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Full Length Research Paper

Does African catfish (*Clarias gariepinus*) affect rice in integrated rice-fish culture in Lake Victoria Basin, Kenya?

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An experiment was conducted for 98 days in the Lake Victoria Basin to investigate the interactions of fish and rice growth performance in rice paddies. The experiment was laid out in a split-plot design, with rice cultivar as the main plot and method of rice-fish culture as the sub-plot. Treatments consisted of two levels of rice-fish culture and three cultivars of rice. Rice cultivars used were; ITA, BR 11 and IR 2793-80-1 obtained from the National Irrigation Board (NIB), Kenya. *Clarias gariepinus*, (15 ± 0.4 g) were stocked at 6 m^{-2} and given supplementary diet containing 35% crude protein and 7% lipids at 2× maintenance level. There was significantly less incidence of stem-borers in rice-fish polyculture compared to rice monoculture ($P < 0.05$). Rice-fish polyculture gave significantly higher rice yield than rice monoculture (453 ± 1.0 gm^{-2}). The seed yield differed significantly ($P < 0.05$) between the rice cultivars with ITA giving the highest yield followed by IR and BR. There were significant differences in growth performance of *C. gariepinus* in the treatments ($F = 4.518$, $df = 2$, $P = 0.014$) with best growth recorded in the Fish-ITA and least in Fish-BR. Mean net annualized fish production was highest (3,767 ± 300 $Kgha^{-1}yr^{-1}$) in the ITA-Fish plots with no statistical differences recorded between BR-Fish and IR-Fish plots. Fish survival ranged from 79.9 to 82.6 percent in Fish-IR, Fish-BR and Fish-ITA respectively.

Key words: African catfish, rice-fish culture, rice yield, fish yield.

INTRODUCTION

Fish production from aquaculture in Africa is still insignificant at the global level and according to the FAO 2004 aquaculture data and statistics from FISHSTAT Plus (FAO, 2006a; FAO, 2006b), the continent as a whole contributed only about 1.0 per cent to the total world aquaculture production. A significant increase in aquaculture production in the continent can be realized through refocusing aquaculture development strategies such as widening the range of production systems.

Currently the dominant aquaculture production systems in Africa and particularly in sub-Saharan Africa are earthen ponds. Other production systems such as rice paddies have hitherto been neglected and need to be explored. The rice paddies are potential fishponds since in its aquatic phase the rice field can produce a crop of fish. The use of rice fields to grow rice and raise fish concurrently or rotationally is one way of increasing productivity of rice paddies. 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. The accessibility of rice fields to the rural poor, and the fact that little initial capital investment is required to implement aquaculture in rice fields compared to pond based culture should prove more attractive to the small scale fish farmers who are the majority and who

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view aquaculture as a low investment, low risk enterprise.

The practice of culturing fish in rice fields started in China 2000 years ago. It has been successfully practiced for centuries by most tropical Asian countries. Integrated rice-fish farming is therefore not a new technology. However, although there are similarities, common practices and common problems in rice-fish farming, each of these Asian countries have evolved there own unique approaches and procedures.

Efforts are currently being made to extend this technology in sub-saharan Africa particularly in the Lake Victoria Basin (LVB) countries (Rasowo and Auma, 2006). To ensure increased adoption of rice-fish farming, we have to be certain that practices and adoption of these technologies fit within the available resources, the socio-cultural and economic conditions of the Lake Victoria Basin (LVB). Practices and technologies from Asia may be inappropriate due to differences in agro climatic zones, fish species and rice cultivars grown in different regions of LVB.

The aquatic phase of rice production creates a highly productive biological system that generates and sustains a wide range of organisms. However, the aquatic environment in the rice fields is also characterized by shallow waters, variation in turbidity as well as fluctuations in temperature, pH and dissolved oxygen (DO). Usually, a flooded rice field functions like a greenhouse with short wave radiation (light) from the sun heating up the water column and the underlying soil while the long wave radiation (heat) is blocked from escaping thus raising the temperature (Roger, 1996). A major source of DO in the water column is the photosynthetic activity of the aquatic plant biomass that often leads to super-saturation in the mid-afternoon. At night the oxygen is used up by the respiring aquatic organisms and oxidation processes often resulting in anoxic conditions during the night and pre-dawn period (Fernando and Halwart, 2000; Fernando, 1993; Halwart and Gupta, 2004).

The fish stocked in rice fields should therefore tolerate the harsh environment characterized by the high (up to 40°C) and variable temperatures (range of 10°C in one day), low oxygen levels and high turbidity (Khoo and Tan, 1980). Fast growth is also a desirable characteristic so that the fish can attain marketable size when the rice is ready for harvest. The two main aquaculture species in the LVB, the African catfish (*Clarias gariepinus*) and the Nile Tilapia (*Oreochromis niloticus*) have high tolerance levels to various environmental characteristics which favour their culture in the rice field environment. These include an ability to tolerate poor water quality, an ability to withstand high diurnal temperature fluctuations as well as tolerance to low oxygen and rapid growth (De Kimpe and Micha, 1974; Clay, 1979; Hecht et al., 1996; Henken et al., 1986; Huisman and Richter, 1987; Hepher and Pruginin, 1982).

The emergence and adoption of culture of high yielding rice varieties (HYV) have created several problems to rice-fish culture. Among these are concerns about the suitability of short-stemmed rice varieties because of the deeper standing water required in the rice–fish farming (Rosario, 1984). Another concern is the reduced growing period of the HYVs. Many of these new varieties mature within approximately 100 days or less and with such a short culture period for fish there is a need to either stock large fingerlings with the associated problems in fish dislodging and eating rice plants, or to harvest the fish early for further on-growing. Several rice cultivars are grown in the LVB hence the need to evaluate the most appropriate for rice-fish culture.

Although experience has shown that the rice yield often increases in rice-fish culture, farmers in the LVB still need convincing evidence that shows that the small percentage of cultivable paddy area lost through the creation of fish refugia does not result in net loss but rather a net gain in both rice and fish production. The current study was therefore carried out to assess the influence of African catfish on growth and yield performance of rice and to determine which of the three rice cultivars, commonly grown by small-holder farmers in the South West Kano Irrigation Scheme (SWKIS) in LVB would perform best in the rice-fish culture.

MATERIALS AND METHODS

The on-station experiment was carried out at the Kabonyo Fisheries Station, Kisumu District, Nyanza Province, Kenya. The government owned fisheries station is situated within the SWKIS in Nyanza Province. The scheme lies between 00° 6'S and 00° 12'S latitude and 34° 48'E and 34° 57'E longitude and at an altitude of 1137 m above sea level. SWKIS is a Small Holder Irrigation Scheme fully owned and managed by small-scale farmers through self help groups. The experiment was carried out during the August to December 2007 cropping season; normally a dry season.

The experiment was laid out in a split-plot design, with rice cultivar as the main plot and method of rice-fish culture as the subplot. Treatments consisted of two levels of rice-fish culture and three cultivars of rice replicated in three blocks. Rice (*Oryza sativa* L.) cultivars used were; ITA, BR 11 and IR 2793-80-1 while the fish species used was the African catfish, *C. gariepinus*. The rice cultivars were sourced from NIB while the fish was obtained from Lake Basin Development Authority fish farm in Kisumu.

Nine experimental plots with an average size of 54 m^2 were used. Each plot had elevated dikes with base widths of 0.5 m, top widths of 0.3 m and heights of 0.4 m, and separate screened water inlets and outlets. The inlets connected the plots to the main irrigation channel. Those plots for integrated rice-fish were physically modified to provide refuge for the fish by constructing peripheral trenches (refuge) each with an area of 18 m^2 and a depth of 0.5 m. Water height in all the plots was maintained at an average of 25 cm.

The plots were ploughed two times with all the plots receiving basal fertilization of 23 kg of $P_2 0_5$/ha (Triple super phosphate) prior to the transplanting of rice. Rice seedlings were transplanted from the nursery into the experimental plots at 35 days after Seeding (DAS) and at a spacing of 20 cm between the rows and 10 cm within the rows, with 2 seedlings per hill. The seedlings were allowed to establish at a shallow water level of less than 5 cm be-

Table 1. Mean water quality parameters (mean ± SEM) in plots containing rice-fish and rice only.

Parameter	Rice - Fish	Rice only
Water pH		
9.00 h	6.4±0.1	6.8 ±0.1
16.00h	6.7± 0.2	7.2±0.2
Temperature (^{0}C)		
9.00 h	23.8± 0.7	24.1±1.3
16.00 h	29.6 ±0.2	29.3± 2.1
Dissolved Oxygen (mgl^{-1})		
9.00 h	4. 9 ± 0.5	5.5 ±1.1
16.00 h	6.9 ± 01.3	7.5 ±1.5
NH_4-N (mgl^{-1})	Trace	Trace
NH_3-N (mgl^{-1})	0.38±0.3	0.47±0.2
Alkalinity (mgl^{-1})	25.8±1.5	24.3±0.8
NO_2-N (mgl^{-1})	0.13±0.02	0.18±0.01

before stocking of the catfish.

Fish were released into the plots at 14 Days After Transplanting (DAT) at a density of 6 fish per m^2 and water level subsequently raised to 25 cm. The average weight of the catfish fingerlings at stocking was 15.4 ± 0.6 g. During the experiment the fish in therice-fish plots received supplementary feeding with a 35% protein, 7% lipid and 3711 kcal/kg feed**.** As catching and weighing of the fish were not feasible, the amount of feed ration given to the fish was based on the prospective development of the body mass, assuming a metabolic growth rate of 8 g kg $^{-0.8}$ at 2x maintenance feeding (Frei et al., 2007, Frei and Becker, 2005). The feeding rate was adjusted fortnightly. Feeding was started 1 day after stocking and was provided manually in two equal daily portions at 9:00 h and 15:00 h until 97 DAT.

Water quality was monitored weekly at 09.00 h and 16.00 h for temperature and pH (JENWAY 3405 Electrochemical analyzer, UK) dissolved oxygen (Oxygen meter, YSI, Model 55), ammonia (NH_4-N), Alkalinity and Nitrites (NO_2-N) (LaMotte Test Kit, Model AQ-2).

Data on several parameters were collected at various stages of growth of rice. The parameters included plant height, tillers per stool, panicles per stool, harvest index, 1000-seed weight and seed yield per square meter. The incidence of stem-borers was monitored by taking counts of dead tillers (dead hearts). This was done 84 DAT, the stage it was reckoned that stem-borers would have inflicted maximum damage to the rice plant.

Fish were harvested 98 DAT by draining out the water from the experimental plots. They were then counted and weighed to the nearest 0.1 mg (Callibron Precision Beam Balance Scale, USA). Net fish yield and survival (recovery) were evaluated as shown below:

(i) Net Fish Yield (NFY) = Total fish weight harvested- Total fish weight stocked
(ii) Survival (% Recovery) was calculated as $Nt/No \times 100$

Where Nt = Total number of fish harvested (recovered)

No = Total number of fish stocked

Statistics

Quantitative values were expressed as treatment means ± standard error. All data except fish growth and yield were analyzed through two-way split-plot ANOVA and the means separated by LSD at $P \geq 0.05$. Comparison of mean values of fish growth and yield was made by one-way analysis of variance (ANOVA), followed by Duncan's multiple range test at a significance level of $P< 0.05$. We used Statistica, Version 5 for MS Windows (Statsoft Inc. Tulsa, Oklahoma, USA) software to analyze our data.

RESULTS

Mean values (S.E.) of the water quality parameters measured in the plots during the experimental period are given in Table 1. They were within the recommended acceptable range for growth of *Clarias* spp. (Viveen et al., 1985).

Ambient water temperatures in the morning were more or less equal in all the treatments. However, there was great fluctuation in the afternoon pH values in all the treatments although the morning values were fairly constant. Dissolved oxygen showed a similar pattern with morning values being low but uniform in all the rice-fish plots. The values were however higher in the rice only plots and ranged from 5.5 - 7.5 mg l^{-1}.

There were no significant interactions between treatments ($P\geq0.05$). Consequently the results presented reflect the main effects of the various treatments. Plant height was used to evaluate the effects of treatment on plant growth. Rice-fish polyculture resulted in significantly ($P<0.05$) taller plants than rice monoculture (Table 2**).** When the different cultivars were compared, the IR cultivar had an average height of 76.7 cm which was significantly taller than the other cultivars (Table 3).

There was significantly less ($P\geq0.05$) incidence of stem-borers in rice-fish polyculture compared to rice monoculture (Table 2). Rice-fish polyculture gave signifycantly higher ($P\leq0.05$) yield than rice monoculture (Table 2). The seed yield differed significantly ($P\geq0.05$) between the rice cultivars with ITA giving the highest yield, followed by IR and lastly BR (Table 3).

Growth performance of *C. gariepinus* in the three cultivars of rice is presented in Figure 1. There were significant differences in growth performance of *C. gariepinus* among the three types of rice cultivar treatments ($F = 4.518$, $df = 2$, $P = 0.014$). Growth was best in Fish-ITA and least in Fish-BR integration.

Table 4 compares the fish yield performance in the rice-fish treatments. Although there were no significant differences in the initial weights of the fish stocked, the fish yields differed significantly ($P< 0.05$) in terms of weight gain.

There was no statistical difference ($P > 0.05$) between BR and IR. Mean net fish production was highest in the ITA-Fish plots with no statistical differences recorded between BR-Fish and IR-Fish plots.

Fish survival in all treatments (percent recovery) was reasonably good ranging from 79 to 82.5% (Table 4).

Table 2. Influence of fish on selected performance indices of rice in a rice-fish culture.

Treatment	Plant height (cm) 98DAT	Tillers stool^{-1} 63 DAT	Panicles stool^{-1} 98 DAT	Harvest Index (%)	1,000-seed weight (g)	Seed yield (g m^{-2})	Dead hearts stool^{-1} 84 DAT
Rice monoculture (No. fish)	66.6^{b}	10.4^{a}	2.0^{b}	26.9^{b}	19.8^{a}	276^{b}	1.5^{a}
Rice and Fish	74.9^{a}	9.6^{a}	6.3^{a}	34.4^{a}	19.1^{a}	453^{a}	0.9^{b}
LSD 0.05	6.9	Ns	0.7	5.2	ns	10	0.5

Values in the same row with the same superscript are not significantly different (P≥0.05), DAT = Days after transplanting rice.

Table 3. Influence of rice cultivar on selected performance indices of rice in a rice-fish culture

Treatment	Plant height (cm) 98DAT	Tillers stool^{-1} 63 DAT	Panicles stool^{-1} 98 DAT	Harvest Index (%)	1,000-seed weight (g)	Seed yield (g m^{-2})	Dead hearts stool^{-1} 84 DAT
BR Cultivar	67.2^{b}	7.9^{c}	3.9^{b}	31.8^{ab}	21.0^{a}	308^{c}	1.4^{a}
IR Cultivar	75.7^{a}	10.1^{b}	3.5^{b}	26.3^{b}	18.4^{b}	369^{b}	1.6^{a}
ITA Cultivar	69.5^{ab}	11.9^{a}	5.2^{a}	33.8^{a}	19.1^{b}	417^{a}	0.7^{b}
LSD 0.05	8.4	1.7	0.9	6.4	1.8	12	0.6

Values in the same row with the same superscript are not significantly different (P >0.05).
DAT = Days after transplanting rice

Table 4. Fish yield parameters (mean ± SEM) in plots containing rice-fish cultures

Parameter	IR-Fish	BR-Fish	ITA-Fish
Mean initial fish weight (g)	15.4± 0.6^{a}	15.6± 0.4^{a}	15.3 ±0.7^{a}
Mean final fish weight (g)	69.6 ±1.52^{a}	66.27 ±1.71^{a}	75.51± 3.14^{b}
Recovery (%)	79.9	81.5	82.6
Mean Net fish yield (NFY) (kg/plot)	4.67 ±0.03^{a}	4.51± 0.01^{a}	5.46 ±0.08^{b}
Mean Net annualized production (NAP) (Kg ha^{-1} yr^{-1})	3232± 287^{a}	3111 ±189^{a}	3767± 300^{b}

Values in the same row with the same superscript are not significantly different (P >0.05), SE, standard error of the mean.

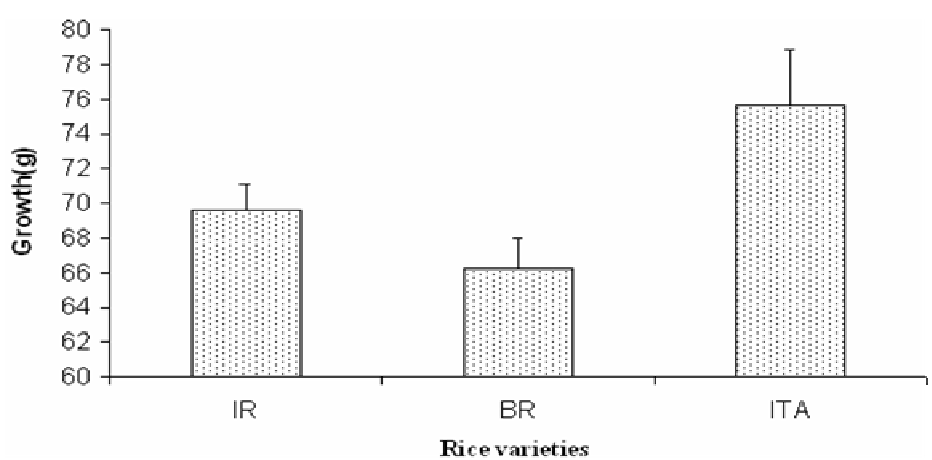

Figure 1. Growth performance of *C. gariepinus* under different rice cultivars.

DISCUSSION

Plant height may be determined by the genetic constitution of the cultivar. Additionally plant height may be influenced by external factors, including status of soil fertility. The IR cultivar was significantly taller than the other cultivars in our experiment and this was attributed to the genetic differences between the cultivars. However, the significantly taller rice plants in rice-fish culture compared to that of rice monoculture was ascribed to the better growing conditions in the rice-fish integration. This was probably due to improved nutrient availability resulting from the excrement produced by fish as well as to aeration of the growth medium as the fish move around. Fertilizer requirement is known to reduce with the introduction of fish (Gupta et al., 1998) and a rice field with fish has a higher capacity to produce and capture nitrogen (N) than one without fish (Cagauan 1995).

A comparison of panicles per stool and dead hearts per stool revealed that stem borers reduced the potential yield of rice by 43% in rice monoculture compared to only 13% in rice-fish polyculture. Fish in the rice field have been shown to be capable of devouring some insect pests not the least of which are stem borers in addition to eradicating weeds by eating or uprooting them. Our results would advocate the reduced use of pesticides by simply stocking fish. This is advantageous to the rice farmers in SWKIS and the environment in general. Our results further support the work of Gupta et al. (1998) who have shown that rice-fish farmers use less than 50% pesticides than that used by rice-only farmers in Bangladesh.

The cultivars in our study also differed in the extent to which they were prone to attack by stem borers. ITA was significantly more tolerant to attack by stem borers compared to the other cultivar. Stem borers reduced the potential yield by 12, 26 and 31% in the cultivars ITA, BR and IR respectively.

Seed yield may be determined by several factors that influence one or more of the yield components. Genetic differences among crop cultivars may also influence seed yield.

Rice-fish polyculture gave significantly higher yield than rice monoculture and this could be attributed to the more favorable growing conditions in the rice-fish polyculture. In these circumstances, some of the critical yield components such as panicles per stool and harvest index were enhanced. These differences in cultivar seed yield were ascribed to the differential effects of cultivars on seed yield components especially tillers per stool, panicles per stool and harvest index. Although the culti-var BR had significantly heavier seeds (1,000-seed weight), this yield component alone could not adequately compensate for the differences.

This study demonstrates that integrated rice-fish farming has no adverse effects on rice growth in SWKIS. Instead the technology appears to offer potential for food security and poverty alleviation as it gives an additional crop of fish while reducing the use of pesticides. Fish is an important source of animal protein, essential fatty acids, vitamins and minerals. Our results show that net fish yields ranging from 4.6-5.5 Kg plot^{-1} giving an annual net production ranging from 3.2 – 3.8 tons ha^{-1}yr^{-1} of fish could be produced as an additional crop in the paddies.

To date, rice-fish culture is most prevalent in China while in Africa, it is practiced most prominently in Egypt (Halwart, 1998). Egypt has exploited this system so successfully that the fish production from rice fields is reported to account for over 30 per cent of the country's total aquaculture production (Shehadeh and Feidi, 1996). The LVB can also benefit greatly from adoption of this technology considering its huge water resources, the climatic conditions, soils, large areas under rice cultivaion, fish eating culture and declines in Lake Victoria capture fisheries (LVFO, 2005).

Conclusions

The performance of rice was significantly improved by the rice-fish polyculture compared to the rice monoculture. The cultivar ITA performed best under the rice-fish polyculture trial. ITA matured within 4 months and would be appropriate in a rice-fish fingerlings polyculture. ITA would not be appropriate in a rice-fish ployculture in which fish for table consumption is expected to be produced. This can however be overcome by stocking larger fish which would result in bigger fish being harvested.

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