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A Study on the Profitability of Fish and Horticulture Integrated Farming at Nono District, West Shoa Zone, Ethiopia

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ABSTRACT

The study on integration of tilapia and vegetable cultivation was conducted at Silkamba, in west shoa zone, Ethiopia. The Nile tilapia fingerlings were stocked (3/m²) in an earthen pond fertilized with cow dung and poultry excreta at 3:1 ratio. A control pond was maintained without fertilization. The seedlings of the tomato (Cochoro variety) and onion (Bombay red) were planted on twelve plots prepared adjacent to the ponds. The seedlings on six treatment plots were grown by addition of the fertilized fish pond water and control plants were supplied with the control pond water. Physico-chemical parameters like dissolved oxygen, pH, carbon dioxide, alkalinity and nitrate in the treatment pond remained within the required level for the growth of Nile tilapia. The water temperature was comparatively high which was more suitable for the production of fish food organisms as well as the fish growth in the pond. The level of nitrate and total phosphorus in the treatment pond was at the suitable level which enhanced the growth of plankton and benthic organisms in the pond. The bottom soil in the treatment pond showed comparatively high level of organic carbon and organic matter than the control pond. The number of tomato fruit and their size were higher in the treatment plots. Similarly the yield of onion from the treatment plots was higher than the control plot. The total yield of fish from the treatment was 27.22kg. The results on the analysis of expenditure and income indicated that the integration of vegetable cultivation using fish pond water alone was more profitable than the conventional method of vegetable cultivation with the application of fertilizer.

Key words: Tilapia, Daily Growth Rate, Specific Growth Rate, Weight Gain.

INTRODUCTION

Tilapia culture in tropical and subtropical countries is practiced at either extensive or semi-intensive levels in earthen ponds particularly in remote, rural areas, where agricultural by-products are available as supplementary feeds. The semi-intensive culture of tilapia is particularly ideal in developing countries because it provides a wide variety of options in management and capital investments (Kamal *et al.*, 2008). The adoption of both fertilization and supplemental feeding would be more appropriate and cost-effective (Diana *et al.*, 1994; Green *et al.* (2002) for the small scale farmers. Management strategies in the lower levels of intensification involve the use of fertilizers to encourage natural productivity and to improve the levels of dissolved oxygen. Fish yields from such techniques have been found to be higher than those from natural unfertilized systems (Green, 1992). The integrated fish farming is a diversified and coordinated way of farming with fish as the main target (Ayinla, 2003) along with other farm products to maximize the utilization of the available resources without much wastage. Earlier researchers suggested that application of livestock manure in fish ponds enhances the production of natural fish food organisms progressively (Wilber, 1971; Jhingran, 1982) and cut down the expenditure towards feeds for fish (Kapur, 1984; Yadava, 1987) and improve the nutrient content of fish (Kapur and Lal, 1986).

Integrated fish culture has been considered an ideal method of land use, which has been practiced in Asia for several centuries (Eyo *et al.*, 2006) where the common practice is cultivation of fish with rice and vegetables. Although significant breakthrough has been achieved in these countries with this type of integration, not much has been achieved in Africa except some countries like, Ghana, Malawi, Nigeria and Kenya (Eyo *et al.*, 2006). Erick *et al.* (2013) suggested that livestock-fish integration is one of the most practicable solutions to food insecurity and malnutrition in East African community. In Ethiopia a few attempts have been made on the integration of fish with crop cultivation (Kebede Alemu, 2003; Lemma Desta *et al.*, 2014). In continuation of those studies the present research on integrated fish-vegetable culture has been initiated at Silkamba, Nonno district, West Shoa Zone, Ethiopia.

MATERIALS AND METHODS

Study area

The experiment was conducted in two earthen ponds (100m² each) supplied with Wenni river water near Silkamba town, located at 1820 masl with varied climatic conditions in Nonno district of West Shoa Zone, Ethiopia. One of the pond bottom was fertilized with cow dung and poultry waste at the ratio of 3:1 and the control was maintained without any fertilizer. The pond was fertilized with the mixture of cow dung and poultry waste at the rate of 1.5kg / m² every 15 days for a period of three months until harvesting. The tilapia fingerlings were stocked at the rate of 3/m² in treatment pond after recording their initial length and weight. Adjacent to the ponds twelve plots each having a size of 2x4m (total area 96m²) were prepared for the cultivation of tomato and onion. Among these, six were treatment plots and the rest control plots. The treatment plot plants were grown with the water from the fertilized fish pond and the control plot plants were cultured with the water from the control pond. Seedlings of tomato (Cochoro variety) and onion (Bombay red) were planted after 35 days of raising in the nursery on both treatment and control plots. Tomato and onion plants were supplied with the pond water once in three days with 108 l of water.

The soil samples were collected from the pond and crop land during the site selection and after the completion of the experiment. Soil texture was analyzed by Pipette out method (Krumbein and Pettijohn, 1938) and soil organic carbon and organic matter following the method described by Walkley and Black (1945) and Boyd *et al.* (2002) respectively. Soil nitrogen and phosphorus were estimated in the laboratory by using Micro-Kjeldahl (Tandon, 1993) and Olsen *et al.* (1954) respectively as described by (Maiti, 2004).

Water quality parameters of the control and fertilized fish ponds were determined on monthly intervals throughout the study period. In the field, the water temperature, pH and conductivity were measured using digital probes. The total dissolved solids were measured using TDS meter. The dissolved oxygen, carbon dioxide, total hardness, total alkalinity and chloride were estimated as described by Strickland and Parsons (1972) and APHA (1980).

The qualitative and quantitative analyses of plankton were done after collection using plankton net (#20 Bolting Silk) on monthly intervals in order to estimate the availability of the natural food for the fish. The length and weight (2/3rd) of the fishes were recorded every month to ascertain the growth of fish. The growth of the plants was also estimated monthly (Causton and Venus, 1981; Hunt, 1990). The yield of the plants in the treatment and control plots were analyzed following one way Analysis of Variance. The amount incurred for establishment of the farming system (expenditure) and total amount gained from fish and crops were estimated for calculating the profitability of the type of farming.

RESULTS

Soil parameters

The soil parameter like composition, nitrogen, phosphorous, organic carbon and matter estimated in the crop plots are given in table 1. The amount of total nitrogen in the tomato and onion treatment and control plots showed very little variation from the initial level (Table 1). The concentration of total phosphorus in the treatment plots increased from 0.794-2.822mg/kg (tomato) and 2.0223mg/kg to 3.262mg/kg (onion). But in the control plots the phosphorus content declined from the initial values. The soil in the control and treatment plots was dominated by clay fraction. The organic carbon in the tomato treatment plot increased slightly (3.833to 4.353 mg/g) whereas in all the crop plots it slightly decreased after the growing period.

Water Quality parameters in the treatment and control ponds

The data on the various abiotic factors of the water of the treatment and the control ponds are presented in Table 2 and 3. The Level of dissolved oxygen in the water was comparatively high throughout the study period varying from 6.8mg/l (December) to 9.66mg/l (April) in the treatment pond compared to control pond (4.59mg/l to 6.33mg/l). The amount of carbon dioxide was relatively lower (15.84mg/l to 37.12mg/l) in the culture pond than in control pond (21.32mg/l to 41.01mg/l). The pH of the water in treatment pond was 7.1 before stocking the fish and varied between the months, and reached maximum 7.25 in February. However, it was fluctuated considerably from 6.55 and 7.8 in control pond. The conductivity values showed increase in both treated (from 190.5µS to 253 µS) and control (from 181.1 µS to 214 µS) ponds. The alkalinity of the water varied from 11mg/l (December) and 18.71mg/l (April) in treated pond and it was 9.6mg/l (January) to 18.35mg/l (April) in control pond. The total phosphorus value was 1.209mg/l after fertilizing the pond and the concentration declined to 0.923mg/l in April, whereas in control pond the value slightly increased from the initial 0.202 to 0.244mg/l at the end of the experiment. In contrast, the nitrate value was minimum 0.771mg/l in December and it increased to 1.79mg/l finally in the treatment pond, whereas the values decreased from 1.632mg/l to 0.133mg/l in the control pond.

Production of Plankton and benthic fauna

The plankton population observed in the treatment and control ponds during the experimental period is shown in Table 4. The phytoplankton was constituted by diatoms, green algae and blue green algae. The diatoms recorded were *Navicula*, *Synedra* and *Bacillaria*. The total number of diatoms was high 434/l in treatment pond and 35/l in the control pond. The Chlorophyceae members observed are *Chlorella*, *Closterium*, and *Ankistrodesmus* together formed 584 cells/l in the treatment pond and 465 cell/l in the control pond. Among these *Closterium* showed the highest density in the fertilized pond. The blue green algae such as *Spirulina* and *Oscillatoria* appeared in large numbers in treatment pond than control pond. The zooplankton like *Brachionus*, *Lecane*, and cyclopoid copepods. The numerical density of *Brachionus* (320/l) and copepods (235/l) in the treatment pond whereas in the control pond they were less abundant. The macro benthos in the pond were predominantly nematodes, oligochaetes, insect larvae and gastropods. Among these *Chaetogaster* and insect larvae were abundant.

Plant growth parameters

The growth of the tomato and onion plants cultured in control and experimental (treatment) plots were estimated on monthly intervals. The average height of the tomato plant in the treatment plot was 35cm and control plot 24cm. The branches in the plants of both the sets of plots were same 3/plant however the branch length in the treatment plants was higher (average 26.4cm) than the control plants (18.3cm). The number of fruit per branch also showed distinct variations. The range was 9-12 and 3-5 in the treatment and control plots respectively. The number of fruits per plant was also high in the treatment plants (20-26) and that of control (14-16) and the average being 24 and 15 respectively. The yield comparison of the experimental tomato plants are presented in Table 5. The mean weight of the tomato fruit in the treatment plots were 118.69g, 12.958g and 117.51g in P1, P2 and P3 respectively. In the control plots the fruit weight was 70.632g, 71.688g and 70.564g P1, P2 and P3 respectively. The total yield of fruits in all the treatment plots were higher (3039) than the control (1516) plots. The average fruit yield was 1013 and 505 respectively in treatment and control plots. The total number of marketable and unmarketable size of treatment plots was 2839 and 1327 and control 200 and 189.

The data collected on the growth and yield of onion cultivated with the fish pond water and the control pond water are given in Table 5. The total number plants per plot ranged from 450-600 and 400-430 respectively in the treatment and control respectively. The plant height was average 68.3cm and 46.7cm in treatment and control plots. The total number of bulbs harvested from all the treatment plots was 1570 and from the control 1240. The average number of bulb collected was 523 and 413 respectively in treatment and control. The total number of marketable size onion obtained was 1417 and 1079 from the treatment and control plots respectively. The number of unmarketable bulbs was 153 and 161 respectively in treatment and control plots. The average weight of the bulb in the treatment plots were 128.942g, 91g and 109.878g P, P2 and P3 respectively, where in control plots the average weight was 72.18g, 68.74 and 70.66g respectively.

Fish Growth parameters

The data on the length and weight of 100 fishes at the time of stocking and later every month were recorded until the final harvest. The initial length of the fishes stocked in the treatment pond ranged between 7cm and 10.4cm. The weight of the fish varied from 17g and 25.31g. The average length of fishes stocked was 8.68cm and weight 21.403g. In the treatment pond, the final length of fish ranged from 10 cm to 16.2cm. The average final length was 14.201cm and weight 90.735g. The final weight of the treatment pond fishes varied from 40.6g to 117gm. About 44% of the fishes attained weight greater than 100g. Out of the total fishes measured 23% were in the range of 110-119g. About 25% of the fishes fall in the category of 90-99g. The rate of increment in length of fishes was high from February to April than the previous months, whereas the weight of fishes increased at all months especially from February to March in the treatment pond. The weight of fish increased at a higher rate from December to January and later February to March (Fig 1).

Table 1: Soil characteristics of treatment and control plots

Parameters	Tomato Treatment plot		Tomato control plot		Onion Treatment plot		Onion control plot	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Sand (%)	7.215	6.65	9.7	9.6	6.45	6.1	6.55	6.34
Silt(%)	8.43	7.77	2.32	18.6	7.235	5.95	6.82	2.35
Clay(%)	91.57	85.6	87.98	71.8	92.76	87.95	93.18	91.21
Organic carbon (mg/g)	3.833	4.353	4.418	4.093	4.677	4.093	5.002	4.158
Organic matter (%)	6.6.8	7.504	7.616	7.056	8.064	7.056	8.624	7.168
Total Nitrogen (%)	0.33	0.375	0.381	0.353	0.403	0.353	0.431	0.358
Available Phosphorus (mg/kg)	0.794	2.822	1.499	1.234	2.028	3.262	7.23	1.234

Table 2: Water quality parameters of treatment pond

Parameters	December	January	Feb	Mar	Apr
Water T (°C)	26.8	27.67	27.3	28.3	29.94
pH	7.1	6.5	7.25	6.65	7.02
DO(mg/l)	6.8	6.9	7.3	8.2	9.66
CO ₂ (mg/l)	15.84	18.7	27.72	35	37.12
Conductivity (µS)	190.5	253	240	236	208
Alkalinity (mg/l CaCO ₃)	11	12.31	18.35	17.2	18.71
Hardness (mg/l Ca CO ₃)	72	59	61.5	63.4	65.1
Soluble Phosphors(mg/l)	1.209	1.032	1.011	1	0.923
Nitrate (mg/l)	0.771	0.824	0.932	1.234	1.79

Table 3: Water quality parameters of control pond

Parameters	December	January	Feb	Mar	Apr
Water Temperature(°C)	26.5	28.6	27.3	29.1	29.8
pH	7.2	6.55	7.8	6.55	6.8
DO(mg/l)	4.59	5.25	5.7	5.82	6.33
CO ₂ (mg/l)	21.32	22	37.84	39.6	41.01
Conductivity(µS/cm)	181.1	269	209	211	214
Alkalinity (mg/l CaCO ₃)	11	9.6	18.35	15.3	16.2
Hardness (mg/l Ca CO ₃)	74.2	67.5	18.3	43.5	51.7
Soluble Phosphors(mg/l)	0.202	0.2	0.198	0.199	0.244
Nitrate (mg/l)	1.632	1.572	1.421	0.731	0.133

Table 4: Plankton and Benthic population in the ponds

Groups	Treatment pond (No/l)	Control pond (No/l)
DIATOMS		
<i>Navicula</i>		102
<i>Synedra</i>		96
<i>Bacillaria</i>		153
Total	434	351
CHLORO PHYCEAE		
<i>Chlorella</i>	168	145
<i>Closterium</i>	230	164
<i>Ankistrodesmus</i>	186	156
Total	584	465
CYANOPHYCEAE		
<i>Spirulina</i>	189	128
<i>Oscillatoria</i>	230	174
Total	1437	1198
EUGLENOPHYCEAE		
<i>Euglena sp</i>	200	186
ZOOPLANKTON		
<i>Brachionus</i>	320	163
<i>Lecane</i>	192	112
Copepods	235	210
Total	947	671
BENTHOS		
Nematode	72	103
<i>Dero</i>	43	84
<i>Chaetogaster</i>	234	195
Chironomus larva	165	127
Gastropods	245	186
Other insect larvae	335	210
Total	1094	905

Table 5: Yield comparison of Tomato and Onion

Treatment				Control			
Tomato (#)	Yield (kg)	Onion (#)	Yield (kg)	Tomato (#)	Yield (kg)	Onion (#)	Yield (kg)
1038	63	600	52.89	621	34	430	31.07
1018	62	450	39.67	432	23	410	29.63
983	60	520	45.84	473	27	400	28.9
3039	185	1570	138.4	1516	84	1240	89.6

Fig 1: Mean monthly values of length and weight of fish in the treatment pond

Table 6: Details of Expenditure

No	Expenditures	Treatment	control
		Birr	Birr
1	Land preparation	120	120
2	Preparation of Plot	120	120
3	Pond construction	5000	5000
4	Organic manure preparation	200	-
5	Herbicides and insecticides	100	100
	Seedling pulling and transplanting	35	35
7	Purchase of Fingerlings	750	750
8	Guarding and bird scaring	125	125
9	Supplementary feed	200	200
10	Harvesting and trashing	430	430
	Total	7080	6880

Table 7: Income realized from fish and vegetable Concurrent farming

Particulars	Yield			
	Treatment (Kg)	Price(Birr)	control(Kg)	Price(Birr)
Tomato	185	1480	84	672
Onion	138.4	1570	89.6	1016
Adult fish	27.22	2041.5	10.91	818.25
Fry and fingerlings	200	1400	150	1050
Total		6491.5		2884.25
Gross income	9375.75 (Birr)			

Total expenditure=13960

Gross income=9375.75

DISCUSSION

Culture of tilapia in small ponds is the most popular system in African countries like, Nigeria, Kenya, Ghana and Tanzania than the adoption of cages and raceways (FAO, 1995a) and significantly improved the health and income of rural households (El-Sayed, 2006). The fertilization of ponds is the key factor in the fish production in semi intensive culture and in integrated farming where the crops are grown by using the pond water as a source of nutrient. However, El-Sayed *et al.* (1996) stated that the rate of growth and survival of Nile tilapia in earthen ponds were significantly affected by pond depth and temperature. The dissolved oxygen is the most important and critical parameter requiring continuous monitoring due to the fact that fish requires dissolved oxygen for aerobic metabolism (Timmons *et al.*, 2001). In the present study, dissolved oxygen in the pond was always above 5mg/l. The range of pH in the treatment pond was within the level required for Nile tilapia and the alkalinity was below 20mg/l which is also suitable for the production of planktonic population and conducive for the fish. It has

been reported that when water is alkaline, the decomposition of applied manure will be faster (Boyd, 1988). This will increase the nutrient availability in water, ultimately increasing plankton concentration and finally the fish production (Verma *et al.*, 2002). The total hardness showed decreasing trend in fertilized pond compared to control where it showed increasing trend. The results are in conformity with the statement of Boyd, (1982). Phosphorus is the least abundant and commonly limits the biological productivity in aquatic ecosystems (Wetzel and Likens, 2000), it exists in several forms. It generally regulates the phytoplankton production in the presence of nitrogen (Stickney, 2005). The level of phosphorus in the treatment pond was found to decrease, which may be due to the excessive growth of phytoplankton.

The nitrate content increased in the treatment pond at the end of the growing period indicating the increased rate of mineralization and nitrification in the fertilized pond through microbial activity, facilitated through the increase in water temperature and suitable environmental conditions. Decrease in the nitrate in control pond may be related to the utilization of this element for the phytoplankton growth and the absence of supply from the bottom soil. The plankton population constituted by Chlorophyceae followed by Bacillariophyceae and Cyanophyceae was high in the treatment pond. This could be due to the prevalence of suitable water quality parameters and nutrients as stated by Sreenivasan *et al.* (1979). The basic process of phytoplankton production depends upon temperature, turbidity and nutrients. Zooplankton population in the fertilized and control ponds was found to be dominated by rotifers followed by copepods. This might be due to the impact of physico-chemical parameters of the water and availability of plankton-based food particles. Among benthos the insect larvae are more abundant in both ponds. This might be due to the nature of bottom sediments which hold nutrients that support their growth. The clay proportion was found to be more in the pond bottom soil followed by silt and sand. The amount of organic carbon increased in all ponds but higher in treatment pond which may be due to decomposition of plankton and addition of fertilizer.

The growth and yield parameters of tomato and onion were comparatively high in the treatment plots supplied with fertilized pond water, rich in plant nutrients and other biofertilizers. The weight of the fruits and onion was relatively high in the treatment plots which resulted in the high yield with more number of marketable fruit and onion bulb. Brummett and Nobel (1995) stated that integration of fish with vegetable cultivation resulted in significant increase in yield of crops. The fishes in the fertilized pond showed better growth rate in terms of weight gain and length. At the time of harvest, the total weight of the fish was 27.22 kg. According to Solomon *et al.* (2002) and Kebede Alemu (2003) the ponds fertilized with organic manure showed higher growth rate of fish than inorganic fertilizers. Brummett and Noble (1995) and Brummett and Williams, (2000) have demonstrated that integration of tilapia with vegetable culture would improve the productivity of the land, profit and generally encourage farmers to adopt such practices.

The results indicate that the pond with abundance of planktonic and benthic food organisms, the climatic condition, the temperature (26.8-29.9°C) in the Silkamba area is favourable for fish production. The yield of tomato and onion grown with fertilized fish pond water was higher than that of the plants grown with control pond water. The experimental results clearly demonstrate the cost effectiveness of the cultivation of vegetable crops with minimum amount of organically fertilized fish pond water. It is realized that if farmers continue such integrated farming they can earn more than from monoculture of crops through reduction in the cost fertilizer as well as they can manage the farming with less amount of water.

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