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Research Article

Paddy cum fish culture: Growth performance of *Channa punctatus*, paddy yield and economics

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Abstract

Integrating fish and paddy culture may enhance the production with maintaining equitable use of the available land and human resources to ensure global food security. Hence the present study has been carried out to explore the possibility of culture of fish, *Channa punctatus* in paddy fields with/without supplementary feed. Four treatments (T1: No fish, no pesticide in paddy fields; T2: Fish in paddy fields without pesticide exposure; T3: Fish in paddy fields with are commended dose of pesticide and T4: Fish in paddy fields with pesticide dose as per farmers) were maintained in both experiments (with/without supplementary feed) in 120 m^2 paddy plots. Farmers' treatment without fish was also considered (T5). Fingerlings (15.50±0.40 g) were stocked with 1 fishper 3m^2. Water quality, growth performance, carcass composition, paddy yield and economics were studied. Water quality remained in the optimum range for fish culture (D.O. 4.-7.1 mg l^{-1}, pH 7.5-8.8).Growth performance and carcass composition revealed significantly ($P<0.05$) higher valuesin T2(SGR: 52.03, 129.73; crude protein: 14.8%, 15.0%). The values for paddy productions and economics increased from T1(24±0.326 q ha^{-1} and INR 32,850.00) to T3(55±0.475 q $ha^{-1}$and INR 111,672.00), decreased thereafter. Results of supplementary food experiments clearly revealed that although fish growth/yield was higher in T2 (659±0.514 kg ha^{-1}), rice production per hectare (57±0.891 q ha^{-1}) and net revenue gain (INR 237,457.00) was high in T3 with recommended pesticides use. Thus, fish-cum paddy culture can yield economic benefits contributing significantly towards sustainable food security.

Keywords: Carcass composition, Fish growth, Fish cum paddy culture, Supplementary feed, Water quality

INTRODUCTION

The worldwide food security scenarios are turning into an intense issue due to the expanding total populace, the restriction of agricultural assets, and the impacts of global change in the climate on crop production. Rice is viewed as a significant segment as it is the principal component of diets for around half of the world's population, particularly Asians (Tsuruta *et al*., 2010) with enhanced assortments grown worldwide in a wide scope of ecological conditions and water systems, providing 13.3% intake of protein. But, India's per capita accessibility of land has declined due to because of fast industrialization and urbanization (Pandey and Seto, 2015). The alliance of rice with fish production is a high-yielding approach for agricultural land use that may propose extraordinary potential in terms of animal protein supply, income generation by two-fold usage of land for small scale farmers(Kumaran *et al*., 2020). Fish culture in paddy field help in biological fighting against the pests, disease and weeds. Besides insects, larva, worms and weeds control either through direct consumption of weeds or through specific feeding behaviour, the rice-fish co-culture provide natural food of fish leading to its enhanced growth and reduced the requirement for pesticide, increased the farm house-

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hold income and diversified agriculture production (Abbas *et al*., 2018). Rice acts as a nitrogen sink and assists to decrease the ammonia released by fish and make the water cleaner. Excretion of fish could be considered as a good source of fertilizer for the rice.

The highly priced freshwater food fish species, spotted snakehead *Channa punctatus* (Bloch, 1973) is one of the most important fish species of Indian flood plains with great demand in the market owing its high nutritive value (Baghel *et al*., 2019). It is carnivorous, feeding mainly on live animals (invertebrates, frog and smaller fish) and can tolerate varying water quality characteristics including low dissolved oxygen; therefore, suitable for paddy cum fish culture. No reports are available on the culture of this fish with paddy, with and without supplementary feed in India especially in Haryana. Therefore, the present study was undertaken with an attempt to study the physicochemical characteristics of rice fields' water, growth performance of *Channa punctatus*, and economics of paddy cum fish culture with and without supplementary feed.

MATERIALS AND METHODS

Study area

Paddy cum fish culture experiments were conducted at Village PipalTha, District Jind (29˚ 48' N and 78˚ 26' E), Haryana (India). Two experiments were conducted each with five treatments in replicates of three.

Experiment 1 – Evaluation of growth performance of *C. punctatus* in paddy cum fish culture fields without supplementary feed

Experiment 2 – Evaluation of growth performance of *C. punctatus* in paddy cum fish culture fields with supplementary feed

Experimental treatments

12 paddy plots of 120 m^2 were selected for treatment T1-T4 and T5 was farmers' plots. Each experiment was carried out in four treatments and each treatment was conducted in triplicate including farmer's treatment:

Treatment 1: No Fish, no pesticide in paddy fields (T1)

Treatment 2: Fish in paddy fields without pesticide exposure (T2)

Treatment 3: Fish in paddy fields with recommended dose of pesticide (T3)

Treatment 4: Fish in paddy fields with pesticide exposure whatever the dose used by farmers (T4)

Treatment 5: Paddy fields without fish but pesticide exposure according to farmers that means farmer's treatment (T5). Its data was used only for comparison to estimate per hectare paddy production. Here, no fish refuges or trench were constructed and the water level was also not raised. Water quality was also not monitored in this treatment. Only paddy production was recorded.

Selection of fish species

C. punctatus (Bloch, 1973) were stocked with paddy in respective experiments. Thefingerlings (15.50±0.40 g) were procured from progressive fish farmers. This species is carnivorous air breather, hardy fish and can tolerate low oxygen level(3-5 mg l^{-1}).

Paddy fields design

12 paddy plots (for treatments T1-T4) of 120 m^2 were selected at Village PipalTha (Jind). Farmers' treatment (T5) was rice fields without fish, but pesticide exposure without modification was maintained. Several physical modifications were devised for making the paddy fields suitable for culture of fish. The fields were fertilized using cow dung (2000-2500 $kgha^{-1}y^{-1}$). During field's preparation, the height of bunds was increased up to 30-35cm in height to keep the fish from bouncing over.Fish shelters were prepared to furnish the fish with better access to paddy fields for feeding. A trench of 1m^2 wide and minimum of 50 cm deep was prepared in between or along the side of paddy plots for maintaining the water level. Subsequent to stocking the fish in paddy fields endeavours were made to keep them from getting away with water, screens made up of fishnet material were introduced over the water stream. Plastic tubes were provided as a permanent way of conveying water in or out just as in a regular fish pond.PB 1121, a rice variety of 120 days duration was used. The fingerlings of *C. punctatus* (15.50±0.40 g) were stocked in paddy fields at the rate 1 fish per 3 m^2, on 25th day after transplanting the seedling.

Use of agrochemicals

Pesticides such as insecticide, herbicides and fungicide were used to control rice crop's disease *viz.,* stem borer, leaf roller, sheath blight, leafhopper and root borer. Organic and inorganic fertilizers were applied in rice fields and beneficial for both paddy and fish. Fertilizers such as urea (46%N) and zinc sulphate monohydrate (33%Zn and 15%S) were used in all the treatments viz., T1, T2, T3, T4 and T5. Pesticide (Cartap hydrochloride) and insecticides (chlorpyriphos and herbicide pretilachlor) were sprayed only in T3, T4 and T5. In treatment T1 and T2 there was no pesticide treatment. In treatment T3 these pesticides were sprayed according to recommended doses and on suggested days (Shende and Bagde, 2013). Carbendazim, Lambdacyhalothrin and Imidacloprid were sprayed only on leaves. Fertilization of rice fields was done in 3 split-up doses. Zinc sulphate monohydrate (33%Zn and 15% S) (10 kg) and DAP (Diammonium phosphate) (50 kg) were applied before rice seedling transplantation and application of Pretilachlor 50% EC (500gmAcre^{-1}) was done on 4th day after paddy seedling transplantation. Chlorpyriphos 20% EC (1 lAcre^{-1}) and 25 kgAcre^{-1} urea was given on 15th day. Cartap hydrochloride (5kgAcre^{-1}) was applied on 20th day. Fingerlings were stocked in paddy fields on 25th day. Cartap hydrochloride 4% EC (2.5 lAcre^{-1}) and 25 kgAcre^{-1} urea (46% N), were used on 40th day. Carbendazim (46.27%), 0.5 lAcre^{-1} acts as a fungicide and was sprayed on 45th day. Lambda-cyhalothrin 5% EC (250 mlAcre^{-1}) and Imidacloprid 17.8% (150 mlAcre^{-1}) were sprayed on 55th day. Carbendazim (46.27%), 0.5 lAcre^{-1} were sprayed after 65-70 days. For treatment T4, 10 farmers of the district were approached and details about pesticide usage in their fields were collected. Based on that details, it was observed that farmers use these doses three to four times and twice the amount of recommended doses. Therefore, in treatment T4 the pesticides were used thrice as per the suggestion of the farmers. The use of pesticides in T5 was similar to T4 without any fish. Whenever weed or pest was seen, the respective agrochemicals were sprayed in this treatment as in practice.

Supplementary feed

In experiment 1, no supplementary feed was given to the fish whereas in experiment 2 supplementary feed of freeze-dried tubifex worms or blood worms were given to *C. punctatus* at the rate 4% of their body weight (not introduced in treatment 1 as it serves as control). The amount of feed was increased fortnightly in proportionate to weight increments. Fish were harvested on day 110 after seedling transplantation, which means 10 days before paddy harvesting. Paddy cum fish plots were dewatered and fishes were collected in the trench before harvesting. Thus, the fish culture period was 85 days. Paddy was harvested on 120th day.

Water quality characteristics

Water samples in paddy season were collected during the preparation of fields before seedling transplantation and during seedling transplantation at fortnightly intervals in plastic containers and analysed by standard methods (Garg *et al*., 2002; APHA, 2005) for both experiments. Dissolved oxygen, pH, salinity and conductivity were analysed at the site itself using Multiple F-Set III (Emerck) multiparameter instrument whereas calcium, magnesium, chloride, hardness, ammonia, o-phosphate, nitrite and nitrate were analysed in the laboratory.Water quality characteristics were analysed in treatments T1 to T4. Treatment T5 was farmers plot; hence water quality was not determined. Its data was used only for comparison to estimate per hectare paddy production.

Growth monitoring

50 fingerlings (15.16±0.593) of *C. punctatus* were stocked in paddy fields on day 25. Fish were kept in fields with and without pesticide exposure. No supplementary feed was given in Experiment 1. Fish fed on planktons, insects and pests of paddy fields. Paddy fields were dewatered 10 days prior to harvest, allowing the fish to take refuges in rescue pits.

Freeze dried Tubifex worms (52% Crude protein, 12% crude fat, 2% crude fiber, 12% ash, 5% moisture) and freeze-dried blood worms (60% Crude protein, 8% crude fat, 3% crude fiber, 12% ash, 5% moisture) were used as supplementary feed in Experiment 2. Paddy fields were dewatered 10 days prior to harvest, allowing the fish to take refuges in rescue pits. Fishes were recovered from each treatment soon after harvest. Fish were kept in fields with and without pesticide exposure (T2-T4) from July to September. A top pan balance (AFCOSETEX-1200) was used for recording the individual weight of fish, and lengths of the fish were measured using a simple centimetre scale at the initiation as well as at the end of the experiment. Various growth parameters were calculated using standard formulae (Garg *et al*., 2002):

Weight gain

Weight gain was measured in terms of differences between final weight and initial weight.

$$\text{Weight gain (g)} = W_2 - W_1 \qquad \text{Eq. 1}$$

Growth per cent gain in body weight

Growth per cent gain in body weight was measured by:

$$\text{Growth per cent gain in body weight} = \frac{W_2 - W_1}{W_1} \times 100 \qquad \text{Eq. 2}$$

Specific Growth Rate (SGR)

Specific growth rate was calculated by using the following formula:

$$SGR = \frac{\ln W_2 - \ln W_1}{t} \times 100 \qquad \text{Eq. 3}$$

Where,

W_1 = Initial Weight (g)

W_2 = Final Weight (g)

t = Days of experiment

Economics of paddy cum fish culture

Economics of the paddy cum fish culture was calculated per hectare taking into account of expenditure on field preparation, agrochemicals etc. and cost(Indian rupees, INR)of the fish and paddy.

Statistical analysis

Analysis of variance (ANOVA) followed by Duncan's multiple range test (Duncan, 1955) for all the experiments was used to determine the significant variation between the different treatments. Statistical significance was settled at a probability value of $P<0.05$.

Table 1. Overall mean (±S. E. of mean) of physicochemical characteristics of water in paddy fields with *C. punctatus* without supplementary feed.

Parameters	T1 (No fish, no pesticide)	T2 (Fish but no pesticide)	T3 (Recommended dose of pesticide + fish)	T4 (Pesticides dose used by farmers + fish)	Acceptable/ Desirable Standard values for fish culture*
pH	8.8±0.17^{A}	8.4±0.34^{AB}	8.5±0.24^{AB}	7.5±0.23^{B}	7.0-9.5
Free CO_2 (mg L^{-1})	Absent	Absent	Absent	Absent	0-10
DO (mg L^{-1})	5.4±0.45^{B}	7.1±0.42^{A}	6.2±0.53^{AB}	4.5±0.25^{C}	4.0-5.0
Alkalinity (mg L^{-1})	602±21.42^{A}	590±31.21^{AB}	523±26.13^{B}	512±31.47^{B}	50-200
TDS (mg L^{-1})	597.43±44.12^{C}	634.53±55.12^{AB}	699.00±57.12^{AB}	732±45.32^{A}	-
Conductivity (µm cm^{-1})	639±125.00^{C}	687±130.05^{C}	729±132.27^{B}	782±172.74^{A}	-
Chloride (mg L^{-1})	22.41±2.32^{C}	34.10±3.98^{C}	48±5.16^{B}	51.06±7.34^{A}	-
Hardness (mg L^{-1})	140±7.67^{A}	144±9.77^{A}	124±8.23^{B}	115±8.21^{C}	>20.0
Turbidity (NTU)	132.12±26.23^{B}	157.00±20.22^{AB}	180±18.02^{AB}	188.00±15.28^{A}	-
Calcium (mg L^{-1})	24±3.54^{A}	25±3.47^{A}	18±2.03^{AB}	16.93±2.64^{C}	4.0-160.0
Magnesium (mg L^{-1})	42.70±3.21^{A}	34.00±2.80^{A}	35.00±2.27^{A}	38.56±1.92^{A}	-
Ammonia (mg L^{-1})	0.230±0.05^{C}	0.242±0.03^{B}	0.360±0.06^{AB}	0.587±0.07^{A}	0.0-0.2
Nitrate (mg L^{-1})	0.202±0.02^{A}	0.200±0.03^{A}	0.172±0.03^{AB}	0.185±0.15^{B}	0.0-4.5
Nitrite (mg L^{-1})	0.265±0.02^{AB}	0.248±0.02^{B}	0.267±0.02^{AB}	0.280±0.02^{A}	0.02-2.0
o-Phosphate (mg L^{-1})	0.080±0.01^{B}	0.093±0.03^{AB}	0.098±0.01^{A}	0.092±0.03^{AB}	0.03-2.0
Gross primary productivity (g cm^{-3} d^{-1})	2.0±0.32^{A}	2.02±0.53^{A}	2.01±0.42^{A}	1.80±0.23^{A}	0.016-0.09
Net primary productivity (g cm^{-3} d^{-1})	0.882±0.19^{AB}	0.83±0.12^{AB}	1.4±0.21^{A}	0.6±0.15^{B}	-

All values are Mean±S.E. of mean; Means with different letters in the same row are significantly (P<0.05) different; Duncan's Multiple Range test*Bhatnagar and Devi (2013)

RESULTS

Water quality characteristics

Experiment 1: The overall mean values of pH ranged between 7.5 to 8.8 from water sample of rice monoculture and rice cum fish culture fields with and without pesticide exposure from day 2 to 75 (Table 1) in all the treatments (T1, T2, T3 and T4). Overall mean values of pH showed no significant (P<0.05) differences. Dissolved oxygen(DO) varied between 4.5±0.25 to 7.1±0.42 mgL^{-1}. The highest value of DO was recorded in treatment T2 where fish growth was high. Calcium, magnesium and total hardness fluctuated between 16.93±2.64 to 24.86±3.08 mgL^{-1}, 38.56±1.92 to 42.70±3.21 and177.16±8.49 to 191.50±13.75 mgL^{-1} respectively and overall mean values showed no significant (P<0.05) variations. Overall means values of ammonia varied between 0.23±0.05 to 0.58±0.07 mgL^{-1} (Table 1). Values of most of the physicochemical characteristics were within the permissible limits for fish culture.

Experiment 2:The study on water quality characteristics in T1 to T4, indicated that the pH values during the experimental period fluctuated between 7.9-8.4 indicating that field waters were well buffered. No significant (P<0.05) variations in dissolved oxygen (DO), alkalinity, hardness, turbidity, calcium, magnesium and o-PO_4 were observed in different treatments; however, the values were lower in treatment 3 and 4. Total dissolved solids, conductivity, chlorides and ammonia increased significantly (P<0.05) in treatment T3 and T4 in comparison to treatment T2 (Table 2), where fish growth per-

Table 2. Overall mean (±S.E. of mean) of physicochemical characteristics of water in paddy fields stocked with *C. punctatus* with supplementary feed.

Parameters	T1 (No fish, no pesticide)	T2 (Fish but no pesticide)	T3 (Recommended dose of pesticide + fish)	T4 (Pesticides dose used by farmers+fish)	Acceptable/ Desirable Standard values for fish culture*
pH	8.3 ± 0.05^{C}	8.2 ± 0.02^{C}	8.6 ± 0.05^{B}	8.8 ± 0.05^{A}	7.0-9.5
Free CO_2 (mg L^{-1})	Absent	Absent	Absent	Absent	0-10
DO (mg L^{-1})	6.7 ± 0.19^{B}	7.0 ± 0.11^{A}	4.1 ± 0.09^{C}	4.0 ± 0.07^{C}	4.0-5.0
Alkalinity (mg L^{-1})	420 ± 21.18^{B}	427 ± 27.44^{A}	398 ± 20.72^{C}	400 ± 23.65^{C}	50-200
TDS (mg L^{-1})	736 ± 33.77^{C}	750 ± 43.81^{C}	822 ± 28.34^{B}	921 ± 37.85^{A}	-
Conductivity (µm cm)	671 ± 155.22^{A}	653 ± 122.96^{A}	582 ± 131.44^{AB}	568 ± 140.69^{B}	-
Chloride (mg L^{-1})	35.03 ± 1.17^{C}	41.67 ± 1.23^{C}	60.69 ± 0.93^{A}	56.38 ± 1.44^{B}	-
Hardness (mg L^{-1})	120 ± 9.94^{A}	125 ± 8.96^{A}	111 ± 1.44^{B}	105 ± 1.15^{AB}	>20.0
Turbidity (NTU)	136.63 ± 18.35^{C}	155.90 ± 22.38^{B}	189.7 ± 20.49^{C}	196.30 ± 25.44^{A}	-
Calcium (mg L^{-1})	35.6 ± 4.23^{A}	35.88 ± 3.71^{A}	13.45 ± 1.98^{B}	9.27 ± 0.48^{C}	4.0-160.0
Magnesium (mg L^{-1})	20.23 ± 1.17^{A}	22.97 ± 1.65^{A}	17.22 ± 0.48^{B}	15.64 ± 0.03^{AB}	-
Ammonia (mg L^{-1})	0.105 ± 0.006^{B}	0.139 ± 0.001^{A}	0.117 ± 0.002^{B}	0.135 ± 0.001^{A}	0.0-0.2
Nitrate (mg L^{-1})	0.065 ± 0.004^{B}	0.070 ± 0.002^{B}	0.097 ± 0.008^{A}	0.091 ± 0.005^{AB}	0.0-4.5
Nitrite (mg L^{-1})	0.085 ± 0.02^{C}	0.093 ± 0.04^{C}	0.298 ± 0.03^{B}	0.545 ± 0.06^{A}	0.02-2.0
o-Phosphate (mg L^{-1})	0.186 ± 0.03^{B}	0.187 ± 0.06^{B}	0.208 ± 0.04^{B}	0.321 ± 0.01^{A}	0.03-2.0
Gross primary productivity (g cm^{-3} d^{-1})	0.055 ± 0.001^{B}	0.074 ± 0.001^{B}	0.092 ± 0.003^{B}	0.107 ± 0.001^{A}	0.016-0.09
Net primary productivity (g cm^{-3} d^{-1})	0.260 ± 0.11^{A}	0.268 ± 0.02^{A}	0.088 ± 0.03^{A}	0.084 ± 0.04^{B}	-

All values are Mean±S.E. of mean; Means with different letters in the same row are significantly (P<0.05) different; Duncan's Multiple Range test; *Bhatnagar and Devi (2013)

formance was high. The values when compared with standards for fish culture were found to be in acceptable/desirable limits.

Fish growth

Experiment 1: The per cent survival was high in treatment T2 (90%) and lower in treatment T4 (73%). Growth parameters (fish weight gain, growth percent gain in body weight and specific growth rate) were significantly (P<0.05) high in treatment T2(fish in paddy field without pesticide exposure) followed by T3 and T4 (Table 3).

Experiment 2: The per cent survival was high in treatment T2 (90%) and lower in treatment T4 (76%). The growth parameters (weight gain, growth percent gain in body weight and specific growth rate) were significantly (P<0.05) high in treatment T2 (fish in paddy field without pesticide exposure) followed by T3 and T4 (Table 3).

Carcass composition

Experiment 1: Initial and final carcass composition in fish stocked in paddy fields without pesticide exposure (T2) with a recommended dose of pesticides (T3) and pesticide application in paddy fields according to farmers (T4) is summarized in Table 4. Significantly (P<0.05) higher crude protein was found in treatment T2 (14.8±0.072) followed by treatment T3 (14.40±0.11) and lower in treatment T4 (12.6±0.19). The minimum value of crude ash (%) was observed in treatment T2 (3.9±0.07) as compared to treatment T3 (4.7±0.94) and treatment T4 (5.9±0.09). Significantly (P<0.05) higher

Table 3. Growth performance of *C. punctatus* in paddy fields after 85 days without and with supplementary feed.

Parameters	T2 (Fish but no pesticide)	T3 (Recommended dose of pesticide)	T4 (Pesticides dose used by farmers)
Experiment 1			
Plot area (sq. m)	120	120	120
No. of fish stocked	50	50	50
No. of fish recovered	46±0.72^{A}	40±0.54^{B}	36±0.72^{B}
Per cent survival	90±1.88^{A}	84±2.81^{AB}	73±1.44^{B}
Initial weight (g)	15.16±0.59^{A}	15.50±0.40^{A}	15.66±0.54^{A}
Initial Length (cm)	4.23±0.11^{A}	4.33±0.19^{A}	4.66±0.07^{A}
Final weight (g)	62±0.47^{A}	59±0.47^{A}	53±0.94^{B}
Final Length (cm)	14.46±0.11^{A}	13.06±0.31^{B}	11.93±0.19^{C}
Weight gain (g)	46.83±0.59^{A}	43.50±0.23^{A}	37.33±1.08^{B}
Growth % gain in BW (%)	313.36±8.40^{A}	280.98±7.29^{AB}	250±6.59^{C}
Specific Growth Rate	52.03±0.65^{A}	48.32±0.26^{AB}	46.83±0.59^{B}
Experiment 2			
Plot area (sq. m)	120	120	120
No. of fish stocked	50	50	50
No. of fish recovered	45±0.72^{A}	40±0.72^{B}	38±0.94^{B}
Per cent survival	90±1.88^{A}	80±2.37^{B}	76±1.44^{B}
Initial weight (g)	4.9±0.94^{A}	4.9±0.16^{A}	4.9±0.15^{A}
Initial Length (cm)	2.8±0.07^{A}	2.7±0.09^{A}	2.7±0.07^{A}
Final weight (g)	115±3.60^{A}	108.33±3.6^{B}	90±2.35^{C}
Final Length (cm)	17.40±0.21^{A}	15.93±0.33^{AB}	13.43±0.19^{B}
Weight gain (g)	116.76±3.57^{A}	103.36±3.69^{B}	85.06±2.38^{C}
Growth % gain in BW (%)	2240.71±177.35^{A}	2087.93±113.83^{B}	1763.40±5.96^{B}
Specific Growth Rate	129.73±3.96^{A}	114.84±4.10^{B}	94.44±2.67^{C}

All values are Mean±S.E. of mean; Means with different letters in the same row are significantly (P<0.05) different; (Duncan's Multiple Range test)

Table 4. Proximate composition of fish carcass with and without pesticide exposure in paddy fields without and with supplementary feed after 85 days.

Parameter	Initial	T2 (Fish but no pesticide)	T3 (Recommended dose of pesticide)	T4 (Pesticides dose used by farmers)
Experiment 1				
Moisture (%)	65.9±0.36	67±0.71^{B}	71±0.20^{A}	71.7±0.11^{A}
Crude Protein (%)	8.8±0.07	14.8±0.07^{A}	14.4±0.11^{A}	12.6±0.19^{B}
Crude Fat (%)	4.6±0.12	5.2±0.12^{C}	5.9±0.13^{B}	6.9±0.04^{A}
Crude Ash (%)	3.2±0.11	3.9±0.07^{C}	4.7±0.94^{B}	5.9±0.09^{A}
NFE (%)	2.8±0.07	3.4±0.07^{C}	4.9±0.07^{B}	6.7±0.12^{A}
Gross energy (g kg^{-1})	4.4±0.14	8.0±0.11^{A}	5.9±0.07^{B}	5.0±0.04^{C}
Muscle glycogen	2.8±0.07	2.9±0.07^{A}	2.4±0.11^{B}	1.6±0.07^{A}
Experiment 2				
Moisture (%)	65.6±0.42	70.0±0.11^{A}	70.9±0.19^{AB}	71.8±0.36^{B}
Crude Protein (%)	8.8±0.11	15.0±0.09^{A}	13.3±0.19^{B}	11.0±0.32^{C}
Crude Fat (%)	4.6±0.19	6.2±0.11^{B}	6.5±0.11^{AB}	6.8±0.04^{A}
Crude Ash (%)	3.6±0.07	4.0±0.07^{B}	4.4±0.09^{B}	5.3±0.09^{A}
NFE (%)	3.0±0.11	3.7±0.09^{C}	5.0±0.09^{B}	6.7±0.09^{A}
Gross energy (g kg^{-1})	4.8±0.09	8.0±0.09^{C}	6.1±0.09^{B}	5.0±0.14^{A}
Muscle glycogen	3.0±0.09	3.1±0.07^{C}	2.5±0.11^{B}	1.6±0.04^{A}

All values are Mean±S.E. of mean; Means with different letters in the same row are significantly (P<0.05) different; (Duncan's Multiple Range test)

muscle glycogen were found in treatment T2 (2.9±0.07) as compared to treatment T3 (2.4±0.11) and treatment T4(1.6±0.07). Carcass composition revealed higher accumulation of nutrients in fish grown in T2 (No pesticide used) as compared to T3and T4 with no differences in moisture content among all the four treatments.

Experiment 2: Initial and final carcass composition of *C. punctatus* stocked in paddy fields with supplementary feed is shown in Table 4. Crude protein (%) was found to be significantly (P<0.05) higher in T2 (15.0±0.09) followed by T3 (13.3±0.19) and lower in T4 (11.0±0.32). The minimum value of Crude ash (%) was recorded in T2 (4.0±0.07) as compared to T3 (4.4±0.09) and T4 (5.3±0.09). Carcass composition revealed higher accumulation of protein, fat and energy in fish grown in T2 (No pesticide was used) as compared T3and T4.

Paddy yield in Experimental and Farmers' plot

Experiment 1: Paddy production from treatment plots (T1-T4) and farmers' plot (T5) was calculated per hectare and it was observed that the values increased from T1 (38 qha^{-1}) to T3 (55 qha^{-1}) and thereafter decreased in T4 (52 qha^{-1}) and T5 (40 qha^{-1}) (Fig. 1A). Per cent increase in paddy yield in comparison to T1 (No fish no pesticide) revealed a significant increase in T3 (Paddy and fish with recommended doses of pesticide), in comparison to T2 (Paddy and fish but no pesticide), T4 (Paddy and fish with farmers' doses of pesticide), and T5 (Paddy monoculture and pesticide but no fish) (Fig. 2A). 129% increase in paddy yield was observed in treatment T3(Paddy and Fish with recommended agrochemicals) in comparison to paddy monoculture.

Experiment 2: Paddy production from treatment plots and farmers' plot was calculated per hectare and it was observed that the values increased from T1 (28 qha^{-1}) to T3 (57 qha^{-1}) and thereafter decreased in T4 (52 qha $^{-1}$) and T5 (48 qha^{-1}) (Fig. 1B). Per cent increase in paddy yield in comparison to T1 (No fish no pesticide) revealed a significant increase in T3 (103.57%) (Paddy and fish with recommended dose of pesticide) in comparison to T2 (Paddy and fish but no pesticide), T4 (Paddy and fish with farmers' doses of pesticide), and T5 (Paddy monoculture and pesticide but no fish) (Fig. 2B).

Economics of paddy cum fish culture and monoculture of paddy

Experiment 1:Economics of the paddy cum fish culture was calculated per hectare taking into account of expenditure on field preparation, agrochemicals etc. (Table 5). Paddy production was calculated from mono paddy and paddy fish plots. There was a significant increase in paddy yield in the paddy-fish plots in comparison to control (T1). Significantly (P<0.05) high paddy yield was observed in T3 (55 qha^{-1}) where the

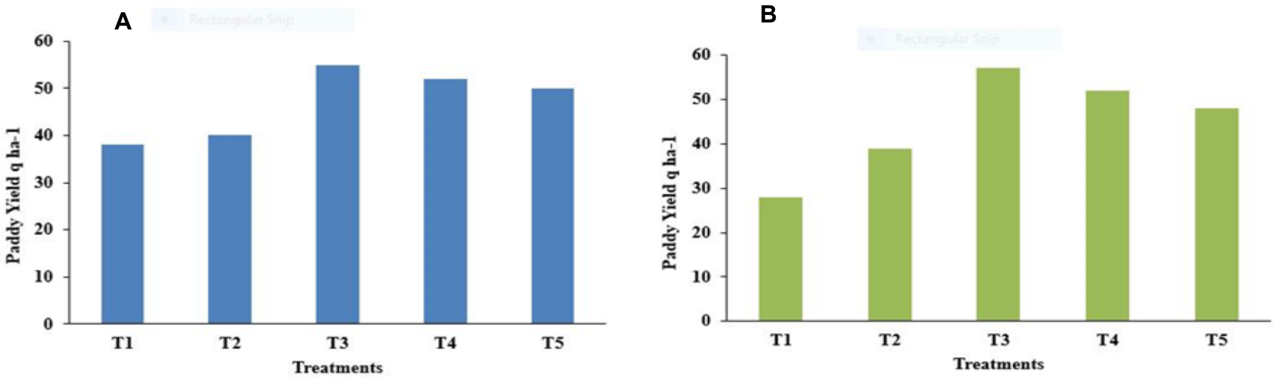

Fig. 1. *Per hectare paddy yield in A. Experiment 1 (without supplementary feed) and B. Experiment 2 (with supplementary feed) Treatment 1(No fish no pesticide), Treatment 2 (Paddy and fish but no pesticide), Treatment 3 (Paddy and fish with recommended doses of pesticide), Treatment 4 (Paddy and fish with Farmers doses of Pesticide), Treatment 5 (Paddy monoculture and pesticide but no fish).*

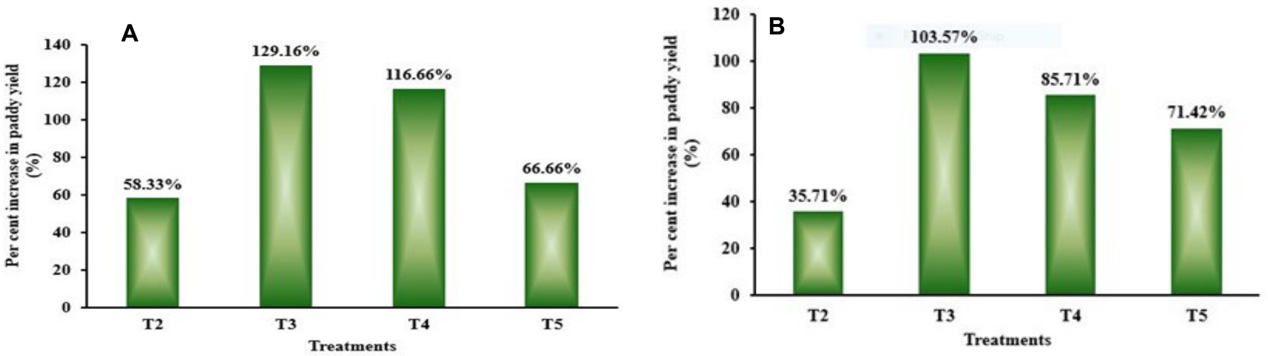

Fig. 2. *Per cent increase in paddy yield in A. Experiment 1 (without supplementary feed) and B. Experiment 2 (with supplementary feed) Treatment 2 (Paddy and fish but no pesticide), Treatment 3 (Paddy and fish with recommended doses of pesticide), Treatment 4 (Paddy and fish with Farmers doses of Pesticide) and Treatment 5 (Paddy monoculture and pesticide but no fish) in comparison to Treatment 1 (No fish andno pesticide).*

Table 5. Economics of paddy cum fish culture and monoculture of paddy and fish yield without and with supplementary feed.

Paddy cultivation and Fish Farming					
Experiment 1					
Treatments	**Treatment 1**	**Treatment 2**	**Treatment 3**	**Treatment 4**	**Treatment 5**
Recurring Expenditure for Paddy and fish farming					
A. Paddy Field Area	1 hectare	1 hectare	1 hectare	1 hectare	1 hectare
Field preparation charges (labour charges)					
B. Total cost (Rs.) (Labour charges and agrochemicals)	19,950	23,700	25728	28760	27,510
Paddy Yield, cost and earnings					
C. Paddy yield (q ha^{-1})	24±0.326	38±0.891	55±0.475	52±0.720	40±0.982
D. Paddy cost (Rs. $Quintal^{-1}$)	2200	2200	2200	2200	2200
E. Total cost (Rs.)	52,800	83,600	121,000	114,400	88,000
F. Total Revenue from Paddy (E-B)	32,850	59,300	95,272	85,640	60,490
Fish Yield, cost and earnings					
G. Fish Yield (kg ha^{-1})	----	238±2.365	205±1.863	182±2.198	----
H. Fish cost (Rs. kg^{-1})	----	80	80	80	----
I. Total cost of fish	----	19040.00	16400.00	16400.00	----
J. Total Revenue from Paddy and Fish (F+I)	32,850.00	78,340.00	111,672.00	97,615.00	60,490
Experiment 2					
Recurring Expenditure for Paddy and fish farming					
A. Paddy Field Area	1 hectare	1 hectare	1 hectare	1 hectare	1 hectare
Field preparation charges (labour charges)					
B. Total cost (Rs.) (Labour charges and agrochemicals)	25,443	29,943	32,093	35,217	30,717
Paddy Yield, cost and earnings					
C. Paddy yield (q ha^{-1})	28±0.625	38±0.731	57±0.891	52±0.544	48±0.720
D. Paddy cost (Rs. $Quintal^{-1}$)	3875	3875	3875	3875	3875
E. Total cost (Rs.)	108,360.00	147,060.00	220,590.00	201,240.00	185,760.00
F. Total Revenue from Paddy (E-B)	82,917	117,117	188,497.00	166,023.00	155,043.00
Fish Yield, cost and earnings					
G. Fish Yield (kg ha^{-1})	----	659±0.514	612±0.720	589±0.431	----
H. Fish cost (Rs. kg^{-1})	----	85	85	85	----
I. Total cost of fish	----	52,720	48,960	52,000	----
J. Total Revenue from Paddy and Fish (F+I)	82,917.00	169,837.00	237,457.00	213,143.00	155,043.00

recommended dose of pesticides was used. Fish production from concurrent paddy cum fish culture system were high in T2 (238 $kgha^{-1}$) as compared to T3 (205 $kgha^{-1}$) and T4 (182 $kgha^{-1}$) where pesticides were used to control paddy pests. Paddy production in farmers' plots (T5) was 40 qha^{-1} which is significantly ($P<0.05$) low in comparisons to paddy cum fish plots with same pesticide dosage (T4).The calculated value of expected total revenue also depicted high values in treatment T3 where fish were stocked with paddy and only recommended doses of pesticides were used. Calculated economic gain also coincided with the highest paddy and highest fish yield (Table 5).

Experiment 2: Economics of the paddy cum fish culture was calculated per hectare taking into account of expenditure on field preparation(Table 5). Paddy production was calculated from mono paddy and paddy fish plots. There was a significant increase in paddy yield in the paddy-fish plots in comparison to control (T1). Significantly ($P<0.05$) high paddy yield was observed in T3 (57 qha^{-1}) where farmers used the recommended dose of pesticides. Fish production from concurrent paddy cum fish culture system were high in treatment T2 (659 kg ha^{-1}) as compared to T3 (612 $kgha^{-1}$) and T4 (589 $kgha^{-1}$) where pesticides were used to control paddy pests. Paddy production in farmers' plots (T5) was 48 qha^{-1} which is significantly ($P<0.05$) low in comparisons to paddy cum fish plots with same pesticide dosage (T3).

The calculated value of expected total revenue also depicted high values in treatment 3 where fish were stocked with paddy and only recommended doses of pesticides were used. Calculated economic gain also coincided with highest paddy and highest fish yield. The reason of this increase in rice production and in turn high total revenue might be attributed to increase in nutrients and productivity of soil due to addition of fish feces and also due to circulation of nutrients due to fish locomotion. Fish excreta improved the soil's fertility, and the introduction of herbivorous fish helped to control weeds and reduced weeding labour and costs. A comparison of the trial conducted with and without supplementary feed on *C. punctatus* revealed that growth performance in experiments with supplementary feed was higher in comparison to trial without supplementary feed. Although there was an extra investment on supplementary feed yet net profit was higher in treatment with supplementary feed.

DISCUSSION

In the present study, *Channa punctatus* was selected owing to its hardiness and air breathing ability, due to which it can survive in shallow waters. The omnivorous *Cyprinus carpio* and the planktivorous *Oreochromis niloticus* has been depicted to be the most common and widespread fish species used in paddy cum fish culture in addition to some air-breathing (*C. striata,Clarias* sp.)which are highly appreciated wild fish in the capture system advocating the selection of *C.punctatus*for rice-cum-fish culture. Fish is usually regarded as a secondary crop, and along with which, require modifications of certain agronomic practices, such as selective pesticides use, involves management techniques, preparation of fish refuges, embankment, trenches, water inlet and outlets; that minimize the harmful effects of fertilizers and pesticides on fish. It was noted that trench could have important functions: providing better access for feeding and as a catch basin during harvest. It was depicted that paddies have peripheral trenches 30 to 50 cm deep, dikes 25 cm high, with bamboo pipes and screens at water inlets and outlets (Mohapatra *et al*., 2015). Rice plots should be suitably renovated for the purpose of fish culture by constructing peripheral trenches (40 cm deep and 45 cm wide), ditch (1 m depth) and dikes (Sarkar *et al*., 2005). Water depth of rice fields ought to be expanded to 20 cm with a persistent expansion up to 35-40 cm, so the rice in rice-fish field will grow in a water depth of 20-40 cm for over 100 days (Yang *et al*., 2006). In the present study, experimental plots were prepared by ploughing, cultivator passing, cleaning of weeds and vegetation, preparing the bunds (embankment), fish refuges, trench, water inlet and water outlet etc. the height of bunds were increased up to 30-35cm to prevent the fish from jumping over. A trench of $1m^2$wide and minimum of 50 cm deep was prepared in between or along the side of paddy plots for the maintenance of water level. Screens made from piece of fish net material were installed across the water flow to prevent the fish from escaping with water. Plastic tubes were used as a water inlet or outlet like a regular fish pond for continuous flow of water, clearly indicating that the modified paddy fields were suitable for paddy-cum-fish culture. *C. punctatus* fingerlings (15.50±0.40 g) were stocked in rice fields at the rate of 1 fish per 3 m^2 and 15-20 days after transplanting the seedling or one month after sowing seeds in direct cropping or after bottom favouring proper rooting of the seedling in respective experiments. Water level was increased up to 12-15 cm before stocking the fingerlings in the rice field on 25^{th} day supporting the available literature and making the result comparable.

Water level, dissolved oxygen (DO), acidity (measured as pH) and unionized ammonia (NH_3) are known to affect the fish in rice fields (Halwart and Gupta, 2004; Shiwanand and Tripathi, 2013). No definite trends of increase and decrease in alkalinity values were observed. Highest values of dissolved oxygen were recorded in treatment T2 and lowest values of water quality characteristics were observed in treatment T4; however, the DO concentration was sufficiently high in all the treatments in beginning of the experiment. The concentration of dissolved oxygen is to a great extent the aftereffect of photosynthetic activity that utilizes the carbon reducing the dissolved CO_2 effectively raising DO level (Saraswathy *et al*., 2018). Three times more pesticides were applied in treatment 4 in the present study, which might have decreased the photosynthetic activity and affected the DO level in rice fields. The values of o-phosphate in all the treatments were within acceptable limits for fish culture (Bhatnagar and Devi, 2013). The presence of ammonia results in the death of fish and other organisms at alkaline pH,especially after applying fertilizer (nitrogen-rich) to the rice fields. The unionized form (NH_3) is highly toxic whereas the ionized form (NH_4^+) is harmless (Momoh and Solomon, 2017). Ammonia is poisonous for aquatic organisms when its concentration is higher than 0.2 mg L^{-1}. Higher ammonia concentrations were noticed in treatment T3 and T4, while low values were observed in T2 and T1in both the experiments of the present study. This may be due to fertilization of rice fields with nitrogen rich fertilizer and excretion of fish. Ammonia increases in the holding water as a result of metabolic wastes of excretion of aquatic organism and depends on the utilization of dietary protein. In treatment T4 high doses of pesticides were used which might have caused stress to the fishes resulting in poor dietary utilization, digestibility and thus high ammonia in the holding water. Mohanty *et al.* (2004) reported that steady increment in nitrite, nitrate and ammonia credited to intermittent fertilization, expanded degree of metabolites and disintegration of unutilized feed without water renewal. Xie *et al.* (2011) reported significantly lower ammonia levels in paddy fields than in fish monoculture during the rice growing season. Das (2018) have also advocated the congenial conditions for fish growth includes optimum DO, phosphate and nutrients supporting optimum DO levels of the present study in paddy cum fish culture fields. Fish decrease photosynthetic action by brushing on the photosynthetic biomass and by expanding turbidity and along these lines keeping the pH lower and lessening volatilization of ammonia. Nitrogen losses through ammonia volatilization have been assessed to be from 2 to 6% of the nitrogen applied. In the current examination, the values of various physicochemical characteristics were compared with standards for fish culture (Bhatnagar and Devi, 2013) and it was observed that the overall mean values of most of the parameters were within permissible limits clearly indicating that the ecology of rice fields are suitable for conducting paddy-cum-fish culture.

The results of present study revealed that survival rates of fish were high in all the treatments between 73-90% for *C. punctatus.* Sarkar *et al.* (2005) reported a higher survival rate (72.2%) in rice-fish culture fields. The high survival in the present studies may be due to better management practices. This supports the claim of some farmers under managed conditions, fish recovery is very high. Fish growth parameters (weight gain, growth % gain in body weight and specific growth rate) were significantly ($P<0.05$) high in treatment T2 and T3 in comparison to T4. Analysis of variance followed by Duncan's Multiple Range Test indicated that there were no significant ($P<0.05$) variations in fish growth parameters in treatments T2 and T3. High fish growth in treatment T2 and T3 also coincides with congenial environmental conditions as indicated by optimum DO, nitrate and phosphate. These results clearly show fish culture in paddy fields can yield optimum accumulation of carcass protein varying between 11.0±0.33 % and 15.0±0.09% and high value coincide with high growth.

Bhatnagar *et al.* (2012), Bhatnagar and Raparia (2014), Bhatnagar and Lamba (2015) have also reported carcass protein in this range where experimental fish were fed on growth promoting diets clearly supporting that flesh quality of fish from rice cum fish culture has same nutritive value as in other intensive nutrition tests. The present study is also in accordance to the enhanced growth performance of *C. carpio* in paddy fields (Bhatnagar *et al*., 2014). Indeed, even the sub-lethal concentrations of the various pesticides are known to pollute the aquatic environment due to their stability and results in lower amount of body protein owing to their accumulate in tissues of aquatic organisms. Singh and Bhatti (1994) reported that 2, 4-D, observed to cause a generous decrease in the protein content in *C. punctatus* and a marked increment in metabolism and excretion of a variety of steroid hormones in animals. Sub-lethal concentration of pesticide changes the behaviour of fish and results in a decrease in liver protein content due to damage caused to the hepatic tissue and increased proteolysis(Banaee *et al*., 2013; Ossana *et al*., 2019). The decrease in protein content of fish in treatment T4 in the present study might thus be due to unmanaged pesticide exposure. Cheema *et al.* (2014) have also investigated the effect of one such rice agrochemical (Chlorpyriphos) on growth performance of fish and reported retarded growth and low protein (%) in fish flesh of the group of fish on exposure to pesticideswhich are in support of present results.

Akegbejo-Samsons (2010) delineated a boost to fish production with its integration with rice. In the present study when rice production was calculated from mono rice and rice fish plots revealed that there was a significant ($P<0.05$) increase in rice yield in the rice-fish plots in comparison to rice monoculture plots. Significantly ($P<0.05$) high rice yield was observed in T3 where farmers used the recommended dose of pesticides. Fish production from concurrent rice cum fish culture system was high in T2 as compared to T3 and T4 because the pesticide might have antagonistically influenced the fish growth.

Rahman *et al.* (2012) observed that the rice fish farming with rice being the major component and fish are taken as complementary, contributes to secure additional income, in addition, to provide employment as well as enhancing the nutrient intake for providing nation's food security supporting the inference of present study.

Conclusion

The present study concluded that rice fields water is congenial for fish growth and appears to be successful approach for double utilization of single piece of land for the integration of rice cum fish culture in Haryana. Feed supplementation not only increase the fish yield but also indirectly fertilized the rice fields. Fish excretory waste adds nutrients to the ponds and movement of fish enhances the circulation of nutrients in integrated rice-fish culture leading to higher rice yield as compared to mono- rice cultureTotal revenue without supplementary feed obtained from rice-fish farming was also high in rice cum fish treatment which was even higher than the plots without fish. Hence, the integration of these two crops, rice and fish, is ecologically beneficial as the availability of nutrients like nitrogen and phosphorus contributes to the enhanced soil fertility. The proper management of rice fields and the use of supplementary feed can enhance fish growth, which will further be economically beneficial and offer great potential for marginal farmers. Planning awareness campaigns for educating farmers may motivate them to grow fish within their paddy fields.

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Conflict of interest

The authors declare that they have no conflict of interest.

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