Effects of different stocking density of Nile tilapia (*Oreochromis niloticus*) and common carp (*Cyprinus carpio*) on the growth performance and rice yield in rice-fish farming system

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Abstract. A 105 day investigation was conducted to measure the impacts of stocking densities at different ratios of Nile tilapia (*Oreochromis niloticus*) and common carp (*Cyprinus carpio*)on their growth and rice yields in rice-fish farming systems. The experiment was conducted by randomized complete block design with three replications. The plot size was 6×3 m, 50 cm height with ditch (3×1 m) for fish. Mean initial weight of *O. niloticus* was 12.2±1.92 g using three different fish stocking densities (4, 6 and 8 fish m^{-2}) in five different ratios (1:1, 1:0, 0:1, 1:2, 2:1) of *O. niloticus* and *C. carpio*. At the end of the investigation specific growth rate, total length (cm), final weight (g), and survival rate (%) for fish were estimated. Plant height and tiller number were also calculated. The study showed that fish growth performance, fish survival rate, plant height, number of tiller, and abundance of plankton were significantly affected by culture system ($p<0.05$). The final weight was higher in 4 fish m^{-2}, followed by 6 fish m^{-2} while the 8 fish m^{-2} treatment recorded the lowest growth performance. The survival showed the same trend, the highest survival rate was found in *C. carpio* - *O. niloticus* ratio of 1:1 (66.67±9.31%) with 6 fish m^{-2} followed by 4 fish m^{-2} then by 8 fish m^{-2} 55.36 ±6.11%, and 49.78±4.17% respectively. The highest rice yield, were found in 6 fish m^{-2} (5.43) that was significantly ($p<0.05$) higher than in 4 fish m^{-2} and 8 fish m^{-2} treatment. The present study revealed that the suitable stocking density was 6 m^{-2} with 1:1 for *C. carpio* and *O. niloticus* for better growth, survival and maximum rice production.

Key Words: integrated farming, plankton, rice production, fish growth, survivability.

Introduction. Integrated rice-fish cultivation have huge possibility for increasing the fish production in rice manufacturing countries. However, to satisfy the world demand for protein and other nutrients to feed the growing populations, there is a requirement to upsurge rice and fish yield at the same time. This analysis focuses on the combined rice and fish cultivating system which is seen as additional profitable through yielding quality rice with combination of fish like common carp (*Cyprinus carpio*) or Nile tilapia (*Oreochromis niloticus*). The incorporation of rice and fish is perceived as a conservative method for horticultural land use and offers incredible potential as far as animal protein supply and means of revenue for the farmers (Yaro et al 2005). Disregarding the reported, rice-fish culture has not been generally received by Asian rice farmers. Fish is normally viewed as an auxiliary harvest. The rice production is being heightened by developing fast, maturing, which require manure and pesticides. These few points of confinement fish production inside the rice field, and in this manner, need adjustment of certain agronomic practices, as particular pesticide use (Cagauan & Arce 1992) and the development of fish refuges. The economic profitability of rice production is affected as a result of such activities (Mohanty et al 2004). Although, after the effective success with regards to fish and rice culture, accomplishments, for example, expanded rice yield, decreased weed rise, lower plot pest and improved soil quality were noted (Bray 1986; Xu et al 2008). Lightfoot et al (1992) in the partner investigation of eighteen rice-fish announced a mean increment of the rice yield by 15%. This was clarified somewhat by the particular rice–fish agronomy, and halfway as an immediate impact of the fish. The high water levels required for fish decreased weed predominance and thus expanded rice yields (Moody 1992). The direct helpful impacts of fish on rice production are connected with weed, irritation and ailment control by fish, and fish waste product which acts as manure to improve soil nutrients (Cagauan 1995). In many studies, rice yields were not influenced by the presence of fish. Fish yields from simultaneous rice-presented fish culture are within 300 kg ha^{-1} (Lightfoot et al 1992). The return of some fish has been accounted for like 88–175 kg ha^{-1} from flooded rice (Ali 1992), and 209 kg ha^{-1} from rain-fed rice (Middendorp 1992). Yield parameters, for instance growth, yield of fish, survival, in addition crustacean species are mostly affected by stocking density (Naranjo-Paramo et al 2004), and economics in the rice-crab scheme is essential. Fish yield differs with size at stocking, stocking density, and whether or not additional feeds were applied. The yield per crop can vary from 100 to 750 kg ha $year^{-1}$ deprived of feeding (Mohanty et al 2016), and the outcome may be up to 1,812 kg ha $year^{-1}$ with feeding. Weed control system or integrated approach is desired, particularly in rain fed low-land rice ecosystem, as well as fish can perform a vigorous role. Fish species being mostly herbivorous greatly contribute to weed control through biological process in intensive rice-fish agriculture by measured water supply (Vinke & Micha 1985). Fish feeds on weeds leading to the death of plants because of trouble by the cruising habit (Gupta et al 1998; Moody 1992; Billah et al 2019). Control of weed by fish was one conceivable unintended appliance for understanding an improved rice growth as well as production as confirmed in previous investigations (Piepho & Alkmper 1991; Rothuis et al 1998). Biological regulation of weeds in rice plots by herbivorous as well as further fish species, for instance *Cyprinus carpio, Barbonymus gonionotus, Oreochromis mossambicus, O. niloticus, Ctenopharyngodon idella*, *Trichopodus pectoralis, Carassius auratus* has been reported (Frei et al 2007; Rothuis et al 1999). *C. idella* was perceived to be a further ravenous feeder on rice weeds in contrast with *C. carpio* and *O. niloticus* as stated in a trial in India (Kathiresan 2007). Nevertheless, understanding the stocking density, growth of fish, survival rate and rice yield are vital conditions for the establishment of a rice-fish integration. So, this study was undertaken on rice-fish integrated farming system to regulate the suitable stocking density, the best ratios of *O. niloticus* and *C. carpio*, on rice yield and fish growth.

Material and Method

Experimental site. The field experiment was conducted at the Bangladesh Agricultural University in Mymensingh, Bangladesh. The investigation farm is located at 24°75′N latitude and 90°50′E longitude and altitude of 18 m above sea level. Normal monthly rainfall was almost 330 mm throughout research. The monthly temperature varied from 17 to 32°C throughout the rainy season and 12 to 31°C throughout the dry season. Farming season was from December 2017 to April 2018 (dry season). The soil at the trial location was a non-calcareous black grey flood plain soil; the texture class was a silt clay loam, with an average pH of 6.2, organic carbon content 1.4% and nitrogen content of 0.25%. The first trial was conducted in 48 investigational plots which had an average size of 720 m^2. Every field had high dikes with an altitude of round 0.5 m, and an outlet, which linked them to two foremost irrigation networks. Those plots comprising fish furthermore had a principal shelter pond with an area of 3 m^2 and a depth of 0.5 m. Furthermore, they were fortified with a well meshed nylon net neighboring the plots to avert the escape of fish or incursion of predators such as snakes.

Experimental setup. There were 48 investigational plots which had a magnitude of around 720 m^2 and were enclosed by raised dikes of about 0.5 m high. The plots having fish as a sanctuary for the fish throughout squat water level or in high water temperatures as well as every plot had an outlet/inlet, which associated them to two dominant irrigation channels. Irrigation water was provided every day to mainatin a water level of 15–25 cm in the fields. Roots and other existing remains from the prior crop were merged into the soil by with preparations 20 days before transplantations, consistent with the local exercise. Plots were cultivated an additional time 5 days prior transplantation then flattened by a hand strained bamboo leveler. An elementary rate of inorganic fertilizer was applied in all fields prior transplantation as stated by the reference by the Bangladesh Rice Research Institute (BRRI 2004), consequently, 140 kg ha^{-1} triple super phosphate (TSP) and 100 kg ha^{-1} muriate of potash (MP) were smeared. Rice (*Oryza sativa* L., BR29 dhan) seedlings were transferred from the nursery to the fields at substitute row layout of 15 and 35 cm and an arrangement of 20 cm within the rows. Fish were unconfined 20 days after transplantation (DAT) at an average initial weight of 12.2±1.92 g using three different fish stocking densities (4, 6 and 8 fish m^{-2}) and five different ratios of *O. niloticus* and *C. carpio* (1:1, 1:0, 0:1, 1:2, 2:1). Plot with rice but without fish was also maintained as control (Table 1). The investigation was lead following randomized complete block design with three replications. Distinct plot size was 5 x 3 m, 50 cm deep with ditch of 3 x 1 m for fish. Specific plot extent was 5 x 3 m, 50 cm deep with ditch of 3 x 1 m for fish. At the conclusion of the experimentation specific growth rate, final weight (g), total length (cm), standard length (cm) and survival rate (%) for fish were estimated. Plant height and tiller number were calculated as well as parameters of water quality (temperature, pH, dissolved oxygen, carbon di-oxide, alkalinity, ammonia-N and nitrite-N) and plankton were measured.

Data collection

Initial weight of fish fingerlings. At the time of releasing the two fish species fingerlings, the initial weight of the two species was recorded in grams (g). *O. niloticus* was at 12.5 g and *C. carpio* at 25.5 g.

Fish final weight. Final weight (g) of fish species was recorded at the time of harvesting according to the treatment plots. The individual fish's weight was recorded from the individual experimental plots by random sampling.

Survival rate of fish. The survival rate of each experimental plot was calculated by considering the no. of fingerlings released and finally no. of fish stock alive at the harvesting period in the individual experimental plots.

$$\text{Survival rate (\%)} = \frac{\text{Final no. of alive fish}}{\text{Total no. of initial fingerlings}} \times 100$$

Water quality parameters. Temperature of water, pH, as well as dissolved oxygen concentration were taken *in situ* with transportable pH meter and a polarographic dissolved oxygen meter amid 06.00 and 08.00 a.m. and infrequently amid 13.30 and 15.00 p.m. at 15 day intervals. A YSI model 58 dissolved oxygen meter (YSI Co., Yellow Springs, Ohio, USA) was utilized for measurements of temperature as well as DO, and a Hanna Instruments model HI 1270 pH probe (Hanna Instruments, Woonsocket, Rhode Island, USA) was utilized to record pH. Samples were conveyed instantaneously to the laboratory and examined and total hardness (EDTA titration) and total alkalinity (acidimetry). All tests were followed by the procedures offered in the Standard Methods handbook (APHA 2005).

Fish yield. The yield of fishes was calculated using the following formula:

$$\text{Fish Yield} = (\text{Final weight} - \text{Initial weight}) \times \text{Stocking density} \times \text{Survival rate} \times \text{Area (Kg ha}^{-1}\text{)}$$

Fish weight gain percent. The weight gain percent was calculated from the formula of initial weight and final weight of fishes:

$$\text{Weight gain percent} = [(\text{Final weight} - \text{Initial weight})/\text{culture period}] \times 100$$

Plant height. Normal plant height was noted from arbitrarily nominated plants in every plot. The plant height was determined from the base to the tip of the uppermost spikelet of the plant and stated in centimeter (cm).

No. of total tillers hill^{-1}. To acquire whole tillers hill^{-1}, all the tillers were calculated from every sample as well as then the average of sample plants was taken. It comprised both actual and non-effective tillers.

No. of effective tillers hill^{-1}. To get the effective tillers hill^{-1}, only the ear bearing tillers were calculated from every sample as well as then the average of samples was taken.

Number of grains panicle^{-1}. The number of grains panicle^{-1} was counted and then the average of samples was taken.

Weight of 1,000 grains. One thousand grains were arbitrarily taken from every plot as well as it was dried to 14% moisture content. Then the weight was measured by an electrical balance (accuracy: 0.1 mg) as well as stated in gram (g).

Grain yield. Grain obtained from every piece field was sun-dried and weighed prudently. Weight of sun-dried grains of each plot was taken and transformed finally in t ha^{-1}.

Straw yield. Weight of sun-dried straw acquired from each unit plot comprising the straw of example plants was taken to top the straw production per plot and it was lastly calculated to t ha^{-1}.

Biological yield. Grain production and straw production together are regarded as biological production. The biological production was calculated with the following formula:

$$\text{Biological yield} = \text{Grain yield} + \text{Straw yield}$$

Harvest index. Harvest index was calculated on the basis of grain production as well as biological production by the following formulation:

$$\text{Harvest Index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Weed measurements. For trough experiments, the whole weed population of each trough was used for data recording, while for field experiments, weeds were sampled from within 25 m x 25 quadrates arbitrarily positioned laterally at four spots in every field. The first wedding was given at 30 DAT, the second weeding at 45 DAT.

Weed rating. Weed growing was visually valued (WR) on a 1 to 9 measure, with 1 for smallest weed growth and 9 for maximum.

Weed density and dry weight. Weeds were pared to pulverized level, recognized as well as calculated by weed species, besides distinctly oven dried at 70^{o} C for 72 hours. Weed density (WD) and weed dry weight (WDW) were conveyed as no. m^{-2} and g m^{-2}, correspondingly.

Summed dominance ratio. Foremost weed species were recognized by means of the summed dominance ratio (SDR) calculated as follows (Janiya & Moody 2008):

$$\text{SDR of a weed species} = \frac{[\text{Relative density (RD)} + \text{Relative dry weight (RDW)}]}{2}$$

Where:

$$\text{RD (\%)} = \frac{\text{Density of a given weed species}}{\text{Total weed density}} \times 100$$

$$\text{RDW (\%)} = \frac{\text{Dry weight of a given weed species}}{\text{Total weed dry weight}} \times 100$$

B - No. of weed species present in treatment B.

Statistical analysis. All data were exposed to one-way ANOVA by SAS 9.4 at $p \leq 0.05$ significance level and mean separations of dependent variables of experimental parameters using Tukey multiple range test (MRT) at $\alpha = 0.05$ (Gomez & Gomez 1984).

Table 1

Different stocking densities and five different ratios of *Oreochromis niloticus* and *Cyprinus carpio* in integrated rice-fish farming system

Treatments	*Stocking density*	*O. niloticus and C. carpio ratios*	*No. of fish/plot*	*Total O. niloticus and C. carpio/plot*
T_0			No fish	
T_1 (30:30)		1:1	30 T +30 C	
T_2 (60:0)		1:0	60 T + 0 C	
T_3 (0:60)	4 m^{-2}	0:1	0 T + 60 C	60
T_4 (20:40)		2:1	20 T + 40 C	
T_5 (40:20)		1:2	40 T + 30 C	
T_6 (45:45)		1:1	30 T + 30 C	
T_7 (90:0)		1:0	90 T + 0 C	
T_8 (0:90)	6 m^{-2}	0:1	0 T + 90 C	90
T_9 (30:60)		2:1	30 T + 30 C	
T_{10} (60:30)		1:2	30 T + 30 C	
T_{11} (60:60)		1:1	60 T + 60 C	
T_{12} (120:0)		1:0	120 T + 0 C	
T_{13} (0:120)	8 m^{-2}	0:1	0 T + 120 C	120
T_{14} (40:80)		2:1	40 T + 80 C	
T_{15} (80:40)		1:2	80 T + 40 C	

T – *O. niloticus*, C – *C. carpio*.

Results

Effects of stocking densities and different ratio of O. niloticus and C. carpio on water quality parameters in integrated rice-fish farming system. Though no significant differences were found for ammonia and nitrite-nitrogen, but the study revealed a slightly higher amount of ammonia (0.22±0.05 mg L^{-1}) in 8 fish m^{-2} T14 and 0.23±0.08 mg L^{-1} in T15 when compared with values obtained from 4 fish and 6 fish m^{-2} (Table 2). However, other water quality parameters were within acceptable culture condition.

Table 2

Effects of stocking densities and different ratio of *Oreochromis niloticus* and *Cyprinus carpio* on water quality parameters in integrated rice-fish farming system

T	*Temperature (°C)*	*CO_2 (ppm)*	*Alkalinity (mg L^{-1})*	*pH*	*Dissolved O_2 (mg L^{-1})*	*NH_3-N_2 (mg L^{-1})*	*NO_2-N_2 (mg L^{-1})*
T_0	30.06 ± 0.22^a	39.62 ± 0.04^a	22.99 ± 0.55^a	7.69 ± 0.18^a	5.87 ± 0.60^a	0.15 ± 0.01^a	0.07 ± 0.03^a
T_1	30.22 ± 0.83^a	39.63 ± 0.22^a	23.34 ± 0.53^a	7.91 ± 0.12^a	5.42 ± 0.13^a	0.15 ± 0.07^a	0.07 ± 0.07^a
T_2	29.59 ± 0.83^a	39.26 ± 0.22^a	23.15 ± 0.53^a	7.74 ± 0.12^a	6.02 ± 0.13^a	0.17 ± 0.07^a	0.09 ± 0.07^a
T_3	30.33 ± 0.83^a	39.01 ± 0.22^a	23.04 ± 0.53^a	7.46 ± 0.12^a	4.91 ± 0.24^a	0.16 ± 0.07^a	0.07 ± 0.07^a
T_4	30.07 ± 0.83^a	39.31 ± 0.22^a	23.32 ± 0.53^a	7.38 ± 0.12^a	4.73 ± 0.24^a	0.16 ± 0.07^a	0.10 ± 0.07^a
T_5	29.67 ± 0.83^a	39.55 ± 0.22^a	23.26 ± 0.53^a	7.56 ± 0.12^a	5.28 ± 0.24^a	0.17 ± 0.07^a	0.11 ± 0.07^a
T_6	30.65 ± 0.87^a	39.71 ± 0.09^a	23.47 ± 0.73^a	8.16 ± 0.15^a	5.79 ± 0.24^a	0.16 ± 0.09^a	0.10 ± 0.07^a
T_7	30.17 ± 0.83^a	39.66 ± 0.22^a	23.31 ± 0.53^a	7.93 ± 0.12^a	5.59 ± 0.24^a	0.17 ± 0.09^a	0.09 ± 0.07^a
T_8	29.81 ± 0.83^a	39.31 ± 0.22^a	23.29 ± 0.53^a	7.58 ± 0.12^a	5.11 ± 0.24^a	0.17 ± 0.09^a	0.10 ± 0.07^a
T_9	30.49 ± 0.83^a	39.57 ± 0.22^a	23.11 ± 0.53^a	7.79 ± 0.12^a	4.96 ± 0.24^a	0.18 ± 0.09^a	0.09 ± 0.07^a
T_{10}	30.14 ± 0.83^a	39.29 ± 0.22^a	23.22 ± 0.53^a	7.59 ± 0.12^a	5.41 ± 0.24^a	0.16 ± 0.09^a	0.11 ± 0.07^a
T_{11}	29.75 ± 0.87^a	38.83 ± 0.26^a	22.84 ± 0.23^a	7.86 ± 0.15^a	5.39 ± 0.24^a	0.21 ± 0.05^a	0.09 ± 0.07^a
T_{12}	29.66 ± 0.83^a	38.16 ± 0.22^a	22.51 ± 0.23^a	7.63 ± 0.12^a	5.31 ± 0.24^a	0.19 ± 0.05^a	0.10 ± 0.07^a
T_{13}	31.09 ± 0.83^a	38.41 ± 0.22^a	22.76 ± 0.23^a	7.49 ± 0.12^a	4.59 ± 0.24^a	0.21 ± 0.05^a	0.11 ± 0.07^a
T_{14}	29.44 ± 0.83^a	38.24 ± 0.22^a	22.10 ± 0.23^a	7.54 ± 0.12^a	4.51 ± 0.24^a	0.22 ± 0.05^a	0.12 ± 0.07^a
T_{15}	29.91 ± 0.83^a	39.32 ± 0.22^a	22.36 ± 0.23^a	7.37 ± 0.12^a	4.63 ± 0.24^a	0.23 ± 0.08^a	0.14 ± 0.07^a

T – treatment. All values represent mean ± SD. Different superscripts within the same column indicates significant differences ($p<0.05$).

Total number of phytoplankton and zooplankton recorded during experimental period, and their relative abundance (%). The study also found that the abundance of plankton was considerably ($P<0.05$) higher in 6 fish m^{-2} treatment (n = 1,901) than in 4 fish m^{-2} (n = 1,344) and 8 fish m^{-2} (n = 1,170) (Table 3). Although, Ankistrodesmus has the highest relative abundance percentage 12.21% with a total number of 541 and the maximum abundance was 303 recorded at 6 fish m^{-2} while 124 and 114 were observed in 4 fish m^{-2} and 8 fish m^{-2} respectively. Nevertheless, a total of 4,415 planktons were recorded in the present work.

Table 3

Total phytoplankton and zooplankton during experimental period, and their relative abundance

Species	*Treatment 1-15 (No. of plankton)*	*Relative abundance (%)*	*4 fish m^{-2}*	*6 fish m^{-2}*	*8 fish m^{-2}*
Anabaena	304	6.89	89	135	79
Ankistrodesmus	541	12.21	124	303	114
Aphanotheca	382	8.7	154	146	82
Chlorella	191	4.33	44	89	58
Cyclotella	117	2.65	34	41	42
Euglena	198	4.48	83	73	42
Navicula	154	3.49	46	67	41
Oscillatoria	202	4.57	68	63	71
Pleurococcus	104	2.35	25	47	32
Microcystis	184	4.17	44	77	64
Nitzschia	166	3.76	55	72	39
Volvox	158	3.58	49	53	56
Tetradon	155	3.51	37	48	70
Asplancha	307	6.95	96	127	84
Cyclops	204	4.62	61	91	52
Daphnia	109	2.47	26	65	18
Diaptomas	251	5.69	73	109	69
Moina	310	7.02	112	124	74
Nauplius	273	6.18	84	145	44
Philinia	105	2.38	40	26	39
Total	4,415	100	1344	1901	1170

Effects of different stocking densities and different ratios of O. niloticus and C. carpio on fish growth performance and survival in integrated rice-fish farming system. In the present investigation, it was noticed that fish growth performance as well as survival rate were significantly affected by culture system ($p<0.05$). The concluding weight, total length and total standard length were higher in 6 fish m^{-2} followed by 4 fish m^{-2} while 8 fish m^{-2} recorded the lowest growth performance (Table 4). However, the survival showed the same hierarchy, the highest survival rate was in *C. carpio*/*O. niloticus* 1:1 ratio 6 fish m^{-2} (T6) while the lowest in T15 (2:1) 8 fish m^{-2} respectively.

Table 4

Effects of different stocking densities and different ratios of *Oreochromis niloticus* and *Cyprinus carpio* on fish growth performance and survival in integrated rice-fish farming system after 105 days

Treatment	*Fish species*	*Initial weight (g)*	*Final weight (g)*	*Weight gain (g)*	*Survival rate (%)*
T_0	-	-	-		-
T_1 (30:30)	T	12.48±0.31	66.94±0.69	54.46±0.88^{ab}	78.88
	C	25.15±0.54	55.97±0.59	30.82±1.65^{c}	75.55
T_2 (60:0)	T	12.40±0.25	52.07±0.74	39.67±0.83^{c}	71.11
	C	-	-		-
T_3 (0:60)	T	-	-		-
	C	25.85±0.92	70.45±0.88	44.60±0.32^{b}	75.00
T_4 (20:40)	T	12.24±0.97	56.03±0.65	43.79±0.26^{bc}	76.66
	C	25.37±0.76	61.17±0.39	35.80±0.48^{bc}	76.66
T_5 (40:20)	T	12.57±0.20	51.53±0.50	38.96±0.21^{c}	85.83
	C	25.53±0.81	50.68±0.86	25.15±0.48^{c}	85.00
T_6 (45:45)	T	12.24±0.07	72.61±0.26	60.37±0.27^{a}	85.55
	C	25.32±0.81	67.78±0.52	42.46±0.52^{b}	84.81
T_7 (90:0)	T	12.35±0.13	76.18±0.08	63.83±0.38^{a}	76.66
	C	-	-		-
T_8 (0:90)	T	-	-		-
	C	25.19±0.85	88.82±0.46	63.63±0.21^{a}	75.92
T_9 (30:60)	T	12.45±0.20	51.64±0.42	39.19±0.48^{b}	63.33
	C	24.87±0.73	65.10±0.81	40.23±0.19^{b}	67.22
T_{10}(60:30)	T	12.21±0.21	52.07±0.74	39.86±0.24^{c}	80.55
	C	25.15±0.74	57.36±0.32	32.21±0.18^{c}	57.77
T_{11}(60:60)	T	12.59±0.94	55.88±0.28	43.29±0.26^{bc}	66.11
	C	25.15±0.92	88.26±0.05	63.11±0.17^{a}	68.88
T_{12} (120:0)	T	12.34±0.17	54.59±0.88	42.25±0.41^{c}	65.27
	C	-	-		-
T_{13} (0:120)	T	-	-		-
	C	25.29±1.83	83.15±8.29	57.86±0.25^{a}	65.55
T_{14}(40:80)	T	12.62±1.03	57.21±8.18	44.59±0.21^{bc}	56.66
	C	25.24±1.57	48.6±7.57	23.36±0.28^{c}	63.75
T_{15}(80:40)	T	12.28±1.27	60.77±10.04	48.49±0.22^{bc}	58.75
	C	25.37±1.65	47.95±3.22	22.58±0.42^{c}	27.91

T - *O. niloticus*, C - *C. carpio*. All values represent mean ± SD. Different superscripts within the same column denote significant differences ($p<0.05$).

Effects of different stocking densities and different ratios of O. niloticus and C. carpio on the growth performance and survival in integrated rice-fish farming system. The present study reported that, number of tillers, plant height, straw as well as rice yield were considerably pretentious by fish stocking thicknesses and different ratios ($p<0.05$). The highest plant height, tiller number and rice yield was found in 6 fish m^{-2}

were considerably ($p<0.05$) higher than those observed in 4 fish m^{-2} and 8 fish m^{-2} (Table 5).

Table 5

Effects of stocking densities and different ratio of *Oreochromis niloticus* and *Cyprinus carpio* on plant height, number of tiller and rice yield in integrated rice-fish farming system

T	*Plant height (cm)*				*Tiller no. hill^{-1}*				*Rice yield*	
	30 DAT	*45 DAT*	*60 DAT*	*75 DAT*	*30 DAT*	*45 DAT*	*60 DAT*	*75 DAT*	*Grain yield t ha^{-1}*	*Straw yield t ha^{-1}*
T_0	27.93^{b}	47.93^{b}	67.13^{a}	84.67^{a}	3.80^{b}	7.07^{c}	7.53^{d}	8.07^{b}	5.55^{a}	9.54^{a}
T_1	32.27^{a}	49.40^{a}	70.60^{a}	80.13^{a}	3.73^{b}	7.40^{c}	7.53^{d}	8.67^{b}	5.19^{a}	8.76^{b}
T_2	29.60^{a}	46.20^{b}	65.87^{b}	76.07^{b}	4.13^{b}	5.27^{e}	6.60^{e}	7.67^{c}	4.93^{b}	8.46^{b}
T_3	31.93^{a}	53.60^{a}	73.07^{a}	85.41^{a}	3.93^{b}	7.27^{c}	8.47^{c}	9.47^{a}	4.87^{b}	8.62^{b}
T_4	32.53^{a}	50.87^{a}	72.80^{a}	84.93^{a}	3.87^{b}	7.53^{c}	8.07^{c}	8.67^{b}	4.79^{b}	8.19^{b}
T_5	30.27^{a}	51.30^{a}	69.53^{a}	85.33^{a}	4.33^{b}	9.33^{ab}	10.80^{a}	10.93^{a}	4.82^{b}	8.52^{b}
T_6	29.73^{a}	50.13^{a}	70.93^{a}	84.87^{a}	5.33^{a}	11.07^{a}	11.33^{a}	11.40^{a}	5.43^{a}	9.34^{a}
T_7	28.13^{b}	51.80^{a}	69.87^{a}	86.2^{a}	4.13^{b}	8.67^{b}	9.20^{b}	9.67^{a}	5.31^{a}	9.14^{a}
T_8	35.07^{a}	52.4^{a}	69.06^{a}	85.67^{a}	4.27^{b}	7.00^{c}	8.20^{c}	8.87^{b}	5.29^{a}	9.12^{a}
T_9	29.68^{a}	47.11^{b}	63.13^{b}	84.13^{a}	4.40^{b}	6.87^{d}	8.27^{c}	8.33^{b}	5.17^{a}	8.97^{b}
T_{10}	26.21^{c}	47.43^{b}	62.47^{b}	82.13^{a}	4.13^{b}	6.93^{d}	7.40^{d}	8.20^{b}	5.34^{a}	9.17^{a}
T_{11}	29.67^{a}	51.22^{a}	69.47^{a}	86.47^{a}	4.20^{b}	8.73^{b}	9.49^{b}	9.87^{a}	4.92^{b}	8.47^{b}
T_{12}	31.4^{a}	52.82^{a}	63.60^{a}	85.07^{a}	3.93^{b}	7.67^{c}	9.40^{b}	9.53^{a}	4.79^{b}	8.24^{b}
T_{13}	25.84^{c}	51.60^{a}	64.47^{b}	86.53^{a}	4.27^{b}	7.93^{c}	9.20^{b}	10.00^{a}	4.67^{b}	8.03^{b}
T_{14}	27.81^{b}	49.07^{a}	64.13^{b}	83.13^{a}	3.93^{b}	6.60^{d}	7.60^{d}	8.60^{b}	4.74^{b}	8.15^{b}
T_{15}	28.54^{b}	50.93^{a}	63.47^{b}	83.42^{a}	5.57^{a}	6.43^{d}	8.40^{c}	8.80^{b}	4.86^{b}	8.35^{b}

T – treatment. All values represent mean±SD. Different superscrips within the same column indicates significant differences ($p<0.05$).

Effect of weeding regime on different stocking densities of O. niloticus and C. carpio in the rice-fish farming system. Various stocking concentrations of *O. niloticus* and *C. carpio* in rice-fish farming has artificial weeding regime in the rice field. However, the control without fish had the uppermost number of the most common weed *Schoenoplectus mucronatus* found on the research area. Nevertheless, it also had the highest dry matter weight 24.6 g (Table 6).

Table 6

Effect of weeding regime on different stocking densities of *Oreochromis niloticus* and *Cyprinus carpio* in the rice-fish farming system

T	*Schoenoplectus mucronatus*	*Digitaria sanguinalis*	*Echinochloa crus-galli*	*Monochoria vaginalis*	*Cyperus difformis*	*Total*	*Dry matter (g)*
T_0	25	0	0	0	0	25	24.6
T_1 (30:30)	10	0	2	2	0	14	4
T_2 (60:0)	3	2	0	0	0	5	10.6
T_3 (0:60)	0	0	0	0	0	0	0
T_4 (20:40)	0	0	0	0	0	0	0
T_5 (40:20)	13	0	2	5	0	20	11
T_6 (45:45)	9	0	2	5	0	16	19
T_7 (90:0)	7	9	3	3	0	22	10.2
T_8 (0:90)	0	0	0	0	0	0	0
T_9 (30:60)	0	0	0	0	0	0	0
T_{10} (60:30)	8	0	4	3	0	15	12.4
T_{11} (60:60)	5	0	4	2	0	11	4.2
T_{12} (120:0)	8	1	1	3	0	13	9.2
T_{13} (0:120)	0	0	0	0	0	0	0
T_{14} (40:80)	0	0	0	0	0	0	0
T_{15} (80:40)	7	2	8	1	0	13	12.4

T – treatment.

Discussion. Water quality is a primordial reference in fish production, where water quality play a vital role in rice-fish integration as well as is prejudiced by biological, chemical, and physical factors. Although the water quality parameters does not significantly varied, but the quantity of ammonia and nitrite-nitrogen was slightly higher at non-significant level in 8 fish m^{-2} compared to 4 fish m^{-2} and 6 fish m^{-2}. Generally, in the present study, the different hydro-biological parameters was in accordance with the literature data's, within the experimental treatments, where the values did not exceed the optimal ranges and did not vary significantly; because of the fertilizer parameter was similar in all the treatments (Chapman & Fernando 1994; Vromant et al 2002). The level of toxic metabolites does not increase drastically due to stable level of temperature (29-30°C), pH 7 and DO (4.5–6.0 ppm) and hence metabolic performances, in 4 fish m^{-2} and 6 fish m^{-2} growing as well as degree of mortality were not high (Babu et al 2013). Advanced nutrient eminence of the pond suggests a increase in plankton compactness, water quality and fish yield (Yaro et al 2005), whereas phytoplankton compactness and assortment is controlled by acquaintance to solar radiation (Mohanty et al 2016). The obtainability of CO_2 for phytoplankton development is connected to total alkalinity, normal pH produce a suitable quantity of CO_2 for plankton yield (Mohanty et al 2010). Throughout the present investigation, the lowest and highest documented alkalinity was 22.10 and 23.47 ppm respectively; were the best water quality was meet in the 6 fish m^{-2} treatment. Furthermore, the growth of phytoplankton and increase in chlorophyll concentration is stimulated by fish (Frei & Becker 2005). Recurrent fertilization, amplified levels of metabolites as well as decomposition of unused feed in the nonappearance of water replacement might be the reason of steady upsurges in nitrite, nitrate, and ammonia detected in the contemporaneous investigation (Mohanty et al 2004; Boyd et al 2002). Shading, which results from the rising rice biomass, is the utmost significant factor preventive aquatic photosynthesis in rice plots (Kropff et al 1993; Mustow 2002; Heckman 1979). Furthermost feed nutrients absorbed by fish in feed-based aquaculture, are unconfined into the instant environment in which they are raised as merely about 1/3 of the nutrients in the feed are used by the yielded biomass (Edwards 2015). Although in the present study no supplement feed was given. Nevertheless, more natural feed intake from the environment due to increased levels of stocking density, overcrowdings and thereby generates additional wastes as observed in 8 fish m^{-2} treatment in the current study (Mohanty et al 2010). The investigation additionally revealed that the abundance of plankton was considerably higher in 6 fish m^{-2} treatment than in 4 fish m^{-2} and 8 fish m^{-2}; amplified plankton density also reflects higher nutrient status of the water body. The water quality and fish production always depends on plankton density (Smith et al 1987), that ultimately reflected the fish growth and rice yields in 6 fish m^{-2} stocking density within the five different ratios of *O. niloticus* and *C. carpio*. Hence the outcome is in accordance with report of Mohanty et al (2009). Fish scratches on the photosynthetic aquatic biomass as well as another rudiments of the scheme, there by assisting in nutrient pedaling (Mohanty et al 2017), diminishing N reduction as well as simplifying P discharge from the soil bottom (Bjoernsson 1994). In this study, higher growth rate was observed in 6 fish m^{-2} compared to 4 fish m^{-2} and 8 fish m^{-2}. The faster rate of growth at 6 fish m^{-2} was in connection to the efficient use of ecological functions in addition to the high detrital food web that was upheld; this approves to the conclusions of Mohanty (1999). But at higher stocking density of 8 fish m^{-2} low weight gain was experimented perhaps because of low natural food disponibility, advanced grade of organic load (Mohanty 1999), increased level of ammonia and low dissolved oxygen concentration which could have effects on the growth performance of the species. Nevertheless, regular reduced growth rate with upsurge in stocking density from 6 to 8 fish m^{-2}, could be explained because of communal antagonism for food as well as space that produce physical stress (Wedemeyer 1976) as well as comparatively altered water quality (Bromley & Smart 1981; Trzebiatowski et al 1981). Still, low survival rate was noticed in

8 fish m^{-2} as a result. The cultured species improved at 6 fish m^{-2} shows higher survival rate, growth and yield performance which may be due to increased amount of nutrients, normal food obtainability as well as less fluctuation of physic-chemical parameters (Mishra et al 1997; Mohanty et al 2010) while general production performance was decent at a stocking density 6 fish m^{-2}. In fact, when the stocking density is amplified elsewhere this level, the total oxygen demand upsurges with dangerous fluctuation of other physic-chemical parameters (Zonneveld & Fadholi 1991; Bjoernsson 1994) with no substantial rise in production. Roy et al (1990) revealed that in customary deep water rice–fish framework in India, the return of rice in a season run somewhere in the range of 1.1-1.4 tons ha^{-1} and fish production somewhere in the range of 50 and 200 kg ha^{-1}, while use of cow dung fertilizer improve the production of rice and fish to 3.1 and 0.67 tons ha^{-1}, respectively. However, a mean efficiency of 62 t ha^{-1} of fish has been accomplished without the utilization of cow manure in some investigations, which was a much higher than the prior recorded profitability in a season. This high production of fish in rice-fish combination farming may most be mostly in connection with the ideal condition of the pond (Mohanty et al 2004).

In the present study, the productions of rice straw as well as rice paddy were considerably influenced by fish stocking density. With regards to different stocking density, 6 fish m^{-2} has the utmost grain production recorded, this was essentially because of higher quantities of grain production t ha^{-1} (5.43) and straw production t ha^{-1} (9.34). Moreover, the beneficial outcome of fish on the dry weight of rice plant material at collecting is likely related to expanded supplement (nitrogen) obtainability in the soil because of fish action inside the field, as found in the reports including in rice-fish environment (Lightfoot et al 1992). Fish in the field have improved soil fertility, recuperate lost energy, and modify the energy flow by weeds, insects, plankton, and microorganisms that compete with rice for food. Also, carbon is upgraded by fish discharging carbon dioxide to plants, the supply of oxygen increments because of the flouting of the soil superficial and oxidization of the layers, in this manner advancing root development and tillering capacity of rice plants. In a survey of eighteen rice–fish experiments, growth and production of rice was improved in 6 fish m^{-2}, Lightfoot et al (1992) found the inclination of enhanced rice productions (4.6 to 28.6%) in the integrated farming of fish with rice. Be that as it may, Rothuis et al (1998) detailed that paddy production were not impressively extraordinary amid in rice-fish culture and rice monoculture. All in all, from different areas, studies concerning rice-crab culture, provided information on rice-fish integration; both systems are highly connected. Significant outcome of fish on paddy production was reported in rice-fish farming where even studies were conducted in controlled conditions at research stations (Suharto et al 1994; Haroon & Pittman 1997). Moreover, the physical-compound characteristic of arable soil improve, the development rate of rice plants quickens, as well as the dry matter besides leaf area record at various development phases builds, all because of the presence of fish in the rice field, along these lines advancing photosynthesis and grain production (Duan et al 2007). In the present study superior rice production was documented in T0 control (5.55 t ha^{-1}), because of the lower chlorophyll and plankton density which diminishes the challenge for nutrients with the rice plants. The results of the present study are in accordance with the reports of Heckman (1979), Kropff et al (1993), and Mohanty et al (2015).

Conclusions. The present study revealed that the integrated rice-fish farming system can be initiated for rice and fish culture while required suitable stocking density of 6 fish m^{-2} with 1:1 ratio of *C. carpio* and *O. niloticus* for better fish growth and survival in addition to maximum rice yields. The results obtained within the present study prove that rice-fish farming guarantees a naturally stable and economically active way to utilize the swamp and lowland environments. Nevertheless, its multi-environmental capacities, for example, its function in saving assorted natural variety, ensuring food security, and advancing soil quality must be investigated. Further research should be conducted with different dosage of organic fertilizer and additional research should be done using feed supplement for a more wide understanding of fish-rice culture.

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