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Biocontrol of weed in summer rice through grass carp (*Ctenopharyngodon idella*)

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Abstract: An experiment was conducted in Assam, India with three replications using 2500 fingerlings of grass carp per acre land for controlling weeds in summer rice. Another plot of one acre of summer rice without grass carp was treated as control for comparison. The experiment revealed that while average number of weed and weed weight per m^2 in the rice monoculture (RMC) plot were 28.64 and 25.21 g, respectively; in the integrated rice fish culture (IRFC) plots number and weight of weeds were 3.4 and 2.99, respectively. Grass carp did not consume *Echinochloa* spp. and *Alternanthera* spp. Rice production was 3002 kg grains/acre against 2295 kg/acre, in IRFC and RNC plots, respectively. There was 30.81% increase of rice yield in IRFC, despite of fact that 11.35% the total rice field was used for trench as fish refuse, where rice was not planted. Total table fish production from IRFC was 2 276.74 kg/acre. The returns from IRFC and RMC were Rs. 20 0775.50 and Rs. 22 950.00 respectively. The BC ratio of IRFC and RMC were 3.05 and 1.48, respectively. The comparative analysis revealed an additional income Rs. 17 7825.50 per acre from IRFC system.
Keywords: Grass carp, integrated rice-fish farming, weed, biocontrol, *boro* rice, rice equivalent.

INTRODUCTION

Rice serves as the basis for life for half of the world's population [1-2] particularly in East and South East. Indica type of rice accounts for 80% of the cultivated rice of the world and 90% of the world's rice is grown in Asia[3]. Infestation of weed is a major problem in rice production. The yield loss due to weed infestation in different systems of rice cultivation ranges from 15 to 90%. It is estimated that yield loss in transplanted rice, direct seeded rice and upland rice to be 15-35, 30-65 and 45-90%, respectively [31]. Poor weed management is the major factor for yield reduction in rice [4] as the weed competes with rice plant for space, nutrient, air, water, light and affects plant height, tillering, leaf architecture, shading ability and growth pattern of rice.

The weeds in rice field consist of about 100 species. Major species are duckweeds (*Lemna minor*), alligator weed (*Alternanthera philoxeroides),* coontail (*Ceratophyllum*, *Rotala indica*, *Myriophyllum spicatum*, *Utricularia aurea*, *Potamogeton crispus*, *Najas minor*, *Sagittaria pyqmaea*, Hydrilla verticillata), barnyard grass (*Panicum crusgalli*, *Cyperus difformis*, *Heleocharis yokoscensis*, *Sparganium racemosum*, *Monochoria vaginalis*), etc in summer rice.

Grass carp (*Ctenopharyngodon idella*) is a potential agent for bio-control of weeds. Recent development of fish culture in rice field in China is based upon the principles of bio-control of weed through grass carp. It saves both labour and money for weeding.

In India, grass carp is cultured as an important species in pond-based composite culture systems consisting mainly of Indian major carps, Chinese carps and Common carp. The grass carp stocking density depends mainly on the availability of aquatic weeds and terrestrial grasses available but is usually 5-20 percent of stocking density. No literature is available on culture of grass carp in rice field in India. A field experiment was conducted in Goalpara district of Assam, India to study the impact of integration of grass carp rearing with *Boro* (summer) rice cultivation on weed biomass and rice yield.

MATERIALS AND METHODS

The experiment was conducted in Goalpara district of Assam, India during 2012-13. Three plots of one acre each were selected for the experiment. The plots were medium low land and fairly levelled. Texture of the plots was sandy loam and the average pH was 5.83 with high in nitrogen and medium in phosphorus and potash content of the soil. All the plots had bore well irrigation system. Another plot of one acre area in the same locality was selected as control for comparison of the results. A peripheral trench of 1.8 m width and

1.5 m depth was dug and a dyke having 1.0 m base was constructed outside the trench using the excavated earth in all the three experimental plots. The height of the dyke was 1.0 m and had 30 cm freeboard. The total area of the dyke and trench was 460 m^2 (trench 230 m^2, dyke 230 m^2), which was 11.35% of the total area of the experimental plots. Land in both experimental plots and control plot was prepared in the month of December, 2010 by ploughing and harrowing properly. Fertilization was done with 54.69 kg urea, 81.75 kg single super phosphate and 18.20 kg murate of potash/acre. In addition, agricultural lime ($CaCO_3$) was applied in the experimental plots @ 70.80 kg/acre/month to maintain the water pH within optimum range (7.0 - 8.5). Puddling was done by irrigating with ground water in the first week of February, 2012 and transplantation was done using 28 days old rice seedlings of *China pajam* variety at 20 x 20 cm spacing in the third week of February, 2012. Package of practices for *Boro* rice cultivation jointly recommended by State Agricultural University and Assam Department of Agriculture was followed for management of the rice crop. Details of the practices adopted are summarized in Table 1.

Table-1: Details of practices adopted.

Sl. No.	Practices	IRFC	RMC
1	Plot size (m^2)	4050	4050
2	Trench and dyke (m^2)	460	0
3	Trench (m^2)	230	0
4	Dyke (m^2)	230	0
4	Rice area (m^2)	3590	14826.34
5	Rice crop	Summer rice (*Boro*)	Summer rice (*Boro*)
6	Seed rate (kg)	25.3	25.3
7	Ploughing (No)	1	1
8	Rotavator (No)	2	2
9	Puddling (No)	1	1
10	Urea (Kg)	54.63	54.63
11	Single super phosphate (kg)	81.75	81.75
12	Murate of potash (kg)	18.2	18.2
13	Agricultural lime (kg)	354	354
13	Farm yard manure (t)	4.05	4.05
14	Spacing (cm)	20 x 20	20 x 20
15	Irrigation ('000 m^3)	2.03	2.03
17	Crop duration (days)	155	155
18	Fingerlings	2500	0

One week after transplanting, water level in the rice plot was increased and maintained at 5.0 cm by pumping out ground water until the onset of first pre-monsoon rain that occurred in the second week of March, 2012. A total of 2500 grass carp fingerlings of 23.50 g (5.00 cm) size were released in the trench area of each experimental plot after six weeks of transplantation. Sample netting was done at fortnightly interval to investigate the growth of fish stock. Ggrowth rate (GR), specific growth rate (SGR), total live-weight gain (TWG) and percentage weight gain (PWG) were calculated as in Davies *et al*. [5]:

$$\mathbf{GR\ (wt\ per\ day)} = \frac{\mathbf{Final\ body\ weight - Initial\ body\ weight}}{\mathbf{Culture\ interval\ (days)}}$$

$$\mathbf{SGR\ (\%\ body\ weight)} = \frac{\mathbf{Final\ body\ weight - Initial\ body\ weight}}{\mathbf{Culture\ interval\ (days)}}\ \mathbf{X\ 100}$$

$$\mathbf{TWG} = \mathbf{Final\ body\ weight - Initial\ body\ weight}$$

$$\mathbf{PWG} = \frac{\mathbf{Final\ body\ weight - Initial\ body\ weight}}{\mathbf{Initial\ body\ weight}}\ \mathbf{X\ 100}$$

Weed sampling and counting were done 15 days after transplanting and before weeding stage when weeds had two or three leaves. The dominant weed species were *E. crus-galli p.beauv.*, *Cyperus difformis L.* and *Alisma plantago aquatic L.* Weed density was determined in quadrants 0.25 m2 at 20 random locations in each plot. Data were converted to density/m2. Data on weed infestation, total number of weeds/m^2, weeds weight/m^2, grain yield t/acre and fish yield/acre were recorded and analyzed. Rice was harvested at maturity in the third week of July, 2011 after 155 days of transplantation. Grass carps were harvested in the last week of September 2011 after harvesting the rice crop.

RESULTS

Weed infestation

Weeds in the control plot *i.e.* the rice monoculture (RMC) plot consisted of *Monochoria vagnialis, Panichum repens, Echinochloa colonum, Echinochloa crusgali, Finbristylis miliacea, Cyperus micheliamus, Cyperus esculenta, Sciepur juncoides, Cynodon dactylon, Eichhornia crassipes, Typha angustata, Hydrilla verticillata casp., Pistia stratiotes L., Salvinia mlesta Mitchell, Ipomoea aquatic, Alternanthera spp., Nuphar spp., Ponterderia cordata and Phragmites communis.* In the integrated rice-fish system a few *Echinochloa* spp. and *Alternanthera* spp. survived. Average number of weed and weed weight per m^2 in the RMC plot were 28.64 and 25.21 g, respectively. In the integrated rice fish culture (IRFC) plots number and weight of weeds were 3.4 and 2.99 respectively.

Rice production

The IRFC plots yielded average 3002 kg grains/acre against 2295 kg/acre from the RMC plot. IRFC system could indeed increase the rice yield by 30.81%, despite of fact that 11.35% the total rice field was used for trench as fish refuse, where rice was not planted.

Table fish production

The fish stock was harvested in September after 231 days rearing. A total of 2352 (94.08%) fishes were harvested. Average weight of the fish was 968.27 g at the time of harvest. The growth rate/day and specific growth rate was (SGR) 408.99, respectively. Total weight gain and percentage weight gain were 944.77 g and 3869.72 g respectively. Average yield per acre was 2276.74 kg (Table-3).

Economics:

The results revealed that total rice production from the IRFC system was 2276.74 kg and rice equivalent fish production was 17075.50 kg. Details of costs in IRFC system and RMC system are given in Table-2. The total operational costs were Rs. 49603.28 and Rs. 9253.28 for IRFC and RMC system, respectively. Whole sale price of the fish and rice were Rs. 75.00 and Rs. 10.00 per kg, respectively. The returns from integrated rice-fish and rice monoculture were Rs. 200775.50 and Rs. 22950.00 respectively. BC ratio of integrated rice-fish farming and rice monoculture were 3.05 and 1.48, respectively. The comparative analysis revealed an additional income Rs. 177825.50 per acre from IRFC system.

Table-2: Operational cost of integrated rice-fish system

Particulars	Qty/area	Unit cost (Rs)	IRFC (Rs)	RMC (Rs)
Trench and dyke (m^2)	460	40	18400.00	0.00
Seed (kg)	25.3	95	2403.50	2403.50
Ploughing (acre)	1	400	400.00	400.00
Rotavator (acre) (2 times)	1	1000	1000.00	1000.00
Puddling (acre)	1	600	600.00	600.00
Urea (Kg)	54.63	12	655.56	655.56
Single super phosphate (Kg)	81.75	13	1062.75	1062.75
Murate of potash (Kg)	18.2	15	273.00	273.00
Agricultural lime (Kg)	354	12.5	4425.00	0.00
Farm yard manure (t)	4.05	400	1620.00	1620.00
Transplanting (acre)	1	600	600.00	600.00
Irrigation ('000 m^3)	2.25	61.54	138.50	138.50
Fingerlings	125	75	9375.00	0.00
Total			49603.28	9253.28

Table 3: Growth performance

Sl No	Parameters	Value
1	Mean initial weight (g)	23.50
2	Mean final weight gain (TWG) (g)	944.77
4	Mean final growth rate (g/day)	4.09
5	Mean final specific growth rate (SGR%)	408.99
6	Mean percent weight gain (PWG) (g)	3869.72
7	Culture interval (days)	231

DISCUSSION

The grass carp (*Ctenopharyngodon idella*) is a voracious herbivore and can quickly eliminate large volumes of vegetation [6]. It can consume three times its body weight in plant matter in a day. The words *Ctenopharyngodon idella* are made up of the Greek word 'ktenos' meaning 'comb', the Greek word 'pharynx' meaning 'throat', the Greek word 'odous' meaning 'teeth' and the Greek word 'idella' meaning 'distinct'. Grass carp has pharyngeal teeth resembling molars located further back in its mouth, at the entrance to the throat (Fig. 1). The pharyngeal teeth having deep groves [7], are in two rows, and may count 2,4-4,2 or 2,5-4,2 [8]. The carp eats grass by using these teeth. The species is probably best known for its ravenous appetite for plant matter, especially the macrophytes. The size at which Grass carp begins to feed on plants depends on temperature, with smaller fish switching to plants in warmer waters [9]. The present study suggested that only young grass carp should be released when the rice stem becomes sufficiently strong. Grass carp must not attain more than 700 g size before harvesting the rice crop. After harvesting the rice, they may be allowed to grow further in the rice field.

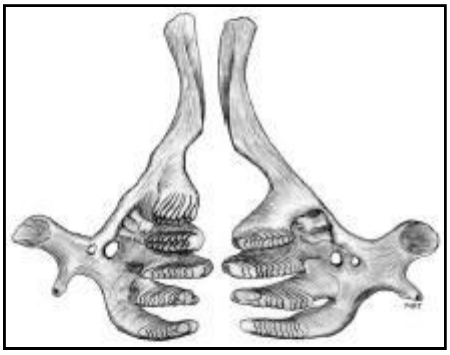

Fig. 1: Pharyngeal teeth (2,4-5,2) of Grass Carp [10].

Grass carp, although is herbivore, particulate feeder, browser; feeds on macrophytes, it also consumes insects and small fish when vegetation is unavailable [11-13]. This helps growing grass carp in rice fields as it offers shelter to number of insects. Feeding of grass carp is strongly affected by temperature; fish begin active feeding as temperatures rise above 7-8°C, with peak consumption at 20-26°C [12]. Larvae begin feeding on rotifers at 2-4 days, changing to larger zooplankton in about a week[9]. Adults feed on a variety of plants [14], consuming filamentous algae, aquatic vascular plants, and terrestrial plant material[15]. Bain *et al*. reported that the aquatic weed, *Hydrilla*, is a preferred food[16].

Grass carp was chosen to cultivate during Tang Dynasty (618-904) in China as the substitute of common carp because selling and killing of common carp was prohibited due to its similarity in Chinese pronunciation with the family name of emperor. Later it was introduced in the rice fields to control weeds [17].

The history of rice-fish farming is not known exactly when or where it was started. Since, it is widely acknowledged that aquaculture started early in China, where pond culture of common carp (*Cyprinus carpio*) began at the end of the Shang Dynasty (1401-1154 BC), it is assumed that rice-fish farming was also started in China [18]. Rice-fish culture was first described by Liu Xun (circa 889-904 AD) [19].

Due to abundant water in rice fields, many fish species prefer the rice field for reproduction and growth [20-24]. A stone tablet from *Sukhothai* period – a Thai kingdom flourished 700 years ago depicts an inscription, 'There is rice in the fields, fish in the water'.

Fish control weeds grown in rice fields. Grass carp eat 21 different species of weeds in 16 families (e.g., *Echinochloa crusgalli*, *Eleocharis yokoscensis*, *Cyperus difformis*, *Rotala indica*, *Sagittaria pygmaea*, *Monochria vaginalis*, and *Marsilea quadrifolia*). Observations in late rice fields in Xiaoxhan in 1987 revealed that there were three different kinds of weeds in rice-fish fields without weeding. The fresh weight of the weeds was 117 kg/ha. This represented a decrease of one kind of weed and 29.7% in fresh compared with rice fields with manual weeding, and a decrease of six kinds of weeds and 97.2% in fresh weight compared with a rice field without fish and without weeding. Integration of grass carp rearing with *Boro* rice cultivation has an additional advantage *i.e.*, no extraneous feed is required for fish as it is provided by the rice field itself. Grass carp feeds on the weeds and old leaves of the rice plants before cutting the crop. After harvesting the crop they feed on the sprouts emerging out of the stubbles. Finally they feed on the stubbles and made the field clean.

Only *Echinochloa crusgalli*, *Paspalum distichum*, and *Alternanthera philoxeroides* survived in the rice-fish fields. *Paspalum distichum* normally extended from border dikes into the rice field. Young buds and stems of *Alternanthera philoxeroides* were eaten by the fish, but they were not well liked. The surface of the rice fields with fish was smooth and grass free. Weed control was more effective than with either manual weeding.

FAO defined rice-fish farming as one of the globally important ingenious agricultural heritage systems (GIAHS) [25], which appears to be important in terms of climate change, shared waters and agricultural biodiversity. It is in fact aquatic life management (ALM) practice which can play a vital role as a vehicle for sustainable crop technologies such as integrated pest management (IPM) [26]. According to Lightfoot *et al.*, transformation of rice system into rice-fish system tends to directly benefit food production and farm income, as well as farm integration [27]. Heckman [28] and Kurihara [29] opined that integrated rice-fish farming is a sustainable form of agriculture providing invaluable protein, especially for subsistence farmers managing rainfed systems.

The results of the experiment revealed integration of grass carp rearing into *Boro* rice field is a viable tool for controlling weed and improving livelihood and restoration of rice ecosystem. The added advantage is on creation of permanent infrastructure *i.e.* the modification of the rice field, which would significantly reduce the costs of production in subsequent years [30].

CONCLUSION

From the result of the experiment, it may be concluded that integrating rearing of grass carp with summer rice can be the best tool for controlling weeds. The results revealed that besides controlling the weeds, it also increases rice yield and farm income. Moreover, faecal matters of grass carp add nutrients to the rice field. Major constraints may be predation on fish fingerlings by snakes, infestation of *Echinochloa* spp. and *Alternanthera* spp. in rice field as it is not controlled by grass carp and large grass carp in rice filed may damage the rice plants.

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