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Effect of plastic tunnel on pond water temperature and growth and yield performance of golden mahseer (*Tor putitora*) in carp polyculture system

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Abstract
Golden mahseer (*Tor putitora*) is an indigenous key stonefish species of Nepal, threatened by anthropogenic activities. Recent studies showed that the golden mahseer could be domesticated and breed in hatcheries. However, many biological aspects of this species are yet to be known such as compatibility with other cultivable carp, and suitability of growth under plastic tunnels. Therefore, in order to evaluate growth performance in polyculture system with and without plastic tunnels, we performed an experiment for 365 days in 12-outdoor earthen ponds of 8-m^2 size each. Experimental ponds without plastic cover were considered as treatment-1 (T-1), while ponds covered with plastic tunnel over the surface was treatment-2 (T-2) having six replications for each treatment. The stocking density was 25,000 ha^{-1} with ratio comprising of 20% mahseer, 40% common carp (*Cyprinus carpio*) and 40% grass carp (*Ctenopharyngodon idella*). The average body weight of stocked fish was 1.4±0.3 g, 4.9±1.4 g, 15.7±2.6 g for mahseer, common carp and grass carp, respectively. The fish were fed with farm-made pellet feed having 23% CP at the rate of 3% body weight. The results showed high (98.3%) survival with no mortality of golden mahseer in T-2 with average harvested size 103.6±11.6 g, 228.3±29.1 g and 114.3±23.0 g compare to 90.8±14.8 g 210.0±40.0 g, 107.5±24.3 g in T-1 for golden mahseer, common carp and grass carp, respectively. The average harvested size of golden mahseer and common carp was significantly higher ($P<0.05$) in T-2 than T-1. So, the overall productivity revealed 21.4% higher in T-2 than T-1. The results imply that polyculture of golden mahseer with carps in plastic tunnel system would be a profitable enterprise for promotion of sustainable small-scale aquaculture.

Keywords: Golden mahseer, growth performance, plastic tunnel, small-scale aquaculture

1. Introduction

The golden mahseer, *Tor putitora* (Hamilton 1822) also known as golden sahar in Nepal is a key stonefish species and one of well-known massive fresh water fish exists in mountainous rocky rivers and lakes of Trans-Himalayan countries. It is not only delicious also very popular in sport fishing among the anglers across the world [1, 2]. The golden mahseer has been reported its distribution from Afghanistan, Bangladesh, Bhutan, India, Myanmar, Nepal, Pakistan including China [3-5]. Joshi *et al.* [6] reported as available also in Iran, Sri Lanka and Thailand. This long migratory fish attains as big as over 50 kg in the wild and available at the altitude ranged from 135-1650 m above the sea level [7].

Golden mahseer tolerate a wide range of water temperature ranging from 7-38 ºC [8] with thermal habitat preference lies within 13-30°C [6]. This excellent famous food and game fish of South Asia and South East Asia is in vulnerable situation and known to be threatened as endangered species in IUCN Red-List [9, 10] and threatened is mainly caused by anthropogenic activities for development works [11, 12]. This situation has led to efforts to conserve, manage and propagate this species through in-situ and ex-situ conservation [13-15]. To enhance the fishery and aquaculture development attempts on seed production techniques have been carried out in most of the tras-Himalayan countries [16-19]. Due to an important aquatic biodiversity is in endangered and vulnerable situation the conservation and aquaculture of this species is vital.

Although the golden mahseer is categorized as a cold water species in some past reports, it lives in wide range of water temperature. Past few studies show better growth in warm water temperature ranges from 20-30ºC compared to the cold or cool waters in captive condition [20, 21]. According to Boyd [22] warm water fishes need above 20 ºC water temperature for their better growth and usually not reproduce at temperatures below 20 ºC.

Thus, the golden mahseer can be classified as a warm water species, because of its spawning occurs when water temperature reaches 20-24 ºC [16, 20, 23]. So, the water temperature suitable for carp culture seems feasible for better growth of this species. However, many biological aspects are yet to be known such as compatibility with other cultivable carp, and suitability of growth under plastic tunnels. As the water temperature is one of the main influencing parameters among the environmental factors affecting to growth, this paper deals with effect of plastic tunnel on changing water temperature and its relation to growth and yield performance of golden mahseer, a potential species of aquaculture in polyculture system. We hypothesized that the various growth parameters in plastic covered ponds would be different than the uncovered.

2. Materials and Methods

2.1 Study site

The study was carried out at Fishery Research Station, Trishuli, at Bidur Municipality, Nuwakot district, the mid-hill eco-region of Nepal situated at 27º53'23.99" N, 85º09'34.99" E, and around 600 masl. The spring water of inside the research station was used for filling and flushing the experimental ponds.

2.2 Experimental design, species and treatments

To evaluate the growth and yield performance of golden mahseer (*T. putitora*), a polyculture experiment using plastic tunnel with plastic sheets of 120 GSM (gram.m^{-2}) was conducted for 365 days from 6th January 2016 to 5th January 2017. The stocking density was 25,000 ha^{-1} with ratio comprising of 20% golden mahseer, 40% common carp (*Cyprinus carpio*) and 40% grass carp (*Ctenopharyngodon idella*) in 12 earthen ponds of 8 m^2 size (4 m × 2 m) each with two treatments. Among the 12, six ponds were uncovered considered as treatment-1, which is supposed as control and remaining six were covered with plastic sheets as treatment-2 having six replications of each treatment. The 2.5 m (top at middle) high iron frames were made from the dike to cover the six ponds.

2.3 Stocking size, feed and feeding

The average body weights at stocking were 1.4±0.3 g, 4.9±1.4 g and 15.7±2.6 g for golden mahseer, common carp and grass carp, respectively. The fish in both treatments were supplied same diet of formulated farm-made pellet feed having 23% crude protein (CP). The fish were fed at the rate of 3% body weight of fish biomass. Due to lower CP content and high energy diet is supplied fish were fed at 3% of their body weight as suggested by Woynarovich [24] and Ghosh *et al.* [25]. The feed was supplied once a day, put in a tray and hanged to about 30 cm above the pond bottom to monitor whether fish finished or not the supplied quantity.

2.4 Growth check

Growth check was scheduled for every month. At least 50-100% fish of common carp and grass carp and 75-100% of golden mahseer from each pond were measured for growth monitoring and determining their feed requirement. The body weight was measured with a sensitive digital electronic balance (Shimadzu UX320G) weighing balance with a readability range of 0.01 g and total length was measured with a measuring board to the nearest 0.01 cm accuracy.

2.5 AGR, survival and FCR

Absolute growth rate (AGR) was calculated using following formula described by Hopkins [26].

AGR = (Wf – Wi)/t, where

Wf = final weight /length, Wi = initial weight/length, and 't' is the time interval.

Survival rate of fish was considered the remaining harvested number after deducting from the number of stocking [27]:

Survival rate (%) = Number of fish at end of experiment /initial number of fish at stock × 100

Feed conversion ratio (FCR) was calculated as total feed consumed divided by weight gain using following formula [28]:

FCR = FC/A2-A1), where,

FC = Feed consumption (dry), A1 = Total weight at beginning of the period (stock)

A2 = Total weight at end of the period (harvest)

2.6 Water quality monitoring

Water temperature and dissolved oxygen monitored every day at morning and evening and pH, Alkalinity, total hardness, nitrate, nitrite and ammonia in every month during growth check. DO and pH were measured by using digital instrument "LABQUEST 2 Vernier" while total alkalinity, nitrate, nitrate, ammonia, phosphorus and total hardness were recorded monthly by using instrument eXact Micro-10 Photometer between 6:00 to 6:30 am. About 25-50% water was added every week for avoiding the higher bloom condition if present and maintaining the water level at 80-90 cm depth.

2.7 Statistical analysis

Paired sample T-test was used to compare the mean of final weight, survival and production among treatments. Differences were considered significant at the 95% confidence level (P<0.05). All tested means were given with standard deviation (±SD). The data were analyzed using statistical tools available in the MS Excel 2013 and XLSTAT 2014.5.03.

3. Results

3.1 Water quality parameters

The variation in monthly mean water temperature was 2.1-2.8 ºC difference with annual mean 25.1±4.8 and 27.3±4.7 in T-1 and T-2 respectively, where higher temperature was observed in T-2 (plastic covered ponds). The temperature difference was ranges from 2.1 ºC (in March, May and August) to 2.8 ºC (in December). Remaining months were recorded the difference from 2.2-2.5 ºC (Fig 1, Table 1). Minimum monthly mean water temperature observed 17.4 ºC during January 2016 followed by 21.6 ºC during December, whereas maximum mean was recorded 31.2 ºC during August followed by 30.2 ºC and 30.1 ºC during June and July, respectively in T-1. Likewise the monthly minimum mean water temperature in T-2 observed 19.7ºC in January 2016 followed by 21.6 ºC in December with maximum 33.3 ºC during August followed by 32.4ºC and 32.3 ºC during June and July, respectively (Fig 1).

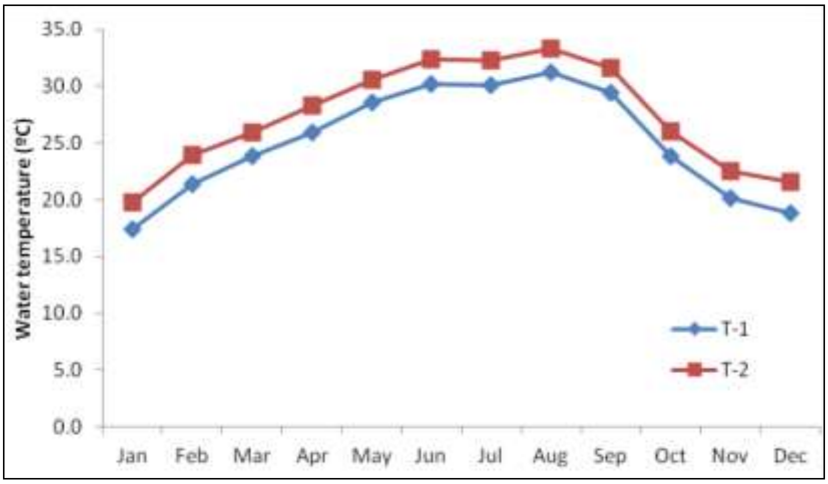

Fig 1: Monthly mean water temperature (ºC) in T-1 and T-2 of experimental ponds

The Dissolved oxygen (DO) and pH including other physico-chemical parameters such as alkalinity, hardness, nitrate, nitrite, ammonia and phosphorus present within the acceptable range for aquaculture (Table 1). The lower DO level (1.5-2.5 mg/L) also was recorded early in the morning of very few cloudy nights in September-October, but, there was no case of fish kill by oxygen deficiency. No mean value of parameters were found significantly different (P>0.05) between two treatments (Table 1).

Table 1: Mean (±SD) values and ranges of water quality parameters

Parameters	T-1		T-2	
	Mean (±SD)	**Range**	**Mean (±SD)**	**Range**
Water temperature (ºC)	25.1±4.8^{a}	17.4-31.2	27.3±4.7^{a}	19.7-33.3
Dissolved oxygen (mg/L)	5.4±0.8^{b}	3.6-6.5	5.1±0.5^{b}	4.0-5.9
pH	7.0±0.2^{c}	6.6-7.4	6.9±0.2^{c}	6.6-7.3
Alkalinity (mg/L)	103.2±28.0^{d}	58.3-146.3	101.2±25.1^{d}	63.7-134.2
Total hardness (mg/L)	39.0±22.8^{e}	17.7-99.0	36.9±18.2^{e}	23.3-81.3
Nitrate (mg/L)	57.3±35.5^{f}	5.7-139.7	57.0±37.1^{f}	9.2-138.8
Nitrite (mg/L)	0.30±0.20^{g}	0.0-0.7	0.40±0.50^{g}	0.1-1.7
Ammonia (mg/L)	0.030±0.003^{h}	0.023-0.035	0.032±0.004^{h}	0.027-0.040
Phosphorus (mg/L)	0.20±0.1^{i}	0.0-0.4	0.20±0.1^{i}	0.1-0.5

Note: Same lowercase alphabets in superscript of each row explains no significant difference in 95% confidence level, while different lowercase alphabets in superscript in same row explains significant difference

3.2 Growth performances

Overall results of experiment with growth and yield performance information are presented in Table 2 (A and B). It explains about the species wise and treatment wise initial and final weight of the species, their comparative growth performance and weight gain during the study period. The average individual body weight of golden mahseer and the common carp harvested from T-2 was significantly higher (P<0.05) than the T-1. The average final weight of grass carp remained lowest difference among the species, which was not significantly different (P>0.05) among the treatments (Table 2).

Table 2: Overall and species wise results of the experiment for growth and yield performance

A. Species wise results						
Growth parameters	**Golden mahseer**		**Common carp**		**Grass carp**	
	T-1	**T-2**	**T-1**	**T-2**	**T-1**	**T-2**
Av. initial wt. (g) ±SD	1.4±0.3^{a}	1.4±0.3^{a}	4.9±1.4^{a}	4.9±1.4^{a}	15.7±2.6^{a}	15.7±2.6^{a}
Av. final wt. (g) ±SD	90.8±14.8^{b}	103.6±11.6^{c}	210.0±40.0^{b}	228.3±28.1^{c}	107.5±24.3^{b}	114.3±23.0^{b}
Total no. of initial stock	24	24	48	48	48	48
Total no. at harvest	21	24	40	47	44	47
Survival (%) (±SD)	87.5±13.7^{d}	100.0±0.0^{e}	83.3±10.2^{d}	97.9±5.1^{e}	91.7±6.5^{c}	97.9±6.5^{c}
Initial mass wt. (g)	33.6	33.6	235.2	235.2	753.6	753.6
Final gross mass wt. (g)	1907	2486	8400	10730	4730	5372
Final mass wt. gain (g)	1873	2452	8165	10495	3976	4618
Final wt. gain ($g.fish^{-1}$)	89.2	102.2	205	223	91.8	98.6
Absolute growth rate ($g.fish^{-1}day^{-1}$)	0.24	0.28	0.56	0.61	0.25	0.27
Body wt. increment (× times)	64.86	74.00	42.86	46.59	6.85	7.28
B. Overall results	**T-1**			**T-2**		
Area/treatment (m^2)*	48			48		
Stocking rate ($fish.m^{-2}$)	2.5			2.5		
Total no. of initial stock	120			120		

Total no. at harvest	105	118
Survival (%) (±SD)	87.5±8.2[a]	98.3±4.1[b]
Initial mass wt. (g)	1022.4	1022.4
Final gross mass wt. (g)	15037	18588
Final mass wt. gain (g)	14015	17566
Consumed feed (g)	64826	70396
Feed efficiency (%)	21.6	25.0
Feed conversion ratio	4.6±0.4[c]	4.0±0.2[c]
Harvest $g.m^{-2}$	313	380
Productivity (total yield $kg.ha^{-1}$)	3133	3800

Note: Same lowercase alphabets in superscript in same row of separate species between treatments explain no significant difference, while different lowercase alphabets in superscript in same row of separate species between treatments explain significantly different, in 95% confidence level

3.3 Growth of golden mahseer

The average stocking size, 1.4±0.3 g of golden mahseer was harvested 90.8±14.8 g and 103.6±11.6 g size from T-1 and T-2, respectively (Table 2, Fig 2). The growth of golden mahseer was significantly higher ($P<0.05$) in T-2. The average individual body weight of golden mahseer at harvest in T-2 was 14% higher than T-1.

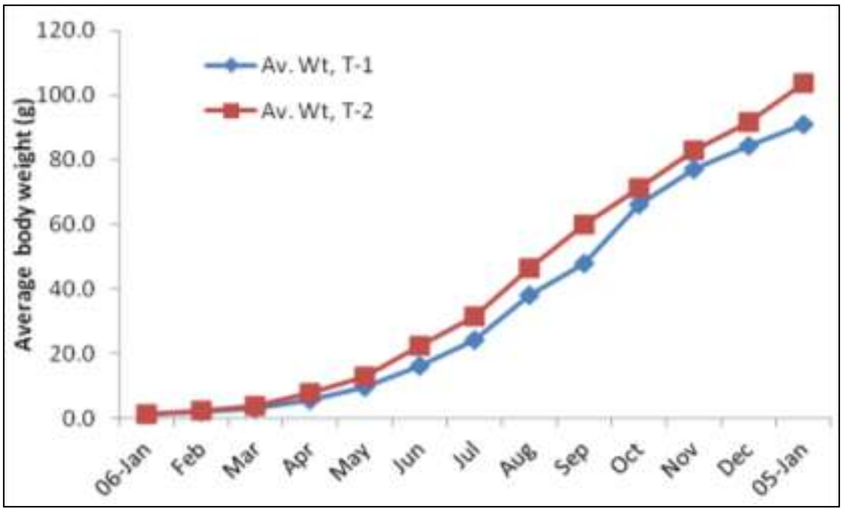

Fig 2: Monthly average body weight (growth) of golden mahseer

3.4 Growth of common carp and grass carp

The common carp of average stocking size 4.9±1.4 g was reached to 210.0±40.0 g and 228.3±28.1 g at harvest from T-1 and T-2, respectively (Table 2, Fig 3). The average harvested size of common carp was significantly higher ($P<0.05$) by 8.7% in T-2 compare to T-1.

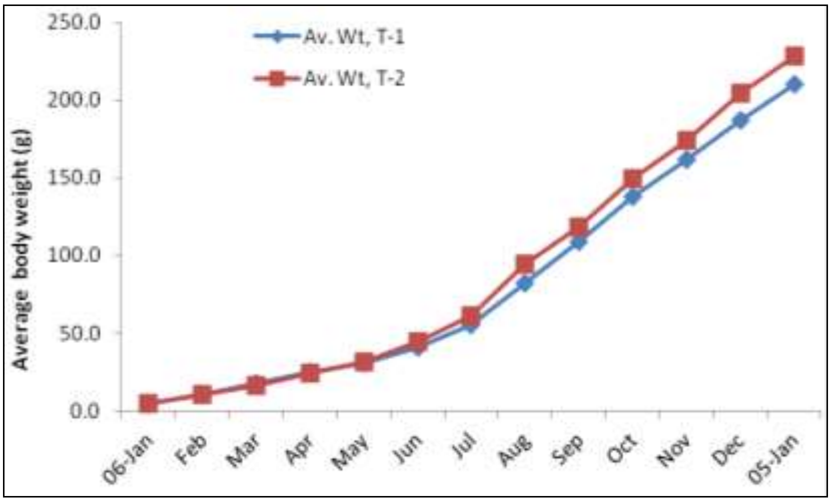

Fig 3: Monthly average body weight (growth) of common carp

Similarly, 15.7±2.6 g average size grass carp in was reached to 107.5±24.3 g and 114.3±23.0 g from T-1 and T-2, respectively (Table 2, Fig. 4). The harvested size of grass carp was 6.3% higher in T-2, but results shows no significant difference ($P>0.05$) among the treatments.

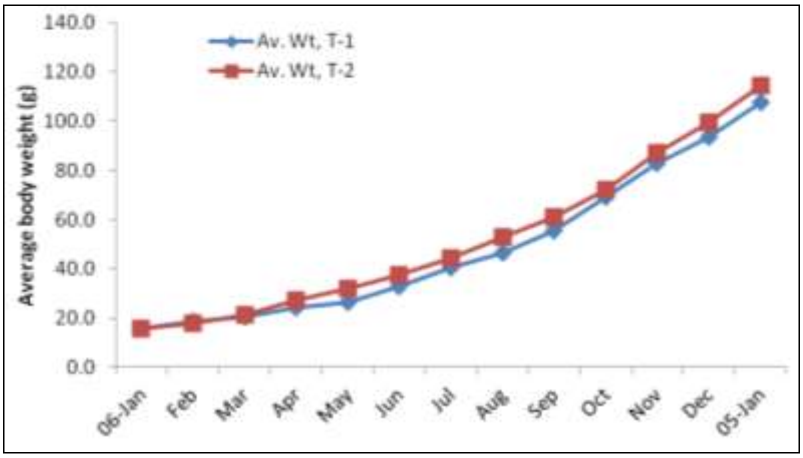

Fig 4: Monthly average body weight (growth) of grass carp

3.5 Survival, feed efficiency and FCR

The golden mahseer showed no mortality (100% survival) in T-2, where 87.5% survival was observed in T-1. The overall survival, 98.3% was significantly higher (P<0.05) in T-2 compare to 87.5% in T-1. Similarly, in the case of common carp and grass carp survival rate remained 97.9% for both species in T-2, but it was only 83.3% and 91.7% respectively, in T-1 (Table 2). Survival of common carp was significantly higher (P<0.05) in T-2, whereas there was no significant difference for grass carp among the treatments. Overall feed efficiency remained 25% in T-2, which is 3.4% higher than T-1. The feed conversion ratio (FCR) was 1:4.0 fish to feed in T-2, followed by 1:4.6 in T-1. The results showed that about 15% lower feed was consumed to produce per kg of fish in T-2 compare to T-1 (Table 2).

3.6 Species wise AGR and average increment

The average growth rate (AGR) for golden mahseer was 0.24 and 0.28 g.fish^{-1}.day^{-1}, in T-1 and T-2 respectively (Table 3). Common carp had the highest AGR, 0.56 and 0.61 g.fish^{-1}.day^{-1} in T-1 and T-2, respectively. Among the species. Likewise, the grass carp had AGR, 0.25 and 0.27 g.fish^{-1}.day^{-1}, in T-1 and T-2, respectively. There was almost similar growth rate of golden mahseer and grass carp in T-1. Based on the stocking weight golden mahseer gained 74.00 times of increased weight in T-2, followed by 64.86 times high in T-1 (Table 2, Fig 5). The result showed that smaller the stocking size gained the more rate of increment. For golden mahseer difference in increment was 9.14 times higher in T-2 compare to T-1. The common carp increased 46.59 times from the stocking size in T-2, which is only 3.73 times difference (higher) than T-1. In present experiment the least rate of increment remained for grass carp, where 15.7±2.6 g initial size was increased only by 7.28 times in T-2, which was 0.43 times higher than T-1 (Table 2, Fig. 5).

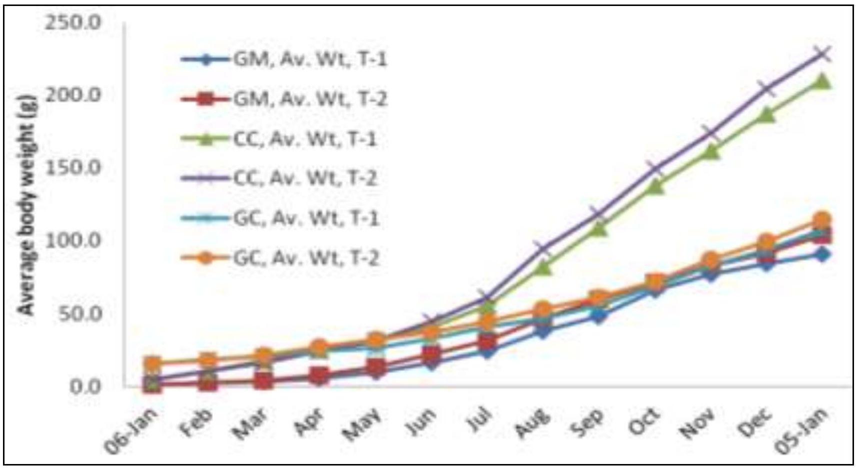

Fig 5: Species wise and treatment wise comparative growth trend and monthly body weight of stocked fish, golden mahseer (GM), common carp (CC) and grass carp (GC)

3.7 Productivity and yield contribution

The overall productivity in T-2 was 21.4% higher than T-1, which was 3.80 and 3.13 metric ton.ha^{-1}.year^{-1} in T-2 and T-1, respectively (Table 2). In species wise yield contribution the total production, 2.48 kg of golden mahseer in T-2 was 30.3% higher than 1.91 kg of T-1 (Table 3). Similarly, the production of common carp 10.73 kg in T-2 was 27.7% higher than 8.40 kg of T-1. Among three species the yield of grass carp was lowest rate of production difference, having only 13.5% higher with 5.37 kg in T-2 than 4.73 kg of T-1. In overall yield contribution golden mahseer with 20% stocking composition individually contributed 13.1% of total yield with 25.6% in gross income. Even the lower (20%) stocking composition, golden mahseer contributed almost equal income as of grass carp due to mahseer fetches more than double selling price than common carp and grass carp (Table 3).

Table 3: Species wise average harvested yield and income contribution

Species	Stocking rate (no.m^{-2})	Stock composition (%)	Species wise yield contribution (kg)				Selling price.kg^{-1} (US$)	Total income			
								Amount (US$)			%
			T-1	T-2	Total	Contribution in total (%)		T-1	T-2	Total	
GM	0.5	20	1.91	2.48	4.39	13.1	6.835	13.05	16.95	30.00	25.6
CC	1.0	40	8.40	10.73	19.13	56.9	2.990	25.12	32.08	57.20	48.7
GC	1.0	40	4.73	5.37	10.10	30.0	2.990	14.14	16.06	30.20	25.7
Total	2.5	100	15.04	18.58	33.62	100.0		52.31	65.09	117.40	100.0

GM= golden mahseer, CC= common carp, GC= grass carp

US$ 1= NPR 117.04 (25 May 2021), Source: Nepal Rastra Bank

4. Discussions

4.1 Water temperature and growth performance

Although the mean value of water quality parameters were found no significant different ($P>0.05$) among two treatments the mean value of water temperature ranged from 2.1 to 2.8°C difference with annual mean 25.1±4.8 and 27.3±4.7 in T-1 and T-2, respectively observed higher temperature in T-2, where golden mahseer (*T. putitora*) and common carp (*C. carpio*) gained significantly higher growth ($P<0.05$) by 14% and 8.7%, respectively (Table 2). These results of fish growth are consistent with the findings of Morgan *et al.* [29], who have observed a change in water temperature of only 2°C has been shown to stimulate the metabolism, appetite and growth by 30-60% of some stream fish. The findings of Boyd [22] and Fatma and Ahmed [30] also supports to the results of present study, who found that the water temperature is one of the greatest influencing parameters among the environmental factors affecting to growth performance of fish. Similarly, the findings of present study is a consequent with the conclusion of an observation of Shcherbina and Kazlauskene [31] where, they concluded that an increase in water temperature increases the activity of digestive enzyme, which may accelerate digestion of the nutrients, thus result is better growth of the fish. Freshwater fish have an optimum growing temperature in the range of 25-30^{0}C [32] at which they grow quickly. However, the final weight of grass carp (*C. idella*) in present study was only 6.3% higher in T-2 compared to T-1 with no significant difference ($P>0.05$). Comparatively lower growth rate of grass carp than golden mahseer and common carp may be due to lower utilization of supplementary feed, while the feeding habit of grass carp is herbivore, which loves to feed the plants high quantity if available, but other two species love more to feed on formulated supplementary diet due to omnivore feeding habit. The grass carp eats the food grains or supplementary feed supplied to them, but extent of such utilization is little [24]. At favorable temperature, about 25°C a grass carp eats plants equal to 25-60% of its own body weight [24, 33].

The final mean weight of golden mahseer 90.8±14.8 g and 103.6±11.6 g at harvest from initial mean weight, 1.4±0.3 g with absolute growth rate 0.24 and 0.28 g.fish^{-1}day^{-1}, in T-1 and T-2, respectively in present study found better growth than the past study conducted by Bista *et al.* [34], where the fry of 1.0 g initial size at 10,000 ha^{-1} stocking rate harvested 39.0 g in mid-hill and 60.8 g in Terai (warmer region), in 210 days, with growth rate 0.18 g.fish^{-1}day^{-1} and 0.28 g.fish^{-1}day^{-1} in mid-hill and Terai with survival rate 87.0% and 91.6%, respectively. Similarly, Rai [8] observed the golden mahseer of 1.3 g size reached 29 g within 7 months at water temperature of 12-21°C, but 0.5 g initial size reached 90-160 g within 12 months at above 18.5°C, in earthen ponds. A past experiment conducted by Rahman *et al.* [35] shows that golden mahseer would be a best alternative of mrigal (*Cirrhinus mrigala*) in polyculture system. Thus, better growth rate of golden mahseer including common carp in present study may be attributed to the higher water temperature in T-2 compare to T-1, which was the result of increased water temperature, which influenced to better feed intake and metabolic rate of the fish.

The results of previous experiments support to the present study that the golden mahseer can grow 90-160 g in the first year if water temperature remains higher than 20°C [8], because the water temperature has foremost effect on fish metabolism [22, 30]. These past and present studies showed higher the growth rate of golden mahseer in warmer water condition of sub-tropical climate than in the cooler climates of mid-hill Nepal. However, one of the reasons for slow growth and harvested smaller size than common practice for all three species in present study might be due to the low CP content in diet and high rate of stocking density (25,000 fish.ha^{-1}) because, the government recommends 15,000 fish.ha^{-1} in Nepal for table fish production [33].

4.2 Survival rate, FCR, FE and AGR

In present study the excellent survival with better feed conversion ratio (FCR), feed efficiency (FE) and absolute growth rate (AGR) in T-2 might be attributed by increased water temperature compare to T-1. The excellent survival (97.9%) for common carp and grass carp with no mortality (100%) of the golden mahseer observed in T-2 (Table 3) and 3.4% higher feed efficiency with 15% (0.6 kg) lower FCR obtained in T-2 is consistent with Goolish and Adelman [36] who observed that the food conversion efficiencies generally increased with higher temperature in juvenile common carp and the maximum specific growth rate was estimated to occur at a temperature, 27°C. Kausar and Salim [37] concluded that water temperature ranging from 24-26°C seemed to be the most effective for rearing of *Labeo rohita* and the fish kept under 20-22°C and 22-24°C were lower in body weight gain and higher FCR may be due to less feed intake than those kept under higher water temperature, 24-26°C. Most species cease to feed at lower water temperatures below 16°C [38]. The probable causes other than water temperature for excellent survival and higher growth rate in T-2 might be maintaining higher water level, less evaporation, fish felt their safety and keeping calm consequence for good health even in the adverse climatic condition in plastic covered ponds.

4.3 Productivity, yield and income contribution

The overall productivity in T-2 (3.80 metric ton.ha^{-1}.year^{-1}) with 21.4% higher than T-1 (Table 2) in present study is 34.7% higher than the annual productivity (2.82 metric ton.ha^{-1}.year^{-1}) of 2018 from mid-hill districts in Nepal [39], the present study site. It is a highly encouraging result compare to the productivity of mid-hill region of Nepal. Overall production contribution of golden mahseer with only 20% stocking composition individually contributed 13.1% of total yield with 25.6% in gross income (Table 3). Highest income was made 48.7% by common carp followed by grass carp (25.7%). Even the half in stock composition, golden mahseer contributed almost equal in income value as the grass carp, because of golden mahseer fetches more than double selling price than common carp and grass carp (Table 3).

5. Conclusion

The increased monthly mean water temperature by 2.1-2.8°C in T-2 (ranging 16.7-29.4°C in T-1 and 20.0-33.5°C in T-2) influenced to be more feasible for the significant growth of golden mahseer and common carp. The average body weight in ponds with plastic tunnel (T-2) gained significantly higher ($P<0.05$) by 14% and 8.7% for golden mahseer and common carp, respectively but only 6.3% for grass carp as compared to the uncovered ponds (T-1). The other water quality parameters was within the acceptable range for aquaculture and no mean value of parameters were significantly different ($P>0.05$). The increased water temperature in ponds with plastic tunnel played an important role to increase fish growth, contributing higher productivity by 21.4% in T-2 than T-1. Considering the findings, it is concluded that culture of golden mahseer is compatible species for polyculture with common carp and profitable aquaculture enterprise. With a view to enhancing productivity and taking advantage of economic scale more comprehensive research should be done with application of different diets, feeding rates/methods and various densities in different scale of plastic tunnels or poly-house which may further enhance the productivity thereby profitability. The findings of this study may imply that the polyculture of golden mahseer with carps in plastic tunnel would be a profitable climate smart technology for promotion of sustainable small-scale aquaculture in similar agro ecological regions similar to the mid-hill region of Nepal.

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