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Effects of Stocking Density on the Growth Performance and Production of Male Nile Tilapia (*Oreochromis Niloticus*) in Concrete Ponds Bahir Dar, Ethiopia

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ABSTRACT

Stocking density is considered as one of the important factors that affect the growth and production of fish in aquaculture ponds. However, information related to the effect of stocking density on the growth performance and production of male *O. niloticus* in pond culture conditions has not been well studied in Ethiopia. Therefore, this study aimed to compare the growth performance and production of male tilapia at various stocking densities and to determine an ideal and economical stocking density for the culture of male *O.niloticus* fingerlings in pond culture. Male fingerlings were selected by examining the genital papilla region and stocked at three stocking densities 3, 5, and 7fingerlings m^{-2} in triplicates with an initial live weight of 26.31 ± 0.06 g and grown for six months in a 10 m^{-2} concrete pond for each. The final mean weights of the fingerlings stocked at densities of 3, 5, and 7 fingerlings were 182.58 ± 0.39, 163.33 ± 0.78, and 153.57 ± 0.34 g, respectively. The growth performance of fish decrease (153.57 ± 0.34 g) with increasing the stocking density (7fish m^{-2}). The gross yield obtained at the end of the experiment was 0.51 ± 0.01 kg/m^2, 0.75 ± 0.02 kg/m^2 and 0.98 ±0.01 kg $m^{-2}$for 3, 5 and 7fingerlings m^{-2}, respectively. The higher stocking density (7fish m^{-2}) showed the uppermost total fish production and net profit. The overall results emanating from this study indicate that even if a higher growth rate was obtained at the lower stocking densities after ending the trial period the highest stocking density gave a significantly higher yield per m^{-2} and can be very useful to give good returns for local consumption and efficient utilization of resources. Therefore, further study should be conducted to investigate better stocking density beyond 7fishes m^{-2} and whether it will be possible to get more yields per unit area, but need optimum management (quality feed and secured water supply) are necessary to fish growth under high-density culturing systems.

1. INTRODUCTION

The production of fisheries in the major lakes of Ethiopia is decreasing at an alarming rate and failed to meet the ever-growing demand for fish (Mulugeta Wakjira *et al* 2013). The current increasing market demand for fish protein in Ethiopia can be met only when the capture fishery is supplemented by aquaculture (Ashagrie Gibtan *et al* 2008). However, aquaculture in Ethiopia remains more potential than actual practice because, currently, there was not this much plentiful production of aquaculture in this country, and didn`t benefit from this sector (Natea Gadis 2019). Aquaculture development in Ethiopia has been very limited and the practice mainly consisted of stocking fish fingerlings (Lema Abera and Zenebe Tadesse 2009). The problem of overpopulation in ponds caused by uncontrolled reproduction is a major limitation for further development of the aquaculture sector. Mostly, small-scale aquaculture is implemented with mixed-sex *O. niloticus* fishes (Erkie Asmare *et al* 2019).

Due to precocious maturity and uncontrolled reproduction of females, overpopulation in ponds is evitable which results in stunted fish and failure to get market-sized fish (Ashagrie Gibtan *et al* 2008). In the Amhara region, most of the farmers' ponds became overcrowded by fish fingerlings with stunting growth and seem like multiplication ponds than production (Erkie Asmare *et al* 2019). The culture of all-male *O. niloticus* is well established for increased production potential and low management requirements in a semi-intensive pond culture system since there is no energy to be utilized for reproduction and there exists no competition with younger fish (Adamneh Dagne *et al* 2013).

Apart from using all male *O. niloticus*, stocking density is another key factor to achieve optimum production because it has a direct effect on the growth performance and total production of the fish, nutrition, and type of culturing system (Islam *et al* 2006). This is because the growth rate of fish progressively increases at lower stocking densities. The reason is that a lesser number of fish in a pond of a similar size helps fish to get more space and food at the same time (Hasan *et al* 2010). But, if the stocking density is too low, the fish grow faster and reach larger sizes but, the per-unit area production is also low (Ashagrie Gebitan *et al* 2008). On the other hand, male mono-sex culture permits the use of higher stocking rates (Nahid *et al*., 2012). High stocking densities reduce individual growth rates, but yields per unit area are greater (Ashagrie Gibtan *et al.,* 2008). However, excessive stocking densities produce fish below marketable size and fish yields are not improved (Jha and Barat 2005). Furthermore, fish intensification by increasing stocking density is also found suitable to overcome the problem of land shortage and increase the profitability of the farm (Khattab *et al* 2001).

Therefore, proper stocking density is considered one of the most important variables in aquaculture because it directly influences the growth and production of fish and the profitability of the farm. However, information related to the effect of stocking density on the growth performance and production of male *O. niloticus* in pond culture conditions has not been well studied in Ethiopia. Therefore, this study aimed to compare the growth performance and production of male tilapia at various stocking densities and to determine an ideal and economical stocking density for the culture of male *O.niloticus* fingerlings in pond culture and generate baseline information for improving fish production in pond farming.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The pond experiment was conducted at Bahir Dar Fisheries and Other Aquatic Life Research Centre (BFALRC) located at nearest to Lake Tana and a distance of 563 kilometers from Addis Ababa, the capital of Ethiopia Situated at 1800 m above sea level (11036'36" N and 37022'35.5" E). The average air temperature varied between 22 and 29^{0}C and dissolved oxygen was in between 3 and 8 mg/L during the experimental period

2.2. Experimental Setup and Design

The trial was conducted in concrete ponds with a dimension of 5x2x1 m ($10m^{-2}$) for a period of six months i.e., from February up to August 2021. The concrete ponds were first placed and arranged randomly and assigned for each treatment group. The ponds were similar in respect to depth, basin configuration, and patterns including water supply facilities. The ponds have an appropriate inlet overflow and outlet system to maintain a suitable water level. The ponds were covered by fine-meshed nylon nets to prevent the entrance of frogs and other predators. The experiment was carried out by using three treatments (different stocking densities) using male *O. niloticus* fish in triplicate. The treatments were labeled as treatments 1, 2, and 3 for the corresponding stocking density of 3, 5, and 7 fingerlings m^{-2}, respectively. The total number of experimental fingerlings stocked at treatment one (T1) was 30 fingerlings per pond, 50 fingerlings per pond for treatment two (T2), and 70 fingerlings per pond for treatment three (T3).

Figure 1: Experimental fish pond

2.3. Experimental fish collection, Sex identification, Measuring, and Stocking

2.3.1. Experimental fish collection

A total of four hundred fifty *O. niloticus* fingerings were collected from Bahir Dar Fishery and Other Aquatic Life Research Center fish multiplication ponds using a beach seine net with a mean length of 11.42± 0.12 cm, and the mean weight of the fingerlings was 26.31 ± 0.06.

2.4. Sex identification of experimental fish

Before stocking, sex identification was done manually through the inspection of their genital organs visually and with the aid of magnifying hand lens. The relatively higher initial body weight of fish was intentional to reduce the percentage of errors in identifying the sexes of *O. niloticus*. Fish with opening and genital papillae are males and were selected for this experiment and those with two openings are females and shall be sent back.

2.5. Measuring and stocking of experimental fish

All the experimental fishes in each treatment group were measured in weight and length at the start (stocking) using an electronic weighing balance (WAGTEGH Model SKX2201) with 0.01 g precision and a measuring board with 0.01 cm and recorded in a recording sheet. The mean initial weight of 3 fingerlings m^{-2} was 26.31 ± 0.06, 26.28 ± 0.08, and 26.33 ± 0.1 for 5 fingerlings m^{-2} and 7 fingerlings m^{-2}, respectively. The mean initial lengths were 11.42± 0.12 cm, 11.44±0.04 cm, and 11.47±0.6 cm for 3, 5, and 7 fingerlings m^{-2} respectively. There was no significant difference between treatments in terms of initial weight and length of the fingerlings at stocking by using fisher's LSD test. The experimental fish fingerlings were acclimatized in ponds for about two weeks before starting the actual experiment.

Figure 2: (a) Experimental fish collection (b and c) six identification (d) Measuring experimental fish

2.6. Feed and feeding of the Experimental fish

The feed used during the experiment was commercial feed (Alema Koudijs's animal feed). The feed was administered to fish at a rate of 5% of their body weight up to an average weight of 102 grams and then reduced to 3% of their body weight until finished the experiment (Craig *et al* 2017). The ratio was split into two portions and fed twice a day morning at 10:00 pm and afternoon at 4:00 am (Chapman 2000) for 6 months. Feeding was done by hand at a constant place and time as this method enables regular inspection of the fish. The daily ration was then calculated and adjusted regularly according to the body weight gain of the fish every month.

2.7. A sampling of the Experimental fish

Experimental fishes were sampled every month using a seine net to observe and record their growth. During the period of sampling, the water level in each pond was first lowered and then, the fingerlings were caught using a scoop net and stocked in a bucket till their weight was recorded. According to the previous suggestions made (Zenebe Tadesse *et al* 2012), 30% of the experimental fishes were sampled from each pond. The sampled fish were handled carefully to avoid stress and their weight and length were recorded using an electronic weighing balance (WAGTEGH Model SKX2201) with 0.01 g precision and a fish length measuring board with 0.01 cm and recorded in a recording sheet. Once the relevant record was taken from individual fingerlings a fish was gently returned to its pond. At the end of the experiment, a harvest was made and the total fish produced in each pond was taken, and calculated the total biomass of the fish between different stocking densities.

2.8. Growth parameters

The growth performances of fish were determined and feed utilization was calculated as cited by Ridha (2006) and Alhasan *et al* (2012) as follows;

Weight gain (WG) = Final weight (g) – Initial weight (g)

Daily growth rate (DGR) = weight gained

(g)Culturing days Specific growth rate/day (SGR) = In(final weight)- ln (Initial weight) Culturing period

Food Conversion Ratio (FCR) = The total feed is given (g)Total Weight gain (g)

2.9. Total biomass and yield

Total biomass (BM) = Number of fish produced × Mean weight of fish

Productivity or yield =NW/SA, Where N = the average number of fish produced, W= mean weight of fish, and SA = the surface area of the pond in m^{-2} (Alayu Yale 2018).

2.10. Partial budget analysis

A partial budget analysis was performed to estimate the net profit from this culture operation. The fingerling price and feed costs were calculated. But, facility (fixed) costs and labor were not included in the analysis, because they were common for all experimental ponds. The selling price for the harvested fish was based on retail prices. Net profit for each treatment group was estimated using the following formulas:

Net profit (P) = GI – TC

Where (TC) =Total costs of production = cost of fingerlings + cost of feed and

(GI) =Gross income = total fish output × sales price (Hasan *et al.,*2010)

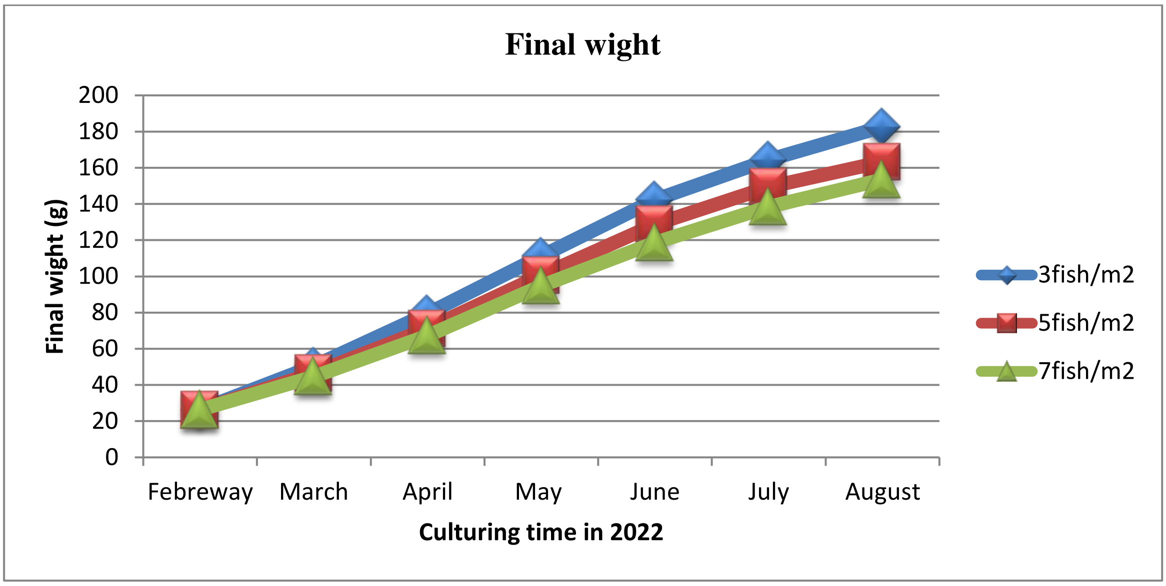
2.11. Statistical Analysis

SAS software was used to compute descriptive statistics and plot graphs. One-way Analysis of Variance (ANOVA) at $\alpha = 0.05$ was further used to test the significant difference among mean values of the different stocking densities of male *O. niloticus* on the various parameters and used Fisher's LSD test to separate the means.

3. RESULTS AND DISCUSSIONS

3.1. Growth Performance

The different growth parameters (the final body weight, the final body length, weight gain, daily growth rate, and specific growth rate of *O.niloticus* fingerling) in all of the treatments at different stocking densities were taken (Table 1). The results showed that the different growth parameters of male *O.niloticus* fingerling were significantly affected by stocking density ($p < 0.05$). In all growth parameters, the highest value was attained at a density of 3 $fingerlings^{-2}$ followed by 5 and 7 fingerlings m^{-2}.



(g).

Figure 4: Trend of growth in terms of weight

Table 1: Summary of different growth parameters during culturing time

Growth parameter	Stocking densities			
	3 fingerlings m^{-2}	5fingerlings m^{-2}	7 fingerlings m^{-2}	P-value
Mean initial length(cm)	11.42± 0.12[a]	11.44±0.04 [a]	11.47±0.06 [a]	0.97
Mean final length(cm)	23.46±0.03 [a]	21.56±0.21 [b]	20.23±0.07 [c]	<.0001
Mean length gain (cm)	12.03±0.1 [a]	10.11±0.25 [b]	8.77±0.14 [c]	0.005
Mean initial weight(g)	26.31±0.06 [a]	26.28±0.08 [a]	26.33±0.1 [a]	0.89
Mean final weight(g)	182.58±0.39 [a]	163.33±0.78 [b]	153.57±0.34 [c]	<.0001
Mean weight gain(g)	156.26±0.41 [a]	137.05±0.83 [b]	127.23±0.29 [c]	<.0001
Percentage weight gain (%)	593.95±2.3 [a]	521.53±4.4 [b]	483.19±1.8 [c]	<.001
Daily growth rate(g/day)	0.9±0.01 [a]	0.79±0.005 [b]	0.73±0.001[c]	<.0001
Specific growth rate	1.11±0.002 [a]	1.05±0.004 [b]	1.01±0.001 [c]	<.001

Note: Means within a column followed by a different letter (s) are significantly at p<0.05, LSD test.

The growth performance of individual fishes decreased as the stocking density increased indicating an inverse relationship between stocking density and growth of male *O.niloticus* fingerling. Because the growth of tilapia (*O.niloticus*) depends on the stocking density, feed quality, and others (Khattab *et al*., 2001). The lower growth performance of tilapia exhibited at higher stocking density could have been caused by energy expenditure because of competition for feed and living space and increased stress. It has been reported that the high stocking density of *O.niloticus* fingerlings might lead to 'social stress' which eventually leads to impaired fish growth (El-Sayed, 2002). In line with the present study, different scholars, Herrera (2015) studied the effects of stocking density on growth performance and production of male tilapia in the three different densities (3, 3.2, and 3.5 fingerlings m^{-2}), Diana and Lin (2004) stocked male tilapia at 3, 6, and 9fish m^{-2}, and Sophia *et al*. (2010) all those scholars abstracted that the highest weight of fish was attained at a density of 3fish m^{-2} than the other density of fish m^{-2}. Fish stocked at the lower density (3fish^{-2}) had significantly higher (156.27±0.38 g) mean weight gain than higher stocking density. These results were similar to the finding of Hasan *et al*. (2010) the mean weight gain of 155.0 g in the stocking density of 3.7 fish m^{-2}.

Daily growth rates and Specific growth rates observed in this study increase in stocking density decrease and the growth rates were affected by the density of fish in the pond. Because, increased stocking density results in competition for space, food, and increase activity levels, and fish use more energy deriving in high metabolic rates and then a growth decrease (Ellis *et al.*, 2002). This is in agreement with Gillian-Klanian and Arámburu-Adame's (2013) daily growth rate of lower density (0.96 g day-^{1}) higher than higher density (0.73 g day-^{1}). Islam and Begum (2019) also reported that the lowest stocking density had a significantly higher mean weight, daily growth rate, and specific growth rate than did the higher density treatment, and the growth of *O. niloticus* fish was found to be density-dependent. Similar growth scenarios were also obtained with many other culturing systems with similar species (Ashagrie Gibtan *et al.*, 2008; Abou-Zied and Ali, 2012; Yakubu *et al.*, 2013; Daudpota *et al.*, 2014).

3.2. The Total Fish Production Harvested at the end of the Experimental Period

The total biomass (kg) harvested from the treatment ranged from (4.9 kg) up to (10.2 kg). The mean total fish harvested in 3 fingerlings^{-2} was 5.11±0.11 kg and 7.57±0.22 kg and 9.78±0.14 kg for the stocking density of 3, 5, and 7 fingerlings m^{-2}, respectively. There existed a significant difference ($p < 0.05$) among treatment groups in the total fish harvest (Table 2).

Figure 5: Fish production at a different stocking density

The mean fish yield was varied between treatment groups 0.51 ± 0.01 kg^{-2}, 0.75 ± 0.02 kgm^{-2} and 0.98 ±0.01 kg m^{-2} for 3, 5 and 7fingerlings m^{-2}, respectively (Table 2).

Table 2: Production of *O. niloticus* between treatments

Total fish harvested	Experimental group/ stocking densities			
	3fingerlings m^{-2}	5fingerlings m^{-2}	7fingerlings m^{-2}	P-value
The total biomass kg/treatment	5.11±0.11 [c]	7.57±0.22 [b]	9.78±0.14 [a]	<.0001
Yield kg m^{-2} / 6 month	0.51±0.11 [c]	0.76±0.02 [b]	0.98±0.01 [a]	<.0001

There was a strong trend for a total production increase with increasing stocking density. The highest productivity was obtained in T3, followed in decreasing order by T2 and T1, respectively; high-density 7fish m^{-2} was given significantly higher biomass yield per pond than low-density. This might be due to a higher number of individuals contributing to the final harvest. Herrera (2015) studied the effects of stocking density on growth performance and production of male GIFT tilapia in three different densities 3, 3.2, and 3.5 fish m^{-2}, Sophia *et al.* (2010) studied the stocking density of 3 and 5 fish m^{-2}, Hasan *et al.* (2010) stocked 3.7, 4.9, 6.2 m^{-2} and Ribera *et al.* (2009) stocked 2, 4, 6, 8 m^{-2} all those scholars abstracted that the production of fish increased with increasing stocking density and the production of the fish was affected by the stocking density of the fish in the pond.

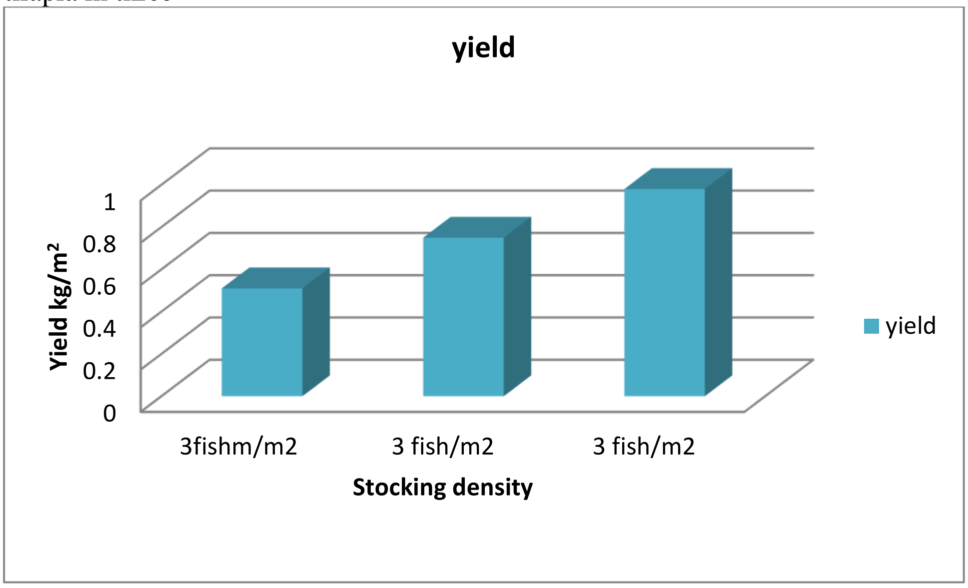


Figure 6: Production of *O. niloticus* at the different stocking densities

In the present study, the lower stocking density means 3fish$^{-2,}$ obtained a high individual growth rate, but, the total production per pond was lower than other stocking densities. This is confirmed by Ashagrie Gebitan *et al.* (2008) stocking density is too low, the fish grow faster and reach larger sizes but, the per-unit area production is also low. In contrast, with a higher stocking density of 7fishm^{-2} individual growth rate of fish decreases, but yields per unit area are greater. This result also in agreement with (Nahid *et al.*, 2012; Ashagrie Gebitan *et al.*, 2008). In the present study, male *O.niloticus* fingerlings stocked 7fishm^{-2} were the best stocking density to obtain maximum production. Herrera (2015) the optimum stocking density is the level where the maximum yields are reached. This is indicated that stocking density is one of the most important factors in determining the production of a fish farm.

3.3. Total Food provided for the Experimental fish and Feed conversion ratio

The total feed provided in the stocking density 3, 5, and 7 fingerlings m^{-2} was 13,061.22 g 19,854.59 g, and 25,555.11 g respectively. The total feed provided by *O. niloticus* fingerlings during the culturing period was affected by stocking densities. The feed conversion ratio (FCR) obtained from *O. niloticus* fishes at different stocking densities during the culture period ranged from 2.91 to 3.18. The lowest (best) means feed conversion ratio (2.98 ± 0.04) was obtained at the stocking density of 3 fingerlings m^{-2} and the highest (poorest) mean feed conversion ratio (3.15 ± 0.01) was observed at the highest stocking density of 7 fingerlings m^{-2}. The experiment revealed that the food conversion ratio was affected by stocking density and the difference was significant ($p < 0.05$).

Table 3: Total amount of feed provided and feed conversion ratio

	Treatment			
	3fingerlings m^{-2}	5fingerlings m^{-2}	7fingerlings m^{-2}	P-value
Total feed provided (g)	13,061.22[a]	19,854.59[b]	25,555.11[c]	<.0001
The feed conversion ratio	2.98 ± 0.04[b]	3.12± 0.02[a]	3.15 ± 0.01[a]	<.01

The total feed provided to the experimental fish was positively related to stocking density, the total feed offered increased with an increased stocking density because the feed offered was based on average live weights in each pond multiplied by the number of fish. This result is in agreement with (Sophia *et al.,* 2010) abstracted that the highest density received more feed. The ability of fish to convert feed given to biomass (Feed conversion ratio FCR) was affected by increasing stocking density. The best FCR was obtained with a lower stocking density than higher densities. It might be feed computation during feeding. This is proven by (Thorarensen and Farrell, 2010) under cultural conditions, the fish obtaining feed increase their swimming speed; these activities require energetic cost, which increases due to agonistic interactions. This contributed to lower growth performance in the higher stocking density. In the present study, the growth performance of fingerlings decreases with increasing stocking density it might be due to poor feed utilization. Because daily weight gain and specific growth rate generally decreased with increasing stocking density indicating the decreasing feed utilization ability. This was in agreement with different scholars (Hasan *et al*., 2010; Garcia *et al.* 2013; Herrera, 2015) reported that, by reducing the initial stocking density from higher stocking density to lower stocking density, the growth performance of tilapia fish was higher and the feed conversion rate was better.

3.4. Partial Budget Analysis

After ending the experiment the net profit was highest (384.3 Birr) in 7 fingerlings m^{-2} (306.75 Birr) in 5 fingerlings m^{-2} and (216.95 Birr) in 3 fingerlings m^{-2} respectively. It was also observed that the net profit m^{-2}/6 months was highest (38.39 Birr) with a stocking density of 7fingerlings m^{-2} while the lowest net profit m^{-2}/6 months (21.69 Birr) was obtained with a stocking density of 3fingerlings m^{-2}. Regarding the profit contribution, 7 fingerlings m^{-2} contribute the highest (42.31%) followed by 5 fingerlings m^{-2} (33.76%) and 3 fingerlings m^{-2} (23.91%), respectively.

Table 4: Partial budget analysis of male *O. niloticus* fingerlings at different stocking densities

Parameter	3fingerlings m^{-2}	5fingerlings m^{-2}	7fingerlings m^{-2}
Production period (day)	174	174	174
Stocking density fingerlings/10m^2	30	50	70
Cost of fingerlings (Eth. Birr)	30	50	70
Cost of feed used (Eth. Birr)	391.8	589.5	768.2
The total cost of production (Eth. Birr)	421.8	639.5	838.2
Total production (kg)	5.11	7.57	9.78
The selling price of fish/kg (Eth. Birr)	125	125	125
Gross income from the fish sale (Eth. Birr)	638.75	946.25	1222.5
Net profit (gross income-total cost) (Eth. Birr)	216.95	306.75	384.3
Net profit/m^2/6 months (Eth. Birr)	21.69	30.63	38.43
Net profit contribution (%)	23.9	33.75	42.35

When the stocking densities of the fish increase the net profit also increases indicating a positive relationship between stocking densities and net profit. This might be due to a higher number of individuals contributing to the highest net profit contribution. This result was in agreement with Islam and Begum (2019) reported that the higher density could be more profitable for tilapia than the lower density in terms of cost-effectiveness and meet the demand for large-scale fish production.

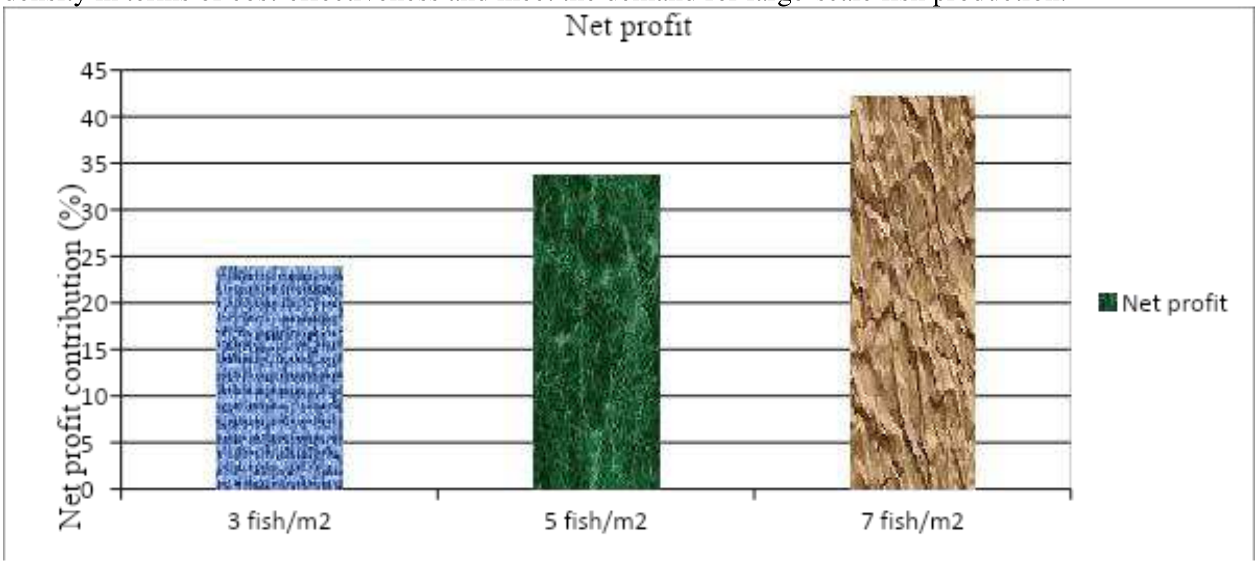


Figure 7: Net profit contribution (%) at a different stocking density

In the lower stocking density, the 3fish m^{-2} individual growth rate was higher but after the end of the experiment, the total production and the net profit contribution (23.91%) were the fish was high, but the fish product obtained per meter square was very low, due to this difficult to compensate production cost and the profitability of the farm is decreased. On the other hand, the higher stocking density 7fish m^{-2} obtained maximum production and contributed to the highest net profit (42.31%). Khattab *et al.*, (2001) also proved the present result, increasing the stocking density of fish within a limited area results in full utilization of space

lower relatives to other stocking densities this indicated that in the lower stocking density individual growth rate of

for maximum fish production and can improve the profitability of the fish farm. This is indicated that stocking density is one of the important variables to determine the profitability of the fish farm.

4. CONCLUSION AND RECOMMENDATIONS

The overall results emanating from this study indicate that even if a higher growth rate was obtained at the lower stocking densities (3fish m^{-2}) after ending the trial period a higher stocking density of 7fish m^{-2} gave a significantly higher yield or production per meter square and contribute the highest present of net profit than the lowest and intermediate stocking density and can be very useful to give good returns for local consumption and efficient utilization of resources. Therefore, stocking density is an important indicator that determined the production and profitability of the tilapia fish farm. This was important as baseline information on male *O.niloticus* culture and stocking density of pond fish farming to improve food security, reduce poverty and nutrition deficiency and maximize the contribution of aquaculture to the economy of the country. Therefore, further study should be conducted to investigate better stocking density beyond 7fishes m^{-2} and whether it will be possible to get more yields per unit area. But need optimum management levels (quality feed and secured water supply) are necessary to fish growth under high-density systems.

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