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Journal of Institute of Science and Technology

Volume 22, Issue 2, January 2018

ISSN: 2469-9062 (print), 2467-9240 (e)

JIST, **22** (2): 92-102 (2018)

Published by:

Institute of Science and Technology

Tribhuvan University

Kirtipur, Kathmandu, Nepal

JIST 2018, 22 (2): 92-102
ISSN: 2469-9062 (p), 2467-9240 (e)

Research Article

EFFECTS OF ALTERNATIVE FISH SPECIES *AMBLYPHARYNGODON MOLA* FOR TRADITIONAL CARP POLYCULTURE IN NEPAL

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Received: *22 April, 2017;* ***Revised:*** *5 October, 2017;* ***Accepted:*** *6 November, 2017*

ABSTRACT

To increase the maximum productivity is prime aim in fish aquaculture from past few years. The increase in maximum standing crop of a pond depends upon the wider range of available foods in ecological niches from the selection of complementary species growing together. The present work was conducted in an attempt to identify the suitable fish species combinations among *Hypophthalmichthys molitrix*, *Aristichthys nobilis*, *Ctenopharyngodon idella*, *Cyprinus carpio* with the introduction of *Amblypharyngodon mola* in the prevalent method of fish polyculture system practiced in Nepal. The experiment was conducted for 120 days, in twelve 100 m^2 earthen ponds which comprised the initial growing period of fish. As control, one pond was stocked with a species ratio usually employed in the country; *H. molitrix* (35 %), *A. nobilis* (10 %), *L. rohita* (15 %), *C. mrigala* (10 %), *C. idella*, (5 %) and *C. carpio* (25 %). Treatment 2 was stocked with the *H. molitrix*, *A. nobilis*, *L. rohita* and *C. mrigala*. Treatment 3 was stocked with the *H. molitrix*, *A. nobilis*, *L. rohita*, *C. mrigala* and *C. idella* and Treatment 4 was stocked with the *H. molitrix*, *A. nobilis*, *L. rohita*, *C. mrigala* and *C. idella* and *C. carpio*. Each treatment had three replicates. Carp fishes were stocked with stocking density 15000 ha $^{-1}$ in all treatments. *A. mola* was stocked @ 50000 ha^{-1} in treatments, 2, 3 and 4. No significant correlation was found between the growth rate of fish species and the water quality parameters. The final weight of different species, in different treatments, showed statistical differences. Considering growth parameters, the best result was obtained in treatment 2. A complete exclusion of the *A. mola* in treatment 1 had no advantage over the other treatments; however, the combination of *Hypophthalmichthys molitrix*, *Aristichthys nobilis*, *Labeo rohita* and *Cirrhinus mrigala* allowed the introduction of *A. mola*, with positive effects. In addition, the introduction of *A. mola* in the polycultures tested had no effect over the other carp species.

Keywords: Small indigenous fish species, Phytoplankton, Polyculture, Carps, Growth performance.

INTRODUCTION

Fish polyculture is practiced aiming to increase productivity. Complementary species of fishes can increase the maximum standing crop of a pond by allowing a wider range of available foods and ecological niches (Da silva *et al*., 2006). Fisheries activities are split by policy guidelines into inland aquaculture and natural water fisheries. Aquaculture involves all activities where complete or partial control of the fish production cycle is undertaken (FAO, 2014). The long term goal for fisheries and aquaculture development is to enhance livelihoods through sustainable fisheries and aquaculture technology for food, employment and income (Rai *et al*., 2008). Fishes are considered auspicious and symbolize as sign of fertility, power and prosperity in Nepal (Gurung *et al*., 2003). Fish is acceptable to every segment of the population, but still Nepal has a low per capita consumption compared to neighboring countries despite of the increasing trend of fish production (Rai *et al*., 2008). The per capita consumption of fish per gram per day was 5.39 in 2010/2011 (Environment Statistics of Nepal, 2013). The majority of rural and urban peoples have less access to the fishes in spite of increase in insufficient fish production. So the problem of fish consumption is concerned with the production of fish in national level. There is urgent need of changes in the existing method of fish farming practices as well as of natural water fisheries management that may be problem solving approach. The use of piscicides before stocking of carps in present fish farming system removes almost all indigenous fishes including catfishes and small indigenous fish species (SIS) which were also earlier called as weed fish. The small indigenous fish species (SIS) are generally considered to be those fishes which grow to be length of about 25 cm or 9 inches (Hossain & Afroze, 1991; Felts *et al.,* 1996). The early concept of food competition between large carp species and SIS may be major cause of removal of SIS without of scientific study in Nepalese context and condition of pond polyculture practice. Nepalese women and children suffer from malnutrition of animal source of protein and micronutrients; vitamin A, iron, calcium, phosphorus, zinc etc (MOPH, 2014). The present existing semi-intensive carp polyculture system in Nepal cannot promote to the household fish consumption rapidly. Present trend in fish polyculture system of Nepal shows once carp fingerlings are stocked in the ponds, farmers have to wait for income and family member fish consumption either one or more than one year, till their entire crop is not harvested for the sell purpose. They keep the family members unfed from the fishes and the farmers cannot get short time monetary return from the whole duration of fish culture period.

If Indigenous fish species and carp fishes are cultured together, farmers would have opportunity to harvest small indigenous fishes in short time of stocking. They can fed the family members with small indigenous fishes or will have option for selling them also before of carp as the cash crop. Hence, the semi intensive aquaculture system in which the carp and SIS can be grown together seems to be a new approach in the fish farming sector of Nepal. The carp SIS culture system is cost effective and it gives relatively high fish production per unit area, monetary return etc than the traditional semi intensive fish culture system (Roy, 2004). The carp-SIS fish culture practice may have great potential in rural aquaculture of Nepal. This experiment was basically designed therefore to investigate the suitable combination of carps which can be reared with alternative SIS species *A. mola* in ponds condition of Janakpur.

MATERIALS AND METHOD

Experimental fish species and pond preparation

The carp fishes like silver carp (*Hypophthalmicthys molitrix*), bighead carp (*Aristychthys nobilis*), grass carp (*Ctenopharyngodon idella*), common carp (*Cyprinus carpio*), rohu (*Labeo rohita*) and naini (*Cirrhinus mrigala*) and Mara (*Amblypharyngodon mola*) were used for the experimental fish. Prior to stocking, all the ponds were drained, dried and limed with powdered $CaCO_3$ at a rate of 500 kg ha^{-1}. Ponds were filled up with water up to 1.0 m deep. Ponds were fertilized with semi-decomposed cattle dung, urea and DAP at the rate of 1000, 25 and 25 kg ha^{-1} after one week of liming (Roy, 2004). Fish species were stocked after 7 days of the use of manuring and fertilizer. Re fertilization was adjusted in ponds on the basis of secchi disc reading @ 12.5 kg urea and 25 kg DAP ha^{-1}.

Fish stocking and post stocking management

The silver carp (*H. molitrix*), bighead carp (*A. nobilis*), rohu (*L. rohita*), naini (*C. mrigala*), grass carp (*C. idella*), common carp (*C. carpio*) were stocked @ 15000 fingerlings $ha^{-1}$and Mara (*A. mola*) @ 50000 ha^{-1}. The experiment was conducted in three treatments T2, T3, and T4 and a control (ctrl) T1 for experiment in CRBD (complete randomized block design) method. Three replications were allocated for each treatment of experiment.

The ponds for each treatment and control were allocated randomly. Three replications were allocated for each treatment as p3, p6, p8 for T1 treatment p2, p9, p12 for T2 treatment p4, p5, p11 for T3 treatment and p1, p7, p10 for T4 treatment. Details of carps and SIS stocking in the experiment is shown in table 1.

Out of six different species of carps; silver carp, bighead carp, rohu, naini, grass carp and common carp, only three different combinations of carp fishes were tested in the experiment as follows; treatment 1or control (T1- silver carp, bighead carp, rohu, naini, grass carp and common carp), treatment 2 (T2- silver carp, bighead carp, rohu, naini and mara), treatment 3 (T3- silver carp, bighead carp, rohu, naini, grass carp and mara) and treatment 4 (T4 - silver carp, bighead carp, rohu, naini, grass carp common carp and mara). The details of stocking weight of fingerlings of silver carp, bighead carp, rohu, naini, grass carp, common carp and mara is shown in table 2.

Table 1: Stocking density of carps and *A. mola* (ha $^{-1}$) in treatments of experiment.

Fish species	Treatments			
	T1(ctrl)	**T2**	**T3**	**T4**
silver carp	5200	6400	6000	5200
bighead carp	1500	2600	2200	1500
rohu	2300	3400	3000	2300
naini	1500	2600	2300	1500
grass carp	700	0	1500	700
common carp	3800	0	0	3800
A. mola	0	50000	50000	50000

Supplementary food in the form of mustard oil cake and rice bran (1:2) ratio were provided to standing fishes of pond according to 5 % their body weight. Fertilization with urea, DAP and cattle dung were reused at the rate of 12.5 kg ha $^{-1}$, 12.5 kg ha $^{-1}$ and 375 kg ha $^{-1}$ to maintain natural food in the ponds, respectively according to the secchi disc reading (Roy, 2004). All experimental fishes were harvested by repeated netting and dewatering of the ponds using diesel pumps, the remained fishes were caught by hand picking to determine the yield of fish species. All the harvested fish species were washed, counted, weighed and measured separately to keep the record for assessment of survival rate and production. Net yield was determined by deducting stocked experimental fishes from harvested fishes. The following parameters were used to evaluate the growth of fishes:

Total Weight gain (g) =
Total final weight (g) – Total initial weight (g)

Survival rate (%) =

$$\frac{\text{No.of fish harvested}}{\text{Initial no.of fishes stocked}} \times 100$$

Water quality analysis

Monitoring of water quality parameters such as water temperature, transparency, dissolved Oxygen (DO), pH, total alkalinity and CO_2 was performed every fortnight during the experimental period. Temperature and dissolved Oxygen (DO) were measured by a digital DO meter (YSI, model 58), transparency was measured by using a Secchi disc and pH by a pH meter (Hanna microelectronics), total alkalinity and CO_2 was measured by acid titration method following (Stirling,1985). Temperature (^{0}C), pH, transparency (cm) and DO (mg L^{-1}) were measured directly from the experimental ponds between 0800 and 0900 hrs and other parameters were measured at Water Quality Laboratory of the Fisheries Development and Training Centre and laboratory of Ram Swarup Ram Sagar Multiple Campus, Janakpur.

Economic Analysis

Economic analyses of different treatments were performed on the basis of the expenditure incurred and the total return from the selling price of freshwater carp fishes and SIS. The economic analysis (benefit cost ratio) was carried out on the basis of record of inputs (Food, fertilizer, lime, manure, fingerlings of carps and SIS, labor cost, etc.) and outputs (fish sold, fish consumed, etc) were used during the treatments of experiments. All records of investment and return in Neplese Rupees (N Rs) were kept in the record for further analysis, although the price of carps and SIS depended on their size in local market. The net benefit was calculated by using the following formula:

Net benefit = total income – total variable cost

RESULTS

Growth and production assessment among carp combinations with SIS

The growth and production performance of carp species; silver carp, bighead carp, rohu, naini, grass carp and common carp with *A. mola* in all treatments, T1 (ctrl) and T2, T3, T4 are shown in table 2. Net fish production kg ha^{-1}yr^{-1} of experiment is shown in table 3. Net fish production ha^{-1}yr^{-1} was found in the highest quantity in combination of silver carp, bighead carp, rohu, naini with mara of treatment T2 (4559.4 kg ha^{-1}yr^{-1}). The lowest fish production 3184.9 kg ha^{-1}yr^{-1} was found in combination of carps species silver carp, bighead carp, rohu, naini, grass carp and common carp of treatment T1(ctrl).

Table 2: Growth & production performance of carps & SIS of experiment (Mean±S.E).

Parameters	Treatments			
	T1	T2	T3	T4
Silver carp				
Initial mean wt.(g fish^{-1})	9.2 ± 0.48	9.2 ± 0.33	9.2 ± 0.48	9.2 ± 0.24
Initial total wt. (kg pond^{-1})	0.588 ± 0.01	0.588 ± 0.02	0.552 ± 0.01	0.478 ± 0.01
Final harvesting wt.(g fish^{-1})	110±2.35	134±0.81	132.3±1.18	129±1.69
Final total wt.(kg pond^{-1})	5.2±0.11	7.8±0.01	7.0±0.06	6.1±0.08
Daily weight gain (g^{-1}fish^{-1}day^{-1})	0.8±0.01	1.0±0	1.0±0	0.9±0.01
Net mean fish yield (kg pond^{-1})	4.7±0.11	7.2±0.01	6.4±0.05	5.6±0.08
Survival (%)	91.0 ± 1.04	93.0 ± 1.42	88.3 ± 0.05	91.6 ± 0.52
Net fish yield (kg ha^{-1}yr^{-1})	1438.1±0.11^{b}	2198.2±0.01^{a}	1965.2±0.05^{ab}	1724.6±0.08^{ab}
Bighead carp				
Initial mean wt.(g fish^{-1})	8.7±0.21	8.7 ±0.33	8.7±0.16	8.7±0.21
Initial total wt. (kg pond^{-1})	0.13±0.01	0.23±0.01	0.19±0.01	0.13±0.01
Final harvesting wt.(g fish^{-1})	86±0.81	89±1.69	85.6±1.9	85±1.41
Final total wt.(kg pond^{-1})	1.1±0.02	1.9±0.05	1.5±0.01	0.935±0.01
Daily weight gain (g^{-1}fish^{-1}day^{-1})	0.64±0.0	0.66±0.01	0.64±0.01	0.63±0.01
Net mean fish yield (kg pond^{-1})	0.959±0.03	1.6±0.06	1.3±0.01	0.8±0.01
Survival (%)	84.4 ± 1.81	84.3 ± 1.99	80.3 ± 1.50	73.3 ± 3.14
Net fish yield (kg ha^{-1}yr^{-1})	291.6±0.03	514.1±0.06	389.3±0.01	244.5±0.01
Rohu				
Initial mean wt.(g fish^{-1})	8.0 ± 0.62	10 ± 0.62	10.0 ± 0.23	8.0 ± 0.62
Initial total wt. (kg pond^{-1})	0.23 ± 0.00	0.34 ± 0.00	0.30 ± 0.02	0.23 ± 0.05
Final harvesting wt.(g fish^{-1})	71.6±1.36	86.6±1.9	76.6±1.36	76±0.81
Final total wt.(kg pond^{-1})	1.4±0.04	2.5±0.05	1.8±0.04	1.3±0
Daily weight gain (g^{-1}fish^{-1}day^{-1})	0.51±0.01	0.63±0.01	0.55±0.01	0.54±0
Net mean fish yield (kg pond^{-1})	1.2±0.04	2.2±0.05	1.5±0.04	1.1±0
Survival (%)	86.9 ± 2.05	84.8 ± 1.42	82.6 ± 1.08	78.2 ± 4.09
Net fish yield (kg ha^{-1}yr^{-1})	365.9±0.04	702.6±0.05^{a}	483.9±0.04^{ab}	338.2±0^{b}
Naini				
Initial mean wt.(g fish^{-1})	9.0 ± 0.28	9.0 ± 0.16	9.0 ± 0.16	9.0 ± 0.28
Initial total wt. (kg pond^{-1})	0.135±0.00	0.542±0.08	0.207±0.00	0.135±0.00
Final harvesting wt.(g fish^{-1})	72.3±1.18	86.6±1.36	82.3±1.18	77±1.24
Final total wt.(kg pond^{-1})	0.844±0.03	1.9±0	1.5±0.01	0.924±0.01
Daily weight gain (g^{-1}fish^{-1}day^{-1})	0.52±0	0.64±0.01	0.61±0.01	0.56±0
Net mean fish yield (kg pond^{-1})	0.709±0.02	1.7±0	1.3±0.01	0.789±0.01
Survival (%)	79.2 ± 1.92	79.2 ± 1.92	84.3 ± 1.16	80 ±1.54
Net fish yield (kg ha^{-1}yr^{-1})	215.6±0.02^{b}	525.9±0^{a}	420.9±0.01^{ab}	239.9±0.01

Contd. Table 2: Growth & production performance of carps & SIS of experiment.

Parameters	Treatments			
	T1	T2	T3	T4
G. carp				
Initial mean wt.(g $fish^{-1}$)	8.5 ± 0.24	0	8.5 ± 0.24	8.5 ± 0.24
Initial total wt. (kg $pond^{-1}$)	0.059±0.00	0	0.294±0.04	0.14±0.02
Final harvesting wt.(g $fish^{-1}$)	77.6±1.18	0	76.6±1.36	77.6±1.18
Final total wt.(kg $pond^{-1}$)	0.441±0.02	0	0.971±0.03	0.415±0.02
Daily weight gain ($g^{-1}fish^{-1}day^{-1}$)	0.57±0.01	0	0.56±0.02	0.57±0.01
Net mean fish yield (kg $pond^{-1}$)	0.381±0.01	0	0.844±0.03	0.355±0.02
Survival (%)	80.9 ± 3.8	0	84.2 ± 1.72	73.3 ± 5.4
Net fish yield (kg $ha^{-1}yr^{-1}$)	115.8±0.01	0	256.7±0.03	107.9±0.02
C. carp				
Initial mean wt.(g $fish^{-1}$)	9.5 ±0.16	0	0	9.5 ±0.14
Initial total wt. (kg $pond^{-1}$)	0.361±0.00	0	0	0.834±0.13
Final harvesting wt.(g $fish^{-1}$)	87.3±1.18	0	0	100.6±0.54
Final total wt.(kg $pond^{-1}$)	2.8±0.04	0	0	3.0±0.01
Daily weight gain ($g^{-1}fish^{-1}day^{-1}$)	0.64±0.01	0	0	0.75±0.01
Net mean fish yield (kg $pond^{-1}$)	2.4±0.04	0	0	2.7±0.01
Survival (%)	86.8 ± 3.72	0	0	80.7 ± 1.42
Net fish yield (kg $ha^{-1}yr^{-1}$)	757.6±0.04	0	0	828.8±0.01
A. mola				
Initial mean wt.(g $fish^{-1}$)	0	1.2±0.09	1.2±0.12	1.2±0.09
Initial total wt. (kg $pond^{-1}$)	0	1.3±0.21	1.3±0.22	1.3±0.21
Final harvesting wt.(g $fish^{-1}$)	0	3.0±0.05	3.0±0.0	3.0±0
Final total wt.(kg $pond^{-1}$)	0	2.6±0.06	2.4±0.05	2.4±0.01
Daily weight gain ($g^{-1}fish^{-1}day^{-1}$)	0	0.01±0	0.01±0	0.01±0
Net mean fish yield (kg $pond^{-1}$)	0	2.0±0	1.9±0.1	1.8±0.09
Net fish yield (kg $ha^{-1}yr^{-1}$)	0	618.6±0	606.2±0.1	566.6±0.09

Different superscript letters in the same row are significantly different (P<0.05) according to one way ANOVA with Tukey's test.

Table 3: Treatment wise Net fish production kg ha^{-1} yr^{-1} of the experiment.

Fish sps.	T1	T2	T3	T4
silver carp	1438.1±0.11	2198.2±0.01	1965.2±0.05	1724.6±0.08
bighead carp	291.6±0.03	514.0±0.06	389.3±0.01	244.5±0.01
rohu	365.9±0.04	702.6±0.05	483.9±0.04	338.2±0
naini	215.6±0.02	525.9±0	420.9±0.01	239.9±0.01
grass carp	115.8±0.01	0.0±0	256.7±0.03	107.9±0.02
common carp	757.6±0.04	0.0±0		828.8±0.01
A. mola	0.0±0	618.6±0	606.2±0.1	566.6±0.09
Net total $prod^{n}$	3184.9	4559.4	4122.4	4050.8

Different superscript letters in the same row are significantly different (P<0.05) according to one way ANOVA with Tukey's test.

Benefit-cost analysis of carp fishes combination with SIS

The financial characteristics of different treatments are presented in Table number 4 and 5. The major and also variable input costs were mainly due to experimental carps fingerlings, supplemental feeds, lime and inorganic fertilizers. The net benefit was highest in treatment T2 (2601.0±31.31 rupees pond $^{-1}$) followed by treatments T4 (2453.23±44.61 rupees pond $^{-1}$), T3 (2410.0±1043.2 rupees pond $^{-1}$) and T1 (1660.34±17.75 rupees pond $^{-1}$). Net benefit was the highest 352486.6±31.31 rupees ha^{-1}yr^{-1} in treatment T2 and the lowest production was 122965.5±17.75 rupees ha^{-1}yr^{-1}. Treatments that included addition of *A. mola* gave better production as well as financial return than the carps reared without of *A.mola* (treatment T1) but the best financial return obtained from T2 treatment suggests, suitable combination of carps with *A.mola* is silver carp, bighead carp, rohu and naini.

Table 4: Gross return value of different treatments (pond^{-1}) 120 days.

Treatments							
T1		T2		T3		T4	
ponds	Rupees (NRs)	ponds	Rupees (NRs)	ponds	Rupees (NRs)	ponds	Rupees (NRs)
P1	1642.3	P3	2672.872	P2	2470.272	P4	2362.22
P7	1703.6	P6	2588.484	P9	2324.892	P5	2446.372
P10	1635.07	P8	2541.81	P12	2434.898	P11	2551.112
Mean ± SE	1660.34±17.75	Mean ± SE	2601.05±31.31	Mean±SE	2410.02±35.74	Mean ± SE	2453.23±44.61

Table 5: Gross margin analysis of different treatments pond $^{-1}$& ha^{-1}yr $^{-1}$.

Parameters	Treatments			
	T1	T2	T3	T4
Outputs	1660.34±17.75	2601.05±31.31	2410.02±35.74	2453.23±44.61
Inputs	1256.07±0.04	1442.19±0.06	1426.41±0.30	1510.25±0.29
Gross margin pond $^{-1}$	404.27±17.75	1158.86±31.31	983.61±35.74	942.98±44.61
Gross margin ha $^{-1}$ yr $^{-1}$	122965.5±17.75^{b}	352486.6±31.31^{a}	299181.4±35.74^{ab}	286823.1±44.61^{ab}

Different superscript letters in the same row are significantly different (P<0.05) according to one way ANOVA with Tukey's test.

Water quality parameter

The result of water quality parameters are summarized in table 6.

DISCUSSION

Growth and production performance of carps and SIS

Three different combinations of carp species in treatment T2, treatment T3, and treatment T4 stocked with *A. mola* showed variation in growth and production of individual type of carp species treatment wise. Growth of silver carp was the highest in T2 treatment among all. The competition for food did not occur between silver carp and *A. mola* most probably sharing into different feeding niche. The addition of *A. mola* and/or *Puntius sarana* fish in the ponds did not affect the growth of silver and common carps (Kadir *et al.*, 2007). In the present study there were no significant differences (p>0.05) in individual harvesting weight of silver carp, indicating that silver carp production was not affected by the introduction of *A. mola*. Roy (2004) also reported that silver carp production was not affected by the presence or absence of *A. mola* in carp-mola polyculture system. Growth of bighead (zooplankton feeder) carp was the highest in T2 treatment among all. The growth of bighead carp was lower than the growth of silver carp in all treatments that might be due to the inter specific food competition between bighead carp and *A. mola*. Roy (2004) reported that production of catla (zooplankton feeder) was higher in presence of grass carp and in absence of silver carp in his study on carp-SIS polyculture system. The addition of *A.mola* or *puntius sarana* in fish ponds affected rohu and catla's growth but did not affect the growth of common carp and silver carp. The addition of *A. mola* reduced catla's production performance by 20-24% (Kadir *et al.*, 2007). There were no significant differences ($p>0.05$) in harvesting weight survival, total yield and net yield of bighead carp among treatments. Production of rohu was lower in present study in presence of both higher stocking densities of silver carp and *A. mola* respectively. This might be due to the inter specific competition between rohu and these two species. Roy (2004) reported lower growth of rohu in higher stocking densities of *A. mola*. Kohinoor & Wahab (1998) also found that *A. mola* competes for food and space with rohu. The growth of naini and rohu in all treatments were less than silver carp perhaps due to the low stocking density and the slow growth rate of these fishes than the silver carp. Production of naini in this study was high in presence of *A. mola*. Presence of silver carp increased production of mrigal in an experiment conducted by Roy (2004).

Table 6: Mean values (± SE) and water quality parameters.

parameters	Treatments			
	T1	**T2**	**T3**	**T4**
Temperature (^{0}C)	28.4 ± 0.37 (27.2-32.5)	28.5 ± 0.41 (27.2-32.5)	28.5 ± 0.43 (27.1-33.2)	28.2 ± 0.41 (28.2-33.5)
Transparency (cm)	22.7 ± 1.19 (16.0-32.0)^{ab}	20.3 ± 1.40 (24.0-40.0)^{ab}	25.9 ± 1.72 (16.0-35.0)^{b}	21.3 ± 1.21 (20.0-40.0)^{a}
DO (mg L^{-1})	5.4 ± 0.21 (4.1-8.5)	5.4 ± 0.24 (4.2-10.1)	5.4 ± 0.23 (4.6-10.1)	5.5 ± 0.22 (4.6-10.2)
pH	7.4 ± 0.11 (7.7-8.5)	7.4 ± 0.07 (7.7-8.5)	7.4 ± 0.89 (7.7-8.5)	7.4 ± 2.73 (7.7-8.5)
Total Alkalinity (mg L^{-1})	95.4 ± 4.71 (90.0-150)^{a}	91.1 ± 3.66 (84.0-146)^{ab}	90.0 ± 3.46 (76.0-140)^{b}	92.2 ± 4.19 (89.0-152)^{ab}
CO_2 (mg L^{-1})	12.7 ± 0.35 (10.5-16.4)	13.0 ± 0.35 (10.5-16.2)	12.2 ± 0.28 (10.6-16.6)	12.2 ± 0.30 (10.5=16.4)

Different superscript letters in the same row are significantly different ($P<0.05$) according to one way ANOVA with Tukey's test.

Milstein (1992) also reported such synergistic effect between silver carp and common carp. Grass carp growth was high at high stocking density of both silver carp and *A. mola*. Survival was the highest where both silver carp and *A. mola* were stocked in the treatment. Grass carp has antagonistic effect on more than one species in carp polyculture system. Roy (2004) found that grass carp production was not affected by the presence or absence of silver carp, but it performed better growth and production in presence of *A. mola*. The growth and production of common carp was high in combination with *A. mola* in T4 treatment of this experiment. Alim *et al.* (2005) reported that presence of *A. mola* had increased the growth parameter of common carp. These effects are explained and discussed considering fish interactions through the food web (Kadir *et al.*, 2007). Roy (2004) stated that growth of *A. mola* was better with grass carp combination along with other carps reared together than the silver carp combination with other carps. The highest net yield of carps (4559.4 kg $ha^{-1}yr^{-1}$) was found in T2, it may be due to of pond's food proper utilization, suitable water quality condition, and high abundance of planktons in pond water, consumption and conversion of artificial food and fish interactions through the food web. Paul (1998) and Hossain *et al.* (2006) recorded high yield of silver carp with the low production of zooplankton feeder species. The present finding of high yield of silver carp in carp SIS culture experiment satisfy with Paul (1998) and Hossain *et al.* (2006). The gross production of fishes (4559.4 kg $ha^{-1}yr^{-1}$) of present study is higher than that reported by Miah & Siddique (1992), Mazid *et al.* (1997) and Rahman (2006). The gross production of carp fishes of present experiment was lower (6767 kg ha^{-1} yr^{-1}) than those reported by Wahab *et al.* (1995). Lakshmanan *et al.* (1971) obtained the production of carp fishes 4209 kg ha^{-1} yr^{-1} from semi intensive fish culture method which is more or less similar to the gross production of carp fishes in the present study. The present finding is similar with the result obtained by Kunda *et al.* (2008). The gross yield of carps species under the combination of; silver carp, bighead carp, rohu and mrigala gave the better production with *A. mola* in the treatment T2 which was significantly ($p>0.05$) higher than T3 and T4. It was the indication of suitable combination of carp species silver carp, bighead carp, rohu and mrigala in spite of silver carp, bighead carp, rohu, mrigala, grass carp and common carp for the rearing with SIS species *A. mola* in semi intensive pond aquaculture. *A. mola* didn't affect the growth of carps species silver carp, bighead carp, rohu and mrigala in treatment T2 because food efficiency of all niches of pond was properly utilized by the carps and *A. mola* species and there were also no overlapping of food niches among them.

Gross margin analysis

Gross margin analysis showed that all treatments were profitable. Gross margin was higher in combination of silver carp, bighead carp, rohu and mrigala with *A.mola* in treatment T2 than that in the silver carp, bighead carp, rohu, mrigala, grass carp and common carp treatment probably due to low return value from the selling of grass carp, common carp and less quantity of *A.mola* for the sale. Based on fish production and economic return, the silver carp, bighead carp, rohu and mrigala with *A.mola* treatment seemed better for the resource-poor farmers since the *A.mola* is self recruiting species so it's partial harvesting in the ponds with supplemental feed gave high fish production as high as in the only carps treatment. Using on-farm by-products like rice bran and mustard oil cake not only enhances the fish production but also makes venture cost effective. The financial return was Rs 115886 N Rs ha^{-1} in 120 days, which is higher than the net benefit reported by Roy (2004) 94,925, 88,330 and 68,270 Tk. per hectare per 7 months for only carps, carps plus *A.mola* and carps plus chela polyculture systems, respectively. The high financial return (202800.5 ha^{-1} per seven month) of present study was probably due to increase in production of carp from inclusion of rapidly growing bighead carp in spite of Catla catla and *A.mola* in the present experiment and the price value of total variable cost, revenue in local market.

Water quality parameters

The water quality is a paramount factor in ecosystem productivity of fish ponds. The feeding intensity of fishes, their growth, metabolism, reproduction etc. are regulated in the pond ecosystem by water temperature. All water quality parameters remained in the normal range for carp *A.mola* culture. There were no significant effects on addition of fishes, artificial feed and fertilizer on water quality. The water temperature remained from 27.1°C to 33.5°C in the experimental ponds which was suitable for fish culture. It agrees with the findings of Paul (1998) who recorded water temperature between 26.7-33.7°C of carp polyculture with silver carp and *A.mola* fish rearing ponds at the Bangladesh Agricultural University Campus, Mymensingh. Wahab *et al.* (1996) recorded water temperature between 28.5 to 31.3°C in the ponds used for fertilization experiment. Kohinoor (2000) also recorded water temperature between 18.5 to 32.9°C in the experimental ponds. The water transparency is generally expressed as the level of productivity of water body and it also indicates the presence or absence of natural fish food organisms. The transparency of pond water recorded from16.0 to 40.0cm in the present study indicates that the ponds were productive and a little bit turbid. Boyd (1979) recommended the transparency ranged from 15 to 40 cm is appropriate for fish culture. The less transparent or increased turbidity of pond water that appeared might be due to planktonic organisms and presence of common carp which is reported to be the most common natural reason for turbidity. Wahab *et al.* (2002) reported that common carp damages pond embankments by searching for food or burrowing to build nests which results reduced transparency. The transparency observed in experiment signifies that the culture ponds were somewhat suitable for fish culture though it exceeded the preferred range due to biological interaction of common carp. The concentration of dissolved oxygen (DO) in the experimental ponds had generally fluctuated from the range of 4.1 mg L^{-1} to 10.1 mg L^{-1}. Banerjea (1967) reported that dissolved oxygen ranging from 5 to 7 mg L^{-1} was good for fish culture. Ophenheimer *et al*. (1978) and Wahab *et al*. (1995) recorded the dissolved oxygen values from 3.1 to 7.5 and 2.2 to 7.1mg L^{-1}, respectively. Roy (2004) recorded 3.6 to 7.6 mg L^{-1}dissolved oxygen in carp- *A.mola* polyculture ponds in rural farmer's ponds. The upper limit of dissolved oxygen reading in present study was more than Ophenheimer *et al*. (1978) and Wahab *et al*. (1995) that might be due to the increased activity of phytoplanktons in pond water. The pH is an important factor in a fish pond and also called as the productivity index of a water body. An acidic pH of water reduces the growth, metabolism and other physiological activities of fishes (Swingle, 1967). The pH of pond water was between 7.7 to 8.5. It was suitable for fish culture according to Swingle (1967) who suggested the suitable pH of pond water for fish culture lie between 6.5 to 9.0. Kohinoor (1998) recorded the pH between 7.1 to 7.2 in carp- *A. mola* polyculture ponds. The pH reading in treatments of present experiment is more or less similar to Kohinoor (1998). Total alkalinity ranged from 76.0 and 150.0 mg L^{-1} in this experiment. Moyle (1946) stated that water bodies having total alkalinity more than 200.0 mg L^{-1} were highly productive. Bhowmic and Tripathi (1985) recorded the total alkalinity from 91.4 to 92.6 mg L^{-1} in research experiment's ponds of India. The total alkalinity record at present seems to be similar with the finding of Bhowmic and Tripathi (1985). Free CO_2 of pond water ranged from 10.5 mg L^{-1} to 16.4 mg L^{-1} during experimental period and it did not vary among the treatments. The upper limit of free carbon dioxide has been recommended as 25 mg L^{-1} for the safeguard of fish culture (Hynes, 1970). Present finding of free CO_2 seems to be suitable for fish culture according to (Hynes, 1970).

CONCLUSION

It was concluded from the present study that *A.mola* does not compete for food with silver carp (*H. molitrix*), bighead carp (*A. nobilis*), rohu (*L. rohita*) and naini (*C. mrigala*) combination but it showed adverse effect in the growth and production of silver carp, bighead carp, rohu, naini in combination of grass carp and common carp. so *A.mola* can be cultured successfully in semi intensive carp polyculture system in Nepalese condition to improve the economic and malnutrition condition of rural poor fish farmers and fishermen.

ACKNOWLEDGEMENTS

Authors are grateful to Mr. Bijaya Kumar Mallik Ex. Director General, Department of Agriculture, Govt. of Nepal, and Chief of staff Fish farm (Government of Nepal) Mr. Ravi Lal Sharma. This work was financed with a grant from UGC Nepal for the promotion of research work in Nepal.

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