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Comparative evaluation of growth, survival and production of carp species at different stocking densities under polyculture

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ABSTRACT

Experiments to evaluate the growth rates of different carp species, survival levels and biomass production with respect to varied stocking densities ranging between 2000 and 6000 numbers /ha were conducted in six ponds of 0.04 ha each for a period of 11 months. Growth of all the species decreased with increase in stocking densities, with mean size of harvest recorded being 1035 g, 725 g and 550 g in treatments with density of 2000, 4000 and 6000/ha respectively. In general, exotic carp species showed higher growth rates than those of Indian major carps in all the treatments. Even at the stocking level of 35%, the three exotic carp species in combination contributed as much as 47.3 - 50.0% to the harvested biomass in three treatments. The mean gross and net production levels registered in treatment with density of 6000/ha were estimated as 2741 kg/ha and 2706 kg/ha respectively during a culture period of 11 months. The corresponding estimated production levels shown in treatments with density of 4000 and 2000/ha were 2367.5 kg/ha, 2342.5 kg/ha and 1815.0 kg/ha, 1802.5 kg/ha respectively during the same period. The mean FCR values recorded in the three treatments were in the range of 2.69-2.82.

Introduction

Stocking density of fish is one of the key factors, deciding management measures in scientific fish culture practices. It affects the amount of natural food available per fish and the level of supplementary feeding required (Moor, 1986; Hepher, 1988) and hence the intensity of inter and intra-specific food competitions in polyculture systems. The stocking densities and combinations are important issues to be decided depending on the level or intensity of operation and carrying capacity of the system. The rate of stocking is further decided based on the expected growth increment of individual fish, survival levels and biomass production. Carp culture in India involves three species of Indian major carps *viz.* catla *(Catla catla)*, rohu *(Labeo rohita)* and mrigal *(Cirrhinus mrigala)* or six species comprising three species of Indian major carps and three exotic carps, *viz.* silver carp *(Hypophthalmichthys molitrix)*, grass carp *(Ctenopharyngodon idella)* and common carp *(Cyprinus carpio)*. Experiments on mixed fish culture with Indian major carps and exotic carps conducted by Alikunhi *et al.* (1971) during 1962-'63 recorded production levels ranging from 1000 - 4900 kg/ha/yr with the stocking density of 690-15000/ha. He further suggested that for a production level of 3000 - 3500 kg/ha/yr under regular manuring and/or artificial feeding, the stocking density is to be maintained at 3000-3500 fingerlings/ha. Later experiments conducted at different centres with both Indian major carps and exotic carps advocated stocking densities of 4000-6000/ha for optimum production (Lakshmanan *et al.*, 1971, Sukumaran *et al.*, 1972). Various stocking densities ranging from 3000 fingerlings/ha (Alikunhi *et al.*, 1971) to 13320 fingerlings /ha (Chaudhuri *et al.*, 1978) were tried under different experimental trials for maximising the production levels, though not always resulting in increased rates of production. While several such studies provided information mainly on production levels in isolation, comparative evaluation of the growth trends of different species, production levels, percentage contribution of different species in composite culture systems, etc. are scanty. Keeping in view the above aspects, the present experiment was conducted to evaluate various parameters like individual growth rates of different carp species, survival levels, biomass production among others with respect to varied stocking densities.

Materials and methods

Experiments were conducted in a set of six ponds of 0.04 ha (20 m x 20 m) each for a period of 11 months during October 1994-September 1995. Pre-stocking pond management included eradication of predatory and weed fishes with application of bleaching powder (20% available chlorine) at the rate of 525 kg/ha-m. The ponds were left unstocked for a period of ten days for detoxification. Organic manure in the form of cattle dung was applied at the rate of 15 tonnes/ha/yr with 1/5th of the total quantity (3 tonnes/ha) applied as basal dose, a week prior to stocking of fish seed and the remaining amount applied in equal split doses at bimonthly intervals. Inorganic fertilisers in the form of urea and single superphosphate were applied at the rate of 200 kg and 300 kg/ha/yr respectively as a source of nitrogen and phosphorus in fortnightly split doses.

The ponds were stocked at three different stocking densities *viz.* Treatment I with 2000 fingerlings/ha (ponds P-1 & P-2), Treatment II with 4000 fingerlings/ha (ponds P-3 & P-4) and Treatment III with 6000 fingerlings/ha (ponds P-5 & P-6) with combinations of catla 20%, rohu 25%, mrigal 20%, silver carp 15%, grass carp 5% and common carp 15%. The mean initial weight of species stocked were catla 10.0 g, rohu 4.25 g, mrigal 3.75 g, silver carp 5.2 g, grass carp 13.2 g and common carp 4.5 g.

The fishes were provided with supplementary diet comprising traditional mixture of rice bran and groundnut oil cake at 1:1 ratio by weight. The ingredients were soaked in water after thorough mixing and provided in the form of dough. Feeding was provided at 5% of biomass stocked per day during the first month, reduced to 2% from 2nd month onwards and finally to about 1.5% after six months of culture till the end of the culture period. The feeding quantity was adjusted at monthly intervals, after estimating the biomass increase through intermittent samplings at monthly intervals. The assessment of fish biomass was based on mean growth as obtained through samplings and an expected survival level of 80%. Further, the amount of feed provided in each treatment was based on the mean biomass of replicate ponds. Feeding was done twice daily, during morning (7-8 AM) and evening hours (4-5 PM) of the day.

Periodic samplings were carried out for assessment of growth and health of the fish species at monthly intervals. Water levels in the experimental ponds were maintained at a depth of 1.4-1.5 m during the study period, compensating the loss of water due to seepage and evaporation. Fertilisers were applied at the scheduled rates as discussed earlier to keep the sustained production of natural fish food organisms. Liming was done at intervals of three months, to keep the desired pH of water as also pond hygiene, by application of $CaCO_3$ at the rate of 100 kg/ha/application. Harvesting of fishes was done at the end of 11 months of culture period. Selected physico-chemical parameters of the experimental ponds were analysed at fortnightly intervals by following standard methods (APHA, AWWA, WPCF, 1989). Plankton samples collected at monthly intervals were analysed by direct census method (Jhingran *et al.*, 1969) and the counts, expressed as number/litre of water. The sediment samples collected twice during the experimental period i.e. prior to stocking and after final harvest were analysed for pH, organic-carbon and available phosphorus.

Results and discussion

The ranges and mean values of different water quality parameters in the six experimental ponds are presented in Table 1. Among the parameters studied, the water temperature, pH, total alkalinity, total hardness and free carbon dioxide concentrations did not show any marked variations in their values between the different treatments and also between different days of samplings.

TABLE 1. *Variations in water quality parameters and sediment characteristics in different treatment ponds*

Parameter	Treatment I		Treatment II		Treatment III	
	P-1	P-2	P-3	P-4	P-5	P-6
Water						
Water temperature (°C)	19.0-32.5 (26.0)	19.0-32.5 (26.0)	19.0-32.5 (26.0)	19.0-32.5 (26.0)	19.0-32.5 (26.0)	19.0-32.5 (26.0)
pH	7.27-7.90 (7.56)	7.25-8.15 (7.61)	7.14-8.28 (7.63)	7.36-8.25 (7.68)	7.21-8.16 (7.56)	7.23-8.31 (7.56)
Dissolved oxygen (mg/l)	2.4-6.9 (3.9)	2.6-5.9 (4.1)	2.0-6.2 (3.7)	2.0-6.7 (3.7)	1.7-6.8 (3.4)	1.8-5.3 (3.3)
Free carbon dioxide (mg/l)	Tr.-12 (6.8)	Tr.-12 (6.9)	Tr.-12 (7.2)	Tr.-10 (7.3)	Tr.-12 (8.3)	Tr.-12 (8.0)
Total alkalinity (mg $CaCO_3$/l)	72-120 (92.3)	68-112 (91.7)	64-136 (97.2)	64-128 (93.7)	64-156 (94.4)	64-128 (91.5)
Total hardness (mg $CaCO_3$/l)	56-112 (79.1)	56-100 (79.4)	60-108 (81.8)	60-96 (78.3)	60-104 (82.5)	52-112 (77.7)
Ammonium-nitrogen (mg/l)	0.08-0.31 (0.18)	0.06-0.26 (0.16)	0.04-0.41 (0.20)	0.04-0.39 (0.21)	0.10-0.53 (0.29)	0.04-0.47 (0.28)
Nitrate-nitrogen (mg/l)	0.025-0.081 (0.31)	0.028-0.123 (0.34)	0.027-0.201 (0.39)	0.025-0.135 (0.42)	0.027-0.182 (0.51)	0.026-0.297 (0.52)
Phosphate-phosphorus (mg/l)	0.08-0.43 (0.28)	0.014-0.48 (0.28)	0.5-0.42 (0.30)	0.11-0.41 (0.29)	0.14-0.44 (0.29)	0.18-0.54 (0.33)
Total plankton counts (Numbers/l)	4.81×10^2-3.76×10^3 (1.65×10^3)	8.14×10^2-3.99×10^3 (1.79×10^3)	5.24×10^2-4.75×10^3 (1.77×10^3)	4.93×10^2-6.66×10^3 (2.26×10^3)	5.16×10^2-4.90×10^3 (1.91×10^3)	8.66×10^2-4.60×10^3 (2.28×10^3)
Sediment						
pH	6.56-6.68 (6.65)	6.97-7.05 (7.01)	6.38-6.53 (6.46)	6.56-6.72 (6.46)	6.79-6.83 (6.81)	6.59-6.81 (6.70)
Organic carbon (%)	0.59-0.68 (0.64)	0.66-0.75 (0.71)	0.58-0.69 (0.63)	0.73-0.92 (0.83)	0.73-0.89 (0.81)	0.62-0.82 (0.72)
Available phosphorus (mg P_2O_5-P/100 g soil)	2.37-2.52 (2.45)	1.96-2.05 (2.00)	2.15-2.36 (2.26)	2.32-2.37 (2.35)	2.65-3.02 (2.84)	2.35-2.48 (2.42)

The dissolved oxygen concentration did not show any appreciable difference between the treatments during the initial period of culture. However, the values showed an inverse relationship with the stocking densities during the latter part of the culture period, attributable to lower demand of oxygen for their respiration at lower densities and *vice-versa.* The concentration, in general, showed a decreasing trend with the progress of the rearing period with the values lying in the range of 1.7-6.9 mg/l in different treatment ponds. Similar trends in dissolved oxygen levels were also reported by Mohanty (1995) and Jena *et al.* (1998) during raising of carp seed at different densities.

The inorganic nutrients in the form of ammonium-nitrogen, nitrate-nitrogen and nitrite-nitrogen values recorded during the present study were found to be within optimum ranges (Banerjea, 1967; Boyd and Pillai, 1984; Mohanty, 1995; Jana and De, 1988). Marked variations in ammonia, nitrite and nitrate contents were observed among different treatments, with higher values recorded in Treatment III with highest density, followed by Treatments II and I. The concentrations of all the three inorganic forms of nitrogen, in general, were low during the initial period of experiment and found to be increasing with the progress of the experimental duration attributed to the periodical application of both organic and inorganic fertilisers at every fortnightly intervals. Further, higher concentration of both the nutrients in ponds with higher densities are attributable to mineralisation of increased metabolities obtained from higher fish biomass at increased densities. However, no distinct variations were observed in the P_2O_5-P contents among different treatment ponds and also at different days of samplings within the treatments. Banerjea (1967) found maximum fish production under pond conditions with a range of 0.01 to 0.1 ppm phosphate-phosphorus in water. Comparatively high values of 0.05-0.54 mg/l were recorded during the present investigation. These were in line with the results obtained by Lakshmanan *et al.* (1971) and Sinha *et al.* (1973) who recorded values in the range of 0.04-4.2 ppm and 0.12-1.2 ppm respectively under different carp culture experiments.

The pond sediment were acidic to neutral in reaction in most of the ponds which was found to be within optimum range. The organic carbon (0.52- 0.92%) and available phosphorus (1.96-3.02 mg P_2O_5-P/100g soil) levels were lower than the optimum values (Banerjea, 1967; Sreenivasan, 1967), showing low productivity of the ponds. The organic carbon content in general showed higher values during final samplings, possibly due to the deposition of organic matter added in the form of intermediate fertilisation with cowdung and resultant metabolite deposition.

The quantitative estimation of plankton did not show any marked trend in their cell counts between the treatments as also different periods of sampling during the culture period. The plankton counts were low during the initial months of culture in all the treatment ponds and showed maximum concentration during summer months (May-June). The percentage contribution of plankton counts showed that phytoplankton was dominating in most of the samplings in all the treatment ponds and their contribution ranged from 46.5% to 87.3% in different periods of samplings.

As hypothesised growth of all the species decreased with increase in stocking densities, with ponds having highest stocking density of 6000/ha (Treatment III) yielding minimum absolute growth of fish species and *vice-versa.* The mean size of harvest recorded in Treatments I, II and III were 1035 g, 725 g and 550 g respectively, showing significant differences in growth levels between the three treatments (F = 29.14, P <0.05). While the mean growth levels in Treatment I were significantly higher than those of Treatment II (CD = 205.0, P < 0.05) and Treatment III (CD = 376.3, P < 0.01), no significant difference was observed between Treatment II & III (CD = 205.0, P > 0.05). The growth performance of different species recorded at monthly interval show higher growth rates in the initial months of culture period. Working at three different stocking densities of 4450, 5000 and 6250/ha, Lakshmanan *et al.* (1971) recorded similar growth trends in seven important carp species *viz.* catla, rohu, mrigal, silver carp, grass carp, common carp and kalbasu. The reduction in growth levels with increasing stocking densities was also experienced during raising fry and fingerlings of carps (Mohanty, 1995; Jena *et al.*, 1996,1998). Similar poor growth levels with increase in stocking density was also reported in other fishes like rainbow trout, *Salmo gairdneri* (Trzebiatowski *et al.*, 1980); blue gourami, *Trichogaster trichopterus* (Degani, 1991) and Atlanic halibut, *Hippoglossus hippoglossus* (Bjoernsson, 1994).

Among the six species of carps, silver carp showed maximal growth rates followed by catla, common carp, grass carp, mrigal and rohu in Treatment I, with a stocking density of 2000/ha. Similar observations were recorded in Treatment II and Treatment III with regard to growth of silver carp (Table 2). However, growth of catla in these treatments was lower than those of common carp and grass carp, with rohu registering lowest growth rates as in case of Treatment I. In general. exotic carp species showed higher growth rates than those of Indian major carps in all the treatments. Similar observations of higher growth rates in case of Chinese carps over Indian major carps were reported by Chaudhuri *et al.* (1974,1975,1978), Sukumaran *et al.* (1972), Sinha and Gupta (1975) and Sinha and Saha (1980).

The mean survival levels were high in all the treatments under experimentation, with highest survival recorded in Treatment 1(87.5%) followed by Treatment 111(83.3%) and Treatment 11(82.4%). Though the survival levels showed a decreasing trend with increasing stocking density, the statistical evaluation did not show significant differences between the treatments (F = 1.36, P > 0.05). No significant differences between the treatments with varied densities indicated that the highest stocking density tried in the present experiment also did not cause much stress to the fishes resulting in higher survival. Experimenting with stocking densities of 4450 to 6250/ha Lakshmanan *et al.* (1971) achieved survival levels ranging from 74.3 to 88.8%. Similar survival levels of carp species were also reported by Chaudhuri *et al.* (1975) and Sinha and Saha (1980).

Among the species cultured, the contribution of silver carp was maximum ranging from 23.1 - 27.7% in all the treatments, even when stocked at 15% level. Similar results have also been reported by Sinha *et al.* (1973) and Das *et al.* (1975) in experiments conducted with both Indian major carps and exotic carp species. Sinha and Saha (1980) reported silver carp contributing as much as 2.5 times of its stocked ratio in the total production. Among the three Indian major carp species, the contribution of catla was maximum, ranging from 18.6 to 22.8% of the total harvested biomass, when stocked at 20% level. Das *et al.* (1977, 1980) and Sinha and Saha (1980) also reported similar results with higher production of catla than the other two Indian major carp species. Stocked at 25 and 20% levels, the contributions of rohu and mrigal to the total production were 12.1 - 19.2% and 11.7 - 16.7% respectively. Even at the stocking level of 35%, the three exotic carp species combinely contributed as

TABLE 2. *Stocking and harvesting details of different carp species in the experimental ponds*

Treatment	Pond	Species	Biomass stocked (kg)	Survival (%)	Mean size of harvest (g)	Biomass harvested (kg)	Contribution by weight (%)
Treatment I	P-1	Catla	0.16	100.00	1130	18.1	22.7
		Rohu	0.085	95.0	755	14.3	18.0
		Mrigal	0.06	75.0	775	9.3	11.7
		Silver carp	0.06	91.7	1965	21.6	27.1
		Grass carp	0.05	100.0	1100	4.3	5.4
		Common carp	0.055	83.3	1200	12.0	15.1
		Total	0.470	90.0	1105	79.6	100.0
	P-2	Catla	0.16	93.8	1000	14.95	22.8
		Rohu	0.085	80.0	715	11.45	17.5
		Mrigal	0.06	68.8	760	8.35	12.7
		Silver carp	0.06	91.7	1480	16.3	24.8
		Grass carp	0.05	75.0	870	2.6	4.0
		Common carp	0.055	100.0	995	11.95	18.2
		Total	0.470	85.0	965	65.60	100.0
Treatment II	P-3	Catla	0.32	87.5	640	17.9	18.8
		Rohu	0.17	85.0	540	18.3	19.2
		Mrigal	0.12	84.4	560	15.1	15.8
		Silver carp	0.12	87.5	1130	23.7	24.8
		Grass carp	0.10	75.0	935	5.6	5.9
		Common carp	0.11	79.2	780	14.8	15.5
		Total	0.94	84.4	707	95.4	100.0
	P-4	Catla	0.32	96.9	625	19.0	20.2
		Rohu	0.17	65.0	540	14.0	14.9
		Mrigal	0.12	81.2	600	15.65	16.7
		Silver carp	0.12	75.0	1445	26.0	27.7
		Grass carp	0.10	75.0	750	4.55	4.8
		Common carp	0.11	83.3	740	14.8	15.7
		Total	0.94	79.3	740	94.0	100.0
Treatment III	P-5	Catla	0.48	91.6	490	21.55	20.2
		Rohu	0.225	66.6	320	12.9	12.1
		Mrigal	0.18	81.3	410	16.1	15.1
		Silver carp	0.18	86.1	790	24.55	23.1
		Grass carp	0.15	91.7	455	5.0	4.7
		Common carp	0.165	86.1	850	26.35	24.8
		Total	1.410	85.5	517	106.45	100.0
	P-6	Catla	0.48	95.8	455	21.0	18.6
		Rohu	0.225	71.7	430	18.5	16.4
		Mrigal	0.18	66.7	550	17.6	15.6
		Silver carp	0.18	91.7	875	28.85	25.6
		Grass carp	o.15	83.3	580	5.8	5.1
		Common carp	0.165	83.3	700	21.1	18.7
		Total	1.410	80.8	582	112.85	100.0

much as 47.3, 46.7 and 50.0% of the biomass harvested in Treatments I, II and III respectively.

The biomass production showed a direct relationship with the stocking density, with maximum value recorded in Treatment III carrying the highest density of 6000/ha, with the mean gross and net production levels being 109.65 kg/pond and 108.25 kg/pond, estimated as 2741 kg/ha and 2706 kg/ha respectively during the culture period of 11 months (Table 3). The corresponding estimated production levels shown in Treatments II and I were 2367.5 kg/ha & 2342.5 kg/ha, and 1815.0 kg/ha & 1802.5 kg/ha respectively during the same period. While the mean biomass production in Treatment II was significantly higher over Treatment I (F = 1745, CD = 20.07, P < 0.05) and Treatment III over Treatment I (CD = 32.69, P < 0 01). No significant difference was recorded between Treatments I & III (CD = 20.07, P>0.05).

The feed conversion ratio (FCR) in experimental ponds showed lower values in Treatment I (2.69) than the other two treatments. The FCR values showed a marginal increase with the increase in stocking densities, recording the mean values of 2.80 and 2.82 in Treatments II and III, respectively. However, the FCR values did not show significant differences between the Treatments (F = 0.02, P > 0.05) in spite of the increased provision of supplementary feed in treatments with higher stocking densities.

The mean FCR values ranging from 2.69-2.82 in different Treatments under the present investigation are comparable to the FCR values of 2.3 - 3.3 reported by Das *et al.* (1977). However, while Das *et al.* (1975) recorded a low FCR value of 1.9, Sinha and Saha (1980) reported higher FCR value of 3.9 even with commercial fish feeds.

TABLE 3. *Variations in growth, survival, biomass production and feed conversion ratios of different treatments*

Treatment	Pond	Mean growth(g) *	Mean survival(%) *	Gross prod./ pond (kg) *	Net prod./ pond(kg) *	Gross prod./ha (kg) *	Net Prod./ha (kg)	Feed provided (kg)	FCR *
Treatment I	P1	1105	90.0	79.6	79.1	1990.0	1979.5	194	2.45
	P2	965	85.0	65.5	65.1	1640.0	1627.5	194	2.98
Treatment II	P3	707	84.4	95.4	94.4	2385.0	2360.0	262	2.78
	P4	740	79.3	94.0	93.0	2350.0	2325.0	262	2.87
	Mean	724[b]	81.85[a]	94.7[a]	93.7[a]	2367.5	2342.5	262	2.87[a]
Treatment III	P5	517	85.8	106.45	105.05	2661.25	2626.25	305	2.90
	P6	582	80.8	112.85	111.45	2821.25	2786.25	305	2.74
	Mean	550[b]	83.3[a]	109.65[a]	108.25[a]	2741.25	2706.25	305	2.82[a]

Mean bearing different superscripts differ significantly in a column; *P<0.05

The technology of composite carp culture with six carp species has made it possible to raise the productivity of ponds and tanks and ultimately increasing the production many folds during last two to three decades in different parts of the country. Initial experiments conducted at the Pond Culture Division of CIFRI during 1963 to 1968 showed production levels of 2234-4210 kg/ha/yr (average 3083 kg/ha/yr) with combinations of Indian and exotic carps (Jhingran, 1991). Further, experiments conducted at different centres of the All India Co-ordinated Research Project on Composite Culture and Fish Seed Production have demonstrated production levels of 3393 to 6053 kg/ha/yr at Kalyani centre of West Bengal (Sinha, 1978), 3535 to 4648 kg/ha/yr at Badampudi centre of Andhra Pradesh (Rao, 1978), 1504-3526 kg/ha/yr at Ranchi centre of Bihar (Kamal, 1978) and around 3000 kg/ha/yr in centre of Tamil Nadu (Krishnamurty, 1978). The production levels obtained during the present investigations at three different stocking densities were comparable with those recorded by earlier workers (Lakshmanan *et al.*, 1971; Kamal 1978). The results suggested that in spite of reduction in growth and survival level of different species, the fish production increased with increase in stocking densities up to 6000/ha thus providing scope for further increase in production levels at higher densities.

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