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RESEARCH PAPER

Productivity of Nile Tilapia (*Oreochromis niloticus*), Lettuce *(Lactuca sativa)* and Spinach *(Spinacia oleracea)* in an Integrated Aquaculture System

Teklay Gebru Tikue[1,*], Kassaye Balkew Workagegn[2], Natarajan Pavanasam[2]

[1]Kebri Dehar University, College of Natural and Computational Science, Department of Biology, Somali, Ethiopia
[2]Hawassa University, Department of Aquaculture and Fisheries Technology, Hawassa, Ethiopia.

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Corresponding Author
E-mail: teklaygebru331@gmail.com

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Abstract

Integrated fish farming can be a solution to utilize the scarce resources efficiently and reduce waste disposal through recycling of waste. Hence, the main purpose of this experiment was to estimate the profitability and yield of vegetables (lettuce and spinach) from *Oreochromis niloticus* in an integrated fish farming system. A total of 114m^2 lands for vegetable cultivation and a fish pond with a size of 10m×15m×1.7m were used. 200 fingerlings of *Oreochromis niloticus* with an average initial weight of 8.5 gram were stocked and reared at a stocking density of 1.3fish/m.^{2} The experimental design for vegetable production was 2×4 factorial design. The average final weight of *Oreochromis niloticus* after four months of rearing was 61.76g. Four treatments were used for vegetable production; treatment 1 (T1) was vegetable production using pond water, Treatment 2 (T2) was using fertilizer, treatment 3 (T3) was using compost and treatment 4 (T4) was using tap water (control group). Outcomes of the general linear model revealed that lettuce productions of T1, T2, and T3 were significantly higher than T4, while spinach productions of T1 were significantly higher than($p<0.05$), T2 and T4 but there is no significant difference from T3. Depending on the result T1 was 1.8 times more profitable than T2, 2.06 times more profitable than T3, and 11.06 times more profitable than T4. Based on the current finding, integrated fish farmers could improve fish production, vegetable yield, and net returns by integrating fish farming system with other on-farm activities.

Introduction

Integrated aquaculture production system is implemented in many parts across the globe and it has a very long history with the objective of better fish production, minimizing the costs of fish production, protection of the environment from pollution and waste management and increasing income, generating fish feed from waste materials (Prein, 2002). Integrated Agri-aquaculture systems have been extensively advanced in south-east Asian countries where they are well established as an important source of animal and plant protein (Xiuzhen, 2003). While in Africa, the integrated fish farming system is not well developed.

According to Ugwumba *et al.* (2010), the farmer's education, years of experience, and type of integrated farming system are positively correlated with the expected income, which implies that farmers who are educated, have more years of experience and can combine many viable enterprises tend to be more efficient in production and consequently will increase productivity and income. Integrated farming system model consisting of field crops, horticultural crops, vermicomposting, and poultry of a tribal farmer enhance the productivity as well as profitability 7 times higher compared to the conventional farming system (Mohanty *et al.,* 2010). Moreover, integrated aquaculture has a major impact on the recycling of

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nutrients, reducing input cost, improving diversity and quality of agricultural products, improving waste water treatment, creating job opportunity, and improves livelihood (Daba Tugie *et al.,* 2017; Solomon Melaku and Natarajan, 2019).

Integrated aquaculture system is popular in developed countries but, in Ethiopia, it is not well recognized. A few studies have been carried out on vegetable production through an integrated aquaculture system by different authors. Some integrated fish production systems with different vegetables such as tomato, onion, cabbage and carrot have been worked in Ethiopia but the yield and profitability were low (Belay Adugna *et al*. (2016; Daba Tugie *et al*., 2017; Dinku Getu *et al.,* 2017; Lemma Abera, 2017; Teklay Gebru, 2022). Integrated fish production and Beetroot with *O. niloticus* achieves a good profit of fish and Beetroot (Teklay Gebru, 2022). Prinsloo *et al*. (1999) reported high yield and net return of Cabbage, Beetroot, Spinach, and Carrot in an integrated fish farming system. However, in Ethiopia vegetable production (Lettuce and Spinach) through this system was not studied. Therefore, this study aimed to investigate the productivity and profitability of Lettuce and Spinach with *Oreochromis niloticus (O. niloticus)*.

Material and Methods

Description of the Study Area and Experimental Design

The study was conducted at the experimental site of Centre for Aquaculture Research and Education (CARE), Hawassa University, which is located in the southern part of Ethiopia at 275 km south of Addis Ababa, the capital city of Ethiopia. It is located at 7 °3’7” N latitude and 38 °3’17” E longitude and located at 1714m above sea level. The study was carried out from December 2020 to March 2021. The experimental design was 2×4 factorial design with 3 replications.

Pond and vegetable plot preparation

For fish growth, 15m×10m×1.70m size of pond was prepared and filled with water at 1.30m depth. 200 fingerlings of *O. niloticus* were stocked at a stocking density of 1.3fish/m^2. For vegetable yield, a total of 24 vegetable plots with 2m×2m size with 114-m^2 of land were prepared and used for planting of two types of vegetables, namely: Lettuce *(Lactuca sativa)* and Spinach *(Spinacia oleracea)*. After proper preparation of the plots, Lettuce and Spinach seeds were sowed near the pond and transplanted to the plots after five weeks. Each of the 24 plots were planted with these two different types of vegetables in triplicate for four months. Watering was conducted with the respective water types three times a week (Teklay Gebru, 2022). The inorganic fertilizers Di-ammonium Phosphate (DAP) and urea 100 kg/hectare was applied at sowing and after 40 days of vegetable sowing (Dinku Getu *et al*., 2017), respectively. Similarly, compost was added at sowing and after 40 days of vegetable transplanting at a ratio of 5kg/plot (Table 1). Therefore, DAP and urea and compost were added to the vegetables twice during the grow-out period.

Fertilization of Fish Pond and Supplementary Fish Feed Preparation

20kg of supplementary fish feed was formulated by excel spreadsheet from feed ingredients such as soya bean cake (33.4%), wheat flour (25%), bone meal (20.8%), maize flour (18.3%) and soya bean oil (2.5%). These ingredients were mixed and prepared in pellet form. During the four months of fish production, daily feed requirement was calculated based on 2% body weight of fish (El-Sayed, 2013). Daily feed requirement was adjusted based on the average weight calculated from the two weeks of weight gain and feed was given three times per day. Poultry manure was supplied weekly at 10:00 am by broadcasting all over the pond at a rate of 0.1kg/m^2 (Mlelwa, 2016).

Data Collection

Measurements of Physicochemical Parameters

Physicochemical parameters, including, dissolved oxygen (DO), water temperature, pH, and turbidity, were measured once per week. Samples for water temperature and DO values were taken by using HI 9145 DO meter while pH was measured using ECO-CHECK. Secchi-disc was used to measure the turbidity of the pond water once in a week, while Plain test method was used to measure the concentration of ammonia in the laboratory once in a month.

Evaluation of Growth of *O. niloticus* and Vegetable Yield

The major fish body growth parameters such as body length and weight were measured once in two

Table 1. Treatment design for production of vegetables

Code	Treatments
Treatment 1 (T1)	Lettuce and Spinach production with pond water only
Treatment 2 (T2)	Lettuce and Spinach production with tap water + Fertilizer
Treatment 3 (T3)	Lettuce and Spinach production with tap water + compost
Treatment 4 (T4)	Lettuce and Spinach production with tap water only

weeks. Fish body weight was recorded to the nearest 0.1g with a weighing balance (SF 400A, Electronic Compact Scale) and fish length was measured using a graduated ruler to the nearest 0.1cm. During the study, fresh leaves of lettuce and spinach was harvested three times. The production of these vegetables was weighed using a weighing balance (SF 400A, electronic compact scale) and the production of every plot from each treatment was measured. At last, the productions of all vegetables in the four treatments were described as kg/plot and kg/hectare.

Cost Benefit Analysis of the Integrated Fish Farming

The net return of fish and vegetable yield was expressed by calculating the difference of total production cost and total revenue returned from the system. Cost benefit analysis of the system was calculated as used by (Mlelwa, 2016).

Data Analysis

Microsoft excel 2010 and SPSS Statistical package were used for data analysis and the difference at $P<0.05$ were significant (Zar, 1999). Lettuce and Spinach production data was analyzed using one-way ANOVA in SPSS. Lettuce and Spinach production in different treatments were analyzed using General Linear Model (GLM) procedure of SPSS Version 25 (SPSS 2017). Means were compared using Duncan's Multiple range test at $P<0.05$.

Results

Physicochemical Parameters of Pond Water

The physicochemical parameters of pond water recorded during the experimental period, including, pH, temperature, NH_3, and turbidity, are shown in Table 2. There was a decrease in DO content from December (4.3 mg/l) to March (3.9 mg/l), while water temperature showed an inverse relationship with DO. Water temperature increased from the beginning of the experimental period up to the end of the experimental period. The environmental condition was normal for fish growth.

During the experimental period, the trend of growth of *O. niloticus* in weeks was summerized as presented in Figure 1. The average initial weight of the fish was 8.5 gram. The graph revealed that there was a continuous increase in the growth performance of male *O. niloticus* from week 2 to week 16. But, for female *O. niloticus,* there was a slow growth from week 2 to week 10 and there was a slight increase from week 12 to week 16.

Yields of Lettuce and Spinach Across and within Treatments

Lettuce and Spinach production of all treatments is shown in Figure 2. The mean individual weight of the lettuce was 455 g, 468 g, 457 g, and 226 g in T1, T2, T3, and T4, respectively. Furthermore, the mean weight of

Table 2. Results of physicochemical pond water (Mean ±Standard error)

Parameters	Months			
	December	January	February	March
Temperature (°C)	24.6±0.4	24.9±0.2	26.8±0.2	27.3±0.4
PH	8.4±0.2	8.6±0.1	8.0±0.1	8.3±0.2
dissolved oxygen (mg/l)	4.3±0.1	4.2±0.1	4.0±0.1	3.9±0.1
NH_3 (mg/l)	0.05±0.001	0.06±0.001	0.08±0.002	0.07±0.002
Secchi depth visibility (cm)	38±2.0	35±1.0	33±1.0	30±1.0

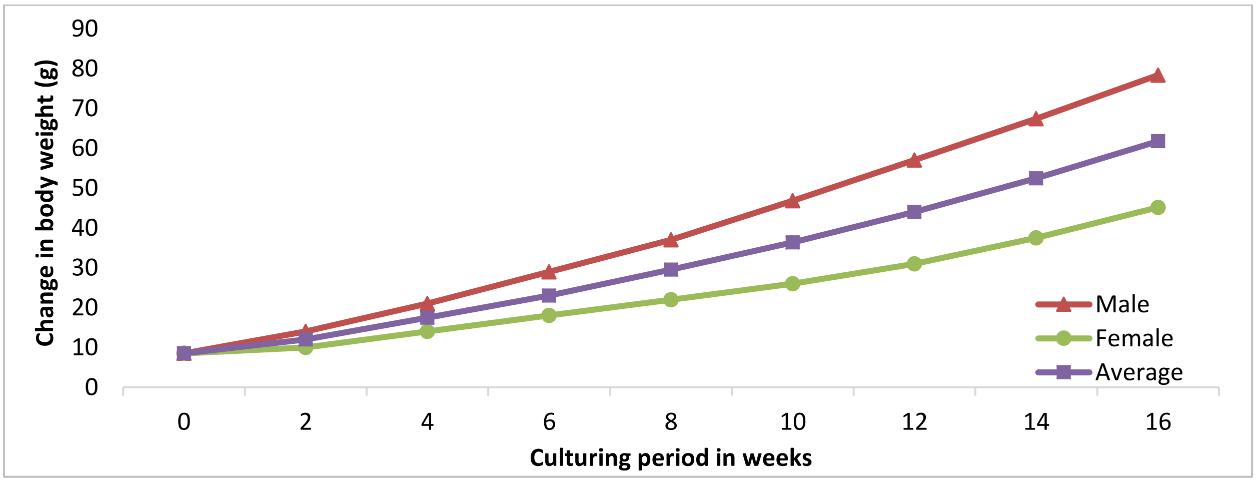

Figure 1. Trend of growth performance of *O. niloticus*.

the Spinach was 588 g, 663 g, 613 g, and 102 g in T1, T2, T3, and T4, respectively.

This study revealed that the average Lettuce and Spinach production at T1 (521.5g) was significantly lower than ($p<0.05$) average lettuce and spinach production at T2 (565.5g) but, significantly higher than ($p<0.05$) T4 (164g) and it was not significantly different ($p>0.05$) from lettuce and spinach production at T3 (535g) (Table 3).

Cost Benefit Analysis

In this experiment, the overall estimated production cost of T1, T2, T3, and T4 was $16, $17, $16 and $16 respectively and the overall estimated cost of production was $ 64 (Table 4). The return obtained from T1, T2, T3, and T4 was estimated to $83, $93, $84, and $28, respectively. A total of $403 was obtained as revenue. The total cost for lettuce, spinach, and fish production was $107. The estimated net return from the four treatments and fish sold was $296 (Table 5).

Discussion

Temperature has a substantial effect on the growth performance of *O. niloticus*. According to Kassaye Balkew (2012), at lower water temperature or below the critical level, fish could stop feeding and would even die. Temperature value of this experiment were to in the recommended ranges of Santhosh and Singh (2007) (24°C to 30°C) and Oben *et al.* (2015) (20°C-29°C). Therefore, the fish was in a normal temperature condition for better growth. The desirable range of pH for pond water is between 6.5 and 9.5 and the acceptable range is between 5.5 and 10.0 (Stone and Thomforde, 2003). pH results of the current finding were within the desirable range of pH for the pond reported by Stone and Thomforde (2003) (6.5-9.5) and FAO (2011) (6.7-8.6). The mean DO value of the present study (4.1 mg/l) corresponds to the results reported by Shoko *et al.* (2011) (3.94mg/l-6.98mg/l) and Adamneh Dagne *et al*. (2013) (3.0mg/l-9.0mg/l).

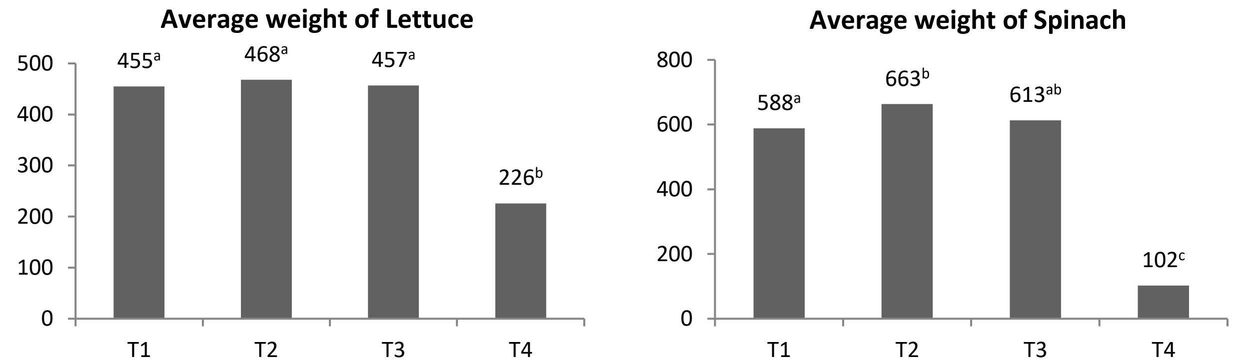

Figure 2. Graphs showing average vegetable production in each treatment.
Note: x- axis is treatment and y-axis are weight gain.

Table 3. Estimated vegetable production kg/plot

Veg. type	Treatment							
	T1		T2		T3		T4	
	Estimated production		Estimated production		Estimated production		Estimated production	
	kg/plot	kg/hec.	kg/plot	kg/hec	kg/plot	kg/hec.	kg/plot	kg/hec.
Lettuce	18.6[a]	46,500	19.6[a]	49,000	18.2[a]	45,500	7.4[b]	18,500
Spinach	19.9[a]	49,750	24.0[b]	60,000	21.2[ab]	53,000	5.2[c]	13,000

Note: different alphabetic superscripts in the same row indicate significant difference at ($p<0.05$). Veg. = vegetable, kg= kilogram, hec= hectare.

Table 4. Partial budget analysis of lettuce and spinach production

Cost lettuce and spinach production in 114m^2 in $	Treatments			
	T1	T2	T3	T4
Vegetable seed purchase	1.5	1.5	1.5	1.5
Vegetable land preparation in	3.8	3.8	3.8	3.8
Fertilizer	-	1.2	-	-
Insecticide	0.72	0.72	0.72	0.72
Monthly workers	9.6	9.6	9.6	9.6
Vegetable sell	83	93	84	28
Total input cost	16	17	16	16
Total income	83	93	84	28
Net profit from each treatment	67	76	68	13
Total profit of the whole system	224			

NH_3 result of the current study was very close to the recommendations by TNAU (2008) (0.02–0.05 mg/l), in fish ponds and better than Santhosh and Singh (2007) (0.1 mg/l). Therefore, the NH_3 concentration of the current study is suitable for fish growth. The current finding of Secchi depth is lower than Oben *et al.* (2015) (46cm - 50.2cm). The finding of Secchi depth visibility reported in this experiment agrees with the report of Boyd (1998) who recommends a healthy fish pond is with Secchi depth of 30-45 cm.

Growth Performance of *Oreochromis niloticus*

In this experiment, there was high growth performance of *O. niloticus*. This was due to the supplementary feed given to fish and the availability of phytoplankton in the culture pond owing to the application of organic manure and the remains of artificial fish feed. Liti *et al*. (2006) reported a high growth rate of fish in ponds receiving poultry manure and supplementary feed. According to Brown *et al.* (2000), supplementary feeding is recommended in small scale and/or commercial fish culture because the natural fish food organisms (plankton) may not be enough to meet the protein requirements of fish. Shoko *et al*. (2011) recorded a higher growth rates of *O. niloticus* on supplementary feed and poultry manure. Besides, Megersa, Endebu *et al*. (2016) also recorded the high growth performance of *O. niloticus* reared on pond water having *Cyprinus carpio* fed with chicken manure only. Similarly, Daba Tugie *et al*. (2017) also reported higher growth performance of *O. niloticus, C. carpio, and C. garipinus* integrated with poultry manure. Furthermore, Mlelwa (2016) recorded a high growth rate of fish in ponds receiving poultry manure and supplementary feed. The results of the present study agreed with earlier studies wherein fish cultured under fish-poultry-vegetable integration attained higher yields of both vegetables and fish (Prein *et al*., 1998; Shoko *et al*., 2011). Higher growth and better production of fish in ponds are due to the fact that the fish are able to convert fertilizers (e.g., household wastes, livestock, and crops) and uneaten feeds into high-quality protein (Prein *et al*., 1998).

Lettuce and Spinach Production of the System

It is known that metabolic wastes, for instance, nitrogen, phosphorus, and total dissolved solids generated through fish activity enhanced vegetable production. Therefore, the use of nutrient rich water from fish ponds to cultivate vegetables increases vegetable production. This could be due to the high nutrient contribution from the fish ponds as a result of inputs (manure and feed). The results from the current experiment agree with other studies (Shoko *et al.,* 2011) which also reported higher yields of both vegetables and fish in an integrated aquaculture system. The current study confirms the importance of integrating fish with other on-farm activities such as vegetable culture and poultry rearing in increasing overall yield.

Spinach production of the present study (19.9kg/plot) agrees with the work of Prinsloo and Schoonbee (1987) that reported a yield of 22.3kg/plot in spinach fish integrated aquaculture system. Besides, the spinach yield reported in this study is also in agreement with the work of Prinsloo *et al.* (1999) who reported a productivity yield of 19.06-20.7kg/plot. Similarly, the spinach yield reported in the current study is also in agreement with the work of Coertze (1996) who reported a yield of 16-24 kg/plot who worked on vegetable fish integrated aquaculture system. Furthermore, the yield of spinach reported by Prinsloo *et al.* (1999) (19.89kg/plot) are very similar to this result which was recorded 19.9kg/plot in this study. Lettuce production of the current study agrees with the work of Prinsloo and Schoonbee (1987), where they reported a yield of 22.8kg/plot.

Table 5. Partial budget analysis of fish and vegetable production

Fish Production cost and net profit in US $	
Pond maintenance	23
Supplementary feed preparation	20
Total cost in fish component	43
Revenue generated from fish sell	116
Total profit (revenue-cost)	72
Vegetable production cost and net profit in US $	
Estimated cost for land preparation, weeding	16
Purchase of vegetable seed	6
Purchase of insecticide and fertilizer	4
Estimated labor workers	39
Total cost	64
Revenue generated	287
Profit from vegetable	224
Net profit of the whole system in US $	
Total cost for fish and vegetables	107
Total revenue generated from fish and vegetable sells	403
Total profit (total revenue-total cost)	296

Cost Benefits of the System

Integration of *O. niloticus*, poultry manure and vegetable farming are a promising technology to generate income for households on a small land having access to water sources. In the current experiment, *O. niloticus* and vegetable production using pond water was 1.8 times more profitable than using fertilizer, 2.06 times more profitable than using compost and 11.06 times more profitable than vegetable production using tap water. The net return from the present study in 12m^2 vegetable plots and 150m^2 ponds is \$ 139 (0.86\$/m^2) higher than the net return of the integrated aquaculture system reported by Daba Tugie *et al*. (2017) who reported a net return of \$ 232 in 260 m^2 land usage and 150 m^2 (0.56\$/m^2) of pond. Furthermore, the net return of the present study is also higher than the net return reported by Dinku Getu *et al*. (2017) who reported a net profit of \$ 180 in 0.25 hectares of land usage and 150 m^2 (0.07\$/m^2) of pond. The reason for the higher net return and yields of the present study may be due to the absence of poultry production cost, lower labor cost, and good management practices both on the *O. niloticus* and vegetables. According to Abdel Wahab and Abdel-Warith (2013) in fish farming about 60 to 70% is fish feed cost. Therefore, the use of poultry manure in fertilized fish ponds may lead to a reduction of supplementary feed and increase yield and income.

Conclusion

In the present finding, there was high growth performance of fish and high lettuce and spinach production. According to the present finding, the highest yield was obtained from *O. niloticus* followed by Spinach and Lettuce. In the current experiment, the highest net return was obtained from the integrated aquaculture system than non-integrated farming system. According to the current study, the integrated fish farming with poultry manure and Lettuce and Spinach production was an excellent package for sustainable production, income generation, and poverty reduction and creates awareness for the farmer towards integration. The results of the present experiment with all components (*O. niloticus* and Lettuce and Spinach)) delivering the expected products at lower costs of input on a relatively small area of land compared to the traditional farming system. Moreover, the system is cost effective and efficient enough to make money for small scale farmers' level on a relatively small plots of land. Fish farmers should be encouraged to use integrated agro-aquaculture innovation for improving the diversification of food production and source of income generation.

Ethical Statement

Not applicable.

Funding Information

Authors declare there are no financial or any sort of conflicts related to this study.

Author Contribution

First Author: Writing -original draft, Conceptualization, Writing -review and editing; Second Author: Data Curation, Formal Analysis, Investigation, Methodology, Visualization and; Third Author: Writing -review and editing; Writing - review and editing.

Conflict of Interest

The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

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