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Integration of Ornamental Fish with Paddy: Performance of Goldfish (*Carassius auratus*) Post-Larvae and Fry in Lowland Paddy Cultivation

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ABSTRACT. *Experiments were conducted in 2003 and 2004 to investigate the performance of goldfish (*<u>Carassius</u> <u>auratus</u> L. *1758) post larvae (PL) and fry in irrigated paddy cultivation with improved protective measures. In the first experiment goldfish PL were stocked at 120 PL/m^2 in the pond refuge of 1 m^2 in two seasons in four paddy plots and in the second experiment goldfish fry were stocked at 80 fry/m^2 in two other seasons in four plots. Indoor tanks stocked at 120 PL /m^2 and 80 fry/m^2 were taken as the control. Total length (TL), standard length (SL), body depth and weight of fish were measured biweekly up to eight weeks of stocking. Condition factor (CF) and survival rate were calculated and the fish were ranked according to morphological merits.*

PL stocked in paddy plots had reached a live weight of 2.20g ± 0.86, CF of 0.68 ± 0.22, TL of 4.5 cm ± 0.85 and SL of 3.2 cm ± 0.33 which were significantly different ($p<0.05$) from the control. The survival rate (15%) was low compared to that in control (27%). A significant difference ($p<0.05$) in the TL, SL and weight of fry in the control and paddy plots were observed from the fourth week of stocking. At harvesting TL and SL of fry were 3.4 cm ± 0.28 and 2.9 ± 0.26 in the control and 7.5 cm ± 0.69 and 5.6 cm ± 0.46 in paddy plots, respectively. Fish produced in paddy plots and in the control were within the marketable size. Live weight of fish in the control and in paddy plots were 0.69 g ± 0.20 and 9.54 g ± 2.88, respectively. Growth of fish fry in the control and in paddy plots was significantly different after the fourth week of stocking. Percentage of fish that developed red metallic, orange and yellow metallic body colours were 78%, 20% and 5% in paddy plots, while it was 43%, 44% and 13% in fry stocked in the control, respectively. The survival rates of fish fry observed in the control was 74% and in paddy plots was 54%. Paddy yield of the plots with protective cover (4054 kg/ha ± 113) was significantly different from yield of other plots which was 3287 ± 126 kg/ha. Results of this experiment indicate that there is a potential for the production of marketable size goldfish 7600/ha at the present stocking rate in eight weeks culture cycle starting with PL or fry integrated in paddy with a complete net cover over the plots as protective measures.

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INTRODUCTION

Paddy-fish integration using organic manure from livestock is an organic farming method that combines paddy and fish production while optimizing labour and paddy field resources utilization (Woynarovich, 1979; Schmidt, 1980; Won *et al.*, 1992). It facilitates recycling of relatively inexpensive, bulky by-products of paddy such as paddy husk and straw (Nagabovanalli *et al*, 2002).

Paddy-fish integration has increased the productivity of paddy fields by 11%, the overall income by 28% (Nilsson and Blariause, 1994) and by reducing the cost of fertilizers and feedstuffs, cost of fish production is reduced and profits are increased (Edirisinghe, 1996). It also lowers the farmer's risk of production failure since it diversifies production activities which do not confront covariant risks (De Silva and Amarasinghe, 1992).

The potential for paddy-fish integration in Sri Lanka is very high (De Silva and Amarasinghe, 1992). Total arable paddy land area of 0.983 million hectares are cultivated and harvested in *Yala* and *Maha* seasons (Central Bank of Sri Lanka, 2004). About 45% of paddy lands are located in wet and intermediate zones where irrigation or rain water is available year-round (Wijeratne, 1994). These paddy lands have the potential to be integrated with fish. Fingerling production of *Oreochromis niloticus* under paddy-fish-livestock integration has been successful in Sri Lanka. This could be a way to satisfy fish fingerling requirement of the country (Edirisinghe *et al.*, 1992).

Paddy farming in Sri Lanka has its own problems. The average yield of the country dropped by 3.4 % approximately from 3.89 t/ha in 2002 to 3.76 t/ha in 2003 and average yield has been 3.71 t/ha over the last decade (Central Bank of Sri Lanka, 2004). Income from paddy farming has been poor recently due to poor yields and low prices and profit margin has been very low due to high cost of inputs (Wijeratne, 1994). Under these circumstances paddy farmers under major irrigation systems in the dry zone of Sri Lanka have converted their paddy plots to highly protected ponds for ornamental fish for export with irrigation water. Farmers in Polonnaruwa and Minneriya area have already started this in large scale. They use these converted paddy plots to grow goldfish and Koi-carp (*Cyprinus carpio*) (Jayaweera, 2004). Goldfish is a popular ornamental fish in local and export market and goldfish produced in Sri Lanka has a higher export demand for its superior quality. Celestial, Lion head, Oranda, Pearl scale and Comet, are some of the varieties of goldfish popular in the export market (Sri Lanka Export Development Board, 2005).

Exports of aquarium fish by Sri Lanka have been increasing substantially over the past two decades. The value of ornamental fish exports increased from Rs. 30 million in 1981 to Rs. 370 million by 1997 (Weerakoon, 1998). In 1999 exports of aquarium fish from Sri Lanka amounted to Rs. 560 million corresponding to a quantity of approximately 100 million fish exported per annum (Sri Lanka Export Development Board, 2005) and in 2004 Rs. 745.2 million (Weerakoon and Senarathne, 2005). This growth has been mainly due to expansion of importing of the international market. Sri Lanka's share in the world trade, at over 1% is projected to increase to 10% in the medium-term (Weerakoon and Senarathne, 2005). More farmers can be expected to move into goldfish farming in mud ponds with the light of this promising industry in the near future. Therefore, it is worthwhile to study the possibilities of growing post-larvae (PL) and fry of export oriented ornamental fish species such as goldfish in mud ponds. It is equally important to develop a methodology to grow export quality fish in commercial scale without affecting paddy production. Therefore, the objectives of this experiment were to study the performance of goldfish PL and fry in paddy field with a net cover for the protection of fish and with organic fertilizer and to study the quality parameters of goldfish produced in paddy to export need.

MATERIALS AND METHODS

Experiment was conducted at the University of Peradeniya (Mid-Country Wet zone) during *Yala* and *Maha* seasons in 2003/2004. Six paddy plots of 49 m^2 each including a pond refuge of 1 m^2 at the centre were used for the experiment. Normal land preparation methods suitable for paddy transplanting were adopted. Air dried poultry manure was applied at the rate of 1000 kg/ha as basal fertilizer (Edirisinghe, 1996). Seedlings of paddy variety BG 379-2 were transplanted at 8 x 8 cm spacing, between rows and within rows in all six plots and water level was maintained at 2.5 - 4 cm.

Four randomly chosen plots were fixed with protective cover. Sides of paddy plots were covered up to 1 m height with black polythene from the bottom. The rest of the sides up to 2 m above ground and the top were covered with 2.5 cm gill nets and cover was maintained from the time of transplanting to the end. Other two paddy plots were kept open as the control paddy plot.

Goldfish post larvae (PL) and fry obtained from the same parent fish were used for this experiment. PL used in the experiment were 0.8 cm ± 0.08 in total length (TL). PL were raised in indoor tanks to produce the required stock of four-week old fry which were 1.7 cm ± 0.12 in TL and 1.4 cm ± 0.05 in standard length (SL). All pond refuges were fully drained, de-silted and bleached (Jhingran and Pullin, 1985) to eradicate all forms of predators after final land preparation for transplanting. Paddy plots were irrigated with water supply from the adjoining fish pond. Inflow of water was diverted through a mesh (2 mm) type water filter to prevent entry of predatory fish. Four paddy plots were stocked with ten-day old goldfish post larvae at the rate of 120 PL/m^2 (24000/ha) two weeks after transplanting. Two indoor tanks with a dimension of 0.5 x 1.5 x 0.5 m (2/3 capacity of 250 *l* of water) were used for the control. Indoor tanks were covered with fish nets to prevent predation of fish by birds. Same indoor tanks were used as the control in the second experiment as well. Selected tanks were filled with de-chlorinated water and stocked with PL of 10 days of age at 60 PL per tank (120 PL/m^2). Post larvae in glass tanks were daily fed with artemia up to four weeks (Pannevis, 1993) and weaned to a formulated ornamental fish feed (SRAC, 1998).

Four paddy plots were stocked with goldfish fry at the rate of 80 fry/m^2 (16000 fry/ha) two weeks after transplanting in the second experiment. Indoor tanks were stocked with fry of four weeks of age at 40 per tank (80 fry/m^2) as the control. Fish in the control were daily fed with a formulated ornamental fish feed (SRAC, 1998).

Poultry litter was applied at 400 kg/ha biweekly for eight weeks as the top dressing, starting from two weeks after transplanting (Edirisinghe, 1996). Hand weeding was practised at four weeks. Chemical fertilizers and pesticides were not used. Integrated pest management technique (IPM) was adopted to keep pest attacks under control. Water level was maintained at 2.5 cm in paddy plots up to two weeks before intended harvesting day.

Physico-chemical parameters of the culture plots and glass tanks were monitored weekly. A sample of six fish was caught from each pond refuge and each glass tank at biweekly intervals for measurements of TL, SL, body depth, weight and colour. PL were measured at the stocking for TL and at harvesting for TL, SL, body depth, weight and colour. Eight weeks after stocking fish were collected by netting and reducing water level and the total numbers were taken. Collected fish were separated into 3 classes of body colour of red-metallic, orange and yellow metallic (Bristol Aquarists' Society, 2005). Percentage survival was calculated. Paddy harvest in each plot was measured. Data on morphology of fish were statistically analysed by pooled *t*-test. Percentage of fish colour categories and survival rate were analysed with the probit procedure.

RESULTS AND DISCUSSION

Observations were made in all four plots before stocking of fish revealed that plots and pond refuges were free from wild fish. Though predatory fish were not found in pond refuges during the period of study, backswimmer (*Anisops* spp.) and dragonfly larvae (*Pantala* spp.) were found in the plots. Entry of piscivorous birds, crawling animals like water snakes was restricted in these plots with polythene side cover, and top net cover but the entry of crabs and frogs could not be restricted and frogs, tadpoles and crabs were found often in paddy plots and pond refuges.

Mosquito larvae were plentiful in all the plots. Eradications of wild fish from pond refuge would have led to this situation. Mosquito larvae were not found in the plots after the introduction of fish. Goldfish fry would have fed on mosquito larvae in paddy plots as goldfish are omnivores. They eat plants, insects such as mosquito larvae, small crustaceans, zooplankton, and detritus (Street, 2002).

During the experimental period, water temperature in pond refuge ranged between 23 – 27 ^{0}C (26.5 ± 0.21), while it was in the range of 19 – 24 ^{0}C (21.2 ± 0.22) in the control. Goldfish thrive well at any temperature above 5 ^{0}C and well adapted to changes in temperature even up to 31 ^{0}C in tropical waters (Andrews, 1987; Street, 2002). Higher temperature however has positive effects on skin colour and the best temperature range to maximize skin pigmentation in goldfish with natural food is 26 – 30 ^{0}C (Gouveia and Rema, 2005).

Water pH of the pond refuge ranged from 6.2 - 8.2 (7.4 ± 0.83) during the culture period while it was 7.0 - 7.6 (7.3 ± 0.23) in the control. This is within the optimum range of pH because the goldfish prefer a pH range of 6.5 - 8.5 and thrive well at the 7.2 - 7.6 pH range (Street, 2002). Dissolved oxygen (DO) in the pond refuge and indoor tanks were significantly different ($p<0.05$). DO in the pond refuge ranged from 2.6 - 6.3 mg/l during the day time with a mean of 3.8 mg/l ± 0.06. DO of the control was 5.2 - 5.8 mg/L range with a mean of 5.6 mg/l ± 0.16. Kumara (2004) reported that ponds fertilized with poultry litter or cow dung contained low DO levels compared to the control due to higher biological oxygen demand (BOD) of the decaying matter. The BOD values were higher in the fish ponds receiving poultry effluents (Preston and Rodriguez 1996). Bulk of organic matter accumulated at the bottom would have resulted low DO level in pond refuge. However, fish did not show behavioural signs of poor DO levels in paddy plots or the control under the present stoking densities.

Performance of post larvae

In the first experiment, PL in paddy plots have reached a TL of 4.5 cm ± 0.85 and SL of 3.2 cm ± 0.33 while the TL and SL of PL in the control was 1.8 cm ± 0.23 and 1.2 cm ± 028 respectively (Table 1). It was significantly different ($p<0.05$). Kumara (2004) has reported higher TL and SL of goldfish PL in indoor system with combination of feed. However, the TL and SL of the goldfish PL in the present experiment in paddy plots (at 120 PL/m^2) were high compared to PL in the indoor tanks and different to the findings of Kumara *et al.* (2004) in the outdoor system in cement ponds (at 300 PL/m^2) who concluded that increasing stocking densities reduced the growth rate of goldfish larvae. Botlinger (2000) has found that neither carotenoid content in the diet nor light type had any influence on lengths and weight of goldfish. Fiogbe and Patric (1993) reported that high protein diet (51% crude protein) was the optimum for juvenile gold fish. Stone and McNulty (2003) reported that stocking rate of 84 -168 PL/m^2 is ideal for goldfish juveniles. Under present stocking density which was within this range, PL had plentiful natural food in paddy plots and varied diet because goldfish are omnivores. They eat plants, insects such as mosquito larvae, small crustaceans, zooplankton, and detritus (Street, 2002). That may have been the reason for high growth performance PL in paddy plots.

Table 1. Growth performance of goldfish post larvae and fry grown in paddy plots and the control in eight week culture period

Parameter [i]	PL in paddy plots	PL in the control	Fry in paddy plots	Fry in the control
At stocking				
MTL (cm)	0.8 ± 0.08	0.8 ± 0.08	1.7 ± 0.11	1.7 ± 0.11
MSL (cm)	0.6 ± 0.01	0.6 ± 0.01	1.4 ± 0.05	1.4 ± 0.05
MLW (g)	0.008 ± 0.00	0.008 ± 0.00	0.12 ± 0.01	0.12 ± 0.01
At harvesting [ii]				
MTL (cm)	4.5^a ± 0.85	1.8^b ± 0.25	7.5^c ± 0.67	3.2^d ± 0.43
MSL (cm)	3.2^a ± 0.33	1.2^b ± 0.27	5.6^c ± 0.46	2.2^d ± 0.26
MLW (g)	2.20^a ± 0.86	0.40^a ± 0.14	9.54^c ± 2.88	0.66^d ± 0.17
GR (g/day)	0.039^a ±0.02	0.007^b ± 0.00	0.168^c ± 0.08	0.010^d ± 0.00
CF	0.68^a ± 0.22	0.33^b ± 0.13	1.70^c ± 0.08	0.30^d ± 0.02
Survival (%)	15^a ± 2.0	27^b ± 3.0	55^c ± 1.41	74^d ± 3.5

i MTL- mean total length, MTW- mean live weight, MSL- mean standard length, GR- growth rate, CF- condition factor.
ii Within rows, means not sharing common superscript are significantly different ($p<0.05$)

The condition factor (CF) reflects information on the physiological state of the fish in relation to its welfare. CF is a good indication of the optimum plane of nutrition and rearing environment (Paulet, 2004). High CF of fish in paddy plots indicates that PL in paddy plots had received better condition for their growth. Colour composition of PL at harvesting was 30% of self-coloured red metallic, 53% of self-coloured orange and 17% of self-coloured yellow metallic in paddy plots (Table 2). Intensity of skin colour is an important quality criterion in Koi carp and goldfish (Gouveia and Rema, 2005). Botlinger (2000) has found that neither carotenoid contents in the diet nor light type had any influence on changing colour of goldfish fry before they were 77 days old. Wallat *et al.* (2005)

reported that the orange–red coloration was enhanced when goldfish were raised in pond water (*i.e.*, no feed was administered). PL in this experiment were 66 day of age at harvesting and had revealed differences in colour development compared to the control. Since PL had been obtained from the same parent fish, difference observed in the fish colour should have resulted from causes besides the genetics.

Survival of PL in paddy plots was significantly different ($p<0.05$) compared to the control. Survival rate of PL in the experiment in paddy plots (15%) and in the control (27.5%) were subjectively poor. Kumara *et al.* (2004) has reported higher survival rate (91-100%) of PL in 20 days culture period starting with day old PL in intensive outdoor system. Kaisar *et al.* (2003) reported that effect of combination of natural and artificial food was not significant on growth and survival of PL in the controlled environment. The frequency of agonistic behaviour of PL increased as fish grew but no cannibalism was recorded in goldfish juvenile in first 20 days (Paulet, 2004). However, cannibalism was observed in the control of this experiment after four weeks of stocking as large juveniles predate on weaker and smaller juveniles under stress. The predatory creatures like backswimmer (*Anisops* spp.) and dragonfly larvae (*Pantala* spp.) found in the paddy plots would have predated on fish fry because backswimmer and dragonfly larvae were potential predators in goldfish ponds (Kumara, 2004). Further studies are underway to identify the optimum stocking ratio of PL and methods to improve the survival rate of goldfish PL in paddy plots.

Performance of Fry

Mean TL and SL of the fish fry in paddy plots and in the control at stocking was 1.7 cm ± 0.08 and 1.4 cm ± 0.05 respectively (Table 1). There was a significant increase in the TL of fry in paddy plots and in the control up to end of eight-week culture cycle (Figure1). There was significant difference ($p< 0.05$) in the TL and SL of fish between the treatment and the control from the fourth week of stocking up to eighth week (Figure 1). Jayaweera (2004) reported that fish grown in the control had a relatively higher SL of 3.3 cm (± 0.17) and the fish in paddy plots fertilized biweekly, recorded a SL of 3.2 cm (± 0.13) at eight weeks at the stocking rate of 100 fry/m^2. However, according to the present findings at the stocking rate of 80 fry/m^2 in paddy plots and control, fish in paddy plots had recorded higher SL of 5.6 cm (± 0.46) in eight weeks of stocking compared to SL of 2.2 cm (± 0.26) in the control, which was significantly different ($p<0.05$). Fertilizing paddy plots weekly with poultry litter at 400 kg/ha would have created a favourable condition for fish.

The final TL of fish in paddy plots and the control were significantly different ($p<0.05$). Fish in paddy plots have reached TL of 7.5 cm ± 0.67 while fish in the control had reached TL of 3.2 cm ± 0.43 at harvesting. In addition, fish in paddy plots had reached marketable body length (SL of 3.0 – 5.0 cm) within 6 to 8 weeks. Chakrabati and Jana (1992) found that growth of carp fry was high when fed with varied diet of live food. Chakrabarty and Hettiarachchi (1982) found that the quality of goldfish was high when grown in mud ponds with combined feeding. Stone and McNulty (2003) reported that goldfish fry reached 1.6 - 1.8 g live weight at 126 days with a diet of 36% crude protein at the feeding rate of 1 - 2% of body weight in aerated indoor tanks. SL of fish in the control with no aeration had not reached marketable size at harvesting while 62% of the fish produced in paddy plots had recorded TL over 5 cm at harvesting. Therefore, culture cycle of fry in paddy plots should be restricted to 6 - 7 weeks to get the required lengths for export. The difference of TL and SL achieved within an eight weeks culture cycle are subjectively important because the most of the new improved paddy varieties cultivated in Sri Lanka have short cropping cycle of 3 to 4 months and the period for grow out cycles of fish with paddy will be limited to eight to twelve weeks.

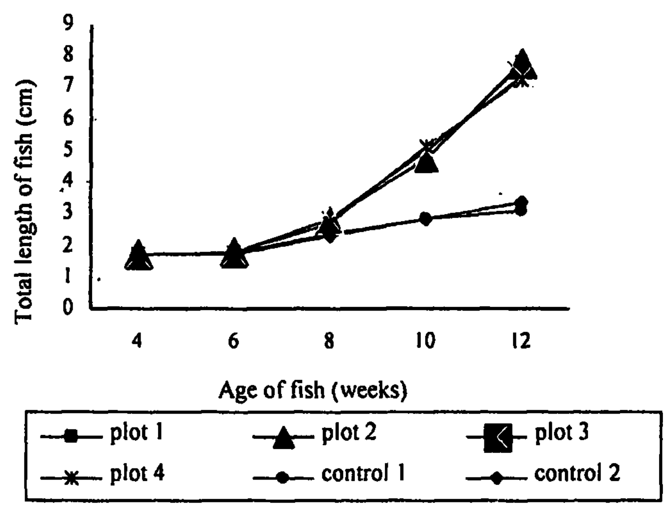

Fig. 1. Increase in total length (TL) of fish fry in paddy plots and in control

The rate of the growth of fish in terms of body weight gain had a significant difference ($p<0.05$) from the fourth week of stocking up to the end of culture cycle (Figure 2). Kumara (2004) reported that goldfish fry that were raised in outdoor tanks fertilized with poultry litter had a rate of growth comparable to fry in indoor tanks fed with formulated ration that contained 53.6 % crude protein and it was found that higher total plankton count resulted from outdoor tanks fertilized with poultry litter. Kumara (2004) found that growth of goldfish fry depends on plankton density of pond. Chakrabarti and Jana (1992) found that growth of carp fry strongly depends on plankton density. Poultry litter in the experiment used as the organic manure would have served dual role as a major source of feedstuff for fish and fertilized pond water for growth of plankton. Supplementary formulated feed, aeration and infrequent water changes cause higher growth rate in Nile Tilapia (*Oreochromis niloticus*) fry (Absalom and Omenaihe, 2000). Infrequent water changes had taken place in paddy plots when the field was irrigated to keep the standing water level at 2.5 cm.

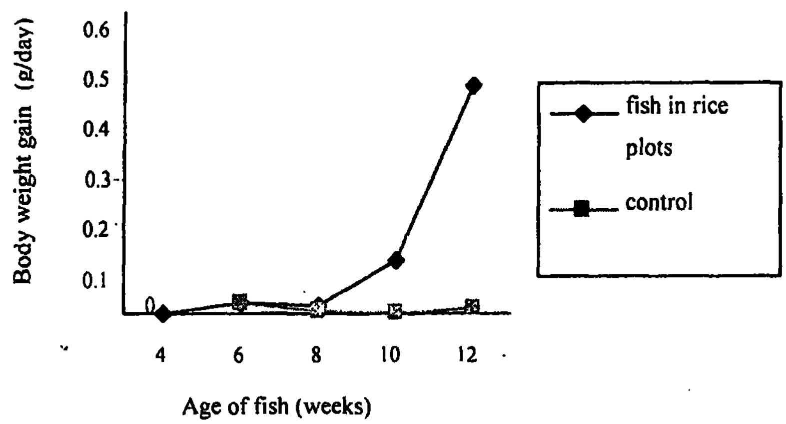

Fig. 2. Growth of fish in eight weeks culture cycle

CF of fry in paddy plots (Table 1) was significantly different ($p< 0.05$) from the control at harvesting. High condition factor of fish in paddy plots (1.70 ± 0.08) reflects information on the physiological state of the fish in relation to its welfare in paddy plots because CF is a good indication of the optimum plane of nutrition and rearing environment (Paulet, 2004).

The percentage of fish number in each colour categories of fish, based on visual colour ranking has shown a significant difference in the two environments. Higher percentage of fish fry in paddy plots has developed self coloured red metallic (78%) compared to that in the control. There was no significant difference ($p>0.05$) of the count of brightly coloured fish fry at eight and ten weeks of age but it was significantly different ($p<0.05$) at 12th week (Figure 3). Orange and yellow metallic coloured fish percentages were high in the control (Table 2).

Table 2. Colour of the Fry and PL grown in the paddy plots and control at harvesting

Colour Category of Fish	Fish from Paddy Plots (%)		Fish from control (%)	
	Fry	PL	Fry	PL
Red metallic	78	30	43	26
Orange	20	53	44	32
Yellow metallic	5	17	13	42

Booth *et al.* (2004) reported that dietary sources of pigments and incident solar radiation helps to manipulate skin colour of Austraiian snapper (*Pagrus auratus).* Diet significantly affected development of color in juvenile goldfish (Wallat *et al.*, 2005). Fish fry in paddy plots get incident solar radiation and a varied diet than the fry fed with formulated ration. It has been found that neither the diet nor light type had any influence on changing colour of goldfish fry before they were 77 days old. Light had no influence on the age at which fish changed colour, whereas water temperature seemed to have an effect. Light intensity had a stronger influence on coloration of goldfish than light type and goldfish in dark condition remains pale (Botlinger, 2000).

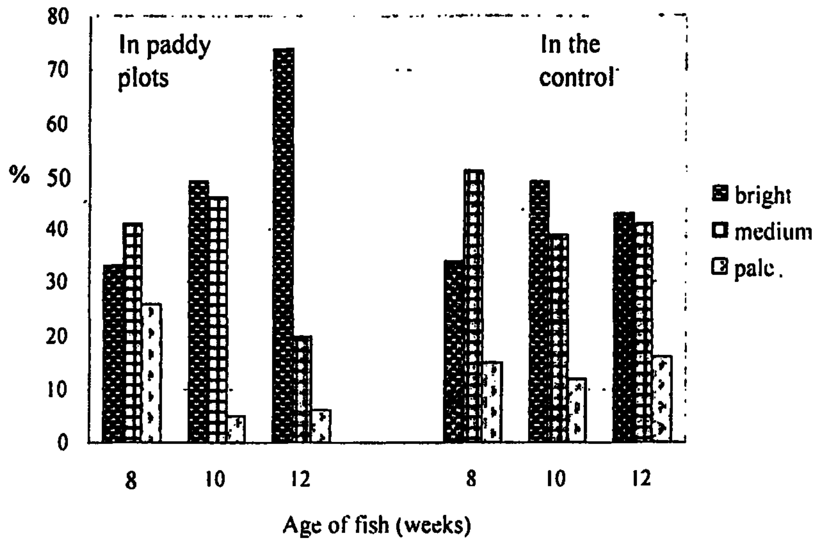

Fig. 3. **Development of skin colour of fish in paddy plots and the control with maturity**

The control in this experiment had no illumination whereas paddy plots experienced bright sun. Brighter colour of fish reported in this experiment could be partly due to higher light intensity prevailed in paddy plots. There was a tendency to an overall improvement of colour parameters in goldfish fed diets with high levels of natural microalgae *Chlorella vulgaris* and the best temperature range to maximize skin pigmentation was 26 – 30 °C (Gouveia and Rema, 2005). Kumara (2004) reported that higher phytoplankton counts were found in outdoor tanks fertilized with poultry litter. Higher availability of varied live-food for fry would have compounded to give brighter colours in paddy plots. Bright colour of fish is subjectively important because goldfish and Koi carp value increases with intensity of skin colour which is an important quality criterion (Gouveia and Rema, 2005).

Survival rate of fish fry in all the paddy plots compared to control was low in general. Higher survival rates of 76% and 71% were observed in the control which is significantly different ($p<0.05$) compared to 56% and 54% survival rates in the two paddy plots. However, survival rates recorded in paddy plots were higher compared to the findings of Jayaweera (2004) with a complete cover over the paddy plots. A few deaths were observed in the control at second weeks of stocking immediately after data collection. Goldfish is a delicate type fish and most vulnerable to stress at PL and fry stages (Street, 2002). Stress of handling would have resulted in poor survival. Protective cover from the sides and net cover from the top would have helped the survival rate of fry in paddy plots.

Kumara (2004) reported 91% survival of goldfish fry from the age of 20 - 80 days of culture cycle in cement pond. It was observed that large juveniles predate on smaller fry in indoor tank in particular when smaller fish were under stress. Backswimmer (*Anisops* spp.) and dragonfly larvae (*Pantala* spp.) found in the paddy plots would have predated on fish fry because backswimmer and dragonfly larvae are considered to be potential predators in goldfish ponds (Kumara, 2004).

Suggestions for further studies

Further studies are necessary to estimate the optimum stocking rates of fry with and without supplementary feed in paddy plots in various agro-climatic zones. An economical protective cover must be developed to reduce predation of fish in the paddy plots and to increase the survival rate of post-larvae and fry.

CONCLUSIONS

Results of the study demonstrate that goldfish fry can be raised in paddy plots to produce fish with a total length of 7.5 cm in eight-week culture period and 3.0 – 5.0 cm can be achieved in 6 weeks, starting from four-week old fry (TL 1.7 cm), using poultry litter as the sole fertilizer. Goldfish with a total length of 3.0 - 5.0 cm could be produced with 10 days-old post larvae (TL 0.8 cm) in eight weeks. It was found that pond refuge and the full cover over the paddy plots help the survival of goldfish post larvae and fry in open paddy plots. Since most of the paddy varieties have a cropping cycle of three months or more, eight weeks or longer rearing period for fish could be achieved in paddy fields. Fish and protective cover have positive effects to paddy harvest and economic returns increase by about 176.7% in paddy-goldfish integration. Goldfish produced in eight weeks in paddy plots comply with the export requirements of 3.0 - 5.0 cm. long brighter fish and 7.5 cm long fish for the local market.

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