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Effects of stocking density on growth performance, feed utilization and economic profitability of juvenile *Heterotis niloticus* reared in a pen fish farming

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Abstract

Diversification and extension of fish species is a reliable solution to increase aquaculture production. But the culture of any species of fish requires the control of several factors, namely the quantity and quality of feed and stocking density that influence survival rate, growth, feed efficiency and production. This study aims to assess the effect of initial stocking density on the growth and economic profitability of juvenile *Heterotis niloticus* reared in a fish pond. Nine (9) stocking densities (D1 = 0.15 fish/m²; D2 = 0.2 fish/m²; D3 = 0.3 fish/m²; D4 = 0.4 fish/m²; D5 = 0.5 fish/m²; D6 = 0.6 fish/m²; D7=0.7 fish/m²; D8= 0.8 fish/m²; D9 = 0.9 fish/m²) were tested with specimens (176.78 ± 24.42g) in pens measuring 20 m² installed in ponds. Juveniles were fed with rice bran (10 % protein) with respective food rations of 5, 4, and 3.5% of biomass for 81 days. The results show better growth of fish in D1 with 12.23 g/d, while the feed conversion ratio, condition factor, annual production were improved in D3 with respectively 1.68, 1.22 and 6.97 t/ha/year. At the level of the economic evaluation, no significant difference was observed ($p > 0.05$) between the densities D1 and D3 concerning profit margins with 828.78 and 788.40 CFA francs respectively. From the results, the density of 0.3 fish/m² seems to be the best option for the good production of *H. niloticus* in a farming environment.

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Introduction

Fish is an important food for food security of people in West Africa (FAO, 2012). A significant part of the currencies of these countries is devoted to massive imports of fishery products to meet the needs of the populations, due to the low national production. To compensate for this importation, countries must produce quality and low-cost fishery products. Thus Aquaculture appeared as a reliable alternative to resolve this situation. In Côte d'Ivoire, the total production of fish products is estimated at 79331 tonnes for a demand of 300 000 tonnes and the part of aquaculture is only 3720 tonnes (FAO, 2014). An Aquaculture characterized mainly by *Oreochromis niloticus* (96%) followed by Catfish such as *Heterobranchus longifilis* and *Clarias gariepinus* (29.24%), whole domestication is under control (Yao *et al.*, 2017). However, the production potential of these majority species is strongly influenced by diet and production practice (Ozigbo *et al.*, 2014). Diversification and extensive of other fish species becomes a reliable solution for increasing aquaculture production. Arapaimidae *Heterotis niloticus* is an African specie with high aquaculture potential but cultivated only in polyculture with *Oreochromis niloticus* (Oswald *et al.*, 2003; Yao *et al.*, 2017).

Its use for fish farming remains very limited despite enormous aquaculture potential such as a high growth rate, short food chain, double breathing, good resistance to handling and transport (Monentcham, 2009). Because of this potential, it would be interesting to develop its culture to master its domestication. The culture of any species of fish requires the control of several factors, namely the quantity and quality of the feed (Erondu *et al.*, 2006) and the stocking density (Chattopadhyay *et al.*, 2012; Tan *et al.*, 2018) that influence survival rate, growth, feed efficiency and production. Knowledge of optimal stocking density of fry improves production and economic profitability in aquaculture (Aksungur *et al.*, 2007; Oliveira *et al.*, 2012). A low or high stocking density is chronic stressor that reduces the zootechnical performance of certain fish species (Chambel *et al.*, 2015). For the best culture of *Heterotis niloticus*, the control of its stocking density appears to be obvious. In this context, our study aims to determine the effect of different stocking densities on growth performance, feed utilization and economic profitability of juvenile *Heterotis niloticus* reared in a pen fish farming.

Materials and methods

Study site, Fish and Experimental system

The study was carried out at the experimental fish station of the "Association Fish Farming and Rural Development in Humid Tropical Africa" (APDRACI), located in Daloa city (south-west of Côte d'Ivoire at 6°53'38" N and 6°27'1" W). The juvenile *Heterotis niloticus* (147.36 ± 6.16 g) used in this experiment was obtained from populations raised in the ponds of the Association. Fish were collected in the pond of 300 m^2 and acclimated to the experimental conditions for two weeks. During the period, fish received a rice bran (10 % protein) thrice daily (9 am, 12 am and 4 pm). The experimental system consisted of 27 rectangular pens of 20 m^2 each (8 m long x 2.5m wide) with a mean water height of 0.83m, made of mosquito net have been installed in the ponds.

Experimental condition

After the acclimation period, the fish were distributed into 27 pens according to the chosen density. Nine stocking densities (0.15; 0.2; 0.3; 0.4; 0.5; 0.6; 0.7; 0.8; 0.9 fish/m^2) were tested in triplicate. These densities were named D1, D2, D3, D4, D5, D6, D7, D8 and D9. After distribution, the fish were fed thrice daily with rice bran for 81 days. The daily ration was 5 %, 4 % and 3.5 % of total fish weight as a function of average weight. Every day at 8 am, before feeding, the temperature (28.65 ± 0.30°C), pH (6.61 ± 0.76) and dissolved oxygen (13.56 ± 0.87mg/L) were recorded using a multi-parameter (BANTE) and were considered favorable in tilapia culture according to Decliné (1992) and Westers and Peterson (2003). Control fisheries were carried out every 27 days to estimate the evolution of the average weight. The fish were measured individually, weighed and counted per pen for the determination of zootechnical parameters.

Zootechnical Parameters

Survival Rate (SR), Daily Weight Gain (DWG), Specific Growth Rate (SGR), condition factor (K), Voluntary Ingesting (VI), Feed Conversion Ratio (FCR), Protein Efficiency Ratio (PER) and Production (Pa) were calculated as follows:

- SR (%) = 100 x (Final number of fish/ Initial number fish);
- DWG (g/d) = (FBW – IBW) / d;
- SGR (%/d) = 100 x (Ln FBW – Ln IBW) / d;
- K = 100 x (FBW / Lt^3);
- VI (%/d) = 100 x D x [(Bf + Bi)/2] / d;
- FCR = Dry feed intake (g) / body weight gain (g);
- PER = Body weight gain (g) / Protein intake (g);
- Pa (t/ha/year) = (Final total weight (g) x 365) / (S x d);

Where IBW (g) is the initial mean body weight, FWB (g) is the final mean body weight, Lt (cm) is the total length of the fish, D (g) is the cumulative amount of feed distributed, Bi and Bf (g) were the initial and final biomass (biomass = IBW or FBW x initial or final fish number), d is the duration of the experiment, S (m^2) is the area.

Economic evaluation

The economic parameters considered were the cost of production, gross income and gross margin:

- Cost of production (F CFA/m^2/year) = Cost of juveniles + Cost of input; input (feed, transport pens, workforce);
- Gross income (F CFA/m^2/year) = (Bf – Bi) x 1300; where 1300 FCFA/Kg is the price of *H. niloticus* on the market;
- Gross margin (FCFA/m^2/year) = Gross income – Cost of production.

Statistica analysis

Data were analyzed using one-way analysis of variance (ANOVA) after prior verification of the homogeneity of the variances and the normality of the data to be analyzed. When significant differences were found, a Tukey HSD test was used for multiple comparisons at the 5 % level of significance. All statistical analyses were performed using Statistica 7.1.

Results and discussion

Survival rate

The results of the growth performance of *Heterotis niloticus* are reported in Table 1. The survival rate ranged from 75.93 to 100%, with the highest values was obtained with D1 and the lowest with D9. No significant difference was observed between the different densities ($p > 0.05$). During this experiment, mean values of temperature (28.65°C), pH (6.61) and dissolved oxygen (13.56mg/L) are within the range of values recommended for the tilapia farming (Melard, 2004; Kestmont, 2004) which are respectively 28 to 35°C for temperature, 5 to 11 for pH and 3mg/L for dissolved oxygen.

The good quality of the rearing environment and the use of a single feed (rice bran) to feed the fish suggest that stocking density of juveniles was the factor which influenced the growth performance and economic profitability of the farm. The stocking density of juvenile did not have an impact on survival of fish. Similar results were reported by Monentcham (2009) with a density of 25 juvenile *H. niloticus*/m^2 weighing between 3 and 62g. However, Faye *et al.* (2018) indicate a strong influence of stocking density on the survival of fingerling *Oreochromis niloticus* (10 g) in lake Guiers of Senegal.

Growth performance and feed utilization

Fig. 1 shows the evolution of fish growth during the experiment. Daily Weight Gain (DWG) and Specific Growth Rate (SGR) varied from 1.25 to 7.33g/d and from 0.68 to 1.99%/d. the values of DWG and SGR increase as the stocking density decreases. Production ranged from 1.67 to 6.97 t/ha/year, with the highest value at D3 ($p < 0.05$).

Growth performance of *H. niloticus* at different stocking densities shows that the final mean weight, Daily Weight gain and Specific Growth Rate of low densities (0.15 to 0.3 fish/m^2) are significantly higher ($p < 0.05$) compared to higher densities (0.4 to 0.9 fish/m^2). Production is function of biomass gain and the overweight of fish, it is logical that the density of 0.3 fish/m^2 is most important with 6.97 t/ha/year.

Table 1. Growth performance and survival rate of juvenile *Heterotis niloticus* as a function of stocking density.

	Parameters					
Density (fish/m²)	IBW (g)	FBW(g)	SR (%)	DWG (g/j)	SGR (%/j)	Pa (t/ha/year)
D1 (0.15 fish/m²)	155.78±7.24^{a}	749.36±51.9^{a}	100^{a}	7.33±0.61^{a}	1.94±0.08^{a}	4.01±0.34^{b}
D2 (0.2 fish/m²)	148.66±6.24^{a}	681.99±10.73^{a}	91.67±14.43^{a}	6.58±0.21^{a}	1.88±0.07^{a}	4.29±0.78^{b}
D3 (0.3 fish/m²)	138.67±9.81^{a}	692.14±7.52^{a}	94.44±9.62^{a}	6.83±0.03^{a}	1.99±0.08^{a}	6.97±0.89^{a}
D4 (0.4 fish/m²)	150.00±15^{a}	497.50±34.44^{b}	87.5±12.50^{a}	4.29±0.28^{b}	1.49±0.17^{b}	5.11±1.25^{ab}
D5 (0.5 fish/m²)	150.77±8.63^{a}	426.24±24.97^{b}	90±10^{a}	3.40±0.20^{b}	1.29±0.17^{bc}	5.28±1.28^{ab}
D6 (0.6 fish/m²)	146.11±11.35^{a}	368.66±56.10^{bc}	88.89±12.73^{a}	2.75±0.62^{bc}	1.14±0.15^{cd}	4.81±0.52^{ab}
D7 (0.7 fish/m²)	145.23±4.13^{a}	307.91±26.81^{c}	85.71±0^{a}	2.01±0.34^{c}	0.93±0.11^{de}	3.74±0.75^{bc}
D8 (0.8 fish/m²)	149.58±5.64^{a}	313.70±13.21^{c}	87.5±6.25^{a}	2.03±0.12^{c}	0.91±0.03^{de}	4.52±0.99^{ab}
D9 (0.9 fish/m²)	141.47±10.32^{a}	243.10±10.50^{d}	75.93±3.21^{a}	1.25±0.04^{d}	0.68±0.06^{e}	1.67±0.56^{c}

Data are mean values ± SD (n = 3), means in the same column with the same superscript were not significantly different ($p > 0.05$).

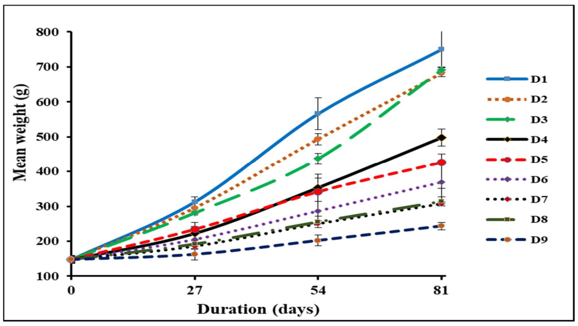

Fig. 1. Evolution of fish growth as a function of stocking density.

Feed utilization parameters (table 2) evolve in the same direction as growth parameters, meaning that fish stocked at densities ranging from 0.15 to 0.3 fish/m² use the food effectively for rapid growth. Voluntary Ingesting (VI) and Feed Conversion Ratio (FCR) varied respectively from 2.69 to 3.69%/d and from 1.68 to 11.88. The highest value of VI was obtained at D9 and the lowest value of FCR at D3. Protein Efficiency Ratio is between 1.75 and 6.09 with the lowest value at D9.

Table 2. Feed utilization parameters of juvenile *Heterotis niloticus* as a function of stocking density.

	Parameters		
Density (fish/m²)	VI (%/j)	FCR	PER
D1 (0.15 fish/m²)	2.85± 0.22^{a}	1.74±0.20^{a}	5.79±0.69^{c}
D2 (0.2 fish/m²)	2.9±0.31^{a}	1.95±0.46^{a}	4.94±1.05^{bc}
D3 (0.3 fish/m²)	2.69±0.03^{a}	1.68±0.06^{a}	6.09±0.06^{c}
D4 (0.4 fish/m²)	2.95±0.14^{ab}	2.56±0.59^{b}	4.48±0.70^{bc}
D5 (0.5 fish/m²)	3.55±0.06^{c}	3.23±0.51^{b}	2.59±0.29^{a}
D6 (0.6 fish/m²)	3.39±0.15^{bc}	3.63±0.09^{b}	3.12±0.44^{ab}
D7 (0.7 fish/m²)	3.60±0.19^{c}	5.13±0.86^{c}	2.49±0.32^{a}
D8 (0.8 fish/m²)	3.59±0.12^{c}	5.03±0.84^{c}	2.43±0.08^{a}
D9 (0.9 fish/m²)	3.69±0.10^{c}	11.88±3.49^{d}	1.75±0.17^{a}

Data are mean values ± SD (n = 3), means in the same column with the same superscript were not significantly different ($p > 0.05$).

These results suggest that the growth of juvenile *H. niloticus* was influenced by stocking density. This growth was enhanced when stocking density was low. The growth performance reported for the species are diverse and vary depending on the experiments carried out in previous studies. Differences in initial mean weights, densities and dietary proteins make comparisons complex. But in several species, zootechnical parameters varied with a stocking density (Chattopadhay *et al.*, 2012, Hasanalipour *et al.*, 2013), because an inadequate stocking density is a chronic stress factor which reduces performance of fish growth due to social interactions for access to food and space (Sugunan and Katiha, 2004). The average daily gains (1.25 to 7.33g/d) are higher than those of Monenteham (2009) which are in the range of 0.29 to 1.29g/d as well as Akande and Omorinkoba (1994) who note 3g/d in polyculture in semi-intensive systems. The growth performances recorded for low densities between 0.15 and 0.3 fish/m² in the study is generally similar to that of the literature whereas the food used, namely rice bran has a lower protein value.

This similarity can be explained by the difference in initial weight as pointed out by Kerdchuen and Legendre (1992). Contrary to the results of our study, Kpogue *et al.* (2018) reported an improvement in the zootechnical parameters of fingerling *Parachanna obscura* (10g) with an increase in stocking density (10 to 25 fish/dm^3). Increasing the stocking density to a certain level reduces aggressiveness and improves the zootechnical performance of certain fish species (Conte *et al.,* 2008; Chattopadhay *et al.*, 2012).

Condition factor

The variation of the condition factors is shown in Fig. 2. Values varied from 0.61 to 1.22, with the highest value was obtained at D3. Condition factor is an indicator of overweight of the fish in the environment. During this study, the best condition factor was obtained with the density of 0.3 fish/m^2, this ratio can be considered as the maximum stocking density of juvenile *Heterotis niloticus* of average weight 100g. Beyond this density, stress is generated leading to a decrease in appetite and a significant loss of energy (El sayed, 2002), resulting in low growth and feed conversion ratio increase.

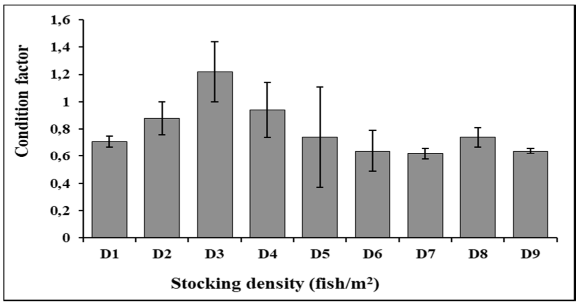

Fig. 2. Condition factor of fish as a function of stocking density.

Table 3. Economic profitability parameters of juvenile *Heterotis niloticus* as a function of stocking density.

	Paramètres		
Density (fish/m^2)	Cost of production (F CFA/m^2/year)	Gross income (F CFA/m^2/year)	Gross margin (F CFA/m^2/year)
D1 (0.15 fish/m^2)	141.88±7.90^h	970.67±18.25^a	828.78±101.86^a
D2 (0.2 fish/m^2)	170.31±11.20^h	855.63±99.26^a	685.31±90.59^{ab}
D3 (0.3 fish/m^2)	231.82±4.88^g	1020.23±110.81^a	788.40±105.93^a
D4 (0.4 fish/m^2)	295.66±1.09^f	901.07±95.08^a	605.40±95.69^{ab}
D5 (0.5 fish/m^2)	397.21±23.89^e	1165.97±296.75^a	768,.76±273.07^{ab}
D6 (0.6 fish/m^2)	437.32±7.57^d	1010.40±93.01^a	573.08±86.07^{abc}
D7 (0.7 fish/m^2)	503.30±2.88^c	960.67±83.63^a	457.37±81.87^{ac}
D8 (0.8 fish/m^2)	578.58±5.44^b	1144.06±127.74^a	565.48±122.40^{abc}
D9 (0.9 fish/m^2)	627.87±6.20^a	863.79±52.43^a	235.92±48.54^c

Data are mean values ± SD (n = 3), means in the same column with the same superscript were not significantly different ($p > 0.05$).

Economic evaluation

The results of the economic evaluation are presented in Table 3. Cost of production ranged from 141.88 to 627.87 F CFA/m^2/year while the gross margin is between 235.92 and 828.78 F CFA/m^2/year. Analysis of variance reveals a significant effect of stocking density on economic profitability.

The highest value gross margin was recorded at D1 (828.78 F CFA/m^2/year), followed by D3 which records 788.40 F CFA/m^2/year.

The gross margin of these two densities do not show a significant difference ($p > 0.05$). The results of economic profitability show the economic interest in using the density of 0.3 fish/m^2 as it gives the best performance in feed utilization. Despite the higher gross margin (828.78 ± 101.86 F CFA / m^2 / year) with the density of 0.15 fish/m^2, this value is not significantly different ($p > 0.05$) that the density of 0.3 fish/m^2 (788.40 ± 105.93 F CFA / m^2 / year).

A density of 0.3 fish/m^2, the feed seems to be better valued to maintain the growth performance at a high level in addition to a better production compared to density of 0.15 fish/m^2. Density of 0.15 fish/m^2 gives good growth performance, only for optimal rations with lower production. The optimal ration could be the one that optimizes economic results rather than production performance (Iga-Iga, 2008).

Conclusion

Growth performance, feed utilization and annual production of juvenile *Heterotis niloticus* were improved when stocking densities of fish remained low. Beyond 0.3 fish/m², growth performance is reduced as density increases. The economic evaluation shows that the density of 0.3 fish/m² can improve economic profitability while maintaining the growth performance of fish.

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