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Optimum Growth Performances of Mono-Sex Tilapia (*Oreochromis niloticus*) Fingerlings Through Different Stocking Density Under Semi-Intensive Farming System

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Abstract: Backgrounds and objectives: Commercially, stocking density can make a significant difference in fish Farming. Based on local environmental factors and management systems, monosex tilapia responses widely to various population density. For maximum production, determining optimum high density of *Oreochromis niloticus* was the soul target of present experiments. Materials and methods: Monosex tilapia were cultured under semi-intensive farming system for 30 days with different stocking density to observe the response of growth curve and production rate. Diets and fertilizations were maintained strictly through these puddles by intense monitoring. Results: Stocking density was 1000, 1200 and 1400 fries per decimal with 1.98 g average initial weight in three treatments. Fertilization rate and feeding frequency as well as feeding rate were constant i.e. 15-20% of fry's bodyweight. Conditional factor (CF) was 2.41 in average with 4.28% growth rate and 3.75% specific growth rate. CF slowed down among first 7 days and was stable afterward. Average length and weight were increased after 7 days. Average gross production was 153.45 kg/ha with highest production (231.87 kg/ha) in T_2. Conclusion: Medium stocking density (T_2) showed significant commercial growth and production rates among treatments rather lower (T_1) or higher (T_3) density under semi-intensive puddle management.

Key words: Stocking Density · Monosex Tilapia · Specific Growth Rates · Semi Intensive · High Production · Conditional Factor

INTRODUCTION

Farming of tilapia is popular in 85 countries which supplied 98% of total production where the global production is 3.4 to 4 million tons by more than two-third is produced in Asia with its highest producing countries like China, Indonesia, Philippine, Thailand and Vietnam [1, 2]. And, the culture practices mainly focused on the Nile tilapia (*Oreochromis niloticus*), Mozambique tilapia (*O. mossambicus*) and blue tilapia (*O. aureus*) [3]. Among them, Nile tilapias are currently very popular farmed tilapia species worldwide and representing 80% plus of total tilapia production and 60% of total Chinese tilapia production is Nile tilapia [1, 4]. Bangladesh is stands for

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8th in global tilapia production and the yearly production is approx. 0.13 million tons [2]. However, tilapia culture is widely varied in terms of geography and methods of culture and production [5]. Traditional culture of Tilapia depended on extensive and semi-intensive systems in cages or earthen puddles. The freshwater shortage and less rural activities have slowly shifted tilapia culture from semi-intensive systems to more intensive culture systems [6].

Nile tilapia performs well in tropical areas with its early sexual maturity and suitable to culture in wide farming systems i.e., extensive to highly intensive [4, 7, 8, 9]. By hybridization, they grow faster with minimum management [10]. Study shows that production of tilapia increased from 18 Mt in 1990 to 15, 000 metric ton in 2000 by considering crop rotation with shrimp [11].

In Bangladesh, capture fisheries covered the economy of country [12]. However, fishermen are gradually introducing themselves to culture practice besides capture fisheries for enriching their socio-economic status [13, 14]. Besides many culture techniques, semi-intensive production system is popular in Brazil, Colombia, Costa Rica and Mexico as well as in Bangladesh [1, 10, 15]. Semi-intensive production is cultured in puddles and small water bodies is a popular method [16, 17]. Intensive production system is practiced in cages, puddles, raceways and secondary or tertiary irrigation channels [18]. The stocking densities vary from 80 to 100 fish.m^{-3} and the yearly production ranges from 1.5 ton.ha^{-1} in rustic puddles to 25 ton.ha^{-1} in raceways with high production [19, 20]. In some countries, 82% farmers are producing tilapia at intensive levels (80 fish.m^{-3}) and 100% use circular tanks [21]. However, the intensification should be increased more than 150 fish.m^{-3} to meet profitable outcomes [22].

Cages disrupted breeding life of tilapia; so mixed-sex population can be cultured without the problems of recruitment and stunting, which are major drawbacks of puddle culture [2]. So, rejecting the extensive system, present study followed the semi-intensive culture system for further study.

Growth observation of tilapia and its juveniles with different stocking densities were monitored in previous researches through earthen puddles, cages, intensive and semi-intensive condition by changing feeding rates, water, pH and bio-chemicals parameters around the world. Under those investigations, positive and negative correlation of growth with stocking density was reported [23-31]. However, changing weather and local environmental factors can make a significant change in growth performances of *O. niloticus.* So, location-based growth performances of tilapia remain unclear. Clearing those statements, the aim and objectives of this study was to evaluate the performance of Nile tilapia fingerlings production under high stocking density in earthen nursery puddles for maximum optimal production and refine aquaculture technologies at farmer's field conditions after a review and comparison of the results with other studies. After getting significant results, adopted technologies will be demonstrated for refinement and development in culture of mono-sex tilapia fry nursing technique in farmer puddles.

MATERIALS AND METHODS

Study Area: The present study of 8 adaptive trials for mono-sex tilapia fingerling production were carried out in four upazilas (sub-districts) of Rangpur district, the command areas of Integrated Agricultural Productivity Project (IAPP) implemented by Bangladesh Fisheries Research Institute (BFRI), Freshwater sub-station, Saidpur, Nilphamari within its close supervision. This experiment was conducted at different selected unions under Rangpur Sadar, Mithapukur, Pirgonj and Gongachora upazila of Rangpur district Bangladesh (Fig. 1).

Experimental Design: A semi-intensive culture system was chosen for this experiment to produce quality mono-sex tilapia fingerlings considering socio-economic conditions of local fish farmers with their farming ability and available farming facilities [33]. A 60-day culture trial (including puddle preparation) was continued under the present experiment of nursing of mono-sex tilapia fry in puddles from April 2015 to June 2015. Thus, 8 (eight) separated puddles were selected for the present study. Average puddle area was 20±0.88 decimal with an average water depth of 3.78±0.25 feet during study period. All the puddles were rain fed and managed by farmers. Experimental fish species was mono-sex tilapia (*Oreochromis niloticus*). Three different treatments were designed and randomly assigned with selected puddles as T_1, T_2 (with three replications) and T_3 (with two replications). The three stocking densities of mono-sex tilapia seeds production were examined with treatment, T_1 = 1000 ind. dec.$^{-1}$, treatment, T_2=1200 ind. dec.$^{-1}$ and treatment, T_3=1400 ind. dec.$^{-1}$ (Table 1). Average size of socked fries was recorded 4.13cm and average initial weight (wt.) was 1.98 g.

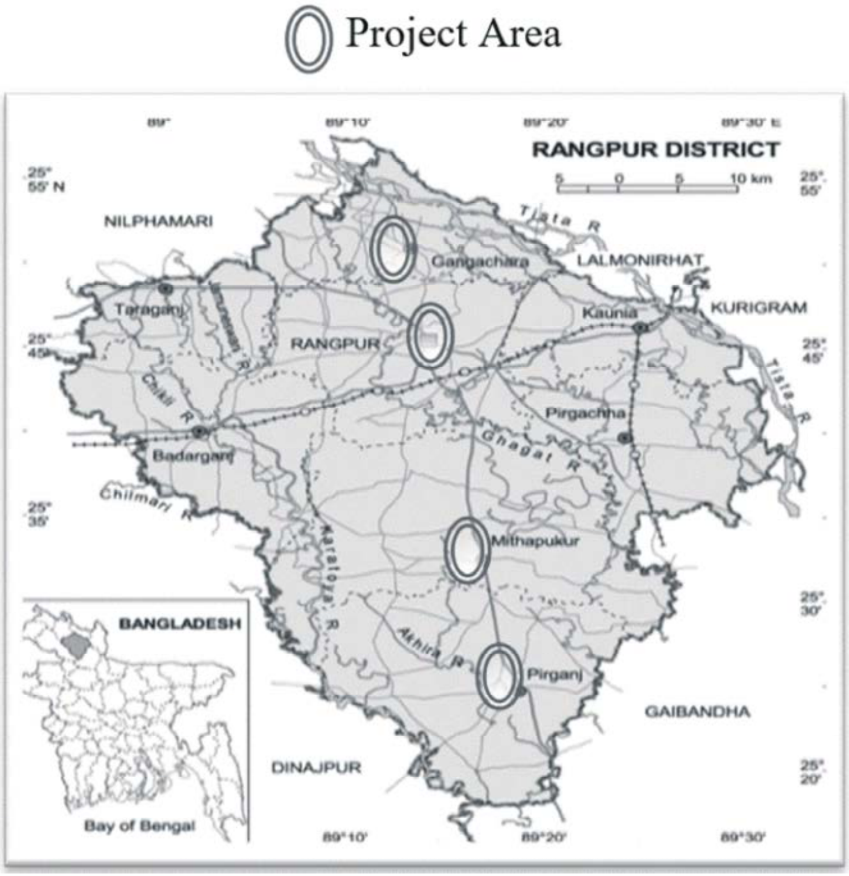

Fig. 1: Show the experimental area in the Rangpur District [32]

Table 1: Experimental design for the selected adaptive trail of IAPP in the different upazilas under Rangpur district.

Sl No.	Location	Water Depth (Feet)	Treatment & Replication	No. of Fry
01	RangpurSadar	4	T_1R_1	20000
02		3.5	T_1R_2	20000
03	Gongachora	4	T_1R_3	20000
04		3.75	T_2R_1	24000
05	Mithapukur	3.5	T_2R_2	24000
06		4	T_2R_3	24000
07	Pirgonj	3.5	T_3R_1	28000
08		4	T_3R_2	28000

Table 2: Fertilizer names, doses and applying methods during pre-stocking management

Name of Fertilizer	Doses	Applying methods
Cow dung (rotten)	3-5 kg. dec.$^{-1}$	Dilute with water then applying around of the puddle by manually.
Urea (46% nitrogen)	200 g. dec.$^{-1}$	Mixer with water then applying around of the puddle by manually.
T.S.P (Triple Super Phosphate)	100 g. dec.$^{-1}$	Mixer with water then applying around of the puddle by manually.

Puddle and Farmer Selection and Preparation: Puddles were selected according to the standard manual of previously reported local research. A series of training sessions on fish seed nursing were arranged for selected farmers before project intervention and the training courses contented fry selection, transportation, puddle preparation, feed selection and feeding, nursing and puddle management, sampling and harvesting of stocked species on the priority basis [4, 33].

Table 3. Mono-sex tilapia feeding trial for 30 days

Age of fry (days)	Quantity of feed (% of body weight)	Feed type (stage)
1-7	20	Pre-nursery
8-14	18	Pre-nursery
15-21	16	Pre-nursery & Nursery
22-30	15	Nursery

Table 4: Fertilizer names, doses and applying methods during culture

Name of Fertilizer	Dose	Appling method
Cow dung (rotten)	250 g. $dec.^{-1}$ @7 days interval	Dilute with water then applying around of the puddle by manually.
Urea (46% nitrogen)	35 g. $dec.^{-1}$ @7 days interval	
T.S.P (Triple Super Phosphate)	21 g. $dec.^{-1}$ @7 days interval	

Puddle preparation was the first step of pre-stocking management during this experiment. Some selected puddle dikes were required to be renovated and all aquatic vegetation's were clearly removed manually by the farmers. Initially, for the removal of predator animals and other undesirable species to fry was done by frequently netting with fine mesh net and secondly, on a sunny day the puddles were treated with 9.1 rotenone at the rate of 30 $g.feet^{-1}dec^{-1}$ puddle water by applying 1/3 of the rotenone as balls mildly throwing on bottom and rest of the chemical splashed out on the entire water column after mixing with ample water. Later, affected fish were caught properly.

Liming was done with 1 kg. $dec.^{-1}$ rate for puddle preparation. After 3-5 days of liming, fertilizers were distributed according to table 2. Both inorganic and organic fertilizers were applied for the natural food production. After 3-4 days of applying fertilizers, Dipterex (*trichlorfon*) was used to remove the grown harmful aquatic insects at least 24 hours prior to restocking of fry. All nursing puddles were properly fenced with nylon net to avoid entrance of any prey animals [4, 5]. 1000 fry's pre one oxygenated polybag was used in transportation with careful handling [33].

Feeding and Fertilization: Pre-nursery and nursery readymade/commercial feeds (*Aftab* floating fish feed; a local famous feed brand) were applied for mono-sex tilapia fry around three times in a day at 09:00 am, 01:00 pm and 05:00 pm (GMT +6) respectively (Table 3). During culture period, a periodic dose of fertilization (both organic and inorganic) was done to maintain abundance of natural productivity within the nursing puddles (Table 4).

Sampling and Data Analysis: Harvesting was done after 30 days nursing of mono-sex tilapia fry. Sites were visited by researcher after every 2 days and puddle conditions and mono-sex tilapia health condition were monitored during the production period. Each data was tabulated in MS excel 2016 and analyzed further through various growth equations. To evaluate the fish growth, some parameters were narrated e.g., survival (%) and production of fish (kg/hectare). Some necessary equations were [3, 14, 34]:

$$\text{Weight (Wt)} = \text{Mean fianl wt gain} - \text{mean initial wt gain} \quad (1)$$

$$\text{Prcent weigth gain (\%)} = \frac{\text{Mean Final wt gain} - \text{Mean initial wt gian}}{\text{Mean initial wt gain}} \times 100\% \quad (2)$$

$$\text{Survial (\%)} = \frac{\text{No. of harvested individuals}}{\text{No. of stocked individuals}} \times 100\% \quad (3)$$

$$\text{FCR} = \frac{\text{Dry feed fed wt}}{\text{Live wt gain}} \quad (4)$$

$$\text{Gross yield at the end} = \frac{\text{Total harvesd fry wt (kg)}}{\text{Total harvesd area (acre)}} \times 100\% \quad (5)$$

$$\text{Condition factor(CF)} = 100 \times \frac{\text{Weigth}}{\text{length}^3} \quad (6)$$

$$\text{Specific Growth rate } (SGR\%D^{-1}) = \frac{\text{Ln (final wt)} - \text{Ln (initial wt)}}{\text{Days}} \times 100\% \quad (7)$$

Cluster analysis was done by MVSP (Version 3.13) for investigating similarity and closer productive relation among treatments. Box-whisker plots were used to reveal the growth range among replicates of current experiments.

RESULTS

Growth Sampling: *O. niloticus* demonstrated a wide fluctuation in growth during experiments. Initial lengths (cm) and weights (g) of fries for each treatment were measured before deploying fish seeds in puddles. With average initial length (Fig. 2A), T_1R_2 grown higher after 7 days of experiments (Fig. 2B). Forwarding, it slowed and stable after 14^{th} and 30^{th} day (Fig. 2C). T_2R_2 possessed lower initial length but it grown highest than other replicates (Fig. 2D). The treatments with highest stocking density (1400 fries/dec.) showed constantly lower length increment through all sampling. Average growth curve was demonstrated the increment tendency of length during experiments (Fig. 2E). On the other hand, fasted weight gaining was observed in all replicates of T_2 (Fig. 3). Lowest weight gaining rate was observe in T_3R_1 and T_3R_2 (Fig. 3A). Weight gaining rates were higher among 7-14 days (Fig. 3B and 3C). The growth become stagnant after 30 days (Fig. 3D). Average weight increment of whole experiment was shown for specific production monitoring (Fig. 3E).

Production Monitoring: Monosex Tilapia showed moderate production rate with higher growth during present experiments. Initially the average weight of fish seeds in all treatments was 1.98 g which made an outcome of 13.17g in average after 30 days of rearing (Fig. 3A).

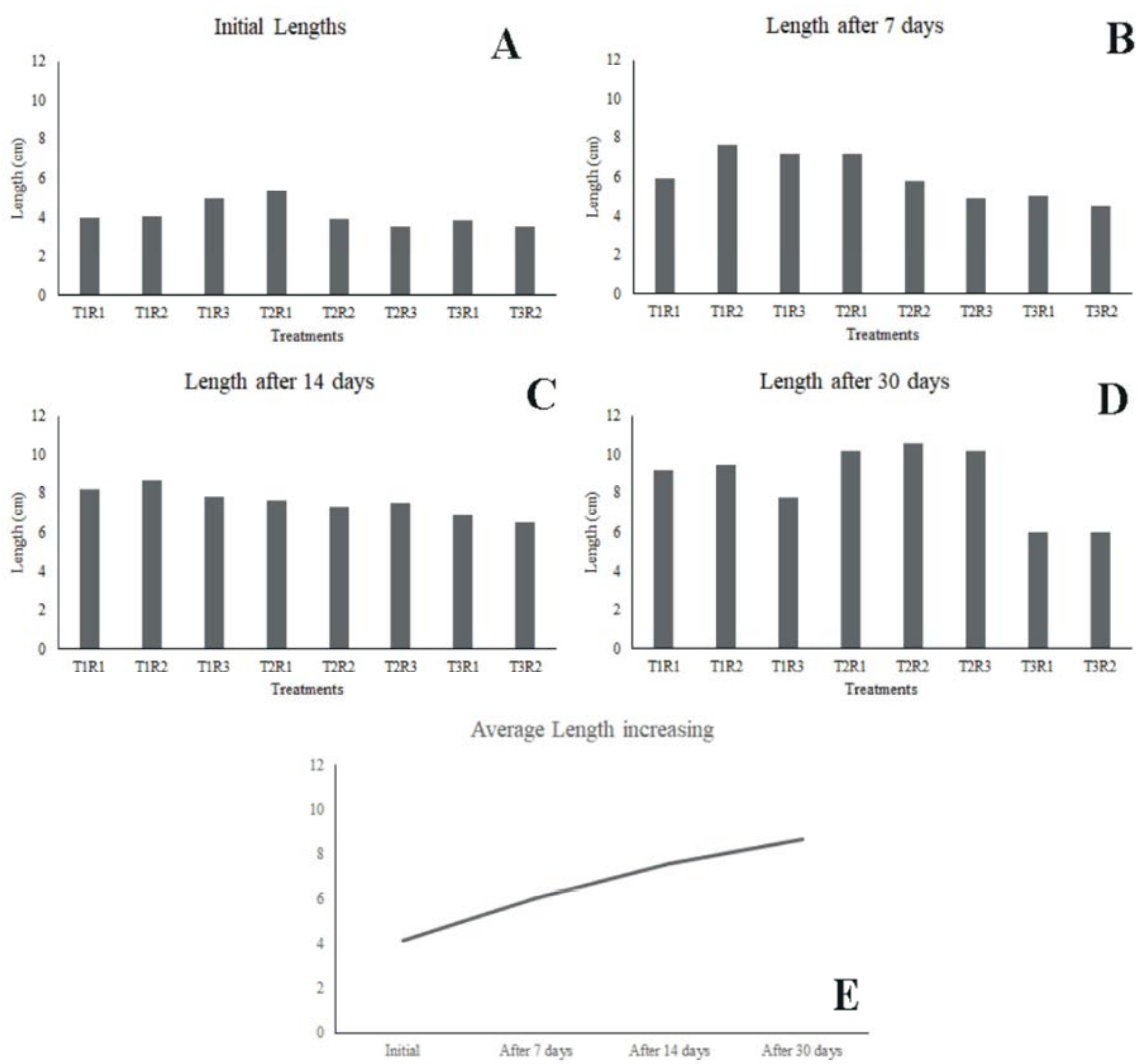

Fig. 2: Variation of Lengths of Monosex Tilapia during present experiment. Calculated lengths i.e. initial lengths (A) and measured after 7 days (B), 14 days (C) and 30 days (D) with an average length increasing curve (E).

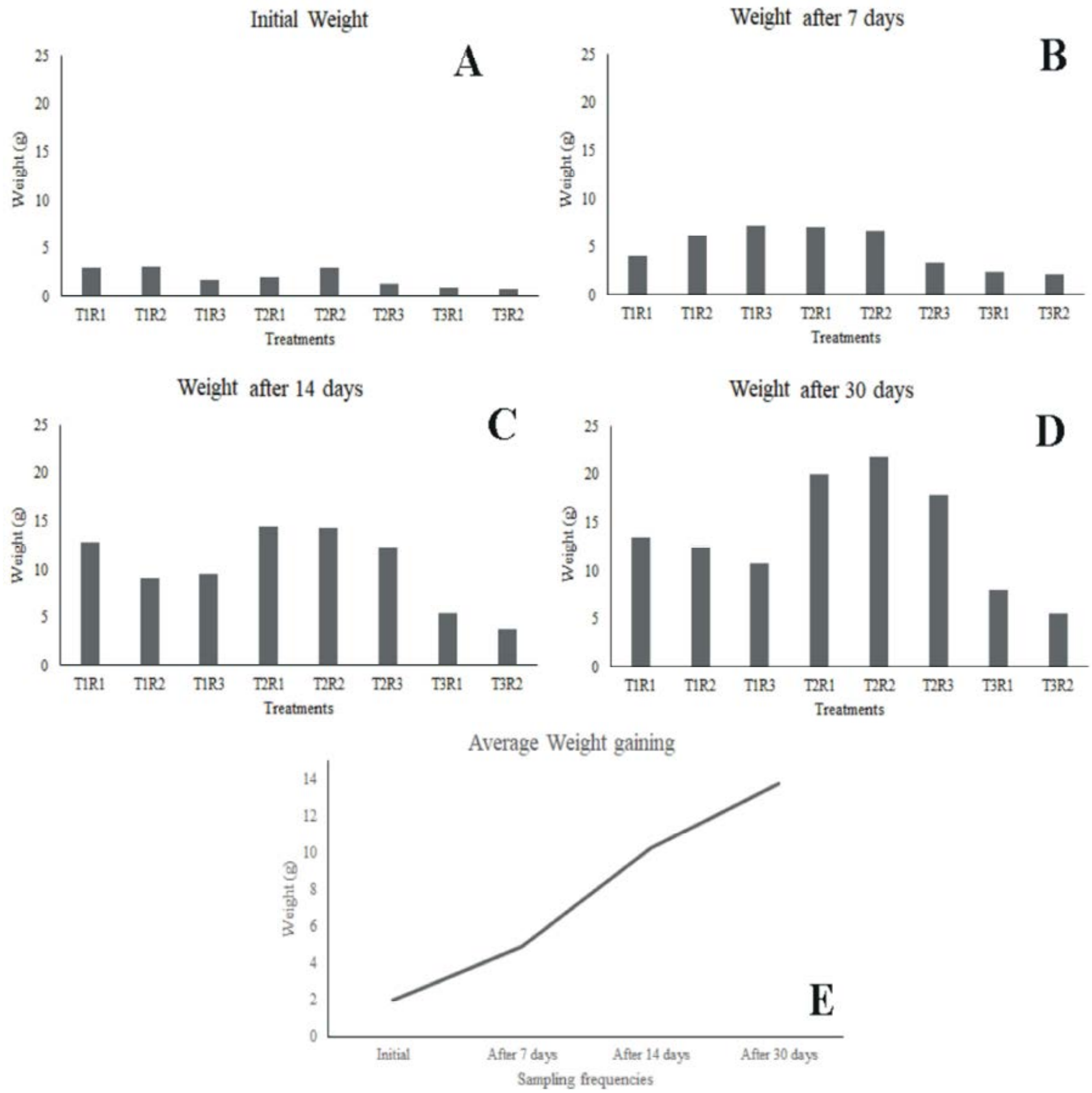

Fig. 3: Variation of weights of Monosex Tilapia during present experiment. Measured weights i.e. initial weights (A) and measured weights after 7 days (B), 14 days (C) and 30 days (D) with an average weight increasing curve (E).

Average survival rate was 78%. In these eight treatments, T_1R_3 and T_2R_2 are showed higher survival rates. Approximately, 100 kg was the final semi-intensive production after examination period with SGR 3.74%. Average length increasing was observed higher after 14 days (Fig. 2C). Continuous growth of lengths (Fig. 2E) and rapid growth of weight (Fig. 3E) was detected during experiments.

Correlations among Replicants: Production calculations in treatments were converted to percentages for identifying comparative high values among replicants (Fig. 4). Highest production was observed in T_2R_2(20.86 kg) and lower average production was detected in highest stocking density (1400 ind./decimal) of T3 (90.04 kg/ha). Fingerlings of T_1R_1 were the highest weight group among T_1 replicates but not up to mark compare to T_2 (Figure 3). Numeric percentages of growth rates were revealing the actual situation of growth through side by side comparison (Fig. 5). Growth rates was observed higher in T_2, especially T_2R_3 (Fig. 5). Average production (Fig. 4) was higher in T_2 (231.87 kg/ha) rather than T_1(117.3 kg/ha). Average FCR and Specific growth rates (SGR) were demonstrate the experiment quality and fry's health as

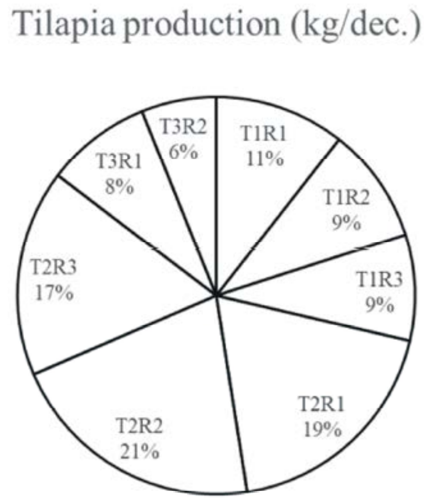

Fig. 4: Production percentages (%) of Monosex Tilapia per decimal during present experiment

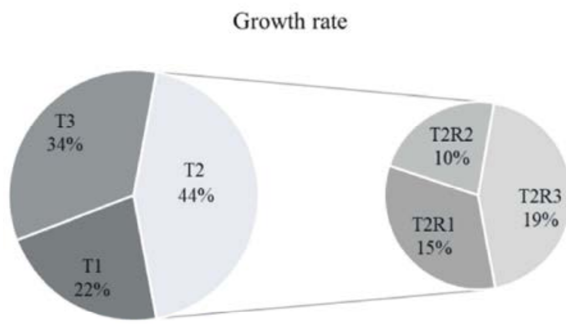

Fig. 5: Growth rates (%) of Monosex Tilapia during present experiment. Replicants (%) of significant production (T_2) were demonstrated in details

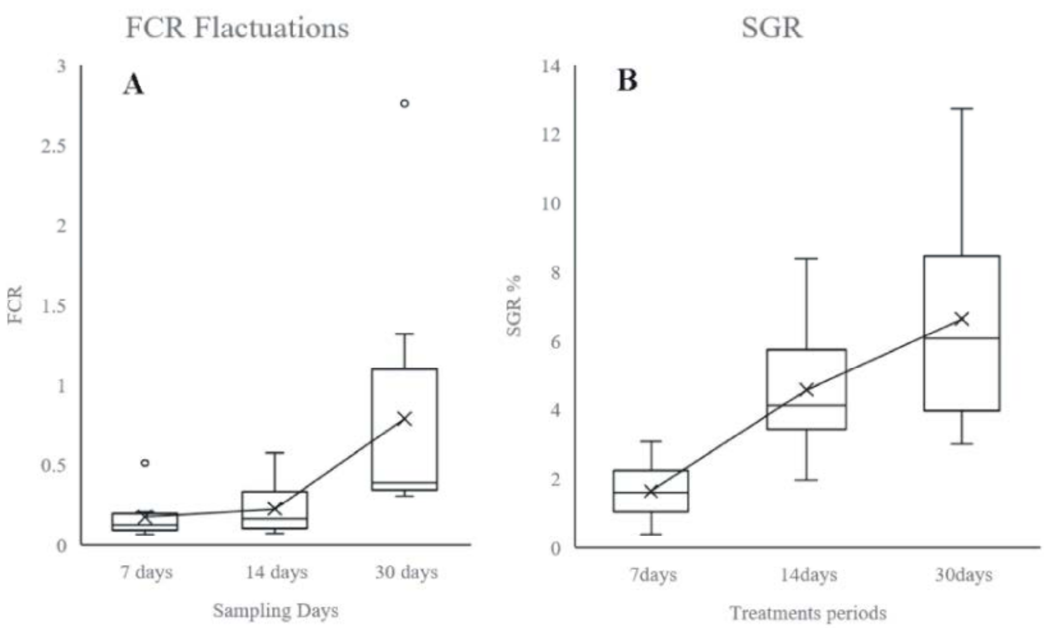

Fig. 6: Average fluctuations of food conversion (A) ratios (FCR) and specific growth rates (SGR) of Monosex Tilapia (B) during present experimental days with median connecting average line

Table 5: Reported specific growth rates in various research on Monosex Tilapia

Duration (days)	Stocking Density (Fry/dec)	SGR (% day^{-1})	System	Authors
60	0.2	0.9	Extensive	Dagne and Yimer [24]
30	1000	5.23	Semi Intensive	This Study
30	1200	7.65	Semi Intensive	This Study
30	1400	6.65	Semi Intensive	This Study
40	300	10.05	Super Intensive	El-Sayed [27]
40	500	9.87	Super Intensive	El-Sayed [27]
40	1000	8.89	Super Intensive	El-Sayed [27]
40	1500	8.11	Super Intensive	El-Sayed [27]
40	2000	7.78	Super Intensive	El-Sayed [27]
56	0.4	3.81	Intensive	Wu *et al.* [29]
56	0.9	3.73	Intensive	Wu *et al.*[29]
56	1.3	3.62	Intensive	Wu *et al.*[29]
56	1.8	3.52	Intensive	Wu *et al.*[29]
56	8	3.64	Intensive	Zou *et al*. [41]
60	9	1.77	Intensive	Lemos [28]
60	18	1.44	Intensive	Lemos [28]
60	36	0.99	Intensive	Lemos [28]
60	40	5.01	Hyper intensive	Klanian and Adame [25]
60	50	4.95	Hyper intensive	Klanian and Adame [25]
60	60	4.8	Hyper intensive	Klanian and Adame [25]
70	15	3.23	Cage Culture	Hasan *et al.* [15]
84	5	1.26	Intensive	Soluma *et al*. [40]
112	112	1.06	Intensive	Paul *et al*. [34]
120	20	3.15	Semi Intensive	Kohinoor *et al*. [26]
120	40	3.12	Semi Intensive	Kohinoor *et al*. [26]
120	60	3.15	Semi Intensive	Kohinoor *et al*. [26]
150	100	0.1	Semi Intensive	Gindaba *et al*. [37]
150	200	0.02	Semi Intensive	Gindaba *et al*. [37]
150	300	2.71	Semi Intensive	Kapinga *et al*. [35]
150	300	0.04	Semi Intensive	Gindaba *et al*. [37]
150	1300	3.47	Semi Intensive	Kapinga *et al*. [35]
155	5	1.03	Cage Culture	Gibtan *et al.* [43]
155	10	0.97	Cage Culture	Gibtan *et al*. [43]
155	15	0.88	Cage Culture	Gibtan *et al*. [43]
155	20	0.79	Cage Culture	Gibtan *et al*. [43]

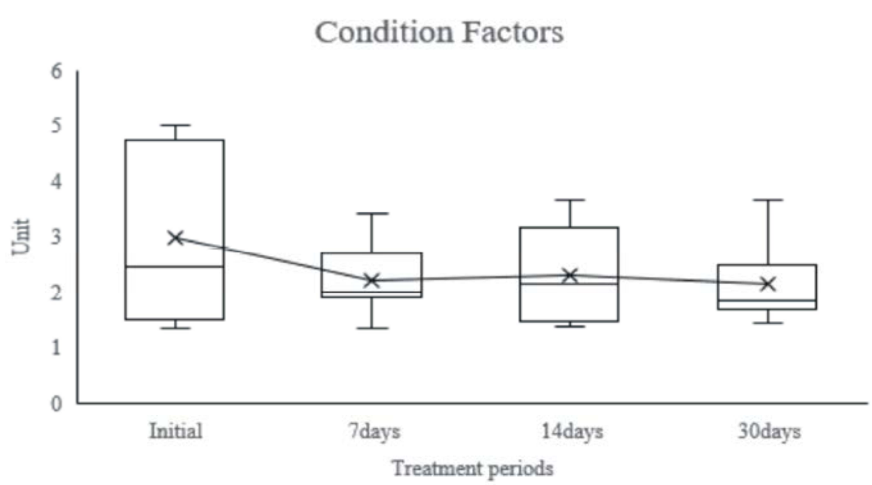

Fig. 7: Average condition factors of monosex tilapia during experimental periods in this study with average line after connecting all medians of each box-whisker

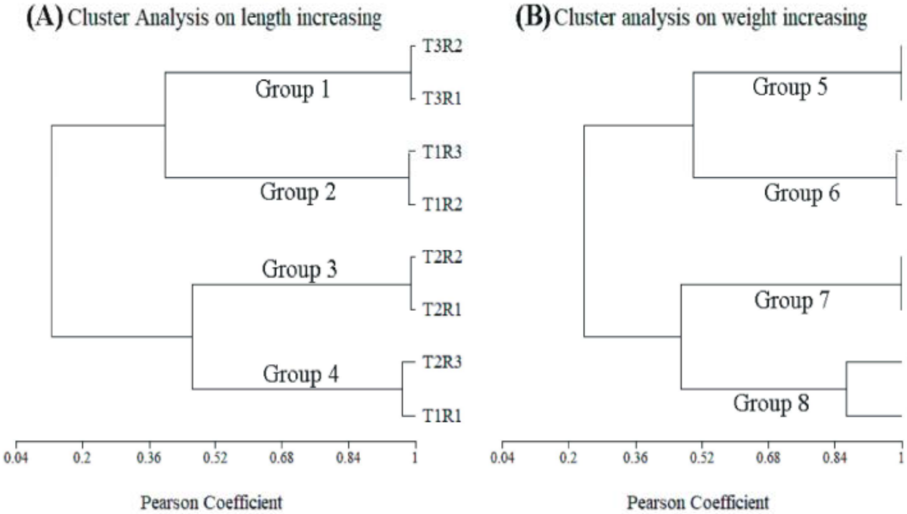

Fig. 8: Cluster analysis on basis of Pearson correlation among replicants of all treatments after considering length (A) and weight (B) increasing rates in 8 groups

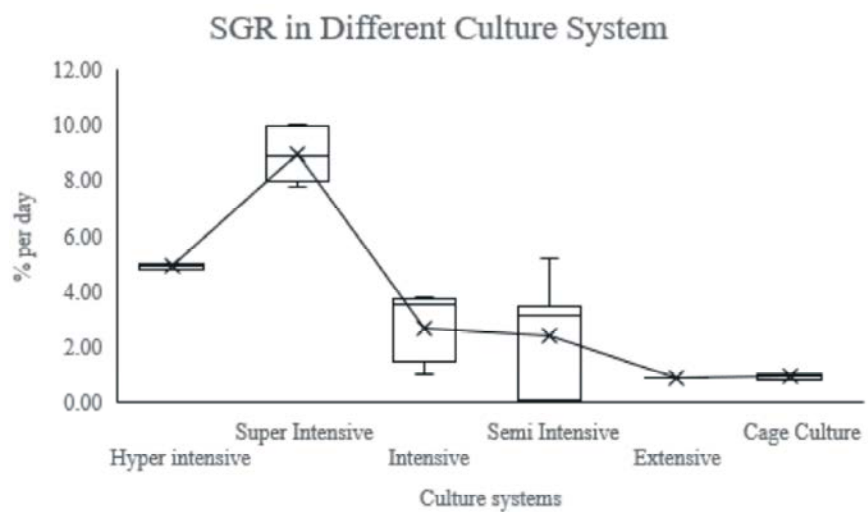

Fig. 9: SGR fluctuations in different studies from Table 5 according to culture system

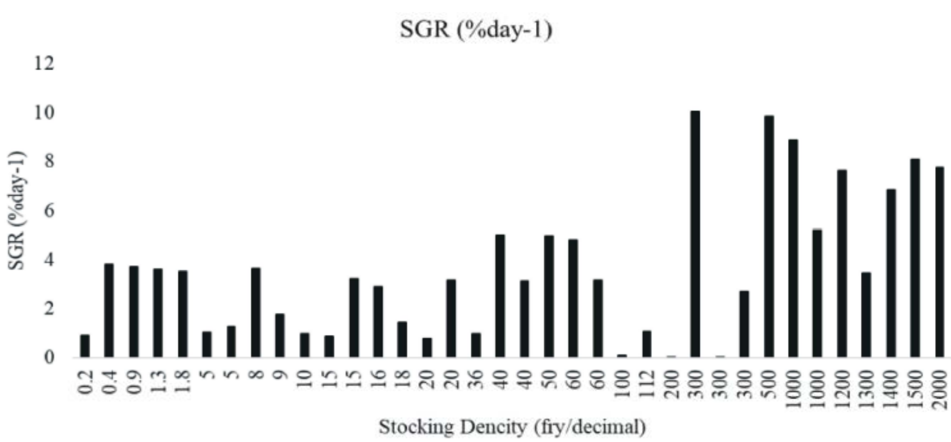

Fig. 10: Comparative view of specific growth rates recorded in various researches from Table 5

well (Fig. 6). SGR were closely similar in T_2 (7.65%) and T_3 (6.85%) and lower in T_1 (5.23%). FCR (Fig. 6A) as well as SGR (Fig. 6B) were moderately lower in initial stage. After 14 days, it picked up near 1 in average (Fig. 6). It seemed that, healthy fries with higher initial weight i.e. T_2R_2 (2.98 g) grown higher (21.73 g) than other fries in different treatments after 30 days of culture period.

Condition factor (CF) was monitored and merged for calculating the metabolic condition of fries and fingerlings of *O. niloticus*. CF was over 2 at initial stage but became stable after first 7 days (Fig. 7). Cluster analysis was performed to find the correlations among treatments and identify the healthy growth relation of replicants accordingly on basis of Pearson correlations as coefficient among samples (Fig 8). Through analysis, T_2R_1 and T_2R_2 showed correlation (Group 3) about length increasing (Fig. 8A). However, T_2R_2 (Medium stocking density) also maintained close relation (Group 5) with T_3R_1 (High stocking density) about weight increasing which indicates good performances of T_2R_2 (Fig 8B). Replicants of all treatments maintained relative growth performances which revealed by similar replicants clustering i.e. T_1R_2 and T_1R_3 (Group 2), T_2R_1 and T_2R_2 (Group 3), T_3R_1 and T_3R_2 (Group 1), T_1R_1 and T_1R_3 (Group 8), T_2R_1 and T_2R_3 (Group 6) accordingly. So, calculating average of growth performances of replicants in related treatment will more appropriate to determine significant stocking density in this experiment.

DISCUSSION

Deploying different stocking density, present study observed potential growth and suitable commercial production of *O. niloticus* in semi intensive farming. Present study demonstrated the moderate high density may increase the production then highest one with profitable resistances (survival rate) at farming stage. Length and weight increased also with medium stocking rate in these puddles. High stocking density decrease growth performance which is similar to the findings from present study [28]. With 1400 mono-sex tilapia per decimal, the SGR was 6.85% which was higher (7.65%) in T_2 (1200 fries/decimal) during the study period. It has been revealed that high stocking density of Nile tilapia fry can cause 'social stress' which gradually leads to impaired growth of fish [27]. Extracting from different research, Table 5 shows the moderate stocking i.e. 300-1200 monosex tilapia per decimal obtained higher SGR in semi intensive as well as Super intensive culture systems including present study [27, 35].

Physical growth performance of *O. niloticus* also depends on its physiological status, the energy content of the diet, reproductive state and environmental factors such as dissolved oxygen, temperature and pH [36]. So, culture system has an impact on growth performance due its intensity. Figure 9 is expressing the clear scenario of SGR of each culture system during past studies (Table 5). Mostly intensive and super intensive culture system has higher growth performance of monosex tilapia with better SGR (Table 5) due to its controlled environment and close monitoring [27, 3]. Figure 10 is stated the SGR against performed stocking density in previous researches for better understanding the growth performances compared to present study (Table 5). Semi intensive culture showed a medium growth rate (average SGR 3.55%) which fluctuates (1.99-5.19%) with stocking density (1000-1400 per decimal) during present study which is similar (Fig. 10) to other semi intensive culture [35]. Some reports of semi intensive culture maintained similar SGR with lower stocking density (Table 5) [25, 26]. Uncontrolled environmental parameter possessed low SGR (0.9%) in extensive Monosex tilapia culture [24].

Rearing days expansion also showed lower SGR in 150-155 days but comparatively higher between 40-120 days [26-27, 37]. This study also observed moderately higher SGR in 30 days. Sirol *et al*. reported that tilapia growth rates were increased while increment in feeding rates from 4% to 16% with impaired FCR [38]. In this study, FCR (Fig. 6A) as well as SGR (Fig. 6B) increased by time; reversely paired with decreasing feeding rates from 20% to 15% (Table 3).

Liu *et al*. [23] reported 3.39-4.45 g. cm^{-3} condition factors of monosex tilapia with healthier fries. In Bangladesh, Islam *et al*. [14] reported the excellent condition factor of available monosex tilapia fries was 1.82 g. cm^{-3} according to the comments of Fulton [39]. During this study, condition factors were fluctuated between 2-3 g. m^{-3} in all replicates which can be consider as treatment's stability rather than other culture system [40, 41].

Culture of tilapia may enhance the livelihood of fisherman biased on locality [42]. This study narrates the acceptable and possible way of increasing stocking density with highest production of tilapia culture in the study area under similar environmental condition and soil texture (Fig. 10). More research should be introduced to broadcast these culture techniques on local basis to choose and determine the suitable stocking density for sustainable economic growth for that region.

Significant Statements: This study discovered the production pattern of mono-sex tilapia (*O. niloticus*) at high stocking density that can be beneficial for commercial profit of culture farm. This study will help the researchers to uncover the critical areas of maximum local production rates that many researchers were not able to explore with lower stocking density with semi intensive culture management. Thus, a new theory on mono-sex tilapia (*O. niloticus*) culture system may be arrived that potential production of fingerlings may obtain through semi-intensive culture with optimal high stocking density of mono-sex tilapia (*O. niloticus*) fries.

CONCLUSION

Growth of fish depended on complex effect of various environmental and physiological parameters. By fixing some hydrological parameters, it showed that moderate stocking density i.e., 1200 fries per decimal of mono-sex tilapia shows higher growth rate as well as production during whole experiments in this study. Higher stocking density is not recommended for mono-sex tilapia (*O. niloticus*) for higher production. Linear increment of length was observed through the experiment and weight was increased sharply after 7 days. Increasing density in smaller water body may cause lower production and profit as well.

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