ORIGINAL ARTICLE

Effects of different stocking densities on the growth performance of Nile tilapia (*Oreochromis niloticus* L) fingerlings cultured in earthen pond system

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ABSTRACT

Fish culture is important to fill the demand of protein source foods and for contributing in poverty reduction in the country. The current experiment was conducted to explore the effect of stocking density on the growth performance and yield of Nile tilapia. Treatments had stocking densities of (2 fish) (control), (4 fish) and (6 fish) m^{-2}. All treatments were in triplicates. Fingerlings with mean 7.96±0.2 g and 8.4±0.6 cm length were randomly stocked into 60 m^2 earthen ponds. The fish were fed on similar locally available feeds such as rice bran, Niger seed cake, soyabean cake and wheat bran for 300 days. The mean final weights of fish were (178.5±6.7 g), (191.5±5.7 g) and (168.7±4.6 g) for2, 4 and 6 fish m^{-2} respectively. The length-weight relationship between the treatments showed strong correlation (R^2>0.9) and the growth parameter 'b'value were indicated negative allometric growth pattern (b<3) in all treatments and showed nonsignificant differences (χ^2, p>0.05). The survival rate (%) was ranged (73-87.2) showed a significant difference when increasing in stocking density (p<0.05). The feed conversion ratio was ranged (1.84-3.4) showed significant difference (p<0.05). However, SGR (% day^{-1} and g day^{-1} ranged 1.0-1.1 and 0.59-0.64 were not density dependent for all treatments (p>0.05). The gross yield (55-123.8 kg $pond^{-1}$) revealed significant differences as the stocking density increases (p<0.05). In conclusion, it is possible to grow 4 fish m^{-2} in addition to 2 fish m^{-2} (control) for larger size fish demand while 6 fish m^{-2} gives higher gross production with supplemented feed.

Keywords: Condition factor, length-weight, negative allometric, survival rate, treatments

INTRODUCTION

The Nile tilapia (*Oreochromis niloticus*) is native to Central and North Africa. The species has the ability to withstand wide range of environmental changes and also the best candidate for the aquaculture. Consequently, the Nile tilapia has been introduced to other parts of Asia, Europe, North America, and South America due to its fitness to aquaculture (Negassa and Prabu, 2008). In Ethiopia, the species has been distributed almost in all drainage basins including in the rift valley, Abay, Awash, Baro-Akobo, Omo-Gibe, Tekeze-Atbara Wabishebele and Genale-Dawa basins (Tesfaye *et al*., 2020; Getahun, 2017; Awoke, 2015; Golubtsov and Mina, 2003). Besides, it is also well adapted fish species in the ecology of tropical and subtropical waters. It is one of the most commercially important fish species landed from lakes, rivers, wetlands and reservoirs of Ethiopia. The species offers about 60% of the total landings from major and small water bodies (LFDP, 1997; Admassu, 1996). However, recently the actual yield declined to 49% (Tesfaye and Wolff, 2014). The sharp decline of fish yield is related to overfishing and ecological changes of water bodies due to population pressure such as extension of agriculture and floriculture around the watershed area. Moreover, land degradation, soil erosion, and nutrient runoff have also contributed in fish biomass reduction (Wakjira *et al*., 2013). Now a days, most water bodies of Ethiopia have been experienced with signs of overexploitation, degradation, losses biodiversity and reduction of fish resources (Merga *et al*., 2020; Kebede *et al*., 2016). The country subjected to frequent drought this is negatively affects crop production. The practices of agriculture sector are dominated by small scale farmers with low productivity this makes difficult to feed for the fast growing population. For this reason, empowering and implementing of the sustainable aquaculture is the alternative option for food security and poverty alleviation.

Makori *et al*. (2017) described the Nile tilapia (*Oreochromis niloticus*) as it is suitable for culture due to acceptance of formulated feed, high growth rates, adaptability to a wide range of environmental conditions, breed in harsh condition. Moreover, the ideal preferred temperature and pH ranges between is 25 to 27 ^{0}C, and 6 to 9 for optimal growth in fish ponds or in cage systems (Makori *et al*. 2017).

Stocking density is the number of fish per unit area or volume in land based or open water systems of aquaculture. Stocking density is an essential parameter for fish culture in order to gain maximum profit and to minimize water quality related incidents (Tammam *et al*., 2020; Ondhoro *et al*., 2019; Santos *et al*., 2019; Dagne and Yimer, 2018; Aryani *et al*., 2017; Limbu *et al*., 2016; Begum *et al*., 2014; Dagne *et al*., 2013; Tawwab *et al*., 2014). Furthermore, it determines the fishes health, growth, survival and yield (Khatune-Jannat *et al*., 2012; Rahman and Rahman , 2003). The application of the recommended stocking density differs with respect to fish species. On the other hand, some authors reported higher stocking densities might be enhance fish yield by lowering the expenses and with limited land, water resources, human power as well (Farhaduzzaman et al., 2020; Khatune-Jannat *et al*., 2012; Abou *et al*., 2007; Ridha, 2005). However, recent studies revealed that (Abaho *et al*., 2020; Mengsitu *et al*., 2020; Makori *et al*., 2017; Gindaba *et al*., 2017; Mapenzi and Mmochi, 2016; Klanian and Adame, 2013) high stocking densities might negatively affect growth performance of fish due to high competition for food access and also affects fish reproductive biology as well. In other way, high growth performances of fish were recorded at lowest fish densities.

Lake Tana (catchment) is a potential area for aquaculture at small-scale and commercial production levels due to the existance of fish market, road access, water availability and good soil in terms of pH and texture (Asefa and Abebe, 2018). Based on the GIS data, 32,678.9 ha (2.7%) is highly suitable while 1,166,594.5 ha (97.2%) is moderately suitable for small scale pond aquaculture systems of the Tana basin. Thus, Fogera district is one of the component for Lake Tana basin. Moreover, the district is endowed with a number of wetlands and water logged areas year round. The Fogera floodplains have been known for rice, onion, cabbage and cultivation due to the accessibility of water (Desta *et al*., 2019; Oumer *et al*., 2015). Few fish farmers have been cultivated fish in small scale and semi-intensively in the district. No scientific findings have been conducted related to fish farming systems particularly on the stocking density from the study area. In addition to this, the practices of fish farming, the number of fish m^{-2}, integrated with rice or vegetable is not well understood by the fish farmers in Fogera district particularily in Kuhar kebele in order to assure food security for domestic or commercial use of the country. In line with this, the small scale fish farmer from Fogera district particularly in Kuhar kebele still they harvested low yields even they supplemented local available fish feeds based on the experts recommendation. Knowledge on the fish farming conditions such as stocking density (the number of fish m^{-2}), water quality, fish feeds, growth rates and the expected yield are vital for proper management and to harvest the expected fish yield. Therefore, the main objective of this study was to know the effect of stocking denisties on Nile tilapia *O. niloticus* in different stocking densities in earhen ponds from Kuhar kebele, Fogera District, Guna-Tana catchment.

MATERIALS AND METHODS

Discripition of the study area

The study was conducted at Kuhar kebele near to Woreta town, Fogera district, South Gondar, Amhara regional state, Ethiopia (Figure 1). Fogera district has 30 rural and 5 urban kebeles. Fogera is known for its floodplain, and chain of wetlands (Oumer *et al*., 2015). Moreover, the area is suitable for fish culture integrating with vegetables and fruits due to the plenty of water availability (Asefa and Abebe, 2018). Fogera district has

an altitude in between 1750 and 2100 m above sea level. Woreta town also, has an altitude and longitude of $11^{0}55'$N $37^{0}42'$E with the corresponding elevation of 1828 m above sea level. The mean annual rainfall is 1225.8 mm and the maximum and minimum atmospheric temperatures were 12.6 and 27.9 °C respectively (Alelign *et al*., 2018).

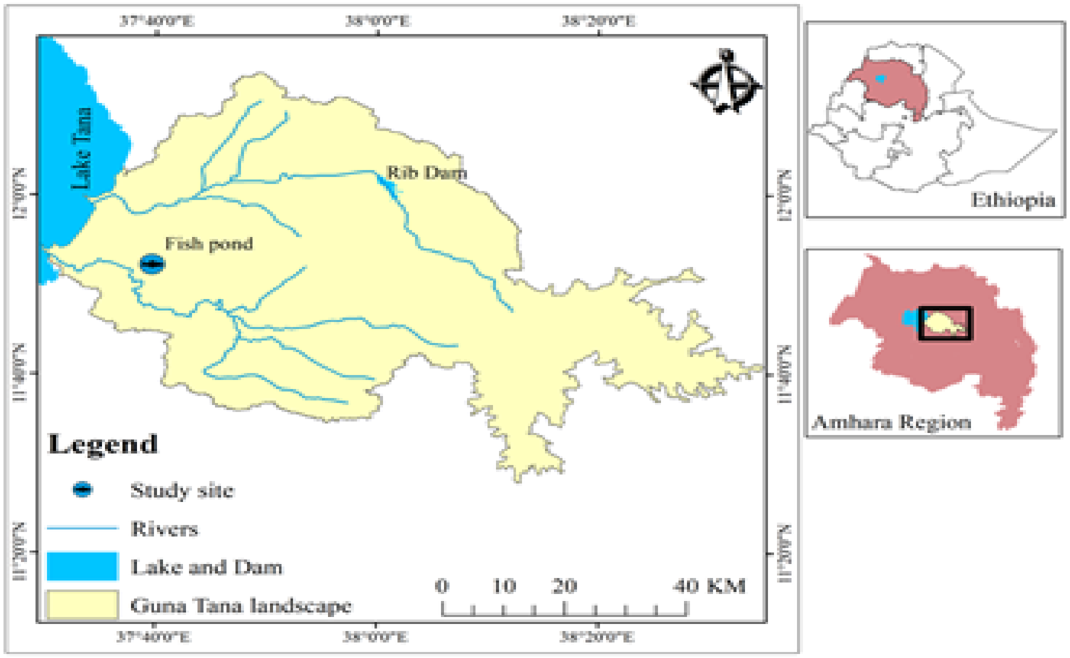


Figure 1. The map shows the studied fish ponds. relation

Experimental fish (fingerlings) collection

The selected strain about 2160 fingerlings ranged from (7.96±0.2 g) and (8.4±0.6 cm TL) were collected from Bahir Dar Fisheries and Other Aquatic Life Research Centre; and transported using oxygenated plastic bags to the experimental unit of the Kuhar fish experimental earthen ponds.

Experimental design

Nine experimental ponds having surface area of 6 m×10 m (60 m^2) and 1 m depth earthen ponds have been constructed (Figure 2). Due to low water retention capacity the ponds were lined by geomembrane sheet to hold enough water to make sustain the culturing system. Then the ponds were filled with water and fertilized enough. Following this, three stocking densities T1 (2 fish) (control), T2 (4 fish) and T3 (6 fish) per m^{-2} were randomly assigned for random distribution of fingerlings into earthen fish ponds. These experimental units were replicated three times to make a total of nine fish ponds. Acclimation and pond fertilization were considered for each of the nine fish ponds. The experimental fish ponds had been fertilized for 7 days before stocking, using organic manures from farm animals at a rate of 5 kg 100m^{-2} week^{-1} (Ngugi *et al*., 2007) to make effective the experimental start-up. Furthermore, water quality parameters were measured based on the standard. The fingerlings were weighed properly before stocking. A total of 2160 Nile tilapia fingerlings were randomly stocked in the experimental ponds. Fingerlings with mean initial weights of 11.2±2 g, 8.4±0.6 g and 9.3±01.1 g were stocked at 2 fish m^{-2} (control), 4 fish m^{-2} and 6 fish m^{-2} respectively. The physico-chemical water quality parameter such as pH, TDS, electrical conductivity and temperature were measured monthly using HANNA multi-meter model(HI-98129) instruments. Dissolved oxygen (DO) were measured by a digital DO meter (DO-520). Turbidity also measured by turbido meter (SGZ-200BS) instrument. Locally available feeds such as nug cake, soyabean, wheat bran and rice bran were used to feed fish in different stocking densities. The proportion and mode of feeding were similar and based on their body weight (5%) to all experimental units because the experiment is aimed to assess the stocking density not feed trial. Moreover, the feeds were supplemented based on the fish weight two times day^{-1} for 10 months.

Figure 2. Photos show that the constructed (a), geomembrane lined (b) and ponds filled with water (c) during the experimental days.

Fish sampling and growth measurement

In each month, 40 fish, 80 fish and 100 fish from 120 fish (T1), 240 fish (T2) and 360 fish (T3) with their corresponding replications were randomly sampled respectively. Fish were caught from each treatment pond using a beach seine. The individual fish weighed to the nearest 0.01 g using digital sensitive balance and the total length to the nearest 0.01 cm measured. Once the measurement per treatment has been completed, the measured fish collected in a plastic jar; finally, returned to the pond for the following measurement. During the sampling month, the water exchange was done when the pond water is suffocated and fish mortality also recorded. At the end of the the experiment all fish from each treatment unit were harvested, weighed and also counted (Figure 3).

Figure 3. Photos were capture ring fish sampling (a) and measurem b and c) at the experimental ponds.

Fish growth performance calculations

The growth performance of the studied Nile tilapia *O. niloticus* within and between the treatments were calculated as the following formulae.

$TW = aTL^b$ ....eq. 1

Where T=total weight of fish in gram (g), T=Total length of fish in centimeters (cm), a=proportionality constant, b=the value obtained from the length-weight equation/coefficient of regression (Bagenal and Tesch, 1978).

$K = (W) \times 100 / (TL)^3$…………....eq. 2

Where W = Weight of individual fish (g), TL = Total length of individual fish, and K = condition factor (Bagenal and Tesch, 1978).

Specific growth rate (g/ day)=(lnwf-lnwi)x100/Time

………eq. 3

Weight Gain (g) = Wf – Wi ……….…….eg. .4

Survival rate (%)= (Number of fish harvested)x100/Number of fish stocked

……....eq. 5

Wi and Wf are the initial and final mean body weights respectively.

Food Conversion Ratio (FCR)= Total feed intake by fish (g)/Total weight gain by fish (g)……eq. 6

Gross fish yield (kg $pond^{-1}$ $period^{-1}$) was calculated as the sum of individual weights of harvested fish. Net fish yield (kg m^{-2} $period^{-1}$) was calculated as sum of individual weights of harvested fish divided by the area of the fish pond i.e 60 m^2. Average yield (kg pond^{-1} period^{-1}) was estimated the average fish yield within each treatment 2, 4 and 6 fish m^{-2}.

Data analysis

The collected data was analyzed using SPSS version 20 and PAST software version 3.25. The water quality parameters, the effect of stocking density and fish yield from fish ponds were computed using one-way ANOVA (tested at P = 0.05) within the consecutive of ten months. The curvilinear regression was used to analyze length-weight relationship data of the treatment fish ponds. PAST version 3.25 used to analyze descriptivedescriptive statistics and to plot the average weight gain within the rearing periods. Moreover, correlation matrix was used to analyze the relationships between fish growth and physico-chemical parameters.

RESULTS AND DISCUSSION

Water quality parameters

VariationsVariations in physico-chemical water parameters were observed during the study period. The monthly recorded environmental variables as mean±SE were presented in (Table 1). Accordingly, pH and water conductivity revealed that a narrow range of variation between different fish pond treatments the values were (7.4±0.1), (7.5±0.1) and (7.2±0.1); (366±46.0 µs), (388±45.9 µs) and (377.8±38.3 µs) for T1, T2 and T3 respectively. However, no significant differences in mean values of pH and electrical conductivity of fish ponds between the three treatments earthen ponds (p> 0.05) (Table 1).

On the other hand, the mean values of the dissolved oxygen (DO) (3.4±0.3 mg l^{-1}), (4.7±0.5 mg l^{-1}) and (3.7±0.3 mg l^{-1}); Temperature (22.7±0.2^{0}C), (24±0.1^{0}C) and (25.4±0.2^{0}C); total dissolved solids (TDS) (218.9±4.7 ppm), (177.6±5.8 ppm), (213.2± 2.5 ppm); and turbidity (8.8±0.1 NTU), (8.9±0.2 NTU) and (7.5±0.2 NTU) for T1, T2 and T3 respectively, showed significant differences (p<0.05) (Table 1). The physico-chemical variables pH and conductivity were found within the acceptable range for Nile tilapia culture and almost uniform results were recorded during the experimental periods. According to Bryan *et al*. (2011) suggests that most fish species showed better growth performances with pH near to 7.0 than the pH less than 6.0 in earthen fish ponds. The acidic fish ponds with pH less 5 can affect, fish biological aspects such as growth rate (length and weight), reproduction the optimum pH ranges between 6.5 and 8.0 for aquaculture (Crane, 2006). In the present study pH values ranged from (7.2±0.1 to 7.5±0.1, p=0.084). Therefore, the mean pH values were found optimal level for optimal fish growth.

The mean values of conductivity regarding different treatments (366±46.0 µs), (388±45.9 µs) and (377.8±38.3 µs) little variation was observed however, insignificant (p=0.94) the mean values were found within the acceptable range. The mean water conductivity would be between 150 and 500 µS cm^{-1} and safe for fish culture (Russell *et al*., 2011). However, Stone *et al*. (2013), recommended the conductivity of water for fish ponds would be between 100 and 2000 µS cm^{-1}. Therefore, the mean values of the water conductivity may not affect the fish growth in the present study.

There was significant variation of dissolved oxygen concentration between study periods (DO) (3.4±0.3 mg l^{-1}), (4.7±0.5 mg l^{-1}) and (3.7±0.3 mg l^{-1}) for T1, T2 and T3 (p=0.000) respectively. This is due to seasonal variation. For instance, the least concentration of DO 1.2±0.01, 1.12±0.1 and 1.3±0.3 mg l^{-1} for T1, T2 and T3 were recorded during April and August. Furthermore, minimum values such as 2.1, 2.3, 2.4 mg l^{-1} were obtained during June, July, September, October, November, December for T1 and T2 and the highest value 7.2±1.1 mg l^{-1} was recorded for T2 during January. Consequently, T1 and T3 were mostly affected than T2 probably by high sediment load, high decomposition rate by the microorganisms (biological oxygen demand), deposition of eucalyptus leaf for 2 fish m^{-2} and high stocking density for 6 fish m^{-2}. Makori *et al*. (2017) noted that DO concentration of 3mg^{-l} should be the minimum for optimum growth of tilapia. In line with this, in the present finding the mortality rates were 12%, 24.6% and 26.6% for 2, 4 and 6 fish m^{-2} respectively (Fig. 7) during April, June, August, July, September, and September in relation to low concentration of DO. Above 5 mg l^{-1} is the preferred level for optimal growth tilapia in ponds (Bhatnagar and Singh, 2010). Fish growth and yield potential in ponds relies on with DO level (Bartholomew, 2010; Bhatnagar and Devi, 2013). Generally, the mean concentration of DO is below the acceptable range in this study. Moreover, the monthly fluctuation of water quality parameters might affect the growth rate of fish in the study area. In the current study, small-scale fish farmers should be advised to take management options such as manage flood prone areas, excessive algal blooms, water exchange, use aerators to optimize DO level in earthen pond (Bhatnagar and Devi, 2013).

The mean temperature showed significant differences (p=0.000) (22.7±0.2^{0}C), (24±0.1^{0}C) and (25.4±0.2^{0}C) of the treatments. The lowest and highest mean temperature were recorded at 2 fish m^{-2} (control) (22.7±0.2^{0}C) and (25.4±0.2^{0}C) T3 respectively. The mean water surface temperatures between 20 and 36 °C have said to be suitable for Nile tilapia culture systems (Makori *et al*., 2017). Moreover, FAO (2011) noted that the recommended temperature ranged between 31 and 36 °C. Higher, SGR (% day^{-1}) ranged from 3.5-4.4 were obtained at 27-35.5 ^{0}C (Abo *et al*., 2009; Makori *et al*., 2017). On the other hand, Ngugi *et al*. (2007) reported between 20 and 35 °C is ideal for optimal growth of tilapia culture. However, in the current study minimum temperature values were recorded within ten months when compared with other findings.

The value of the total dissolved solids between the treatment ponds was significantly high (TDS) (218.9±4.7 ppm), (177.6±5.8 ppm) and (213.2± 2.5 ppm (p=0.000) during the dry sampling periods. The variation could be less circulation of the water and the formation of algal bloom.

Turbidity is vital for water clarity determination. It is helpful to understand for the sediment load and erosion levels of water bodies. Less clarity of water was observed during summer season due to flooding (Higham *et al*., 2015). Turbidity increases water temperature, lowers dissolved oxygen, declines the coming solar radiation, and damage the fish gills (Matveev and Steven, 2014). In this study, the mean turbidity values were (8.8±0.1 NTU), (8.9±0.2 NTU) and (7.5±0.2 NTU) for 2, 4 and 6 fish m^{-2} respectively. Therefore, all the treatment ponds were affected by the less clarity of the water (p=0.000). Correlation between fish and physical, chemical and biological qualities of water for optimal growth is crucial. However, in the present study, the mean length and mean weight of fish did not show positive correlation between water quality parameters. However, the weight positively correlated with DO and Temperature while the mean length only positively correlated with temperature (Makori *et al*., 2017) a study conducted at fish farmers' earthen pond, Kenya. Study similar to the present findings indicates that study, the mean length and mean fish weight were negatively correlated with water conductivity reported by (Makori *et al*. 2017). Good water quality supports diversity of life than the poor water quality (Boyd, 2010). Makori *et al*. (2017) states that fish could indicate stunt specific growth rate due to poor water quality.

Fish needs the optimum physical, chemical and biological qualities of water for optimal growth. Fluctuations in environmental variables cause stress to the fish. The bigger the changes the greater the stress on fishes (Bhatnagar and Devi, 2013). Most of the mean water parameter values were deviated. For this reason, they were not ranged within the desired ranges. Therefore, the values in the fish treatment pond were found in below the optimum condition for fish cultivation.

Table 1. One-way ANOVA of mean water quality parameters at different stocking densities of fish ponds.

Parameters	2 fish m^{-2}	4 fish m^{-2}	6 fish m^{-2}	P value
pH	7.4±0.1^a	7.5±0.1^a	7.2±0.1^a	0.082
DO (mg l^{-1})	3.4±0.3^a	4.7±0.5b	3.7±0.3^a	0.04*
Conductivity (μs)	366±46.0^a	388±45.9^a	377.8±38.3^a	0.94
Temperature (^{0}C)	22.7±0.2^a	24±0.1^b	25.4±0.2^b	0.000*
Total dissolved solid (TDS) (ppm)	218.9±4.7^a	177.6±5.8^b	213.2±2.5^a	0.000*
Turbidity (NTU)	8.8±0.1^a	8.9±0.2^a	7.5±0.2^b	0.000*

**and different superscript letters indicateindicate the mean difference is significant at the 0.05 level.*

Correlation between fish growth (weight and length) and physico-chemical parameters

Based on the available data of the treatment ponds, mean weight and length of fish showed strong positive correlation (r=0.979, p=0.000). Mean weight and dissolved oxygen (r=0.452, p=0.023), mean weight and water temperature (r=0.568, p=0.001) had positive correlation. While no correlation with pH (r=0.019, p=0.490), and turbidity (r=0.017, p=0.545) and negatively correlated with electrical conductivity (r=-0.006, p=0.833) and total dissolved solids (r=-0.004, p=0.889). In similar manner, the mean total length and dissolved oxygen (r=0.321, p=0.031) and water temperature (r=0.531, p=0.001) revealed positive correlation however, no correlation between pH (r=0.025, p=0.376), and turbidity (r=0.013, p=0.631) and negatively correlated with EC (r=-0.004, p=0.896), and TDS (r=-0.002, p=0.946) (Table 2).

Proximate composition of fish feed supplemented

During the experimental period, rice bran, wheat bran, soyabean cake and noug cake were given based on their body weight May, 2020-February 2021. The proportion of dry matter, Ash, crude protein, lipid and crude fiber proximate compositions (%) indicated under (Table 3).

Table 2. Correlation matrix of fish length, weight and physico-chemical parameters in fish ponds

Variables	pH	DO	EC	Temperature	TDS	Turbidity	Mean Weight	Mean length
	1							
pH								
DO	0.082*	1						
	0.003							
EC	-0.136*	0.347*	1					
	0.000	0.000						
Temperature	-0.009	0.041	-0.046	1				
	0.736	0.144	0.097					
TDS	-0.026	0.130*	0.120*	-0.180*	1			
	0.359	0.000	0.000	0.000				
Turbidity	0.174*	0.009	0.010	-0.318*	-0.289*	1		
	0.000	0.751	0.728	0.000	0.000			
Mean	0.019	0.452	-0.006	0.568	-0.004	0.017	1	
Weight	0.490	0.023	0.833	0.001	0.889	0.545		
Mean length	0.025	0.321	-0.004	0.531	-0.002	0.013	0.979*	1
	0.376	0.031	0.896	0.001	0.946	0.631	0.000	

**. Correlation is significant at the 0.01 level.*

Table 3. Nutrient composition of the locally available fish feeds.

Feed category	Dry matter (%)	Ash (%)	Crude protein (%)	Lipid (%)	Crude fiber (%)
Rice bran	90.85	14.79	6.97	13.07	7.2
Wheat bran	90.1	8.96	14.84	9.71	6.12
Soyabean cake	89	6	42	3.5	6.2
Niger seed (Noug cake)	93.2	-	32.89	7.72	21.6

Size frequency distribution

The length-frequency distribution of the *O. niloticus* at Kuhar fish pond center is presented in (figure 4). Accordingly, the total length of the fish samples ranged from 5-28.5, 5.7-30 and 1.7-28 cm TL for 2, 4 and 6 fish m^{-2} respectively. Similarly, the minimum weight was 3.5 g for 2, 4 and 6 fish m^{-2}. The final maximum body weight was 302, 282 to 203 g for 2, 4 and 6 fish m^{-2} respectively. The greater proportion of the cultivated *O. niloticus* was ranged in size class between 15.6-20 cm TL. This length interval contributes (37.8%), (45.3%) and (38.9%) for 2, 4 and 6 fish m^{-2} of fish cultured in ponds (Fig. 4).

Length-weight Relationship (LWR)

The length-weight relationship of *O. niloticus* from Kuhar fish ponds was curvilinear and showed negative allometric growth pattern. The regression equation within the treatments of *O. niloticus* were $TW=0.02TL^{2.86}$ ($r^2=0.92$, N=370), $TW=0.03TL^{2.8}$ ($r^2=0.9$, N=452) and $TW=0.03TL^{2.83}$ ($r^2=0.83$, N=426) for 2, 4 and 6 fish m^{-2} respectively (Fig. 5 a, b and c) and showed significant relationship (curvilinear regression, $p<0.05$). The regression coefficient value of 'b' within the treatments of the *O. niloticus* showed negative allometric growth pattern (b< 3) and showed insignificant difference ($\chi 2$, $p>0.05$). Therefore, from the length weight relationship data of the *O. niloticus* the fish grows length than weight at the study area. The biological parameter like fish body weight was monthly recorded at the study area for the management purposes such as to estimate growth rate, feed conversion ratio, final weight and fish yield. The length-weight relationship reflects the wellbeing of fish in their habitat.

The present study indicated that the very strong relationship ($R^2>0.90$) between length-weight relationship of the three treatment fish ponds with triplicates of each. Negative allometry growths were recorded for all treatment ponds when the 'b' value deviated from three (b<3). Ondhoro *et al*. (2019) reported that similar finding negative allometry (b<3) fish growth in low stocking density treatment while positive allometry was reported fish in high stocking density (b>3) from Uganda fish culture experimental units. Size of fish and size homogeneity might be influenced by the high stocking density. However, couldn't affect the length-weight relationship (Klanian and Adame, 2019). The value of 'b' when less than 3 related with bad water quality lack of food or high stocking (Ricker, 1973; Murphy et al., 1991). Moreover, the length-weight relationship is sensitive in relation to the environmental changes such as disease, stress due to overcrowding and leads to physiological effects and high mortality rates of the suffered fish (Jones *et al*., 1999). This statement agrees with the present study, 26.67% mortality rate was recorded on 6 fish m^{-2} fish ponds due to high stocking density and depletion of dissolved oxygen (Fig. 7). Therefore, results of the current study represented the first report of L-W relationship for *O. niloticus* at earthen fish pond conditions in the study area. Moreover, the relationship of length-weight was not affected by increasing in stocking density of experimental fish ponds.

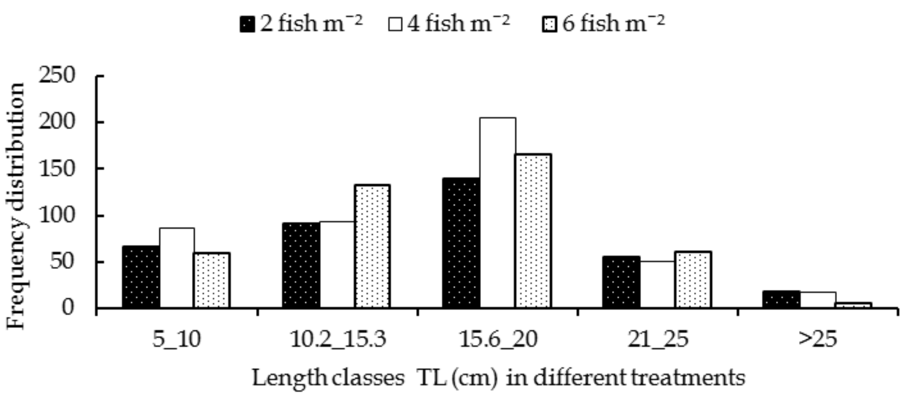


Figure 4. Size frequency-based distribution of the Nile tilapia *Oreochromis niloticus* on treatment ponds at Kuhar (Woreta) fish culture research center (May, 2020-February 2021 data).

Fulton Condition Factor (K)

The condition factor (K) explained that the health and environmental suitability (wellbeing) for fish species. In the present study, the mean condition factors for *O. niloticus* were (1.62±0.3), (1.65±0.3) and (1.92±0.3) in 2, 4 and 6 fish m^{-2} respectively. However, didn't show significant difference ($p>0.05$) (Table 4). factor reflects fish health and suitability in the environment in which they live (Mbiru *et al*., 2016). During the present study the mean condition factors 1.62±0.3, 1.65±0.3 and 1.92±0.3 for 2, 4 and 6 fish m^{-2} were recorded. The mean 'K' values in the present study were greater than the 1.02, 1.12 and 1.51 as noted by (Migiro *et al*., 2014; Mbiru *et al*., 2016), for the same species. However, in the present finding the 'K' values were smaller than 2.73, 2.83, 3.06 and 3.11 at different stocking densities as reported by (Mapenzi and Mmochi, 2016). In the current study, the mean condition factor was density independent. It was increased with increasing in stocking density. The present mean condition factor revealed that fish in a relative condition when the fish increase in weight proportional to its length which tells suitability of the stocking densities for fish growth in earthen fish ponds. This is due to in relation to the mortality rate i.e., the fish at high stocking density will get space while the death of their partner. Dill (2010) documented that condition factor was not influenced by increasing stocking density. However, it was affected by supplementary feeding a study conducted in cage culture system at Lake Wonji, Ethiopia (Dill, 2010).

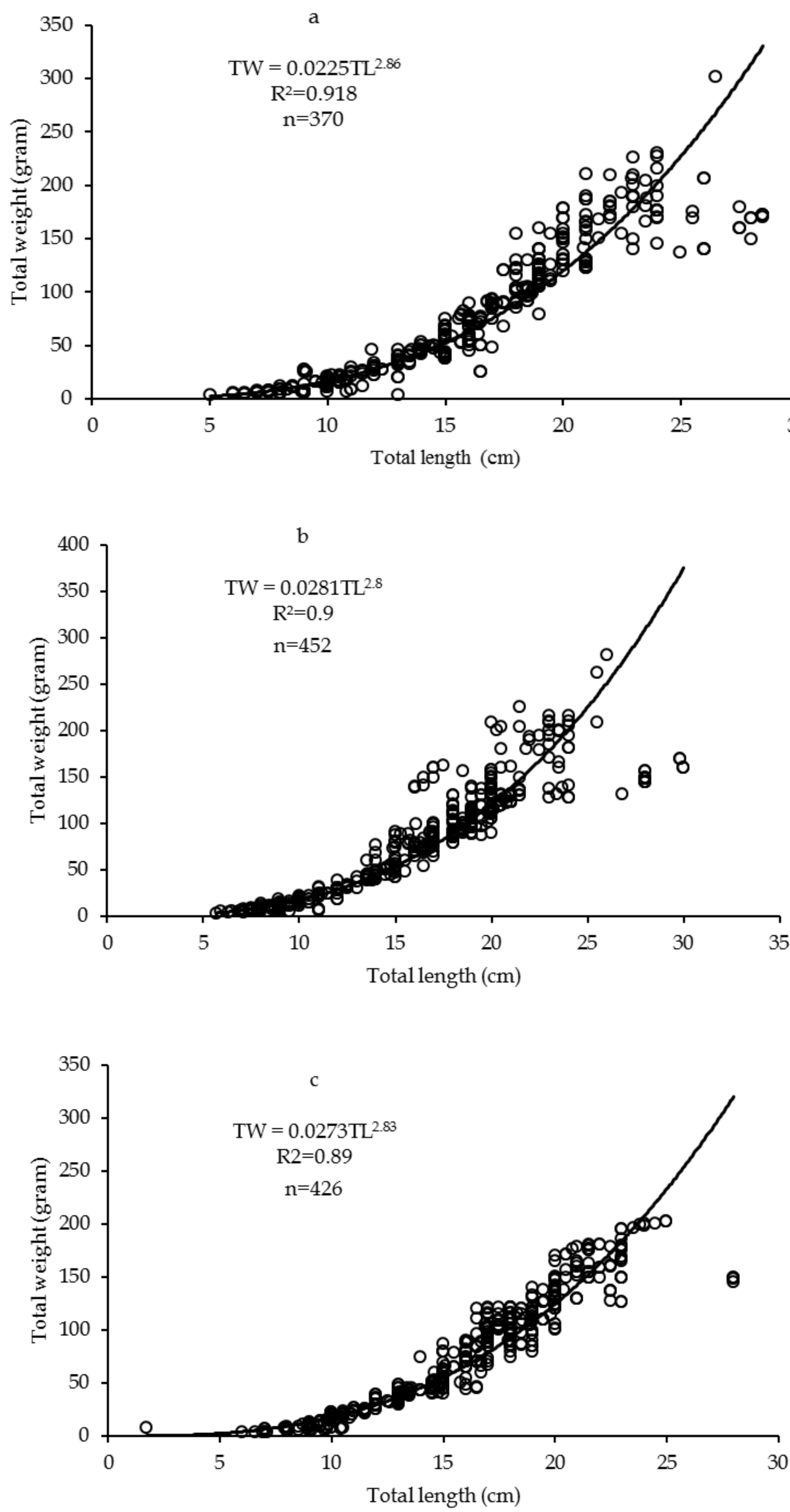


Figure 5. Length-weight (L-W) relationship of Nile tilapia *Oreochromis niloticus* at three stocking densities in earthen ponds from Kuhar fish culture center. a) 2 fish m^{-2}; b) 4 fish m^{-2}; c) 6 fish m^{-2}.

Table 4. Some biological parameters of *O. niloticus* at different treatment stocking densities.

Parameters	2 fish m^{-2}	4 fish m^{-2}	6 fish m^{-2}	P value
a	0.02	0.03	0.03	-
b	2.86	2.8	2.83	-
R^2	0.92	0.9	0.89	-
Mean condition factor (K)	1.62±0.3	1.65±0.3	1.92±0.3	0.37

Growth performance of fish at different stocking densities

In this study, the mean initial length (cm) TL, final length (cm) TL, initial weight (g) and SGR (g day^{-1}) were not affected by stocking densities between 2 fish m^{-2}, 4 fish m^{-2} and 6 fish m^{-2} also showed insignificant relationship ($p>0.05$) (Table 5).

On the other hand, the final mean weight, mean weight gain, survival rate (%), gross fish yield (kg $pond^{-1}$ $period^{-1}$), net fish yield (kg m^{-2} $period^{-1}$) and average fish yield (kg $pond^{-1}$ $period^{-1}$) showed significant difference between treatments ($p< 0.05$), better results in terms of final fish weight and mean weight gain for individual fish were recorded with the 2 fish m^{-2} and 4 fish m^{-2} than 6 fish m^{-2}. The mean final weight and the mean weight gain were increased for 2 fish m^{-2} and and 4 fish m^{-2} while decreased in case of T3. The gross yield and net yield were increased with increasing stocking density (Table 5, Figure 6).

High stocking density is considered as influential factor that limits the growth performance of fish. In this study overlaps of growth performances were observed between the treatments. Although, the observed overlaps in growth may be due to water management related problems (Alhassan et al., 2012). For instance, 2 fish m^{-2} and 6 fish m^{-2} had similar growth rate than 4 fish m^{-2} in December. During June all treatments showed similar growth rate pattern while in May 6 fish m^{-2} had indicated fast growth rate. Inversely, in August 4 fish m^{-2} and 6 fish m^{-2} showed greater performance than 2 fish m^{-2} (Fig. 4). The monthly changes in fish growth performance might be associated with temperature because it had the huge effect on feed conversion ratio and DO affects the physiology of fishes. Therefore, the optimal culturing temperature for Nile tilapia is between 27 and 32 ^{0}C, optimize the concentration of DO (>5 mg/L), stocking density (3-5 fish m^{-2}), and supply supplementary feeds crude protein (25-30%) for better growth performance (Mengistu *et al*, 2020). Reducing the level of DO from 6.5 to 3.0 or 1.5 mg l^{-1} negatively affects the fish growth and feed intake also reported (Tawwab *et al*., 2014). However, in the present finding most water quality parameters were below the optimum level that effects on the retardation of fish growth at the study area.

In the present study, better final mean weights were recorded at low stocking densities in (178.5±6.7 g, 2 fish m^{-2}) (control) and (191.5±5.7 g, 4 fish m^{-2}) than (168.7±4.6 g, 6 fish m^{-2}) within 10 months. Several studies also reported that the better final weight was achieved at low stocking densities either in fish ponds or cage culture systems (Ondhoro *et al*., 2019; Dagne and Yimer, 2018; Mapenzi and Mmochi, 2016; Moniruzzaman et al, 2015; Alhassan et al., 2012; Chakraborty and Banerjee, 2010; Dill, 2010; Osofero *et al*., 2009). However, the proportion of weight gain and final weight is different it depends on the management options such as supplementary feeds, water quality, the initial size of fish before stocking and the duration of the experimental days. Therefore, the present study contradicts with the report of (Ondhoro *et al*., 2019) within five months better results of final mean weight 311.49±114.6 g, 204.8±30.5 g, 138±40.2 g, and 153.3±68.8 g were obtained while the initial weight of the fingerlings was 2.53±1.20 g of the experiment conducted in fish pond of Uganda.

At the end of the experiment, low stocking density (2 fish m^{-2}) control and (4 fish m^{-2}) revealed better growth in terms of weight gain, feed conversion ratio and survival rate than high stocking density (6 fish m^{-2}) (Table 4). In the current study, the specific growth rate was similar throughout the experimental units this might attribute that water quality management problems and the monthly fluctuation of temperature and DO in fish ponds. High fish density in fish ponds declines water quality by making hypertrophic, this results in poor fish health. Therefore, limiting the number of fish m^{-2} is a scientific way to make favorable the water quality for sustainable utilization (Mapenzi and Mmochi, 2016).

In the current study, the survival rate of fish was affected by as fish stocking density increased. Several studies revealed in agreement with the present finding. Accordingly, study conducted at Uganda in Lake Alebert (Abaho *et al*., 2020), Sebeta fish research center (Dagne and Yimer, 2018; Dagne *et al*., 2013), Lake Wonji (Dill, 2010) and India (Chakraborty *et al*., 2010). Survival rate of the fish may not be affected with the availability of supplementary feeds (Dill, 2010).

The performance of Nile tilapia to convert food into body weight (FCR) was significantly affected by stocking density ($p<0.05$). However, according to the report of Alhassan et al. (2012) feed conversion ratio (FCR) was not significantly affected by stocking density ($p> 0.05$) in Hapas a concrete tank. In the present study, the best FCR was recorded at the low stocking density (2 fish m^{-2}) followed by 4 fish m^{-2} than high stocking density (6 fish m^{-2}), implies that better food conversion efficiency at low stocking density. Comparative studies (Tawwab *et al*, 2014) from Egypt, (Dagne and Yimer, 2018) at Sebeta fish research center and (Abaho *et al*., 2020) in lake Alebert Uganda indicated the effect of stocking density on FCR of the Nile tilapia. In terms of scored values, FCR ratio ranged from 1.84-3.4 were recorded from this study. The FCR values of the present study were smaller when compared to between 3.16-3.68 from Uganda in lake Albert (Abaho *et al*., 2020) whereas resemble in between 1.81-2.05 for 2 fish m^{-2} and 4 fish m^{-2} (Dagne and Yimer, 2018) from Sebeta fish research center.

A similar specific growth rate (1.01% or 0.6 g day^{-1}) was obtained of the three treatments with triplicates in the present study (, p>0.05). Comparable, study was conducted the daily growth rate was (1.1%, 0.4 g day^{-1}) of the same species from Sebeta fish research center. In the same way the specific growth rate (SGR) density independent hapas in a concrete tank (Alhassan et al., 2012). In contrast, higher the SGR (% day^{-1}) values ranged from 6.84-8.33, 2.02-2.35, and 2.02-2.35, (Mapenzi and Mmochi, 2016), (Abaho *et al*., 2020) and (Dagne *et al*., 2013) from Tanzania and Uganda in lake Albert and Sebeta fish research center were reported respectively. Gindaba *et al*. (2017) reported smaller values of SGR ranged from 0.009-0.022 g day^{-1} and 0.038-0.103% day^{-1} a study conducted from southeastern, Ethiopia for 5 months (Table 5).

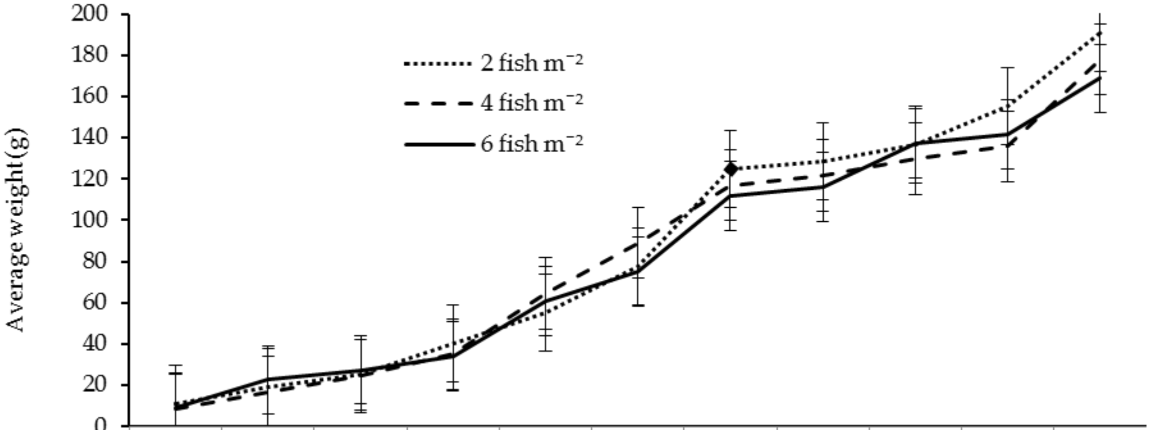
In the current study, the weight gain and final mean weight of the Nile tilapia were higher in the low stocking densities (2 and 4 fish m^{-2}) that of the higher density (T3). Several authors were in agreement with the present finding (Abaho *et al*., 2020; Mengistu *et al*., 2020; Tammam *et al*., 2020; Gindaba *et al*., 2017; Mbiru *et al*., 2016; Mapenzi and Mmochi, 2016) of the same species.

In the present study, the mean final weight and the mean weight gain were increased from 2 to 4 fish m^{-2} while decreased at 6 fish m^{-2}. The remaining growth performance parameters were increased with increasing of stocking density. Higher biomass of fish yield was harvested at 6 fish m^{-2} followed by 4 fish m^{-2} (Table 5). Therefore, yields of Nile tilapia within different treatments were in contrast to the mean weight gain, survival rate, feed conversion ratio and the final mean weight gain. In the same way, Gindaba *et al*. (2017) reported the heavier fish were caught at low stocking density and huge biomass fish yield with supplemented feed were harvested from high stocking density a study conducted from southeastern Ethiopia. Many authors also have reflected large sized fish in terms of weight obtained from low stocking density (Gibtan *et al*., 2008; Abou *et al*., 2007; Osofero *et al*., 2009; Ridha, 2005; Rahman and Rahman, 2003).

Table 5. Growth performance of *O. niloticus* at different treatment stocking densities

Variables	2 fish m^{-2} control	4 fish m^{-2}	6 fish m^{-2}	P value
Initial length (cm) TL	8.6 ± 0.4^{a}	7.96 ± 0.2^{a}	8.5 ± 0.2^{a}	0.124
Final length (cm) TL	22.5 ± 0.4^{a}	22.7 ± 0.3^{a}	21.9 ± 0.3^{a}	0.23
Initial weight (g)	$11.2\pm2^{a}11.2\pm2^{a}$	$8.4\pm0.6^{a}8.4\pm0.6^{a}$	9.3 ± 1.1^{a}	0.33
Final weight (g)	178.5 ± 6.7^{a}	191.5 ± 5.7^{b}	168.7 ± 4.6^{a}	0.02*
Mean weight gain (g)	167.9 ± 7.7^{a}	183.2 ± 5.9^{b}	159.4 ± 5^{a}	0.029*
SGR (g day^{-1})	1.02 ± 0.04^{a}	1.1 ± 0.03^{a}	1.02 ± 0.04^{a}	0.534
FCR	1.84 ± 0.24^{a}	2.55 ± 0.22^{a}	3.4 ± 0.25^{b}	0.012*
Survival rate (%)	87.2 ± 0.04^{b}	76.8 ± 2.3^{a}	73.3 ± 4.8^{a}	0.047*
Gross fish yield (kg pond^{-1} period^{-1})	55.83	97.4	123.8	0.0321
Average yield (kg pond^{-1}period^{-1})	18.6 ± 2.4^{b}	32.5 ± 3^{a}	41.3 ± 2.3^{a}	0.02*
Net fish yield (kg m^{-2} period^{-1})	0.31 ± 0.04^{a}	0.54 ± 0.05^{b}	0.69 ± 0.04^{b}	0.02*

**and different superscript letters indicate the mean difference is significant at the 0.05 level.*



	Initial	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
2 fish m^{-2}	11.2	19.2	25.5	40.5	55.3	77.6	125	128.7	136.7	155.4	191
4 fish m^{-2}	8.4	16.9	24.9	35.1	64.6	89	117	121.8	129.8	135.8	178
6 fish m^{-2}	9.25	22.6	27.5	34.1	60.9	74.9	111.9	116.4	137.4	141.6	168.7

Figure 6. Increase in mean weight of the *O. niloticus* with at different stocking densities during the sampling period.

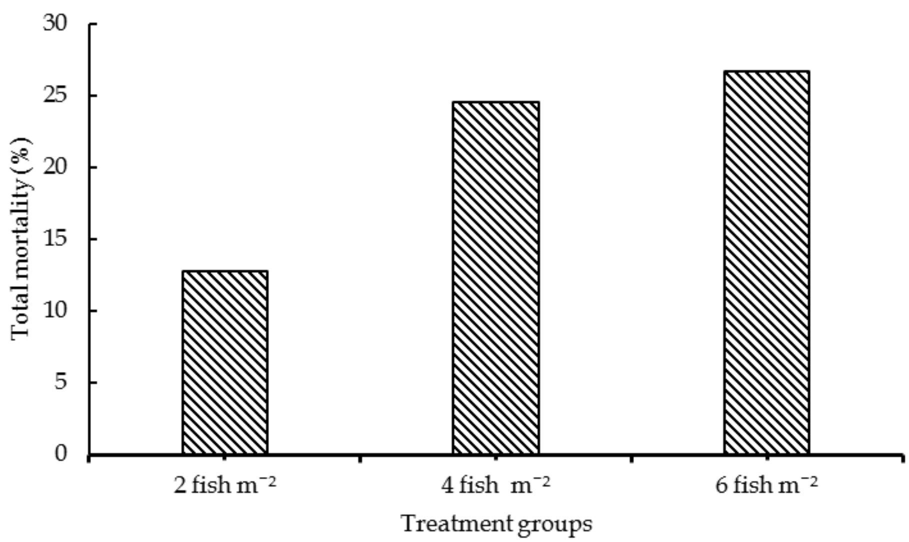


Figure 7. Total mortality of fish during the experimental days.

CONCLUSION

This study discovered that the possibility of 4 fish m^{-2} in addition to the recommended 2 fish m^{-2} than 6 fish m^{-2}. The present finding pointed out that the Nile tilapia is stock density-dependent species. The mean initial length (cm) TL, final length (cm) TL, initial weight (g) and SGR (g day-1) were density-independent growth parameters in all treatments. The final mean weight, mean weight gain and survival rate (%) were density-dependent. Gross fish yield (kg $pond^{-1}$ $period^{-1}$), net fish yield (kg m^{-2} $period^{-1}$) and average yield (kg $pond^{-1}$ $period^{-1}$) were increased with increasing stocking density. The mean monthly fish growth has been interrupted due to water quality parameter fluctuations. This finding will help the fish farmers to enhance fish production. Thus, a new theory on the effect of stocking density regarding the growth performance of fish may be arrived at.

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