MLW: mean live weight, GR: growth rate, CF: condition factor.
ii. Within rows, means not sharing a common superscript are significantly different at p<0.05.

CF of fry in paddy plots (Table 1) was significantly different ($p < 0.05$) from that of the fish in indoor tanks. The higher Condition Factor reflects information on the physiological state of the fish (Hile, 1996) because CF is a good indication of the nutrition availability and rearing environment (Paulet, 2004). The percentage of fish count in each colour categories of fish, based on visual colour ranking showed a significant difference ($p<0.05$) in the two environments after 12 weeks of stocking. Higher percentage of fish fry in paddy plots developed self-coloured (even coloured body) red metallic (56% and 71%) compared to these in the indoor tanks. A higher number of fish (90%) in six-week age group was bright red metallic or orange (Figure 2).

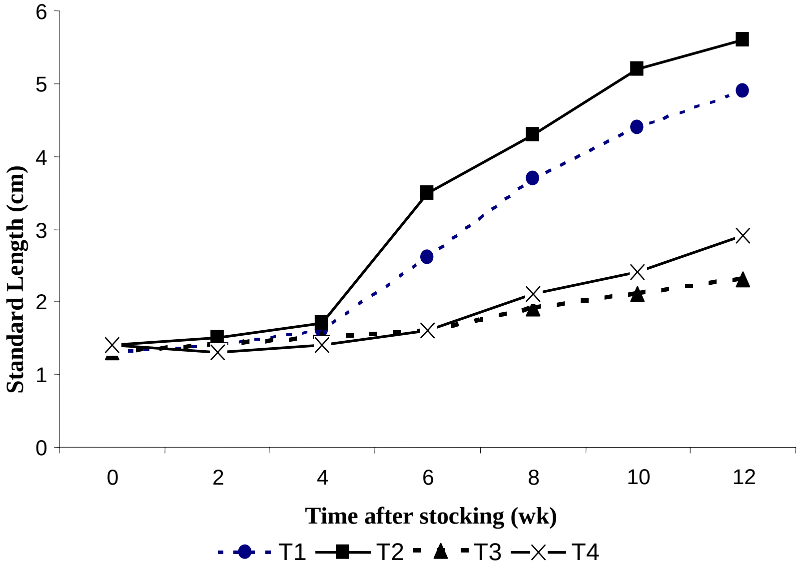

Figure 2. Increase in standard length (SL) of fish fry in paddy plots and in the indoor tanks with time after standing.

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Note: T1: 4 weeks old fry in paddy plots; T2: 6 weeks old fry in paddy plots; T3: 4 weeks old fry in indoor tanks; T4:6 weeks old fry in indoor tanks.

The skin colour of an orange–red hue in the red variety of goldfish *Carassius auratus* is identified as a desirable and essential sales factor by hobbyists and commercial producers (Geoffrey *et al*., 2005). The two treatments of straw at 3000 kg/ha and paddy husk charcoal at 2000 kg/ha gave higher yields in the experiment with the paddy variety BG 379\2 compared to the paddy yield of the control. Organic manure with fish integration have compounded to higher yields of 3891 ± 155 kg/ha compared to a yield of 3457 ± 111 kg/ha with paddy husk charcoal only in paddy varieties BG 379\2 which were significantly different ($p<0.05$) compared to 2963 ± 74 kg/ha and 2631 ± 109 kg/ha in the control.

The paddy varieties has given higher yields compared to national average of 3400 kg/ha (DOA, 2005) in all the plots except in the control. Cost of production and economic analysis of the rice ornamental fish system would be published elsewhere.

Additional labour requirement for application of straw was compensated by higher yield. Any form of organic matter would increase grain yield (Weerakoon *et al*., 2000) and long-term experiments have indicated that straw compost application in wetland rice fields cause an increase in the organic C, N, P and grain yield (Ponnamperuma, 1984).

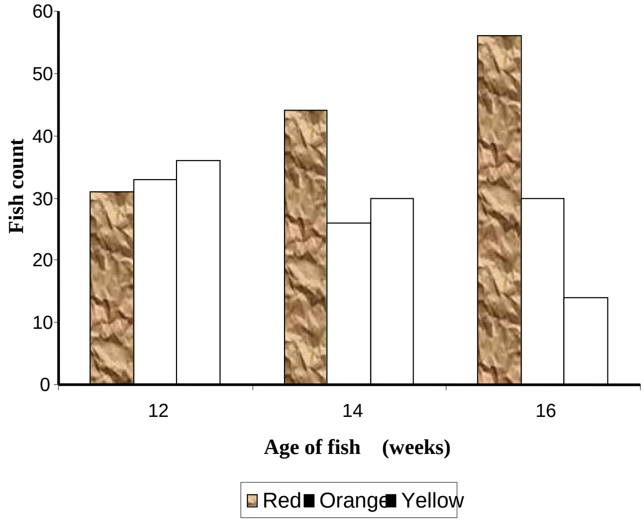

Figure 3. Development of skin colour of four-week old goldfish fry in paddy plots with the age of fish.

Dobermann and Fairhurst (2000) found that paddy husk charcoal supplies silica to the paddy soils and has several implications in paddy cultivation. Silicon is a 'beneficial' nutrient for rice. This farmer is benefited by increased yield, reduced lodging and reduced incidence of biting and sapping insect pests. Khandaker *et al.* (2004) found that paddy yield and yield components were significantly higher at soil pH 7.5 with paddy husk charcoal. According to the findings of the experiments, recycling of paddy by-products within the rice-fish system is feasible and it leads to increased production.

Lodging of the crop was 23% with the paddy variety BG 379-2 in four experimental periods. Lodging was not observed in the paddy plots cultivated with the variety BG 300 with the application of paddy straw and paddy husk ash. Khandaker *et al.* (2004) found that lodging of paddy plant is low when paddy husk ash is used as a fertilizer.

Rice leaf folder (*Cnaphalocrocis medinalis)* damage was the most noticed pest damage in paddy plots in every season. Prolonged standing water was required for fish and seems to favour the colonization of leaf folder. Heong and Escalada (1997) and Vromant *et al.* (1998) found that standing water, higher fertilizer levels, shady plots and weeds in the dikes and in the surroundings increase the incidence of leaf folder in paddy cultivations.

CONCLUSIONS

Fish with mean lengths of 8.3 cm ± 0.73 and 9.4 cm ± 0.90 can be produced in twelve-week culture cycle starting with four-week and six-week old fry, respectively, in paddy plots using poultry layer manure, paddy straw and paddy husk charcoal as the fertilizer. Fish with a marketable length can be produced in eight weeks starting with four-week old fry by supplementing fields with chicken manure at 400 kg/ha fortnightly. Higher percentage of bright coloured goldfish can be produced by stocking goldfish in paddy plots. Use of organic manure in rice ornamental fish culture increases paddy yield and creates a suitable culture environment for fish.

ACKNOWLEDGEMENTS

Authors would like to thank Aquatic Resources Development Project (ADP) for the financial support provided. Authors appreciate the support extended by Mr. K.H. Nandasena, and staff of the Aquaculture laboratory, Department of Animal Science Faculty of Agriculture, University of Peradeniya, Mr. K.H.M.I. Karunaratne, Mr. H.A.C.K. Jayathilaka, and Mrs. K. Weerasinghe, Computer Centre, Wayamba University of Sri Lanka, Makandura for their cooperation.

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