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Effect of organic and inorganic fertilisers on natural food composition and performance of African catfish fry produced under artificial propagation

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ABSTRACT

In recent times, the African catfish, *Clarias gariepinus* has gained popularity in the aquaculture sector of Tanzania. However, many aquaculture farmers face the challenge of unreliable supply of seed due to difficulties of reproducing in captivity and high larvae mortality. This study was conducted to determine the effect of organic and inorganic fertilizers on natural food composition and performance of African catfish fry produced under artificial propagation. A completely randomized and factorial experimental design were adopted with three replication for a one week and two months period of time, respectively. Plankton abundance and diversity, growth performance and survival rate of African catfish fry were determined. One way and two way analysis of variance (ANOVA) were used to determine differences between treatments ($p<0.05$). Post-hoc analysis was done where significant differences existed between treatments using Tukey's Test. Results indicated that phytoplankton abundance and diversity were significantly higher ($p<0.05$) in di-ammonium phosphate (DAP) fertilizer applied tanks compared to chicken manure and no fertilizer. Zooplankton diversity was also higher in tanks applied with chicken manure in comparison with other treatments. Growth performance was higher in fertilized tanks compared to unfertilized tanks at low stocking density (5fry/m^2). There was no significant difference ($p>0.05$) in fry survival rates between chicken manure and DAP fertilized treatments across stocking densities. Water quality parameters were within the optimum ranges.

Key words: Chicken manure, *Clarias gariepinus*, DAP fertilizer, growth performance, Plankton

RÉSUMÉ

Ces derniers temps, le poisson-chat africain Clarias gariepinus a gagné la popularité dans le secteur aquacole de la Tanzanie. Cependant, de nombreux aquaculteurs sont confrontés au défi de l'approvisionnement en semences non fiable en raison des difficultés de reproduction en captivité et de la mortalité élevée des larves. Cette étude a été menée afin de déterminer l'effet des engrais organiques et inorganiques sur la composition des aliments naturels et la performance des alevins des poissons-chats africains produits sous propagation artificielle. Un plan expérimental entièrement aléatoire et factoriel a été adopté avec trois répétitions pour une période d'une semaine et deux mois, respectivement. L'abondance et la diversité du plancton, la croissance et le taux de survie des alevins africains ont été déterminés. Une analyse bidimensionnelle de la variance (ANOVA) a été utilisée pour déterminer les différences entre les traitements ($p <0,05$). Une analyse post-hoc a été réalisée lorsque des différences significatives existaient entre les traitements utilisant le test de Tukey. Les résultats ont indiqué que l'abondance et la diversité du phytoplancton étaient significativement plus élevées ($p <0,05$) dans les réservoirs fertilisés par l'engrais à phosphate de di-ammonium (DAP) que dans ceux fertilisés par la fiente de poule ou sans engrais. La diversité du zooplancton était également plus élevée dans les réservoirs fertilisés par la fiente de poule que dans les autres traitements. La performance de croissance était plus élevée dans les réservoirs fertilisés que dans ceux non fertilisés à faible densité de stockage (5 fry/m2). Il n'y a pas eu de différence significative ($p> 0,05$) entre les taux de survie des alevins entre la fiente de poule et les traitements fertilisés par le DAP selon les densités de population. Les paramètres de qualité de l'eau se situaient dans les limites optimales.

Mots clés: la fiente de poule, Clarias gariepinus, l'engrais DAP, la croissance, les planctons

INTRODUCTION

Demand for fish in both rural and urban areas is very high and continues to grow in Tanzania (FAO, 2007). The African catfish (*Clarias gariepinus*) has gained popularity in the aquaculture sector of Tanzania in the recent times. Its demand has increased as food, control of over-population in tilapia ponds and as a bait for the Nile perch fishery (Musiba *et al.,* 2014). The rearing of *Clarias gariepinus* larvae to juveniles has proved to be challenging due to their small size and a lack of functional digestive system (Govoni *et al.,* 1986; Olurin *et al.*, 2012). Significant losses are incurred in the hatchery, as fry weans over from yolk absorption to exogenous feeding (Adewumi, 2015). This is due to inability to accept large sized feeds and assimilate protein from dry formulated diets (Govoni *et al.,* 1986; Cahu and Zambonino-Infante, 2001). According to Agadjihouede *et al*. (2012), Artemia constitutes an excellent starting food in larviculture of *C. gariepinus*. However, its cost is high and is not readily available in developing countries especially in the rural fish farming communities (Agadjihouede *et al.,* 2012). Due to this fact, it has been found important to provide the larvae with live foods such as zooplankton or algae before they are sequentially acclimatized to accepting formulated diets (Olurin and Oluwo, 2010). Despite significant progress made in aquaculture, larvae rearing remains a bottleneck in *C. gariepinus* production. The use of natural live food at earlier stage of fry development seems to be one of the solutions to improve *C. gariepinus* growth performance and survival.

LITERATURE SUMMARY

Provision of live foods to fish larvae is considered an important aspect because it supplies nutrients to the larvae as well as exogenous materials important for the digestion of other feeds. Live foods are also important facets in enhancing the development of larvae's pancreas (Lubzen *et al.,* 2001). The growth of natural feed in the fish ponds tanks is encouraged by fertilizers application (Chenyambuga *et al.,* 2011). According to Lin *et al.* (1997), fertilization in fish ponds/tanks is known worldwide to improve pond productivity by promoting the growth of phytoplankton thereby increasing natural food available to fish. Among fertilizers, chicken manure and di-ammonium phosphate fertilizers are often used and these are preferred because they are cheaper and locally available to fish farmers (Diana, 2012). Further, these fertilizers contain a good combination of nitrogen and phosphorus in different proportions which increase the quantity of primary producers (Akand, 1986; Kumar *et al.*, 2014).

Survival and growth of catfish larvae and fry are influenced by several factors such as stocking density (Schram *et al.,* 2006) and water quality (Brazil and Wolters, 2002). Stocking density is one of the main determinants of growth (Rahman *et al.,* 2005). Growth of juvenile African catfish is density dependent (Hengsawat *et al.,* 1997). Juvenile African catfish are normally highly aggressive when confined in small numbers in a large volume of water. However, aggressiveness can result in stock losses, reduced food conversion efficiency and slower growth. There is certainly a density from which both growth and production decrease with increasing stocking density (Toko *et al.,* 2007). Water quality, mainly dissolved oxygen and pH levels, are considered as the limiting factors in intensive fish culture. High levels of dissolved oxygen increase growth in channel catfish (*Ictalarus punctatus*) larvae reared in tanks (Brazil and Wolters, 2002).The decreasing trend of dissolved oxygen in tanks with high stocking densities is attributed to the gradual increase in biomass, resulting in higher oxygen consumption at varied stocking densities (Pangni *et al.,* 2008). Therefore the objective of the present study was to determine the effect of organic and inorganic fertilizers on natural food composition and performance of African catfish.

STUDY DESCRIPTION

The study was conducted from March 2015 to June 2015 at aquaculture research facility in Magadu farm at Sokoine University of Agriculture (SUA), Morogoro, Tanzania. Two experiments were conducted for one week and two months, respectively. Experiment 1 involved determination of abundance and diversity of natural food in tanks applied with different type of fertilizer, while experiment 2 involved evaluation of growth performance and survival of African catfish fry stocked under two stocking densities (5 fry/m^2 and 10 fry/m^2), in tanks supplied with different types of fertilizer.

Determination of abundance and diversity of natural food. In Experiment 1, chicken manure and di-ammonium phosphate fertilizer were used. Fresh manure from layers kept in the cages were collected from poultry unit belonging to the Department of Animal Science and Production, SUA. Nitrogen

(2.55%) and Phosphorus (0.95%) in chicken manure was determined using proximate analysis at Animal Science laboratory according to Association of Official Analytical Chemists (AOAC, 2002). Di-ammonium phosphate fertilizer was purchased from a local agro-input shop in Morogoro containing 18% N and 46% P as indicated on the package. Nine concrete tanks having an area of $7m^2$ each were laid out with 10cm of soil and then filled with water to a depth of 0.8m. Three treatments; 2 kg of chicken manure, 42 g of di-ammonium phosphate fertilizer and no fertilizer (control) were randomly assigned to the tanks. Each treatment was replicated thrice. One week after fertilization, water samples were collected with a 10L bucket from four locations within each concrete tank for all nine tanks at 08:00am. Water samples were placed into a plankton net with 20µm mesh size and left for about 20 min. The concentrated sample from plankton net was transferred into 200 ml plastic bottles. Five drops of 70% alcohol were added to each sample to fix the organisms. Plankton identification was done on a light microscope 100x magnification using identification keys according to UNESCO (2006). One milliliter (1 ml) of the water sample was taken from the collecting bottles (200ml bottles) using micropipette and transferred to the Sedgewick Rafter cell then covered with a slide at the top and placed under microscope. From 10 randomly selected squares of cell, planktonic organisms were enumerated and numerical abundance was calculated. Phytoplankton and zooplankton abundance were calculated using the formulas as described by Wetzel and Likens (1991) and Greenberg *et al*. (1992). Species evenness and richness were calculated from the equation as described by Sundar *et al*. (1995).

Determination of growth and survival of African catfish fry. In experiment 2, random fertilization of tanks used in this experiment was done one week before fry stocking. A total of 18 concrete tanks ($7m^2$ each) were used. Six tanks were fertilized with chicken manure and the other six tanks fertilized with di-ammonium phosphate at the rate of 286 g/m^2 and 6 g/m^2, respectively, while the remaining six tanks were not fertilized (control). The experiment was laid out in a Factorial Design where catfish fry were assigned randomly in 18 concrete tanks. *Clarias gariepinus* fry (one month old) with average weight of 0.5g ± 0.01g from hatchery tank were randomly assigned to treatment tanks. Two stocking densities (5 fry/m^2 and 10 fry/m^2) were used. Each stocking density was assigned once and replicated three times. All 18 concrete tanks were covered with plastic nets to prevent predators. Fertilization was repeated every week for a period of two months. During this period, all treatments were supplemented with the same diet formulated at 25% body weight per day. Once every week in the rearing period of two months, the catfish fry from each concrete tank were harvested using a seine net, placed in 10 L buckets and taken to the hatchery where they were weighed using analytical balance. The fry performance was determined using the formula as outlined by Kang'ombe *et al.* (2006). In both experiments, water quality parameters were monitored. Temperature (^oC) and dissolved oxygen (mg L^{-1}) were monitored on daily basis at 08:00hrs and 16:00hrs and measurements were taken using a DO meter. The pH was monitored every week (08:00hrs-16:00hrs) and measurements were taken using a pH meter. Ammonia and nitrite (ppm) were determined once a week by using Ammonia-nitrogen by salicylate and Nitrite-nitrogen by diazotization method, respectively.

One way and two way analysis of variance (ANOVA) (Experiments 1 and 2, respectively) were used to compare differences between treatment means at 5% level of significance. Post-hoc analysis was done where significant differences existed between treatments means using Tukey's Test. Analyses were performed using SPSS software version 20 (SPSS Inc.) (Ott and Longnecker, 2001).

RESEARCH APPLICATION

Among the phytoplankton, chlorophyta, cryophyte and diatomae were significantly higher ($p<0.05$) in tanks fertilized with chicken manure and di-ammonium phosphate fertilizer compared to the control. Variation in Euglenophyta was highly significant ($p<0.05$) when di-ammonium phosphate fertilizer was used in comparison to other treatments used in this study (Table 1). Phytoplankton diversity was higher in tanks supplied with DAP fertilizer, followed by tanks supplied with chicken manure and least in tanks with no fertilizer as indicated with Shannon-Wiener indices (H') and evenness (J') values (Table 2). Similar results have been reported by Padmavathi (2009) and Kumar *et al.* (2014). The significantly higher abundance and diversity of phytoplankton in DAP fertilizer could likely be due to the increased availablity of nutrients in the water. All zooplankton groups had significantly ($p<0.05$) higher abundance in tanks fertilized with di-ammonium phosphate fertilizer (DAP) compared to chicken manure and control (Table 1). This might be due to feeding effects of zooplankton on phytoplankton earlier observed by Guangjun (2013). Zooplankton diversity was also higher in tanks applied with chicken manure, followed by tanks applied with DAP fertilizer and least in tanks with no fertilizer (Table 2). This might be due to phytoplankton particle size and cell abundance which influences zooplankton communities (Bell, 2002). The larger size of phytoplankton cells were not consumed by smaller zooplankton hence higher abundance of phytoplankton communities than zooplankton in DAP fertilized tanks. Soderberg (2012) reported that organic fertilizers require bacteria and other microbes for decomposition, and thus offer a wider diversity in fish ponds, particularly zooplankton. Also, chicken manure have been reported to provide a substrate for zooplankton production (FAO, 2003) which enhances high diversity.

Growth performance of catfish fry was higher in fertilized tanks compared to unfertilized tanks. Similar results have been reported by Muendo *et al.* (2006). At low stocking density (5fry/m^2) fry had better growth performance compared at higher stocking density (10fry/m^2) across all fertilizer types. This indicated that the growth performance of catfish fry was influenced by stocking density and fertilizer type. Jamabo and Keremah (2009) reported significantly higher growth rate at a stocking density of 5fry compared to 10fry and 15fry per 55m^3 tank. This might be due to the presence of high natural food organisms in fertilized tanks at low stocking densities compared at high stocking densities (Bahnasawy, 2009). In addition, higher survival rate was observed in tanks fertilized with di-ammonium phosphate fertilizer and control tanks under low stocking density (Table 3). This might be due to low dissolved oxygen and NO_2 concentration recorded (Table 4). Similar results were reported by Sophin and Preston (2001) in tilapia where poorer survival rates were observed in the ponds fertilized with chicken manure as compared to the inorganic fertilizers (urea and DAP) and unfertilized ponds.

Among water quality parameters, dissolved oxygen during the afternoon and nitrite varied significantly ($p<0.05$) with stocking densities and fertilizer types (Table 4). This might be due to ammonia utilization by phytoplankton (Boyd, 1998) or oxidation of ammonia nitrite especially in high dissolved oxygen level conditions (Boyd, 2000). In addition, the range in pH values were similar for all stocking densities under chicken manure and DAP fertilizer but different ranges were observed in the control experiments (Table 5). Boyd (1990) reported that the application of ammonium and urea-based fertilizers can cause acidification of pond water because of nitrification, which produces two hydrogen ions from each ammonium ion. Similarly, Saad *et al.* (2014) reported high pH values in treatments that received inorganic and organic fertilizers compared to group given feed only.

DISCUSSION

The results indicated that phytoplankton diversity was higher in tanks applied with DAP fertilizer than in chicken manure and the control. Similar results have been reported by Padmavathi (2009) and Kumar *et al.* (2014). The significantly higher abundance and diversity of phytoplankton in DAP fertilizer could likely be due to easy availabilty of nutrients in the water. Zooplankton diversity was higher in tanks applied with chicken manure than in DAP fertilizer and control. This might be due to zooplankton feeding effect on phytoplankton particle size and cell abundance (Bell, 2002). Indeed Soderberg (2012) reported that organic fertilizers require bacteria and other microbes for decomposition, and thus support a wider diversity in fish ponds, particularly zooplankton. Also, chicken manure has been reported to provide a substrate for zooplankton production which enhance high diversity (FAO, 2003).

Growth performance of catfish fry was higher under low stocking density (5 fry/m^2) compared to high stocking density (10 fry/m^2) across all fertilizer types. This indicated that the growth performance of catfish fry was influenced by stocking density and fertilizer type. Jamabo and Keremah (2009) reported significantly higher growth rate at a stocking density of 5 fry compared to 10 fry and 15 fry per 55 $m.^3$ tank. This might be due to high availability of natural food organisms (zooplankton) in fertilized tanks at low stocking densities compared to at high stocking densities (Bahnasawy, 2009). In addition, higher survival rate was observed in tanks fertilized with DAP fertilizer and control tanks under low stocking density. This might be due to low dissolved oxygen and NO_2 concentration recorded. Similar results were reported by Sophin and Preston (2001).

Table 1. Phytoplankton and zooplankton abundance (individuals/L) observed in tanks fertilized with different type of fertilizers (Mean ± SE)

Treatments	Phytoplankton				Zooplankton		
	Chlorophyta	*Cynophyta*	*Euglenophyta*	*Diatomae*	*Rotifers*	*Copepods*	*Cladocerans*
Chicken manure	52750±10528^{a}	18833±3346^{a}	9917±1109^{a}	10375±2376^{a}	157±23^{a}	257±8^{a}	167±14^{a}
DAP fertilizer	71833±11383^{a}	25458±4616^{a}	14917±1500^{b}	19833±3840^{a}	1207±388^{b}	667±133^{b}	640±69^{b}
No fertilizer	12542±2648^{b}	3333 ± 417^{b}	2500 ± 224^{c}	1542 ± 384^{b}	33± 4^{a}	40±10^{a}	17±7^{a}
P-Values	0.001	0.001	0.0001	0.001	0.004	0.0001	0.0001

Means with different superscript within columns indicate significant differences (Tukey's multiple range test at $p<0.05$).

Table 2. Shannon-Wiener indices of phytoplankton and zooplankton diversity (individuals/L) in tanks applied with chicken manure DAP fertilizer and no manure application.

Treatments	Phytoplankton/L			Zooplankton/L		
	H'	H'_{max}	*J*	*H'*	H'_{max}	*J*
Chicken manure	1.1300	1.3863	0.8151	1.0728	1.0986	0.9765
DAP fertilizer	1.1797	1.3863	0.8509	1.0526	1.0986	0.9581
No fertilizer	1.0489	1.3863	0.7566	1.0431	1.0986	0.9494

Table 3. Growth parameters and survival observed in chicken manure, di-ammonium fertilizer and no fertilizer at different stocking densities

Parameters	Initial mean weight (g)	Individual final mean weight (g)	Weight gain (g)	Increase mean weight (g)	Specific growth rate (%)	Survival rate (%)
Stocking densities						
5fry/m^2	0.5	24.1^{a}	6.3^{a}	90.7	21.6^{a}	97.8^{a}
10fry/m^2	0.5	18.3^{b}	4.6^{b}	80.6	16.5b	87.2^{b}
SEM	0.01	2.1	0.4	10.9	1.7	0.9
P-values	0.17	0.047	0.008	0.62	0.034	0.0001
Fertilizers						
Chicken manure	0.5	25.6^{a}	6.5^{a}	90.8	22.5^{a}	92.1
DAP fertilizer	0.5	20.5^{a}	5.2^{a}	84.3	18.7^{a}	93.9
No fertilizer	0.5	17.5^{b}	4.5^{b}	81.7	15.8^{b}	91.5
SEM	0.01	2.5	0.5	13.4	2.1	1.2
P-values	1.0	0.047	0.034	0.886	0.042	0.32
Stocking density* Fertilizer						
5fry/m^2* chicken manure	0.5	29.2	7.6	92.6	25.6	93.3^{a}
5fry/m^2* DAP fertilizer	0.5	24.3	5.9	90.9	20.6	98.1^{b}
5fry/m^2* No fertilizer	0.5	18.8	5.2	88.5	15.6	97.3^{b}
10fry/m^2* Chicken manure	0.5	21.9	5.4	89.0	19.6	90.8^{a}
10fry/m^2* DAP fertilizer	0.5	16.7	4.4	77.7	16.7	87.9^{a}
10fry/m^2* No fertilizer	0.5	16.3	3.9	74.9	13.1	82.9^{c}
SEM	0.01	3.6	0.8	19.0	2.9	1.7
P-values	1.0	0.73	0.87	0.95	0.94	0.0001

Means with different letters in the same columns are significantly different (Tukey's multiple range test at $p<0.05$); SEM-Standard error of the mean

Table 4. Water quality parameters observed in fertilizer type and different stocking densities

Parameters	Temp (^{0}C) at am	Temp (^{0}C) at pm	DO (mgL^{-1}) at am	DO (mgL^{-1}) at pm	NO_2 (ppm)	NH_3 (ppm)
Stocking densities						
5fry/m^2	26.8	28.6	4.2	6.2	0.2	0.5
10fry/m^2	26.8	28.5	4.3	6.3	0.3	0.5
SEM	0.1	0.1	0.1	0.1	0.1	0.2
P-values	0.61	0.71	0.29	0.43	0.21	0.86
Fertilizers						
Chicken manure	26.7	28.6	4.3	6.1^{a}	0.2^{ab}	0.3
DAP fertilizer	26.8	28.5	4.3	6.5^{b}	0.4^{a}	0.8
No fertilizer	26.8	28.6	4.3	6.0^{a}	0.04^{b}	0.3
SEM	0.1	0.1	0.8	0.1	0.1	0.2
P-values	0.78	0.85	0.96	0.016	0.031	0.113
Stocking density*Fertilizer						
5fry/m^2*chicken manure	26.7	28.7	4.2	6.1^{a}	0.1^{a}	0.4
10fry/m^2*chicken manure	26.8	28.5	4.3	6.1^{a}	0.3^{a}	0.3
5fry/m^2*DAP fertilizer	26.8	28.5	4.2	6.3^{b}	0.3^{b}	0.9
10fry/m^2*DAP fertilizer	26.8	28.5	4.3	6.7^{b}	0.5^{b}	0.9
5fry/m^2*no fertilizer	26.8	28.7	4.2	6.0^{a}	0.02^{c}	0.3
10fry/m^2*no fertilizer	26.9	28.6	4.3	6.0^{a}	0.07^{c}	0.3
SEM	0.2	0.2	0.1	0.2	0.1	0.3
P-values	0.95	0.88	0.92	0.03	0.018	0.99

Means with different letters in the same columns are significantly different (Tukey's multiple range test at $p<0.05$); SEM-Standard error of the mean.

Table 5. The pH values observed during the experiments.

Parameters	Experiment 1	Experiment 2	
		5 fry/m^2	10 fry/m^2
Chicken manure	6.0-9.0	6.0-8.0	6.0-8.0
DAP fertilizer	6.0-8.0	5.0-7.0	5.0-7.0
Control	7.0-9.0	6.0-8.0	7.0-8.0

Among water quality parameters, levels of dissolved oxygen and nitrite during the afternoon were significantly ($p<0.05$) higher and varied with the stocking densities and fertilizer types. This might be due to ammonia utilization by phytoplankton (Boyd, 1998) or oxidation of ammonia nitrite especially in high dissolved oxygen level conditions (Boyd, 2000). In addition, the range in pH values were similar in all the stocking densities under chicken manure and DAP fertilizer but different ranges were observed in the control experiments. Boyd (1990) reported that the application of ammonium and urea-based fertilizers can causeacidification of pond water because of nitrification, which produces two hydrogen ions from each ammonium ion. Similar results were reported by Saad *et al.* (2014). Therefore,catfish fry should be raised in tanks fertilized with chicken manure at low stocking density (5 fry/m2) due to low cost and easy availability for better growth and survival in aquaculture practices.

CONCLUSION

This study therefore showed that zooplankton diversity is higher in chicken manure applied conditions. It is recommended that for better growth and survival in aquaculture practices, catfish fry should be raised in chicken manure fertilized tanks at low stocking density.

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STATEMENT OF NO CONFLICT OF INTEREST

We the authors of this paper hereby declare that there are no competing interests in this publication.

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