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EFFECT OF STOCKING DENSITY ON GROWTH AND SURVIVAL OF THE JUVENILE CRESCENT PERCH, *THERAPON JARBUA* (FORSSKAL 1775) REARED IN SEAWATER TANKS

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ABSTRACT

Increase in stocking density of fish is one way to optimize productivity in intensive rearing system. However, high rearing density is a potential source of stress that may constrain fish growth. In order to investigate this detrimental effect on growth and survival, the juveniles of *Therapon jarbua* were studied under various stocking densities. Five groups of juveniles of *T. jarbua* (mean initial weight 3.1±0.07 g and total length 13.1±0.1 mm) were reared in seawater tanks of 0.06 m^3 at different densities (10, 20, 30, 40 and 50 fish) for 45 days. The juveniles were fed three times a day with a compound diet of 40% protein. Differences in food consumption, mean body weight gain and survival rate of the stocking groups were found throughout the experimental period. At highest density (50-fish/0.06 m^3) fishes showed the lowest growth and survival rates with low feed conversion efficiency. Maximum growth rate (4.49 g/fish/day) was obtained at the optimum stocking density of 39 juveniles per 0.06 m^3. Statistical analysis showed that the growth rate was a quadratic function of stocking density: $\hat{G} = 1.1733212 + 0.0025563\ D - 0.0005260\ D^2$, while the estimated survival rate showed a linear model of $\hat{S} = 0.5108531 - 0.0042239\ D$, indicating that the survival rate was negatively proportional to the stocking density. Feeding cost for optimum stocking density (39 fish/0.06 m^3) at feeding rate of 2% wet body weight gives a cost of Rs. 48.00 per kg biomass.

Key-words: Biological study, rearing of crescent perch, growth and survival

INTRODUCTION

The crescent perch *Therapon jarbua* (Theraponidae) (Forsskal 1775) is widely distributed in the Indo-west Pacific, from Red Sea to Southeast Asia and north to southern Japan (Talwar & Jhingran 1991). It is reported to attain a length of 25 cm in coastal waters of Pakistan (northern Arabian Sea) and moves to considerable distances upstream into freshwaters (Bianchi 1985). Although it is a very robust and hardy fish for brackish aquaria, there is no interest in its fisheries even in inland waters (Anon. 1992). Its low protein requirement, good growth rate and wide temperature tolerance makes it sustainable for aquaculture practices (Rajaguru & Ramachandran 2001, Rajaguru 2002a,b). In Pakistan, culture of *T. jarbua* may reduce the pressure on under-sized fishing of edible species, being caught illegally with small-meshed nets for fishmeal. As a result, aquaculture of *T. jarbua* will increase chances for juveniles of edible fish to attain full adult size (Abbas & Siddiqui 2001).

With regard to proper aquaculture management, stocking density plays a predominant role in influencing growth and survival of reared stocks. The growth, survival and even breeding of fish in captivity is also affected by water temperature which is known as an important abiotic factor (Jobling 1985, Jobling & Reinsnes 1986, Jobling *et al.* 1989, Jobling 1994, Jobling *et al*. 1998a,b, Satpathy *et al.* 1986, Hansen *et al*. 1993, Welch *et al.* 1998, Sigholt *et al.* 1998, Graynoth & Taylor 2000, Yamamoto *et al*. 2003, Van Ham *et al.* 2003, Golombieski *et al.* 2003, Imsland *et al.* 2003). Knowledge of temperature tolerance of fish is of great significance in assessing fish sustainability in aquaculture operation. A number of recent studies on temperature tolerance of some estuarine fishes have suggested that *Etroplus suratensis*, *Ambassis commersoni* and *T. jarbua* in tropical waters might be well suited for aquaculture because of their good temperature tolerance (Rajaguru & Ramachandran 2001, Rajaguru 2002a,b). But none of these species have ever been artificially propagated. There has been no quantitative report evaluating the effects of stocking density on growth and survival rates of these fishes. The present study was therefore planned to investigate growth and survival of juveniles of *T. jarbua* under various stocking densities to determine an optimal stocking level for this fish under laboratory conditions.

MATERIALS AND METHODS

Fish:

Juveniles of *T. jarbua* were collected from Sandspit backwaters near mangrove swamps by using a beam-trawl (length 1.75 m; width 1.15 m; 3 mm mesh). Juveniles were initially placed in an indoor plastic tank (500 litres) in laboratory for acclimation for seven days. During this period, the tank was supplied with aerated seawater at a stocking density of 300 fish. Fish were fed a 0.5 to 1% wet body weight daily ration. Feeding was discontinued 48 hours before transfer into the experimental tanks. Faeces and other particulate matter that settled on the bottom of the tanks were removed daily.

Experimental set-up:

The experimental circular plastic tanks (0.06 m^3 each) were illuminated with two white fluorescent tube lights (40-watt), so as to provide natural hours of light and dark cycles (sunrise: 0700 a.m.±5 min; sunset: 1800 p.m.±5 min). Each tank was aerated and half of the seawater changed daily. Ten, twenty, thirty, fourty and fifty fishes (mean initial body weight 3.1±0.07 g and total length 13.1±0.15 mm) were transferred into five separate tanks designated as group I, II, III, IV and V, respectively for quantitative study. Prior to the transfer, each fish was weighed, measured and distributed among the tanks. Each fish was weighed to the nearest 0.1 g and total length measured to the nearest 1 mm. Weight and total length of each individual fish was taken fortnightly. Water quality parameters were monitored daily utilizing modern techniques available. The tanks were checked daily for mortalities.

Diet:

A test-diet (Table I) was formulated on dry matter basis (g/100 g) in one batch containing 40% protein as described by Abbas (2002). The prepared pellets were stored in polythene bags at –10^{o}C. The diet was analyzed and gross energy value was calculated according to AOAC (2000).

Feeding regime:

During the experiment, fish were fed by hand at a ration of 2% of wet body weight (Abbas 1999), thrice a day, at 10.00, 13.00 and 16.00 hours for a period of 7 days. The amount of daily food was adjusted fortnightly. Feeding behaviour of juvenile fish was observed and recorded immediately after each group was fed. After one hour of each meal, the amount of uneaten diet was siphoned and weighed so as to determine the total consumption of the experimental diet. The fish were not fed before harvesting; they were collected and individual weights and total lengths noted to determine the net yield.

Calculation:

Performance of *T. jarbua* juveniles was evaluated by the following formulae:

1. Specific growth rate (SGR) = ln final body weight – ln initial body weight / duration of the experiment (days)
2. Survival rate (S) = number of fish surviving on last day / number of fish initially stocked
3. Gross feed conversion efficiency (GFCE) = weight gained / feed consumed
4. Weight gain (WG) = final body weight – initial body weight / initial body weight
5. *Statistical analysis:*
6. A multiple regression model (Daniel 1978) was applied to the experimental system as:

$$Y = \beta_o + \beta_1X^1 + \beta_2X^2 + \beta_3X^3 + \beta_4X^4 + \beta_5X^5$$

Where, X = Stocking density, Y = Growth rate or survival rate, β_o = Intercept on Y-axis and β_1, β_2, β_3, β_4 and β_5 = Regression coefficients.

2. Length-weight relationship was estimated by the exponential equation as:
$W = a L^b$. Where, a and b are regression constants (Zar 1996).

RESULTS

Water quality:

Water temperature did not vary more than one degree among replicates throughout the 45-day study period; ranging from 13.2 to 33.4^{o}C; mean 26.5^{o}C. Salinity of the tank water remained uniform 34.5$^o/_{oo}$. No statistically significant difference (P>0.05) was observed in dissolved oxygen (DO) concentration (4.9 to 5.9 ml/l) of seawater in each experimental tank. Significant changes in DO were observed in experimental tank IV (P<0.05), DO concentration was reduced to 4.4 ml/l and 4.0 ml/l in tanks IV and V, respectively. There was no significant effect of introduced feed on pH of seawater in each tank. The pH values ranged between 6.6 and 8.3.

Growth and survival rates:

Highest specific growth rate (SGR) of fish (Table II) was observed in-group III (4.49 g/fish/day) which was significantly different from other density groups (I, II, IV and V). The exact optimum level estimated from the lack of best fit to specific growth rate is 39-fish/0.06 m^3 (Fig. 1A). This shows that growth rate of *T. jarbua* is a quadratic function of stocking density as described by equation $\hat{G} = 1.1733212 + 0.0025563\,D - 0.0005260\,D^2$, where $\hat{G}$ is an expected growth rate and D is stocking density. The estimated survival rate with respect to linear polynomial regression $\hat{S} = 0.5108531 - 0.0042239\,D$ (where $\hat{S}$ is expected survival rate and D is stocking density) indicated best linearity between survival rate and stocking density (Fig. 1B). The analysis of variance (ANOVA) in growth and survival rates, as influenced by stocking density, is significant ($P < 0.025$; Table III).

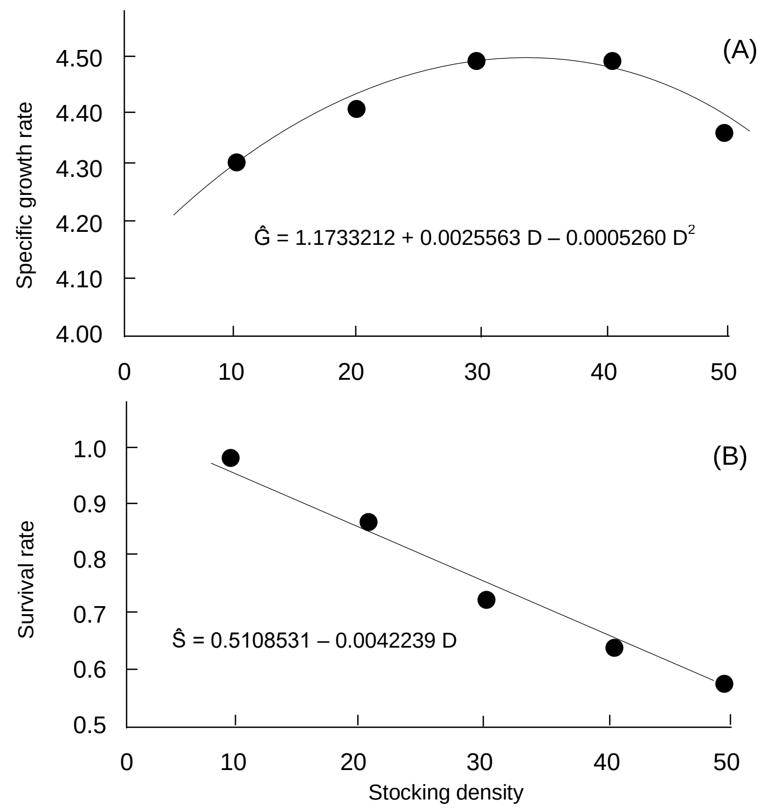

Fig. 1. Estimated specific growth rate (A) and survival rate (B) of *T. jarbua* at varied stocking densities. The round signs indicate average experimental data points.

Feeding behaviour, feed consumption and net yield:

The feeding behaviour of the juveniles of *T. jarbua* was carefully observed. Juveniles eagerly grasped the formulated diet pellets and engulfed them immediately. The weight of feed consumed in each experimental tank increased with stocking density (Table II). Gross feed conversion efficiency (GFCE) of fish in-groups I and II was significantly different ($P < 0.05$) from groups III, IV and V (Table II). The net yield ranged from 226 g (group I) to 1010 g (group V) per 45 days experimental period. However, mean fish body weight gain and total length decreased ($P < 0.05$) in-groups IV and V having high stocking densities. In-groups I, II and III cost estimates were significantly different ($P < 0.05$) from groups IV and V.

DISCUSSION

In the present study, *T. jarbua* juveniles fed with diet containing 40% crude protein at a daily ration of 2% wet body weight showed an appreciable increase in net yield with increased stocking density. Stocking group III had maximum ($P < 0.05$) SGR values, which was significantly different from groups I, II, IV and V. On the basis of maximum SGR produced, the optimum stocking density was 39-fish/0.06 m^3 (305 fish/m^3). As density level was above 39-fish/0.06 m^3 (groups IV and V), mean fish body weight, GFCE and SGR along with DO concentration and pH values decreased significantly ($P<0.05$). This indicates that high rearing density is a potential source of stress on fish survival, growth rates and feed conversion (Papoutsoglou *et al*. 1979, 1980, 1987, Gatlin *et al*. 1986, Vijayan & Leatherland 1988, Kjartansson *et al.* 1988, Holm *et al*. 1990, Pickering 1993, Ross & Watten 1998, Lefrancois *et al*. 2001, Raune *et al.* 2002, EI-Sayed 2002, Boujard *et al*. 2002). Acute and chronic stresses trigger a series of defense mechanism that are generally energy demanding and therefore induce an elevation of the animal metabolic rate (Barton & Iwama 1991) which causes growth depletion (Vijayan & Leatherland, 1988, Jorgensen *et al*. 1993).

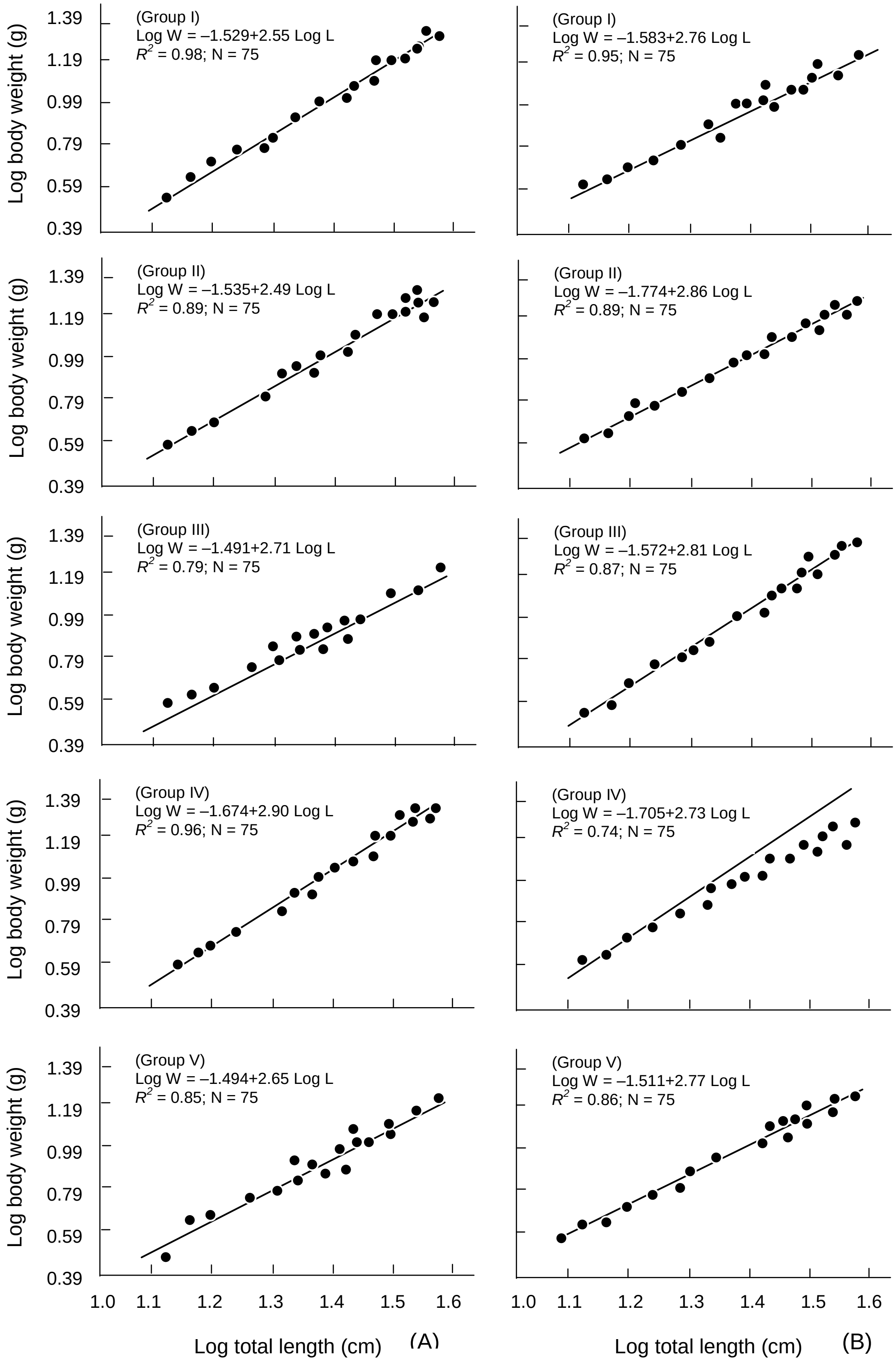

Fig. 2. Length-weight relationship of *T. jarbua* juvenile at stocking (A) and harvest (B).

Table 1. Formulation and chemical analysis of the test diet.

	Quantity in diet (g/100 g dry matter)
Ingredients	
Fish meal	25.0
Soybean meal	20.0
Liver meal	7.5
Tapioca flour	9.0
Wheat flour	15.0
Lupin seed meal	7.5
Blood meal (ring dried)	5.0
Fish oil	5.0
Vitamin and mineral premix[1]	5.0
DL-methionine	0.5
L-lysine	0.5
Proximate analysis (dry matter basis %; mean ± S.E., n = 5)	
Moisture	10.3±1.2
Crude protein (N × 6.25)	38.9±1.0
Carbohydrates (NFE)[2]	18.5±0.8
Crude lipid	11.4±0.5
Ash	13.7±0.9
Crude fiber	5.8±1.1
Gross energy (kJ/g)	20.9±1.4
Cost of feed per kg (Rs.)	48.00

[1]In g/100 g of vitamins and mineral mixture: Ascorbic acid, 15.36; inositol, 39.5; vitamin A, 1.0; choline chloride, 3.5; vitamin D3, 7.5; vitamin E, 5.5; vitamin K, 0.03; vitamin B12, 0.006; riboflavin, 1.5; thiamin, 1.0; calcium, 1.25; phosphorus, 3.5; magnesium, 2.5; copper, 1.0; zinc, 1.0; manganese, 2.0; iodine, 2.0; iron, 1.0; phospholipids, 3.5; nicotinic acid, 4.3; sodium, 1.0; biotin, 0.35; folic acid, 0.4; pyridoxine, 1.3.
[2]NFE = nitrogen free extract [carbohydrate content = 100 - (% protein + % fat + % ash + % fiber)].

Table 2. Mean stocking weight, total ration fed and its consumption, specific growth rate, gross feed conversion efficiency, survival rate, net yield and feed cost of Therapon jarbua at varied stocking densities.

Stocking density group (number of fish per tank)	Mean stocking weight (g)	Total ration fed per 45 days (g)	Total feed consumption per 45 days (g)	Specific growth rate (SGR) (gram per fish per day)	Gross feed conversion efficiency (GFCE)	Survival rate	Net yield (g per 45 days)	Feed cost (Rs)
I = 10	3.2 ± 0.5[a]	192.0	154.5	4.33 ± 0.1[a]	0.0390 ± 0.5[a]	1.00	226.0	45.03
II = 20	3.3 ± 0.4[a]	401.3	383.0	4.35 ± 0.6[a]	0.0159 ± 0.5[a]	0.98	472.5	45.01
III = 30	3.1 ± 0.8[a]	589.4	544.1	4.49 ± 0.2[b]	1.0120 ± 0.3[b]	0.97	702.0	44.49
IV = 40	2.8 ± 0.5[a]	740.0	727.6	4.38 ± 0.3[a]	0.0085 ± 0.3[b]	0.54	824.5	47.57
V = 50	3.2 ± 0.6[a]	999.5	906.5	4.09 ± 0.3[a]	0.0058 ± 0.5[b]	0.52	1010.0	52.45

Values are means ± S.E. of two replicates. Means in each column having the same superscript are not significantly different at the 5% level of Scheffe's multiple range test.

Table 3. Analysis of variance on growth, survival, pH and dissolved oxygen (DO) concentration influenced by stocking density

Source of variation	Degrees of freedom (*d.f.*)	Sum of squares	Mean squares	*F*-ratio	*P*-value
ANOVA on growth and survival rates affected by stocking density					
Growth rate					
Total	15 - 1 = 14	1.2664			
Stocking density	5 - 1 = 4	0.7494	0.1874	3.62	0.1 < *P* < 0.05
Random error	10	0.5170	0.0517		
Survival rate					
Total	15 - 1 = 14	1.2998			
Stocking density	5 - 1 = 4	0.7768	0.1942	3.71	0.1 < *P* < 0.05
Random error	10	0.5230	0.0523		
Sequential test of polynomial stocking density effects on growth and survival rates					
Growth rate[1]					
Stocking density	5 - 1 = 4	0.7494	0.1874	3.62	0.1<*P*<0.05
Linear	1	0.1033	0.1033	1.99	0.1<*P*< 0.25
Deviation from linear	3	0.0225	0.0075	0.15	*P*>0.25
Quadratic	1	0.0038	0.0038	0.07	*P*>0.25
Deviation from linear and quadratic	1	0.0010	0.0010	0.02	*P*>>0.25
Survival rate[2]					
Stocking density	5 - 1 = 4	0.7768	0.1942	3.71	0.1<*P*<0.05
Linear	1	0.1032	0.1032	1.97	0.1<*P*<0.25
Deviation from linear	3	0.0262	0.0087	0.17	*P*> 0.25
ANOVA on pH affected by stocking density					
Total	200 - 1 = 199	3.6912			
Stocking density	5 - 1 = 4	1.2288	0.3072	7.55	P < 0.0001
Tank	10 - 1 = 9	0.3662	0.0407		
Period[3]	20 - 1 = 19	1.5521	0.0817	204.25	P < 0.0001
Stocking density × Period	76	0.5112	0.0067	16.75	P < 0.0001
Random error	91	0.0328	0.0004		
ANOVA on DO affected by stocking density					
Total	200 - 1 = 199	30.7211			
Stocking density	5 - 1 = 4	9.7767	2.4442	33.11	*P*<0.0001

Tank	10 - 1 = 9	0.6644	0.0738		
Period[3]	20 - 1 = 19	18.7439	0.9865	448.41	$P<0.0001$
Stocking density × Period	76	1.3318	0.0175	7.95	$P<0.0001$
Random error	91	0.2043	0.0022		

[1]Mean standard error = 0.0517 (with 10 *d.f.*) is the divisor for *F*-ratios.

[2]Mean standard error = 0.0523 (with 10 *d.f.*) is the divisor for *F*-ratios.

[3]Twenty repeated pH and dissolved oxygen measurements for each tank during the 45-day period.

Despite this stress, in maximization of yield of cultured fish, a number of other factors are directly related to the stocking density, such as, the water quality, production system, type and size of the rearing tanks, water exchange rate, size of the fish and quantity of the ration (Brett & Groves 1979, Pickering & Pottinger 1987, Björnsson 1994). Of these, water temperature is one of the most important abiotic factors affecting growth and survival of fish in captivity (Odum 1983, Rajaguru 2002a,b). Evidenve to support this fact is available in other studies of Van Ham *et al.* (2003) and Golombieski *et al.* (2003). According to them, higher temperature (32^{o}C) rather than lower (16^{o}C) have negative effects on growth, survival, feed conversion, body composition and nutrient retention of juvenile turbot and catfish under high stocking densities. The present communication indicates that the expected growth rate for 45-day period at stocking density of 39-fish per 0.06 m^3 is based on the temperature of 26.5^{o}C. A possible explanation for this is the fact that the growth performance of experimental fish in each group was near ideal (mean length exponent b=2.66; Fig. 2) and was not significantly different from ideal slop (b=3) (Wootton 1990). This indicates that fish stocked at the start and at the end of the experiment were normal and healthy (Abbas 1999).

Net yield in farming systems is described as a summation of individual weight gain of all reared organism, or a cross product of the number of surviving organisms and their mean weight gain (Allen *et al*. 1984). It means that survival and growth rates have significant effects on yield, which in turn affect total revenue. In the present study, net yield of each group (I-V) increased significantly ($P<0.05$). However, mean fish weight gain fell down significantly ($P<0.05$) with increase in fish density in tanks. In-groups IV and V, this decline may reflect fish response in reducing their food intake and increased DO. This results in impaired growth rates and feed conversion efficiencies (Cui & Wootton 1988, Holm *et al.* 1990, Russell & Wootton 1992, Strubbe 1994, Wang *et al.* 1998). Despite this, specific daily ration of fish is related to the economics of aquaculture production, as feed constitutes a major expense in fish cultivation (FitzGerald 1988). Generally, taking into consideration the relationship betweenbiological and economical data of the present work, at optimum stocking density the cost would be minimum. Increase beyond optimum stocking density will decrease the growth rate of *T. jarbua* juveniles and increase the cost.

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