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Lemma Desta
Ambo University, PO. Box 19, West Shoa Zone, Ambo, Ethiopia

L. Prabha Devi
Ambo University, PO. Box 19, West Shoa Zone, Ambo, Ethiopia

V. Sreenivasa,
Ambo University, PO. Box 19, West Shoa Zone, Ambo, Ethiopia

Tilahun Amede
ILRI, Addis Ababa, Ethiopia

Correspondence:
L.Prabha devi
Ambo University, PO. Box 19, West Shoa Zone, Ambo, Ethiopia.
Email: drlpraba@gmail.com
Tel: +251 0920117067
Fax: +251112362237

Studies on the ecology of the paddy and fish co–culture system at Dembi Gobu microwater shed at Bako, Ethiopia

Lemma Desta, L. Prabha devi, V. Sreenivasa, Tilahun Amede

ABSTRACT
This study on paddy cum tilapia integrated culture was carried out at Bako, West shoa zone in Ethiopia for a period of four months. The physico-chemical parameters in the water and soil, plankton and benthic fauna and yield were analysed to understand the suitability of the culture system in the study area. The water temperature in the experimental plots was recorded as a minimum of 27 ºC and a maximum 28 °C. The pH of the water declined at the end of the culture, while the dissolved oxygen increased in both paddy-fish and control plots. The CO_2 and conductivity did not show considerable variation. The total alkalinity and hardness of the water increased slightly at the end of the experiment. However the concentration of ammonia remained at a very low level. The dissolved nutrients like nitrate and phosphate in the water decreased from the initial level in the paddy-fish plots. The soil nitrogen was also reduced with respect to the increase in phosphorus levels. The plankton and benthic population in the control plots were higher than in the paddy-fish plots. The texture of the soil showed increase in silt fraction, organic carbon and organic matter in all the plots. However, the yield of paddy in the paddy-fish plot was higher than in the control plots. The possible reasons for the high yield in paddy-fish plots are discussed.

Keywords: Paddy- fish plot, plankton, benthos, NERICA- 4 (SUPERICA-4), *Oreochromis niloticus*

1. Introduction

Rice-fish integrated farming systems are well known as environment friendly and one of the best options to increase fish production from limited water resources. This type of culture is less expensive where the energy resources are recycled in a sustainable manner [8, 24, 13, 23] stated that there exists a mutually beneficial relationship between rice and fish, so farmers have a higher rice yield, since fish devour pests that attack rice and control the growth of weed plants. On the other hand, there is a complementary use of nitrogen (N) between rice and fish resulting in low nitrogen fertilizer application and release into the environment [23]. In addition, this system of farming is helpful in the conservation of biodiversity in paddy fields [40] since the input of chemicals in the form of pesticides, herbicides and inorganic fertilizers is limited [15]. Several studies have revealed the high profitability of integrated rice-fish culture, since farmers produce fish as an additional product with constant or even increasing rice yields. The technology of combining rice-fish culture gives higher net return compared to the traditional rice farming alone, which is believed to increase the livelihood of rural people [2, 35]. Even though the significance of the rice–fish culture has been recognized, the ecological mechanisms underlying the system have not been studied in detail, especially on soil and water chemistry, the impact of stocking density, design and management strategies to enhance yields [13, 21]. The modernization of varieties and uncontrolled use of chemicals lead to a decline in rice production globally [29]. It is suggested that rice-fish integrated farming is more rewarding to farmers in less developed countries. The basic advantage of rice-cum-fish farming is that waste products from one system, such as organic fertilizer or weeds can be used efficiently in other systems [11]. Although the fish cum rice integrated system has been demonstrated to provide necessary carbohydrates and high quality protein, it is still in an exploratory stage in Ethiopia. In this context the present experiment was carried out to evaluate the feasibilities of culture of Nile Tilapia in paddy fields at Bako in West shoa zone of Ethiopia.

2. Materials and Methods

The study on the paddy and Tilapia concurrent farming has been carried out in Dembi-Gobu micro-watershed, which is located near Bako town in West shoa zone, Ethiopia. The total experimental area was 542 m^2, including eight plots, each a size of 5 x 10 m with a total area of 400 m^2 and a trench of 1m in width and depth surrounding the plots. Four control plots were prepared similar to the experimental plot, without trench and fish. Paddy plots were fertilized with organic manure (cow dung and poultry waste) at the rate of 10,000 kg/ha, followed by 5 kg of Ammonium phosphate. High yield variety paddy NERICA- 4 (SUPERICA-4) seedlings were planted on the prepared plots after growing for a period of 1 month in the nursery. The trenches and paddy plots were filled with irrigation water. After 15 days of paddy transplantation, the Nile Tilapia (*Oreochromis niloticus*) advanced fingerlings (30 g) were stocked in the trenches at the rate of 5/m^2. The fish were fed with supplemental feed (grinding meal scraps 70% and nuge oil cake 30%) at the rate of 5% of mean body weight twice a day until the harvest. The growth of paddy and fish were recorded every month along with the physico-chemical parameters of the water and soil.

The water parameters like surface temperature, pH, and conductivity were measured using digital probes at the site. The dissolved oxygen was estimated by the Winkler method and the total hardness by the EDTA method [37]. The total alkalinity, carbon dioxide and ammonia of the water samples were determined by the titration method (APHA, 1980). The texture of soil samples were determined by the pipette out method [27] and classified (Shepard, 1954). Total nitrogen and available phosphorus in the soil were analyzed by the Kjeldahl method [5] and [32] respectively.

Plankton were collected at the beginning and end of the experiment from the trench by filtering the water using a bolting silk net (no. 25), preserved in 4% formalin for quantitative and qualitative estimations. The abundance (no/l) of major taxa was determined by using a rafter cell. The macro benthos were collected from the trenches by sieving the soil samples. The benthic fauna were preserved in 5% formalin for further identification and the population density was expressed as No/m^2.

3. Results

3.1 Physico-chemical Parameters

The water temperature in the present study varied between 28 ˚C and 29 ˚C in Paddy-fish (PF) plots and between 27 ˚C and 30 ˚C in the control plots. The highest and lowest values were observed in April and February in treatment plots and January and March in control plots (Table 1). The pH of the water samples did not vary significantly during the experimental period. However, there was a slight decrease from January (7.99) to April (6.5) in the treatment plots and April (7.5) to May (6.3) in the control plots. The DO in PF plots at the time of planting of the seedlings was 4.6 mg/l in January and increased to 10 mg/l in May. Whereas, in the control plots, the values ranged from 4.5 and 7.0 mg/l. The dissolved carbon dioxide content in the rice-fish field fluctuated (4.2 to 5.6 mg/l) considerably between the months and was comparatively higher than in the control plots (4.1 to 4.7 mg/l).Conductivity of the water was found to be minimum (0.123 µs/cm) and maximum (0.433 µs/cm) in January and May respectively in PF plot. Whereas, the minimum (0.143 µs/cm) and maximum (0.542 µs/cm) during March and April respectively in the control plots. The total alkalinity of the water in the experimental plots was found to be within the limit required for fish. It ranged between 42.6 mg/l $CaCO_3$ (January) and 56 mg/l $CaCO_3$ (May). The alkalinity in the control field was minimum (27.32 mg/l $CaCO_3$) in February and maximum (56 mg/l $CaCO_3$) in March. The total hardness at the time of plantation (January) in PF field was 37.7 mg/l $CaCO_3$. Further it increased to 42.4 mg/l$CaCO_3$ in April followed by a decline (31.3 mg/l) in May. In the control plots it was recorded 35.5 mg/l $CaCO_3$ in March and the maximum (56 mg/l $CaCO_3$) in May. Ammonia in the water remained less than 1 mg/l throughout the study period. The highest value was recorded in April. In the control plot ammonia content was very low and sometimes at undetectable levels. The major nutrients, nitrate and phosphate in the water were measured from the experimental plots during the study period. In PF plots, the phosphate level was 0.07 mg/l in January and reached to 0.31 mg/l in April. Further, it was reduced to 0.24 mg/l in May. However, in the control field, the phosphate level varied between 0.02 mg/l (February) and 0.09 mg/l (April). The nitrate concentration in the paddy-fish plots showed significant variations. The minimum and maximum concentrations were recorded in February and April, respectively.

Table 1: The water quality parameters of paddy fish plots

Parameters	January		February		March		April		May	
	PF	CP	PF	CP	PF	CP	PF	CP	PF	CP
DO (mg/l)	4.6	5	6	7	5	6.3	9	4.5	10	6.5
Temperature (˚C)	28	27	29	29	28	30	29	28.6	28	28.5
CO_2 (mg/l)	4.4	43.5	5.6	45	4.2	43	4.4	41	5.0	47
pH	7.99	7	6.51	6. 56	7.07	7	6.5	7.5	6.81	6.32
Conductivity (µs/cm)	0.123	0.152	0.32	0.221	0.123	0.143	0.42	0.542	0.433	0.333
Alkalinity (mg/l $CaCO_3$)	42.6	42.6	50	27.32	56	56	55	44.30	55	55.23
Hardness (mg/l $CaCO_3$)	37.7	43.2	34.2	37.5	35.5	35.5	42.4	42.4	31.3	56
Ammonia (mg/l)	Nil	Nil	Nil	Nil	Nil	Nil	0.9	Nil	0.5	Nil
Phosphate (mg/l)	0.07	0.07	0.09	0.02	0.23	0.08	0.31	0.09	0.24	0.04
Nitrate (mg/l)	0.312	0.212	0.231	0.021	0.347	0.353	0.474	0.474	0.237	0.237

3.2 Soil composition

The soil analysis was carried out at the time of the site selection process as well as at the end of the experiment. Initially the soil was composed of sand (6.88%), silt (76.62%) and clay (16.5%). The composited soil samples in the rice-fish field after four months of culture showed increase in the amount of silt (88%) and reduction in clay content (6.5%) (Table 2). The sand fraction was reduced to 5.5%. In the control plots the silt fraction reached 80.7% and clay 13.95%. However, the increment in the components was lower than that of the rice-fish culture plots. The available nitrogen concentration of the soil in the rice-fish and control plots showed variations between 0.496 mg/kg and 0.541 mg/kg respectively. The available phosphorus concentration was found to be minimum (14.491 mg/kg) in control and maximum (24.611 mg/kg) in treatment plots. There was not much variation in the composition of the soil. The organic carbon and organic matter content in the control and PF plots increased at the end of the experiment. However, the increment of silt particle was slightly higher in the paddy and fish plots than the control plots.

In the present study a large number of plankton and filamentous alga (*Spirogyra*) were found in the paddy fields as well as in the trench water. The phytoplankton was composed of diatoms (four genera), green algae (four genera) and blue-green algae (two genera) (Table 3). The dinoflagellate, *Euglena* was the predominate species in both PF and control plots. The zooplankton observed were copepods and rotifers (two genera). The total number of plankton in the control plots was comparatively higher than in the paddy-fish plots throughout the experiment. The filamentous algae were abundant at the bottom of the trenches as well as in paddy plots. The benthic fauna recorded in the PF and control plots were Nematodes, Oligochaetes, Gastropods Chironomus and other insect larvae (Table 4.). The population of these fauna was found to be higher in the control plots than in the trench where fish are stocked. The total yield of paddy in the PF plots was 112.3 kg and 95.65 kg in the control plots, which is estimated as 5615 kg and 4802.5 kg/ha respectively in PF and control plots (Table 5). The total weight of fish harvested was 33.339 kg from the trenches and it was estimated at 833.475 kg per hectare.

Table 2: Soil characteristics of treatment and control plots.

Parameters	**Before cultivation**	**After cultivation**	
		PF	**Control**
Texture			
Sand (%)	6.88	5.5	5.35
Silt (%)	76.62	88	80.7
Clay (%)	16.50	6.5	13.95
Organic carbon (%)	3.03	3.27	3.60
Organic matter (%)	5.22	5.64	6.21
Total nitrogen (%)	0.573	0.541	0.496
Available phosphorus (mg/kg)	18.241	24.611	14.491

Table 3: The major plankton species from experimental and control plots.

Plankton groups	**Experimental plot (avg. No/L of sample)**	**Control Plot (avg. No/L of sample)**
Diatom		
Navicula sp	210	400
Synedra sp	84	200
Pleurosigma	100	300
Bacillaria	90	410
Euglenophyceae		
Euglena sp.	307	400
Green Algae		
Chlorella	200	400
Closterium	250	380
Ankistrodesmus	301	200
Spirogyra (filamentous)	100	103
Blue Green Algae		
Spirulina	47	92
Oscillatoria	90	400
Zooplankton		
Rotifera		
Brachionus	90	380
Lecane	97	120
Copepoda (cyclopoid)	250	350

Table 4: Population density of benthos identified from experimental and control plots.

Group	**Paddy-fish plot (no./m^2)**	**Control plot (no./m^2)**
Nematode	67	150
Dero	58	110
Chaetogaster	230	400
Chironomus larvae	175	250
Gastropods	200	310
Other insect larvae	210	305

Table 5: Yield comparison between treatment (PF) and control plots

Yield	**Paddy yield** in kg		**Fish yield** in kg
	PF plot	**Control plot**	**PF plot**
Total	112.3	95.65	33.339
Estimated Yield /ha	5615	4802.5	833.475

4. Discussion

The physico-chemical parameters of the water in the paddy-cum fish and control plots showed little variation. The temperature variation in the water is directly related to the atmospheric temperature. The range of temperature observed is suitable for the growth of paddy, as well as Tilapia [34]. The pH value of the water in the two sets of plots shifted to a slightly acidic condition towards the end of the culture. This change was not significant enough to influence the growth of fish, the paddy plants nor the fish food organisms in the trenches. It has been reported that slightly alkaline water is more favourable for growth of Tilapia [10, 14]. Dissolved oxygen is an important factor influencing fish growth and survival. The dissolved oxygen in the rice field and trench varied from 4-10 mg/l in the study period which is in agreement with Boyd (1998) [3]. The CO_2 level in the paddy-fish and control plots was within the limits required for the growth of fish (<10 ppm) throughout the study period. Hardness of the water in the experimental plots varied within the range suitable for Tilapia culture (Boyd, 1998) [3]. The optimum level of the physico-chemical parameters in the treatment plots facilitated the high growth rate of Tilapia, which is also in conformity with the observations of El Sherief and El-Feky (2009) [12].

The dissolved nutrients, nitrate and phosphate stimulate the growth of phytoplankton and ultimately enhance production of fish [4]. In the present experiment the values of these nutrients were found to be minimal in comparison with normal culture ponds. This is mainly because paddy plants utilize nutrients for their growth. However, the variation in nitrate and phosphate continued to fluctuate within the optimum range specified for freshwater fish culture. In rice-fish system there is increased nutrient concentration in the water column due to perturbation and nutrient regeneration effected by movements of the fish [33] increased temperature and the resultant microbial activity [31]. In addition, the bioturbation by fish increases soil fertility, prohibits photosynthesis and growth of weeds [6, 38]. The high level of nutrients facilitates the production of a larger number of tillers and panicles, leading to higher paddy yield in such systems [17]. In the present investigation, ammonia was below detectable levels in the water throughout the period of culture. Hargreaves and Tucker (2004) [19] stated that ammonia in water is positively correlated with temperature and fish excretion. The same trend was observed in the present study. Magulama (1990) [28] observed that paddy plants act as nitrogen sink and help to reduce ammonia that may be released by the fish.

The presence of organic fertilizers in paddy plots might have facilitated the growth of the fish food organisms. This observation was in line with that of Kamal *et al.* (2008) [25] who stated that the growth of plankton in culture ponds fluctuated greatly with the temperature and fertilization. In the rice fish plots the numerical abundance of the plankton was comparatively less than that of the control plots. This variation could be related to the effective feeding of the fish on the live food organisms. The benthic fauna population declined considerably at the end of the growing period. This indicates the voracious feeding nature of the adult fish on the detritus matter at the bottom of the trench. The trench being shallow, the fish can reach the bottom and effectively feed on the detritus particles [7, 20]. In the present study the paddy on the experimental plots have grown better, high branching with longer panicles and an effective tillering rate, more grain per tiller and the low rate of empty grains, than in the control plots. As a result the yield of paddy grain was higher in the rice-fish plots. The present study revealed an average of a 16.91% increase in rice yield in the rice-fish integrated plots than in the control plots. Krop *et al.* (1993) [26] also stated that introduction of fish has increased paddy yield by 15% in Indo-Pacific countries, due to better aeration of water; greater tillering effect and additional supply of fertilizers in the form of leftover feed and fish excreta. De la Cruz and Lopez, (1980) [9] reported that the culture of Nile Tilapia in rice fields supplemented with feed and fertilizer in the Philippines was profitable. Similar results were reported by Sevilleja *et al.* (1992) [36]. The present results are in agreement with the above researchers and without doubt the Nile Tilapia is a suitable species for rice-fish culture in warmer areas like Bako in Ethiopia. According to Zhang (1995) [39] fish production in rice-fish integration varies with stocking density, size at stocking and supplementary feed used. Recent studies have also consistently shown higher rice yield in rice-fish fields than in rice field only (Gupta *et al.*, 1998; Mohanty *et al.*, 2004) [16, 30]. The high fish yield obtained in the present study may be related to the availability of live food in the culture system. In the present experiment a total of 33.339 kg of fish harvested from a 100 m^3 trench area, which is less than the yield reported from Japan (Huet, 1994) [22]. In developing countries like Ethiopia with substantial water logged areas (wetlands), rice-fish culture may contribute to solve food insecurity issues and poverty alleviation. The immense resources available in the country could be used for the development of integrated rice-fish cultures which can assure the food insecurity of the country. The present results indicate that integrated rice fish culture is highly profitable for small scale farmers, especially in developing countries like Ethiopia through government policy interventions.

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