On–Farm Trials with Rice-Fish Cultivation in the West Kano Rice Irrigation Scheme, Kenya

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Abstract

The viability of integrating rice farming with fish culture was studied in ten (10) rice plots. The on-farm research was done during one rice-growing season starting May 2003. The rice variety used was IR 2793-80-1 while the fish species was the Nile tilapia, *Oreochromis niloticus*. The fish culture period lasted 77 days. An average fish production of 132.4 kg/ha was obtained. The mean recovery rate of tilapia was 43 per cent. Total rice yield from the fields stocked with fish was lower than from unstocked fields. The net returns were not significantly different.

Introduction

Kenya relies heavily on the agricultural sector as a base for economic growth, employment creation and foreign exchange generation. Agriculture contributes 26 per cent of the GDP, 53 per cent of export earnings, 45 per cent of government revenue and 75 per cent of industrial raw materials (Nalo 2000). The sector also provides income and employment to 80 per cent of the population and more in the rural areas. However, over the years the sector has performed below its potential annual growth rate of over 4 per cent per annum, while the population has grown at a faster rate than food production (Nalo 2000). This has resulted in declining per capita food production and a high incidence of protein and calorie malnutrition, with an estimated 50 per cent of the population living below the poverty line. Food security, defined as access by each citizen to an adequate level of nutritionally balanced food, is now a core component of the food policy in Kenya (Government of Kenya 1994).

Agriculture production can be enhanced by increasing area under cultivation, reducing post harvest losses and increasing yield per unit of production area. The use of rice fields to grow rice and raise fish concurrently or rotationally is one way of increasing productivity without increasing the area under cultivation. It is generally accepted that integrated rice-fish farming often increases rice yield and produces fish while using the same resource base of land, water and labor. Indeed there is a growing recognition of the considerable potential of rice-fish to diversify livelihood options for poor farmers and increase their income while reducing their vulnerability. Rice-fish farming, is therefore, relevant to Kenya's agricultural development plan of increasing productivity, farmers' income, and improving the nutrition of the rural population.

This paper presents the general research findings of the first year of a three year on-farm integrated rice-fish research activity.

Methodology

All the trials were carried out on-farm in the South West Kano Irrigation Scheme (SWKIS) situated in Nyanza Province, Kenya. The SWKIS is a scheme entirely owned by small scale rice farmers who are organized into self help groups. The on-farm trials were expected to increase the relevance of the results and, hence, the degree of adoption of the rice-fish technology. A total of eight resident farmers, each with a minimum of 0.405 ha of rice field, were selected and recruited to participate in the trials. Data from only five out of the eight were used. Each farmer's field had a rice monoculture plot and a rice-fish culture plot averaging 915 m^2 in area.

The field plots for integrated rice-fish were physically modified to provide refuge for the fish by constructing a peripheral trench using about 10 per cent of the area of the plot and having a depth of 0.5 m – 1.0 m on one side of the plot. The fields were provided with separate screened water inlets and outlets. The dikes had base widths of 0.5 m, top widths of 0.3 m and heights of 0.4 m. Water height was maintained at an average of 20 cm in the rice monoculture plots and 25 cm in the rice-fish culture plots. Mixed sex tilapia (*Oreochromis niloticus*) of individual weight of approximately 20 g were stocked at the rate of 6 000 fish/ha in the trench 14 days after transplanting the rice. To monitor fish condition


Peripheral trenches in integrated rice-fish field plots.

and growth, fortnightly fish sampling was done in the pond refugia by netting. The fish were provided with supplementary feed of rice bran at 2 per cent of the total body weight per day. The amount of feed was adjusted after each sampling. Water quality parameters (dissolved oxygen (DO), pH, temperature, alkalinity, orthophosphate, nitrate-N) were monitored every week at 12 noon. The fish were harvested after 77 days of culture and per cent survival, standard length, and total wet weights recorded.

The rice variety IR 2793-80-1 was transplanted at random after seedbed preparation. For seedbed planting, seeds were soaked in water for 24 hours. The pre-germinated seeds were broadcast evenly on a ploughed, puddled and levelled nursery bed. Phosphate and nitrogen fertilizers were applied as recommended in the nursery bed a day before sowing. The seedlings were in the nursery for one month and then transplanted at random in the field.


Sampling to monitor fish condition and growth.

Rice yields were evaluated following the crop cut method wherein panicles were quantitatively collected from a randomly selected area (1 m^2) in the field. These were then sun dried and the grains collected after careful threshing. The rice grains were cleaned and dried to a moisture content of 14 per cent and dry crop yield expressed on the basis of the 14 per cent moisture content.

Computed means were compared using Student's t-test.

Results

The physical and chemical parameters of water determine the survival of fish in a rice field. The mean values (S.E.) of the water quality parameters measured in the pond refugia and the rice fields are presented in Table 1. The temperature, DO and pH values of the water showed diurnal fluctuations. The temperature in both the rice fields and pond refugia was within the optimum range for Nile tilapia (29°C - 32°C) (Balarin and Hatton 1979).

The DO values were significantly (P 0.05) higher in the exposed fields than in the pond refugia. The values gradually declined as the growing season progressed. This was probably due to shading by the rice plant. Photosynthesis by algae, aquatic weeds and phytoplankton contribute to the dissolved oxygen content in the water. Oxygen production through photosynthesis is determined by the light intensity reaching the water and depends on the plant canopy. It has been reported that light is usually reduced by 50 per cent after 15 days, 85 per cent after 30 days and 95 per cent after 60 days under transplanted rice (Halwart et al. 1996).

In the morning hours the DO levels in the pond refugia fell below the 5 mg/l critical value, below which fish growth is retarded (Boyd 1982), but these levels gradually increased during the course of the day.

Both the rice fields and the pond refugia had slightly low pH, but it was within the range considered optimal for fish growth (Boyd 1982). The acidity was probably due to the humic acids resulting from the decomposition of aquatic weeds and rice stalks left over from field preparation and harvesting. The alkalinity in the rice fields and refugia was average and did not show any significant difference. In earthen fish ponds, liming is usually done to increase both pH and alkalinity and this eventually results in an increase in phytoplankton and carbon dioxide for phytoplankton growth. However, liming is not a common practice in rice farming in Kenya and needs to be introduced for effective rice-fish farming.

Table 1. Mean water quality parameters measured in pond refugia and rice fields at 12 noon.

Parameter	**Mean**
Temperature (°C)	
(i) Pond refugia	28.1 ± 1.5
(ii) Rice field	27.3 ± 1.1
Dissolved oxygen (mg/l)	
(i) Pond refugia	4.45 ± 0.13
(ii) Rice field	6.60 ± 0.11
Water pH	
(i) Pond refugia	6.4 ± 0.07
(ii) Rice field	6.3 ± 0.15
Alkalinity (mg/l)	
(i) Pond refugia	26.0 ± 1.5
(ii) Rice field	23.8 ± 0.7
Nitrate-N (mg/l)	
(i) Pond refugia	0.32 ± 0.1
(ii) Rice field	0.35 ± 0.3
Orthophosphate (mg/l)	
(i) Pond refugia	0.07 ± 0.03
(ii) Rice field	0.09 ± 0.02

The nitrate-N in both the pond refugia and the rice fields was fairly high with no significant difference (P 0.05) between the two habitats. The concentrations, however, should have been higher due to the application of fertilizers (urea and NPK) in the fields. Soluble orthophosphate levels were also relatively low considering the amount of fertilizers applied during the growing season. Means for both the refugia and the rice fields were not significantly different (P 0.05).

The rice monoculture crop was shorter in size than the rice-fish culture crop (Table 2). This was not due to spacing differences since the number of hills per square meter was not significantly different between the two treatments (Table 2). The water was maintained at a depth of 25 cm in the rice-fish culture plots and 20 cm in the rice monoculture plots. As a survival mechanism rice is known to grow taller with increase in water depth. This could explain the

Table 2. Rice plant growth and yield parameters for integrated rice-fish (R-F) crop and rice monoculture(R) crop.

Farmer number	Hills/m2		Final plant height (cm)		Effective tillers/m2		Grain yields (kg/ha)		Harvest index (%)		1 000-grain wt (g)	
	R	R-F	R	R-F	R	R-F	R	R-F	R	R-F	R	R-F
1	74	52	76	74	91.8	93.7	7 986	5 686	43.3	40.1	23.74	20.96
2	56	56	72	76	85.5	88.9	6 293	6 163	49.7	40.3	22.84	23.16
3	48	48	72	79	89.4	79.8	5 729	5 122	43.0	39.7	23.46	23.04
4	43	48	54	69	84.4	91.6	6 380	4 687	35.8	44.3	20.55	21.89
5	61	48	52	57	84.6	56.5	2 344	1 953	18.9	21.6	20.54	21.73
Mean	56 ±12	50 ±4	65 ±11	71 ±9	87.1 ±3.3	82.1 ±15.3	5 746 ±2 079	4 722 ±1 646	38.1 ±18.8	37.2 ±8.9	22.23 ±1.57	22.16 ±0.93
CV %	21	8	17	12	4	19	36	35	31	24	7	4

Production data	Rice-fish	Rice monoculture
Stocking density (fish/ha)	6 000	-
Mean stocking weight (g)	20 ± 1.0	-
Mean harvest weight (g)	56.8 ± 10.1	-
Mean weight gain (g)	36.8	-
Recovery (%)	43 ± 18.3	-
Culture period (days)	77	-
Fish yield (kg/ha)	132.4 ± 38.3	-
Rice yield (t/ha)	4.72 ± 1.65	5.75 ± 2.07
Gross returns (US$/ha)	1 530	1 325.2
Expenditure (US$/ha)	533.3	333.3
Net returns (US$/ha)	996.7	991.9

Table 3. Production data for rice-fish and rice monoculture trials.

differences in the height of the rice crop between the two treatments. As a general observation also, the number of hills per square meter achieved by random transplanting (50-56 hills/m^2) gave a plant population equivalent to planting in rows at the recommended spacing of 20 cm x 10 cm. This is a significant finding since farmers had been reluctant to do row planting claiming that it consumed a lot of time and resulted in low plant population.

The growth of the fish was fairly good, with the majority doubling their initial wet weights during the 77 days of culture (Table 3). The average fish production from the plots was 132.4 kg/ha. The average fish size attained was, however, considered undersized by the local people who are used to larger fish of over 150 g usually caught from the adjacent Lake Victoria by the fishermen from the community. Parameters like size at stocking, culture period in the rice fields and the amount and quality of supplementary feed could all have influenced size of fish at harvest. Recovery rates were low and adversely affected the net yields. The poor recovery was probably due to escape of the fish into the inlet and outlet channels because of poor maintenance of the gates by the farmer cooperators, poaching by man, birds and other wild animals and improper puddling and leveling of the rice fields resulting in pockets of un-drainable water in several parts of the fields.

Table 3 shows the returns obtained from both the rice monoculture and integrated rice-fish culture. There was a slight lowering of rice yield from the fields with rice-fish culture as compared to those with rice monoculture. However, when the fish yield was taken into account, it was noted that there was no difference in net returns between the two systems. Of the operational costs required for rice-fish culture, fingerling costs accounted for the greatest proportion, making up 64 per cent of total operational expenses. Apart from fingerlings, rice bran was the primary additional input.

Discussion

Kenya has an estimated 11 000 ha of irrigated and 12 000 ha of rain fed rice fields (Kouko 2000) that can play an important role in fish production. The rice fields are potential fish ponds since in its aquatic phase the rice field is a rich and productive biological system that can produce a crop of fish. Egypt has exploited this system successfully, with fish production from rice field reported to account for over 30 per cent of the country's total aquaculture production (Shehadeh and Feidi 1996). In China, fish farming in rice fields is promoted through the National Aquaculture Development Plan and fish yields ranging from 180-750 kg/ha have been achieved in concurrent rice-fish, with production being twice as high in rotational rice-fish farming systems (FAO and NACA 1997). Kenya also needs to utilize the rice fields to produce fish (Rasowo et al. 2003). Although earthen ponds are the dominant aquaculture production system in Kenya (Government of Kenya 2002; Immink et al. 2001), the potential of other production systems such as rice paddies needs to be exploited fully since the cost of constructing earthen fish ponds is prohibitive for most farmers, who still view aquaculture as a low investment, low risk enterprise. As raising fish in rice fields is an extensive form of aquaculture involving low investment, it should be more attractive to the farmers.

Production of fish from the rice fields will increase the consumption of protein and improve the nutrition of the rural population. Rice-fish technology has another complimentary health benefit. The stagnant or slowly moving water in the paddies is usually a breeding ground for mosquitoes, snails and other worms, leading to the proliferation of associated diseases like malaria, schistosomiasis and worm infestations. Growing fish in paddies has been shown to lead to a reduction of these diseases as the fish feed on the vectors (Halwart 1994; IRRI 1998).

Integrated rice-fish farming is not a new technology. It has been practiced in tropical Asia for centuries. In Africa, it is practiced in several countries, including Senegal, Madagascar, Malawi and, most prominently, in Egypt (Halwart 1998). Information about physical modification of rice fields, fish species, stocking densities and ratios is, therefore, readily available and only needs to be extended in Kenya. However, to ensure its adoption, we have to make certain that the technical research and technology transfer fits within the natural resource, socio-cultural and economic conditions of the specific local area in Kenya. According to Rogers (1983), five characteristics of a technology affect the rate at which it is diffused and adopted. These are compatibility, relative advantage, complexity, triability and observability. Indeed fish farming and rice farming have many commonalities since they require similar resources and inputs and are compatible. By participating with farmers in farm-based trials we hope to address the remaining four characteristics and at the same time build local capacity to ensure sustainability.

Several constraints were observed during the first year of this research. The most serious one was the availability and accessibility of both fish seed (fingerlings) and rice seed. The nearest source of fingerlings was the government owned Lake Basin Development Authority (LBDA) fish farm, a distance of over 30 km. The cost of transporting the fish from LBDA to the project site was almost equal to the cost of purchasing the fingerlings themselves and it was also not easy to get the right sizes and quantities of the fish required. The government owned National Irrigation Board (NIB) at Ahero is the main supplier of certified rice seed to farmers. Very often the rice seed is in limited supply and, therefore, the majority of farmers do not use certified rice seed.

Experience from several countries shows that government firms are usually inefficient as suppliers of seed. We propose to identify and train a few farmers in rice seed and fish seed production techniques. The other farmers will then be able to buy fish fingerlings and rice seed from them locally and this would ensure a ready availability of quality seed as well as create a new business opportunity.

Most of the farmers indicated that they lacked cash to buy the necessary inputs, particularly for purchasing fingerlings, seeds, feeds and fertilizers. Therefore, it is necessary to identify microfinance organisations that will give them credit at reasonable interest rates to purchase the inputs. Land ownership was also a problem as tenant farmers were not willing to invest in modifications of the rice fields to accommodate fish farming. The poaching of fish by other people, wild animals and birds can be reduced by having more farmers adopt rice-fish farming.

The local people around the lakeshore are part time fishers and are used to a fairly large sized fish. Due to the short growing period of 77 days, the fish we produced were comparatively small and were considered undersized. Nonetheless, all the harvested fish were readily consumed by the farmers' families. They also realized that small sized fish could be an asset to the family's nutrition since there is no incentive to sell it. However, it would be better to extend the growing period for the fish to over six months to allow them to attain the required table size.

Conclusion

In this study we were able to demonstrate to the local farmers that rice and fish can be harvested from the same field with minimal additional expenditure. This was a major objective of the first year of research. This demonstration generated a lot of interest in the project site with several visitors coming to view the project, including local administrators, policy makers and rice farmers from other rice schemes.

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