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Polyculture of Carp, Tilapia and Pangas Using Low Cost Inputs

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Abstract: An experiment was conducted to evaluate the water quality, growth and production of fishes at different species compositions in polyculture using tilapia (*Oreochromis niloticus*), pangas (*Pangasius hypophthalmus*), mrigal (*Cirrhinus mrigala*) and silver carp (*Hypophthalmichthys molitrix*). The experiment was conducted for a period of 90 days from September 8, to December 7, 2002 at the Fisheries Faculty Field Laboratory of Bangladesh Agricultural University, Mymensingh. There were three treatments each with three replications. In all the treatments, the stocking density was 100 fish/decimal at different species compositions. All the ponds were subjected to same regime of feeding and fertilization. Fortnightly random sampling was done to adjust the feeding rate. In this experiment, mrigal showed the highest SGR (% per day) value (3.74) in T_2. Tilapia showed the second highest (3.65) SGR (% per day) in T_1. Specific growth rate (% per day) of pangas was comparatively lower in all treatments. Mean survival rates of various species ranged from 90.63 to 91.10%. Comparatively, tilapia showed the highest survival rate where pangas showed the lowest. T_1 showed the highest survival rate but there was no significant variation among the treatments. Weight gain (g) of tilapia, pangas, mrigal and silver carp were 89.18, 30.61, 85.75 and 91.71 g in T_1, 63.95, 37.24, 86.86 and 65.63 g in T_2 and 70.84, 47.65, 70.42 and 72.87 g in T_3, respectively. The highest and the lowest weight gain were found in T_1. Silver carp attained maximum weight gain (91.71 g) in T_1 where pangas showed the lowest (30.61g) in the same treatment. Among the treatments, the highest production was found in T_1 (1974.02 kg/ha/90 days) which was significantly higher than other treatments. The production in T_2 and T_3 were 1405.59 and 1522.01 kg/ha/90 days but there was no significant variation between T_2 and T_3. Considering the above, pangas showed the lowest growth performance and production in all treatments compare with other species. From the findings of the present study, it can be said that polyculture of pangas with tilapia is not suitable, but it may be suitable with carps and for this further research is necessary.

Key words: Polyculture, carp, tilapia, pangas, low-cost feed

INTRODUCTION

Polyculture or composite culture is the system in which fast growing compatible species of different feeding habits are stocked in different proportions in the same ponds[1]. The basic principles of the polyculture; species of different feeding habits are, culture in the same pond to avoid food competition and best utilization of natural foods of different habits without any harm to each other. It is a fact that, polyculture may produce an expected result if the fish with different feeding habits are stocked in proper ratios and combinations[2].

Selection of species plays an important role for any cultural practices. The better utilization of different strata and zones of a pond three or more species must be stocked. In our country, suitable or common combinations of fish for composite culture are rui (*Labeo rohita*), catla (*Catla catla*) and mrigal (*Cirrhinus mrigala*). Sometimes calbaus (*Labeo calbasu*) has been included in polyculture. In recent years, some exotic fish species draw an attention to farmers for their better growth performance. Fish culturist introduced several exotic carps in order to obtain more production at minimum cost and the shortest possible period. They are now being cultured combindly with the local carps. These include silver carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idella*), common carp (*Cyprinus carpio*), raj punti (*Puntius gonionotus*) etc. Among those, silver carp is the most popular species for it's fast growth, lucrative size, good taste and high market demand.

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Now-a-days, pangas (*Pangasius hypophthalmus*) and tilapia (*Oreochromis niloticus*) have also been introduced in fresh water ponds for polyculture. Once a time, *P. hypophthalmus* was also a popular table fish in our country and farmers were economically benefited from this industry. But in recent years, this fishery is being depleted partly because of increasing feed cost, decreasing feed quality, lack of proper management, unavailability of low cost supplementary feeds and socio-economic constraints. So, the production cost became high enough compared to market value and the farmers are discouraged from pangas culture day by day. For this purpose, it is urgent need to find out a suitable culture technique as well as polyculture technique of pangas with local carps to get the sustainable production using low cost feed and fertilizer.

Tilapia is an excellent fish for growing in the shallow and seasonal ponds in a country like Bangladesh[3-5] because Bangladesh enjoys very suitable climate and ecological conditions for culture of warm-water species.

That is why, the present study was undertaken to evaluate the growth performance of fishes (tilapia, pangas, mrigal and silver carp) in polyculture at different species combinations and to determine the suitable species combinations of both Indian major carp and exotic fishes on the basis of their ecological relationships.

MATERIALS AND METHODS

Description of the study area and duration: The experiment was conducted for a period of 90 days from September 8 to December 7, 2002. The experiment was carried out three treatments each with three replications, situated in the Field Laboratory of the Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh. The area of each pond was 200 m^2 (5 decimal) of which 18.5 m length and 13.5 m width with an average depth of 1.2 m.

Pond preparation: During the experiment, all the ponds were freed from predatory and undesirable species by repeated netting. Aquatic weeds were removed from the ponds manually by day labour. All the ponds were limed at the rate of 1 kg/decimal and manured with cow dung at the rate of 10 kg/decimal. One week after liming, the ponds were fertilized with urea and TSP at the rate of 100 g/decimal to stimulate the productivity of the ponds.

Stocking of fish: Two weeks after fertilization, the ponds were stocked with the fingerlings of GIFT tilapia (*Oreochromis niloticus*), silver carp (*Hypophthalmichthys molitrix*), mrigal (*Cirrhinus mrigala*) and pangas (*Pangasius hypophthalmus*). Before stocking, all fishes were measured in length and weight of fingerlings by centimeter scale and electric balance. In all the treatments, GIFT tilapia, silver carp, mrigal and pangas were stocked in different species composition at the rate of 100/decimal.

Fertilization and supplementary feeding: Both inorganic and organic fertilizers were used during the period of experiment. Each pond was treated with urea and TSP at the rate of 100 g/decimal daily. On the other hand, all the ponds were fertilized with organic fertilizer (cow dung) at the rate of 5 kg/decimal at 7 days interval. Everyday, rice bran (60%) and Mustard Oil Cake (MOC, 40%) was used as supplementary feed. The feeds were calculated at a rate of 5-7% of the body weight. Feeds were applied twice a day, half in the morning (9:00 am) and the rest in the afternoon (4:00 pm).

Growth study of fishes: To record the growth of the fishes and adjust the feeding rate, 10% of fishes (tilapia and pangas) from each pond were sampled fortnightly by using a seine net and then the length (cm) and weight (g) of each species were recorded separately. Weight of fishes in each sampling was measured by using a digital electronic balance (Denver Instrument, Model XP-3000). Weight Gained (g) and Specific Growth Rate (SGR) were used to evaluate the growth of fishes.

Water quality parameters: Physico-chemical factors viz., temperature (0°C), Dissolved Oxygen (DO), transparency (cm), depth (cm) and pH were measured daily and Nitrate-nitrogen (NO_3-N), Phosphate-phosphorus (PO_4-P), chlorophyll-a ($\mu g\ L^{-1}$) and total alkalinity ($mg\ L^{-1}$), were measured fortnightly.

Plankton population: Water samples were collected from all ponds fortnightly for qualitative and quantitative study of both phytoplankton and zooplankton. About 10 L of water samples were collected from different depth and area of each pond and was then passed through plankton net of 25 μm mesh size. For the quantitative and qualitative study of plankton, the plankton samples were analyzed in Water Quality and pond dynamics Laboratory, Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh.

Planktons were expressed as cells per liter of water of each pond. The quantitative analysis of phytoplankton and zooplankton was done according to Stirling[6] and qualitative analysis was done according to Needham and Needham[7], Bellinger[8].

Harvesting of fish: At the end of the experiment all the fishes were harvested by netting repeatedly with a fine meshed seine net from each pond and then counted species wise. Then the final growth gained by each species was recorded by measuring the length (cm) and weight (g) of individual fish.

Estimation of survival rate and production of fishes: The survival rate of fishes of each species for each treatment and replication were calculated from the number of fish of each species harvested from each replication at the end of the experiment. The gross and net production for each treatment and replication was determined by multiplying the average gained in weight (g) of each species of fish by the total number of fishes of the same species survived at the end of the experiment. This was done separately for each replication and treatment.

Statistical analysis: Data were analyzed statistically to observe the performances of fishes in different species combinations. Using Analysis of Variance (ANOVA) compared the mean values of growth, survival and yields obtained. The mean values were compared according to Duncan's Multiple Range Test[9].

RESULTS AND DISCUSSION

Water quality parameters: The results of water quality parameters in different ponds such as temperature, transparency, water depth, pH, dissolved oxygen, phosphate-phosphorus, nitrate-nitrogen, total alkalinity and chlorophyll-a monitored during the study period are shown in Table 1.

The water quality parameters measured in different treatments throughout the experimental period were found to be more or less similar and all of them were within the acceptable range for fish culture. Fish culturists are more conscious about the maintenance of optimum condition of water quality parameters. The ranges of water temperature measured were 24.0 to 35.0°C. The present findings agree with the findings of Mollah and Haque [10], Rahman *et al.*[11], Wahab *et al.*[12], Azim *et al.*[13], Hasan [14], Kohinoor *et al.*[15] and Paul[16]. Dewan *et al.*[17] reported a surface water temperature ranged from 30.2 to 34.0°C in polyculture with Indian and Chinese carps. Ali *et al.*[18] also observed temperature range of 20.5-30.5°C in pond water. These findings are also more or less similar to that of the present study. Dissolved Oxygen (DO) content were varied from 4.1 to 8.9 mg L^{-1}. The highest (8.9 mg L^{-1}) and lowest (4.1 mg L^{-1}) dissolved oxygen content were recorded in T_1. The fluctuation in DO value might be due to alteration in the rate photosynthesis in the pond and due to rate of dissolved oxygen consumption by fish through respiration. Wahab *et al.*[12] recorded dissolved oxygen ranging from 2.2 to 7.1 mg L^{-1}. in nine ponds of BAU campus, Mymensingh. Nirod[19] recorded dissolved oxygen ranged from 3.4 to 8.79 mg L^{-1}, Paul[16] found dissolved oxygen 0.85 to 7.85 mg L^{-1}, while Kohinoor [20] measured dissolved oxygen 2 to 7.4 mg L^{-1} in the research ponds of BAU campus, Mymensingh. From the above findings, it is concluded that the oxygen content of the experimental ponds were within the good productive range. The ranges of water pH in different treatments varied from 6.18 to 9.16 which indicate good productive conditions of the ponds. The optimum pH range for carp polyculture in pond is 6.5-9.0[17,21,22]. The weekly variation recorded in pH might reflect the change in plankton abundance. Mean pH value recorded in different months in different treatments in the present study were in the suitable range. In the present study, transparency ranged from 16.0-37.5 cm which was near the findings of Kohinoor[20] who recorded transparency values ranging from 15 to 58 cm. Wahab *et al.*[22] found

Table 1: Mean values (± SD, n=9) with ranges (in parenthesis) of water quality parameters of different experimental ponds during the experimental period under three treatments

Water quality parameters	T_1	T_2	T_3
Temperature (°C)	30.32±2.70 (35-25)	30.22±2.86 (35-24)	30.21±2.87 (34.5-25)
Transparency (cm)	25.67±3.09 (36.0-18.5)	25.26±3.56 (37.5-16.0)	25.18±3.74 (37.0-16.5)
Water depth (cm)	107.53±7.69 (131.0-93.0)	103.68±7.76 (126.0-89.0)	107.27±10.52 (132.0-85.0)
pH	7.89±0.53 (9.16-6.77)	7.82±0.54 (9.1-6.18)	7.82±0.53 (9.14-6.24)
Dissolved oxygen (mg L^{-1})	6.81±0.99 (8.9-4.1)	6.63±0.96 (8.8-4.5)	6.65±0.96 (8.7-4.3)
Total alkalinity (mg L^{-1})	110.14±39.65 (176.0-60.0)	109.95± 42.56 (199.0-61.0)	110.52±45.33 (194.0-63.0)
PO_4-P (mg L^{-1})	0.99±0.76 (3.2-0.23)	1.42±1.01 (3.2-0.15)	1.35±1.02 (3.6-0.19)
NO_3-N (mg L^{-1})	0.62±0.54 (2.1-0.2)	0.76±0.55 (2.3-0.2)	0.85±0.7 (3.5-0.3)
Chlorophyll-a (µg L^{-1})	207.29±72.23 (377.23-117.81)	175.56±69.62 (292.74-82.11)	194.25±83.00 (379.61-73.78)

Table 2: Group wise mean (± SD) plankton cell (×103) count per litre of water in different treatments during the study period.

Plankton-group	T_1	T_2	T_3
Phytoplankton			
Bacillariophyceae	10.39±4.87	15.33±22.13	13.37±5.63
Chlorophyceae	19.22±8.99	26.11±12.77	31.88±11.14
Cyanophyceae	35.16±17.89	31.85±24.74	44.67±49.12
Euglenophyceae	8.34±4.52	10.99±3.07	11.23±6.63
Total	73.11±36.27	84.28±62.71	101.15±72.52
Zooplankton			
Crustacea	11.26±2.10	15.13±0.69	16.45±1.76
Rotifera	1.78±0.52	3.06±0.14	3.24±0.36
Total	13.04±2.62	18.19±0.83	19.69±2.12

Table 3: Growth, survival and production of fish in different treatments during the study period

Parameters	T_1	T_2	T_3	±S.E.
Initial weight (g)				
Tilapia	4.18a	3.88a	3.77a	±0.31
Pangas	5.61a	4.33a	4.45a	±0.40
Mrigal	4.18b	4.28ab	4.34a	±0.03
Silver carp	6.07a	5.93a	5.99a	±0.09
Final weight (g)				
Tilapia	93.36a	67.83b	74.61b	±3.56
Pangas	36.22b	41.57ab	52.10a	±3.77
Mrigal	89.92a	94.47a	74.76a	±7.96
Silver carp	97.78a	71.53c	78.86b	±1.61
Weight gain (g)				
Tilapia	89.18a	63.95b	70.84b	±3.83
Pangas	30.61b	37.24ab	47.65a	±3.89
Mrigal	85.75a	86.86a	70.42a	±8.54
Silver carp	91.71a	65.60c	72.87b	±1.53
SGR (% per day)				
Tilapia	3.65a	3.16b	3.32ab	±0.12
Pangas	2.08b	2.49ab	2.74a	±0.15
Mrigal	3.36b	3.74a	3.08b	±0.10
Silver carp	3.09a	2.77b	2.85b	±0.04
Survival rate (%)				
Tilapia	92.45a	90.76a	91.26a	±0.92
Pangas	87.87a	88.56a	88.85a	±0.91
Mrigal	92.45a	90.88a	90.75a	±0.43
Silver carp	92.70a	90.60a	91.54a	±0.71
Production (kg/treatment/90 days)				
Tilapia	28.88a	18.89b	19.39b	±1.34
Pangas	0.67c	1.64b	3.16a	±0.20
Mrigal	1.91a	1.97a	1.60a	±0.19
Silver carp	8.5a	5.95c	6.66b	±0.18
Total production (kg/treatment/90 days)	39.96a	28.45b	30.81b	±1.55
Total production (kg/decimal/90 days)	7.99a	5.69b	6.16b	±0.31
Total production (kg/ha/90 days)	0.1974a	0.1406b	0.1522b	±76.43

Figures in the same row with same superscripts are not significantly different ($p>0.05$)

transparency depth ranging from 15-75 cm in polyculture pond. Rahman[23] concluded that the transparency of productive water bodies should be 40 cm or less. The observed range of water transparency was more or less similar with the findings of Wahab *et al.*[12] and Paul[16]. Total alkalinity values depending upon the location, season, plankton population, nature of bottom deposits etc.[21]. Boyd[24] advocated that the total alkalinity should be more than 20 ppm in fertilized ponds as production increases with the increase in total alkalinity. The range of total alkalinity during the study period in different treatments ranged from 60-199 mg L^{-1} which was more or less similar to the results of Wahab *et al.*[12], Nirod[19], Paul[17] and Kohinoor [20]. Therefore, it might be concluded that this range was within the suitable range for fish culture. Phosphorus is a major nutrient and very essential for phytoplankton, the primary producer of waters. Phosphate-phosphorus (PO_4-P) in the present study was found to range from 0.15 to 3.6 mg L^{-1}. Wahab *et al.*[12] found the highest concentration of phosphate-phosphorus 0.09 to 5.2 mg L^{-1} in nine experimental ponds of BAU campus, Mymensingh. So, the content of Phosphate-phosphorus in the present study was suitable for fish culture. Nitrate is extremely important as a nutrient in supplying nitrogen for protein synthesis. The ranges of nitrate-nitrogen measured in the present study were 0.2 to 3.5 mg L^{-1}. Bhuiyan[25] reported that the range of NO_3-N from 0.06 to 0.1 ppm is suitable range for fish culture. Alikunhi[26] also stated a concentrated of 0.06 ppm nitrate was good for fish cultivation. The mean values of nitrate concentration in the present study were higher than those of the above statements. The present findings are also more or less similar to the findings of Mollah and Haque[10]. The value of chlorophyll-a (μg L^{-1}) indirectly express the abundance of phytoplankton in a water body. Khatrai[27] found a positive relationship between phytoplankton and chlorophyll-a. The chlorophyll-a values showed a wide variation during the experimental period which might be due to the abundance of phytoplankton by pond fertilization. In the present study, chlorophyll-a values ranged between 73.78 and 379.61 μg L^{-1} which indicate that all ponds under three treatments were highly productive and suitable for fish culture. Comparatively higher chlorophyll-a value was found in T_3 which due to the presence of higher concentration of phytoplankton in pond water. Several others[16,19,20,28] have recorded more or less similar values of chlorophyll-a.

Plankton population: The group-wise mean abundance of plankton observed in three treatments is shown in Table 2. Phytoplankton population was mainly composed of Bacillariophyceae, Chlorophyceae, Cyanophyceae and Euglenophyceae whereas the zooplankton population included Crustaceans and Rotifers. Total phytoplankton was 73.11×10^3, 84.28×10^3 and 101.15×10^3 cells L^{-1} and zooplakton were 13.04×10^3, 18.19×10^3 and 19.69×10^3 cells L^{-1} in T_1, T_2 and T_3, respectively. The mean abundance of phytoplankton 73.11 to 101.15×10^3 cells L^{-1} and zooplankton concentration 13.04 to 19.69×10^3 cells L^{-1} which were more or less similar to that of Wahab and Ahmed[29] who estimated mean phytoplankton population of 17.72×10^4, 9.26×10^4 and 13.87×10^4 cells L^{-1} from three sets of ponds, respectively. Wahab *et al.*[22] also recorded phytoplankton numbers ranging from 2 to 8×10^5 cells L^{-1} and zooplankton between 2 to 3.2×10^4 cells L^{-1}. Application of cattle manure might have enhanced the production of plankton in the present study.

Growth performance of fish: The growth performance of different species of fish viz., Tilapia, pangas, mrigal and silver carp in terms of initial weight, final weight, weight gain, specific growth rate (SGR % per day), survival rate and total production are shown in Table 3.

There was no significant variation in initial weight of various species among the treatments. Mean final weight of different fish species varied significantly among the treatments. Mean final weight ranged between 67.83 and 93.36 g in tilapia, 36.22 and 52.10 g in pangas, 74.76 and 91.14 g in mrigal and 71.53 and 97.78 g in silver carp. The mean final weight of tilapia (93.36 g) in T_1 was significantly ($p<0.05$) higher than the other treatments (Table 3). However there was no significant variation in mean final weight of tilapia between T_2 and T_3.The mean final weight of pangas was significantly different ($p<0.05$) between the T_1 (36.22 g) and T_3 (52.10 g) but there was no significant variation in final weight of pangas between T_1 (36.22 g) and T_2 (41.57 g) and also between T_2 (41.57 g) and T_3 (52.10 g). There was no significant variation ($p>0.05$) in final weight of mrigal among the treatments T_2 (94.47 g), T_1 (89.92 g) and T_3 (74.76 g), respectively. The mean final weight of silver carp was significantly different ($p<0.05$) among the treatments. It grew best in T_1 (97.78 g) which was significantly different ($p<0.05$) from T_2 (71.53 g) and T_3 (78.86 g). Again significant differences were found between T_2 (71.53 g) and T_3 (78.86 g).

Weight gain of all the four species of fishes varied considerably among the treatments. Weight gain (g) of tilapia, pangas, mrigal and silver carp were 89.18, 30.61, 85.75 and 91.71 g in T_1, 63.95, 37.24, 86.86 and 65.63 g in T_2 and 70.84, 47.65, 70.42 and 72.87 g in T_3, respectively. From the results, it is evident that the highest weight gain (g) was in T_1 followed by T_2 and T_3 due to proper utilization of both natural and supplementary feed in all stages by the fishes and also due to good water quality conditions. Among the treatments the weight gain of tilapia was significantly ($p<0.05$) higher in T_1 (89.18 g) than other treatments. This might be due to the fact that tilapia is an omnivorous fish and it properly utilized the supplementary (Rice bran and Mustard oil cake) and natural food (Phytoplankton and zooplankton), as the ponds were fertilized with inorganic (Urea and TSP) and organic (cow dung) fertilizer daily and weekly. On the other hand, the water quality conditions were also found better in T_1. However, there was no significant variation between the weight gain of tilapia in T_2 (63.95 g) and T_3 (70.84 g). The weight gain of pangas was found comparatively lower in all the treatments. This might be due to the fact that it could not compete with other fishes for food and space. Weight gain of pangas was found significantly ($p<0.05$) higher in T_3 (47.65 g) compared to the T_1 (30.61g). There was no significant variation between the weight gain of pangas in T_3 and T_2. Similarly, there was no significant variation between T_2 and T_1. There was no significant variation in weight gain of mrigal among the T_2 (86.86 g), T_1 (85.75 g) and T_3(70.42 g), respectively and expected weight gain was found in all the treatments. The reasons were mrigal being a botton feeder, proper utilizing of bottom feeds and no competitor of it in all treatments. The mean weight gain of silver carp was significantly different ($p<0.05$) among the treatments. The highest weight gain of silver carp was found in T_1 (91.71 g) and the lowest in T_2 (65.60 g). This might be silver carp being a planktivorous fish and utilized phytoplankton properly in T_1 as the lowest amount of phytoplankton was present in T_1. Phytoplankton were used highly by the silver carp, so the amount was found low.

The specific growth rate of tilapia in different treatments ranged between 3.16 and 3.65%. The significantly ($p<0.05$) higher SGR value was recorded in T_1 (3.65%) than the T_2 (3.16%). However, no significant variation in SGR was found between T_1 (3.65%) and T_3 (3.32%) and T_3 and T_2, respectively. The SGR (% per day) in pangas varied between 2.08 and 2.74 in different treatments. Pangas in T_3 showed significantly ($p<0.05$) the highest SGR values (2.74%) while pangas in T_1 showed the lowest (2.08%). There was no significant variation between T_3 and T_2 and T_1. Mrigal showed higher SGR values compared to other species of fish in the present study. The SGR values range between 3.08 and 3.74%. Mrigal in T_2 showed significantly ($p<0.05$) the highest SGR values (3.74%) than the rest of the treatments. However, there was no significant variation between the SGR values of mrigal in T_1 and T_3. The SGR value of silver carp in different treatments ranged from 2.77 to 3.10% and the highest value was recorded in T_1 (3.10%) and the lowest in T_2 (2.77%). SGR of silver carp in T_1 was significantly higher ($p<0.05$) than those in T_3 and T_2. No significant variation was found between the SGR values in T_3 and T_2. In the present study, the fortnightly average specific growth rate (SGR % per day) of fishes was found to increase more or less rapidly at the beginning of the experiment and then slowly after October till the end of the experiment. Relatively slower SGR (% per day) towards the end of the experiment might be associated with the winter season. Among all the species, mrigal showed the highest SGR (% per day) value (3.74) in T_1 both by net increase and percentage of increase in weight than the rest of the species. Tilapia showed the second highest SGR (% per day) among the fishes under different treatments and the highest value was found in T_1. Specific growth rate (SGR % per day) of silver carp and pangas were comparatively lower than mrigal and tilapia. The highest value of silver carp was fund in T_1 and lowest in T_2. On the other hand, the highest SGR value of pangas was found in T_3 where the lowest in T_1. SGR values obtained in the present study are similar to that obtained by Hossain *et al.*[30], Salimullah[31] and Pandey *et al.*[32] fed supplemental feed (mustard oil cake and rice bran, 1: 1) at the rate of 5% of total body weight daily. SGR of fish fed on high protein and energy diet show higher value, but fish fed on supplemental feeds made on-farm could show SGR value between 3-4% per day[33].

The survival rate (%) of different fish species in different treatments was fairly high. This might be due to application of both fertilization and supplementary feed. There was no significant variation of survival rate (%) of different fish species among the treatments. The survival rate of the fishes was in the range of 90.63-91.10 % in different treatments. T_1 showed the highest survival rate (91.10%) where T_3 showed the lowest (90.63%). In general, mrigal showed the highest (91.79%) and pangas showed the lowest (88.43%) survival rate among the treatments. In the present study, mean survival rates of various fish were recorded 91.10, 90.63 and 90.76% in T_1, T_2 and T_3, respectively. Similar types of survival rates were observed by Mostaque[34], who recorded the survival rates of 86 to 95% in a polyculture system in BAU ponds. The survival rate of the present study were higher than the survival rates reported by Wahab *et al.*[35] for Indian major carps in polyculture where supplemental feed (mustard oil cake + rice bran, 2: 1) was given. Lakshmanan *et al.*[36] observed similar survival rate of 80% with seven species composite culture of Indian and Chinese carps in which ponds were fertilized with both organic and inorganic manures at short interval and fish were fed daily with a mixture of mustard oil cake and rice bran. There was no significant difference of survival of each fish species among the treatments. The highest survival rate was seen in T_1 followed by T_2 and T_3. Among all the species relatively higher survival rate was recorded in tilapia which was closely followed by mrigal and silver carp. The lowest survival rate was recorded in pangas. This might be due to the fact that it could not compete with other fishes for food and space.

Production of fish: Species-wise and total production of fish in terms of kg/treatment has been shown in Table 3. Total production ranged between 28.45 and 39.96 during the experimental period of 90 days. From the Table 3, it revealed that all of the fish species showed significantly ($p<0.05$) higher production in T_1 (7.99 kg/decimal/90 days) but there was no significant variation between T_2 (5.69 kg/decimal/90 days) and T_3 (6.16 kg/decimal/90 days). In terms of kg/ha/90 days, the production range was 1406-1974 kg/ha/90 days. The highest production of tilapia was found in T_1 (28.88 kg/treatment/90 days). In T_2 and T_3 the production was 18.89 and 19.39 kg/treatment 90 days. In pangas, the highest production was found in T_3 (3.16 kg/treatment/90 days) where in T_1 and T_2, the production were 0.67 and 1.64 kg/treatment/90 days. The production of mrigal in different treatments was 1.91, 1.97 and 1.60 kg/treatment/90 days. In case of silver carp, T_1 showed the highest production (8.50 kg/treatment/90 days). The production in T_2 and T_3 was 5.95 and 6.66 kg/treatment/90 days, respectively.

The production of tilapia (kg/decimal/90 days) in T_1 was significantly ($p<0.05$) different from the other treatments. However, there was no significant ($p>0.05$) variation between the T_3 and T_2. In pangas, the production (kg/decimal/90 days) in T_3 was significantly ($p<0.05$) different than the other treatments. On the other hand, significant ($p<0.05$) variation was found between T_2 and treatment T_1. The production (kg/decimal/90 days) in case of mrigal, no significant differences were found among the T_1, T_2 and T_3.

Among the three treatments, the highest production of fish was recorded in T_1 which was subsequently followed by the production of T_2 and T_3. The reason behind the highest production in T_1 might be the role of both supplemental and natural food especially phytoplankton and zooplankton and its abundance throughout the study period. Another reason might be the value of individual final weight and survival were found to be averagely higher and better species combination in this treatment than the rest of the treatments. Tang[37], Sinha and Gupta[38,39] have reported that different species in polyculture pond occupy different niches with their complimentary feeding habits, fully utilizing all the natural foods in the ponds, thus increasing the total fish production from the pond. Lakshmanan *et al.*[36] obtained good result in polyculture with Chinese and Indian major carps by stocking in varying proportions in different densities. The fish production recorded by them varied from 2230-4209 kg ha^{-1}/year. Good results were also obtained by Singh *et al.*[40] from polyculture experiment using silver carp, grass carp, common carp together with Indian major carps and the yield recorded by them was 6196 kg/ha/year.

Jhingran[41], Chaudhuri[42], Mathew *et al.*[43] and Gupta *et al.*[44] also reported good results from the polyculture of Indian carps with exotic species and the yield recorded by them were 7000-9000, 7444.8, 10183 and 4917 kg/ha/year, respectively. Whereas, Dunseth and Smitherman[45] find out the effectiveness of polyculture using silver carp and bighead carp in catfish grow out ponds. They noted the yield of catfishes reduce with the combination of carps.

However, the fish productions recorded in the present study were 1974, 1406 and 1522 kg/ha/90 days in treatments 1, 2 and 3, respectively. Mazid *et al.*[46] found a gross production of 3,600 kg/ha/year from composite culture of Indian major carps and Chinese carps in Bangladesh. Wahab *et al.*[12] also recorded 5,294 to 5,670 kg/ha/year productions in the polyculture of carps with silver carp. The total productions of fish to the present experiment were within the range of good production when compared with the above findings.

Among the fish species, expected growth performance of mrigal was found in all treatments. The highest production was found in T_2 and lowest in T_3, but there was no significant variation among the treatments. The reasons were bottom feeds were properly utilized and no competitor of it in bottom layer in all treatments.

Growth and production of tilapia and silver carp were better in T_1 than the other treatments. This might be due to the fact, that in T_1, they properly utilized both natural and artificial feed and successfully compete with other species for food and space. The water quality condition of T_1 was also better which might be the reason.

Pangas was experimentally introduced in this study to observe the growth and production compare with tilapia, silver carp and mrigal. But expected production was not found in any treatment. This might be due to its failure to compete with other species for food and space. So, polyculture of pangas with tilapia, mrigal and silver carp is not suggested. Therefore, more studies are required to establish a suitable species composition of pangas polyculture to observe its growth and production.

The result of the present study demonstrated that stocking density of 100 fish/decimal at different species combination of tilapia, pangas, mrigal and silver carp in T_1 is optimum for polyculture using low-cost feed and fertilizer.

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