Research Article

Growth and Production Characters of African Catfish (*Clarias gariepinus*) Stocked at different Stocking Densities in Earthen Ponds under Local Climatic Conditions of Pakistan

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Abstract | The optimization of the stocking densities in earthen ponds of African catfish is necessary for efficient management, increase in fish production and to maximize the return on investment. So, this study was carried out to investigate the influence of various stocking densities on the production and economic character of African catfish *(Clarias gariepinus)* in Pakistan. After the successful transportation and acclimatization of African catfish, further experiment was performed for optimization of stocking densities in African catfish. For this purpose. fish was stocked at 10,000;15,000 and 20,000 fish/acre in earthen ponds for a period of 120 days. The experimental design was CRD with three treatments (10,000, 15,000 and 20,000 fish/acre) and three replicates (9 earthen ponds of 0.04 ha). Fish was fed three time at rate of 4% of total wet fish body weight daily on sinking pellets containing 35% CP manufactured from locally available ingredients. Sampling on fortnightly basis was done from each pond using drag net (mesh size 3 cm) to record data on growth. At the end of the experiment total number of fish was counted from each pond and various production characteristics were determined for different stocking densities. Water quality analysis was performed for each treatment to record variations for each treatment. The ANOVA (analysis of variance) test was performed to analyze the difference between the means among the three different stocking densities. Significant weight gain (P>0.05) was achieved at stocking densities of 10,000 and 15,000 / acre as compared to fish stocked at highest stocking densities of 20,000 fish/acre. However economic benefits showed increasing trend with increasing stocking densities. By increasing the stocking density, the production parameters were directly increasing, ultimate yield were higher at 20,000 fish/acre followed by 15,000 and 10,000/ acre. Financial analysis assessment of the present study showed encouraging net earnings at all stocking densities. Highest net profit as well as net production achieved at a stocking density of 20,000/acre followed by 15,000 and 10,000/acre stocking density. From this study it can be concluded that African catfish *(Clarias gariepinus)* can be cultured at elevated stocking densities for gaining maximum production in Pakistan.

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Introduction

Pakistan has achieved notable advancements in the domain of aquaculture; however, inland fish culture encounters numerous challenges. The present per unit production is low due to conventional farming system, lack of proper managemental inputs non-availability artificial fish feed, improper species combination and low stocking density. The present level of fish production about 1000-1200 kg/acre can easily enhance to about 1500-2000 kg/acre per year by applying fertilizers (organic and inorganic), use of artificial diets and adoption of the intensive fish culture technology (Jarwar, 2015). Proper stocking density and fish combination in farm ponds also played major role in increasing fish production (Wolnicki, 2005) and may differ significantly between different species reared in different environmental conditions (Zarski *et al*., 2008).

All over the world, African catfish has gained the attraction of fish farmers due to high production in ponds. African catfish is more adopted to environment as it has the ability to tolerate high temperature, and can survive at low oxygen and resistant to disease. High fecundity, easy larvae rearing in captivity (Olaleye, 2005), a better survival rate (Van der Waal, 1998) and high stocking densities makes it more profitable for aquaculture (Toko *et al*., 2007). For intensive production of African catfish, tanks are commonly preferred while for semi-intensive or extensive production, earthen ponds are considered more feasible (Keremah and Esquire, 2014). Keeping in view the above-mentioned characters, the exotic African catfish was successfully introduced in aquaculture system of Pakistan (Basharat *et al*., 2020).

The profitability from production systems is determined by the number of fish stocked, because it directly affects fish growth, survival, behavior, health, feeding requirements and water quality (Gibtan *et al*., 2008; El-Sayed, 2006). The relationships between stocking density and growth of fish might be positive or negative (Abou *et al*., 2016; Bosworth *et al*., 2015).

High stocking density can be a cause of stress for fish (Ellis *et al*., 2002; Abou *et al*., 2016) that reflets an inverse relationship between mean final weigh and specific growth rate (Abou *et al*., 2016; Ullah *et al*., 2018) feeding rates and survival (Rowland *et al*., 2006; Das *et al*., 2016). It is well established fact that inappropriate stocking rates have harmful impact on the survival, growth performance, behavior, health, water quality, feeding and fish production, as well as overall welfare parameters of the fish (Ashley, 2007; EFSA, 2008; Gibtan *et al*., 2008). However, more biomass production (i.e., marketable product) is facilitated by higher stocking densities which could potentially have positive influences on overall profitability within a fish farming system.

The stocking density, production efficacy and profitability are closely interacting factors. Fish production is much higher and financial returns is more attractive from intensive culture than those from semi-intensive and extensive aquaculture; the return on investment (ROI) from the intensive culture is less than those from semi-intensive culture due to the high inputs cost (mainly feeds and fry) used in intensive culture. One of the fundamental needs of an investment decision is to establish the best system which can give the maximum profit from least resource usage (Edward *et al*., 2010). Such extensive studies are not available that have provided detailed knowledge regarding the assessment of financial benefits of African catfish in monoculture at different stocking densities in earthen ponds for rural fish farms of Pakistan. So, the present study was designed and performed to evaluate the effects of stocking density on profitability, growth performance and water quality of African catfish in earthen ponds.

Materials and Methods

Study site

This study was performed at Aquaculture and Fisheries Program (AFP) National Agriculture Research Centre (NARC), Islamabad. Having humid and subtropical conditions, the climate could be divided into five seasons viz., Spring (March, April), Autumn (September, October), Summer (May, June), Rainy Moon Soon (July to August) and Winters (November to February). Minimum air temperature range (3.9-20 °C) was observed in January and extreme high temperature was recorded in June (38-46°C) (Pakistan Meteorological Department, 2013). Rainy Moon Soon (July to August) and Winters (Nov to Feb).

Experimental design and procedure

A four months experiment was conducted in nine newly constructed earthen ponds, each measuring

0.04 ha. Experiment was performed in CRD design with three treatments T1 (10,000 fish per ha), T2 (15,000 fish per ha) and T3 (20,000 fish per ha) with three replicates. All the ponds filled with the tube well water up to a level of 5 ft and was maintained throughout the experiment. At the time of stocking weight and length of the fish was recorded. Fish was fed three time @ 4% of total wet fish body weight (for 20 minutes) daily on sinking pellets containing 35% CP manufactured from locally available ingredients. To adjust the amount of feed sampling on fortnightly basis was done from each pond using drag net (mesh size 3 cm). After recording the desired measurements, fish was put back into their respective ponds. According to the biomass of fish in each pond, the amount of feed offered was calculated and adjusted accordingly.

Data collection

At the end of the experiment, water was completely drained out of the ponds, and all fish from each pond were collected and counted. Various Water-quality parameters including dissolve oxygen, temperature, Alkalinity, Hardness and PH were checked weekly to perceive the usual environmental conditions in the experimental fish ponds. Temperature was recorded by using thermometer while hardness, Alkalinity and dissolve oxygen were measured by using titration methods. Economic analysis for this farm study was carried out by calculating the total cost of fish crop, total cost of feed consumed, profit index and net profit. All fish harvested from each pond were then weighed for determination of gross fish yield (GFY). The fish from each pond was measured individually to determine the final mean weight (FMW). Net fish yield (NFY), specific growth rate (SGR), feed conversion ratio (FCR) and percentage survival (%), were calculated using the following formulae:

$$NFY = W_h - W_s/P$$

Where W_h = Total weight of fish harvested (kg), W_s = Total weight of fish stocked (kg), and P = Pond area (ha).

$$DWG= Wf-Wi/t$$

Ehere Wf = Final mean weight (g) and Wi = Initial mean weight (g)

$$SGR= \ln Wf - \ln Wi /t X100$$

$$FCR= TFC/TWG$$

Where TFC = Total feed consumed (dry) (kg) and TWG = Total weight gained by fish (wet) (g).

$$\text{Percentage survival}= Nh/NsX100$$

Where N_h = Total number of fish harvested and N_s = Total number of fingerlings stocked.

Profit index= fish cost/feed cost

Net profit= fish cost-feed cost

Performance index = weight gain x fish harvested in no / duration of culture

Statistical analysis

The ANOVA (analysis of variance) test was performed to analyze the difference between the means of growth parameter among the three different stocking densities. The comparation of the measured parameters among the three stocking densities was performed by Duncan multiple range test. All statistical analyses were performed using SPSS version. Significant differences were considered at the significance level of 0.05.

Results and Discussion

The growth and survival of fish is directly affected by stocking density. To get maximum economic returns, optimum growth and productivity in relation to inputs, a proper number fish is necessary to stock in the ponds. The fortnightly growth trend of African catfish stocked at various stocking densities in earthen ponds is shown in Figure 1. The average individual fish weight was highest at lowest stocking density (10,000) followed by medium stocking density (15,000) and highest stocking density (20,000), respectively. There was an overall increase in weight all fish during the experimental time period and similar trend was observed in this study (Oyedeji and Nike, 2016). The fish with low stock density were significantly different in growth from those fishes kept with high stock density. These results are in agreement with the studies on the African catfish *(Clarias garierpinus)* where randomly stocked fish grew more gradually than those in pairs or at high density. However, it is more probable that the stocking density never touched the threshold at which food accessibility and struggle among individuals negatively affected the growth rate (Adewolu *et al*., 2008).

Table 1: *Growth performance parameters of African catfish at different stocking densities in monoculture system of earthen ponds.*

Parameters	10,000/acre	15,000/acre	20,000/acre
Mean initial weight (g)	2.03±0.05a	3.42±0.07a	2.30±0.02a
Mean final weight (g)	532.6±0.67a	456.2±0.87b	402.3±0.62c
Mean weight gain (g)	530.57±0.57a	452.78±0.82b	400.0±0.49c
Mean weight gain/day (g)	4.42±0.02a	3.77±0.01b	3.33±0.04c
Feed conversion ratio	1.70±0.02a	1.63±0.09a	1.55±0.06a
Feed efficiency	58.7±0.65a	61.16±0.63a	64.50±0.59a
Specific growth rate	4.64±0.06a	3.70±0.03c	4.00±0.09b

Means with different letters differ significantly (P<0.05).

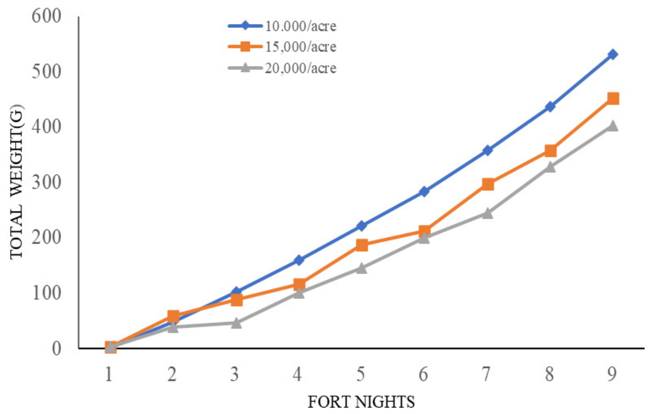

Figure 1: *Fortnightly growth trend of African catfish stocked at various stocking densities in earthen ponds. Different letters show significant difference (P<0.05) between the treatments.*

The different parameters of growth of African catfish cultured at different stocking densities in earthen ponds are given in Table 1. African catfish cultured at lower stocking density have higher average final weight, mean weight gain, mean daily weight gain and specific growth rate compared to higher stocking density (P<0.05). Feed conversion ratio was non-significant (P<0.05) at all stocking densities. This study indicated that mean weight gain, total mean weight and final weight of this species were decreased with the increase in stocking density. Our results are according with studies reporting that *C. gariepinus* stocked at low stocking density and medium stocking density showed significantly higher weight gain, specific growth rate, and final mean weight than those cultured at high stocking density (Shoko *et al*., 2016; Suleiman and Solomon, 2017; Hossain *et al*., 1998). Converse relation was found in growth rates of individual fish and fish density of African catfish at a stocking rate of 2.5, 5.0, and 12.5 fish m^{-2} using ponds (Bok and Jongbloed, 1984). By the increasing stocking density, decrease in the mean weight gain was also reported earlier (Otubusin and Olaitan, 2001). Same results were reported by Eyo *et al*. (1998) and Edward *et al*. (2010). They discovered that stocking density has a converse relationship with growth and survival of other cultured fish species such as Nile tilapia and common carp. The reason for inhibition of growth at high stocking density may be attributed to overcrowding which developed competition for food and space availability. Likewise, stocking density of fingerlings of African catfish effected body weight, survival rate, mean total length, specific growth rate and feed intake (Nieuwegiessen *et al*., 2009). Therefore, excluding for the feed intake the lowest stocking density maintain optimal growth and survival compared to the treatment with the highest stocking density. On the contrary, African catfish and Vundu catfish exhibited increased trend in growth rate with increasing density (Hengsawat *et al*., 1997). Therefore, recognizing the optimum stocking density for a species could be a promising strategy towards planning an effective aquaculture system.

The relative growth was found to be decreased with the increased stocking density. The growth rate observed in this study was in agreement as reported earlier for African catfish in mesh net cages (Otubusin and Olaitan, 2001) and lower than that reported by (Otubusin *et al*., 2004). In present study, the growth rate per day in earthen ponds was found to be the highest while in other culture systems like cemented tank for rearing of hybrid catfish (Boujard *et al*., 2002) and homemade concrete tanks lower growth rate was reported (Egwui, 1986). Indeed, fish experience stress at high stocking rates, as a consequence of aggressive interactions while feeding and consume are less resulting in retardation of growth (Bjoemsson, 1994). This shows that stocking densities beyond 20 fish/70 L may pause the growth in African catfish at fingerlings stage. The influence of stocking density on growth and relative growth rate in *Clarias batrachus* larvae raised in tanks has been also reported (Alatise, 2006).

Researchers has explained that all larvae receive sufficient quantities of food at low stocking densities, compared to those of having high densities. In present study, the feed efficiency and RGR was decreased at high stocking density. Parallel results have been documented in *Tor putitora* larvae (Rahman, 2001) and *Cyprinus carpio* larvae (Jha and Barat, 2005). In agreement with our study, high densities have been revealed to decrease the survival of Nile tilapia (Yi *et al*., 1996) and Tiger puffer (Kikuchi *et al*., 2006). Furthermore, decreased feed intake, feed conversion efficacy and growth and increase in fin rot was reported for rainbow trout (*Oncorhynchus mykiss*) exposed to high culturing densities (Ellis *et al*., 2002).

Table 2: *Production characteristic of African catfish at different stocking densities in monoculture system of earthen ponds.*

Parameters	10,000/ acre	15,000/ acre	20,000/ acre
No of fish stocked	500 fish	750 fish	1000 fish
No of fish harvested	445	617	764
*Survival rate (%)	89.0%	82.3%	76.4%
Net production (kg)	237.0	279.3	307.3
Value of fish crop@ of 250 Rs/kg	59262.8	69844.4	76839.3
Feed input(kg)	451.2	555.2	620.1
Cost of feed used @45 Rs/kg	20304.9	24985.8	27906.2
*Performance index	1967.5	2328.04	2546.6
*Net profit (Rs)	38957.97	44858.6	48933.0
*Profit index	2.9	2.7	2.7

@=at the rate of Survival rate=no of fish harvested/no of fish stockedx100. Performance index= weight gain x fish harvested in no/duration of culture. Profit index= fish cost/feed cost. Net profit= fish cost-feed cos.

Table 2 shows the production characteristic of African catfish at different stocking densities in monoculture system of earthen ponds. Fish stocked at the rate of 10,000 per acre showed higher survival rate (%) compared to 15,000 and 20,000/acre. More survival rate of C. gariepinus at high stocking density was due to air breathing ability and tolerance to hostile quality of water (Hecht *et al*., 1996). African catfish can live at high stocking densities, particularly with fully grown arborescent organs that are helpful in air breathing (Lin and Diana, 1995; Adewolu *et al*., 2008). African catfish at post fry stage, were tested by Nwipie *et al*. (2015) at the rate of 5.0, 10.0, 15.0, 20.0, and 25.0 post fry/L of water. Best growth and survival rates were documented at stocking density of 5.0, 10.0, and 15.0 post fry per L. Though, the reported optimal stocking level for culturing of African catfish at post fry stage using tanks is 15.0 post fry in each litre of water. It was reported by Nwipie *et al*. (2015) that the increase in density influences the growth performance and rate of survival of the fish, but it also increases the recurrent surfacing, swimming and feeding response and as well as aggression.

However, number of fish harvested was maximum in ponds stocked at high density followed by medium and lower stocking density. The African catfish stocked at highest stocking density of 20,000 per acre generated significantly higher yields compared to fish stocked at medium density of 15,000/acre followed by lowest stocking density of 10,000 fish per acre. Similar results were reported for culture of African catfish in cage culture (Hengsawat, *et al*., 1997) and in earthen ponds (Bok and Jongbloed, 1984; Shoko *et al*., 2016). The increase ofproduction with increase of stocking density in current study could be linked to a higher survival and increase in the number of fish harvested. At the completion of the experiment, the number of African catfish survived was maximum at the high stocking densities. Ultimately, the greater number of fish harvested at higher stocking densities led to higher yields (Hengsawat *et al*., 1997).

Financial analysis of the present study showed encouraging net earnings at all stocking densities. In terms of income and net returns African catfish raised at moderate and highest stocking rate generated more profit as compared to those cultured at low stocking rate with minor difference in profits between medium and high stocking densities as shown in Table 2. Findings further suggested that both the net revenues generated (income beyond variable cost) and net yields were relative to stocking density as net production and net profit increased with increasing stocking density. The conclusions are in accordance to those achieved earlier (Nieuwegiessen *et al*., 2009; Hengsawat *et al*., 1997; Bok and Jongbloed, 1984). The net earnings from the 3 stocking densities indicate that a reasonable profit can be gained by stocking African catfish at even at 10,000 fish per ha density (Engle and Sapkota, 2012). However, even more benefits can be gained by maximizing the stocking level of African catfish in this study up to

20,000/acre. Because of better survival rates even at high stocking density, the higher stocking densities of African catfish (15,000 and 20,000/acre) exhibited significantly greater benefits than the lesser stocking density (10,000/acre). Stocking density effects the growth and survival rate of African catfish in a significant way when cultured in floating bamboo cages. According to findings of Dasuki *et al*. (2013), highest stocking density had negative effect on the growth and survival of fish which is contrary to the present study. Their study reported that 50 fish/m^3 is the optimum stocking density giving finest production and profit index value.

Table 3: *Physico-chemical parameters of earthen ponds with African catfish stocked at various stocking densities.*

Parameters	Treatments	Range	Mean	Standard deviation
Temperature (°C)	10,000/acre	17.0-30.8	23.9	5.7
	15,000/acre	20.0-31.2	25.6	5.0
	20,000/acre	17.5-30.0	24.35	5.8
Dissolve oxygen (mg/l)	10,000/acre	5.2-7.6	6.4	1.2
	15,000/acre	5.0-7.7	6.3	1.0
	20,000/acre	5.7-8.0	6.8	1.4
pH	10,000/acre	7.5-8.0	7.7	0.5
	15,000/acre	7.0-8.0	7.5	0.2
	20,000/acre	7.5-8.5	8.0	0.6
Alkalinity (mg/l)	10,000/acre	164.4-177.0	170.7	8.2
	15,000/acre	161.3-169.2	165.2	10.7
	20,000/acre	166.7-178.8	172.7	9.7
Hardness (mg/l)	10,000/acre	166.2-177.3	171.7	11.4
	15,000/acre	164.3-173.7	169.0	11.9
	20,000/acre	163.2-178.4	170.8	11.0

The water temperature was within the best temperature range as essential for culture of catfish in fresh water (Table 3). Temperature ranges for the culture of African catfish in the pond culture (Zakas, 2013). During the experiment, pH of water (ranges from 7.0 to 8.5) remained suitable for fish farming as described by other researchers (Amin and Hashim, 2012; Otubusin and Olaitan, 2001). Dissolve oxygen (8.3mgL^{-1}) as observed in this study designates that it was not restrictive and comparable value previously described in a same work on African catfish by using bamboo net-cages (Otubusin *et al*., 2004).

Conclusions and Recommendations

This study reveals that stocking density is an important parameter for the production of African catfish in earthen ponds. Findings suggested that net production and net profit increased with increasing stocking density. The culture of African catfish in earthen ponds at stocking densities of 15,000 to 20,000 fish per acre gives highest production and profitability compared to stocking of 10,000 fish/acre.

Novelty Statement

African catfish was indigenized in Pakistan After the successful transportation and acclimatization of African catfish in local environment, the optimization of the stocking densities in earthen ponds for African catfish is necessary for efficient management, increase in fish production and to maximize the return on investment.

Author's Contribution

Hasina Basharat: This paper is a part PhD study of 1st author, performed this research study.
Muhammad Ramzan Ali and Shamim Akhter: Supervised research, help in experimental setup, data analysis and manuscript writing.
Aziz Ahmed: Helped in experimental setup and data collection.
Muhammad Zubair Anjum: Helped lab analysis, reviewed and edited the manuscript.
Shamim Akhter: Supervised research and manuscript writing

Conflict of interest
The authors have declared no conflict of interest.

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