INTEGRATING FISH INTO RICE FARMING AS AN ECONOMIC SUBSTITUTE TO CHEMICAL PESTICIDES

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ABSTRACT

In an effort to eradicate pests and significantly increase food production for sustainable agriculture, rice farmers in Kenya have bowed to intensive and indiscriminate utilization of agrochemicals, particularly the chemical pesticides. Consequently, extensive use of pesticides in rice farming has become an integral part of production of the crop. Increasing empirical evidence suggests that chemical pesticides have intrinsic environmental risks during their use, storage and disposal, posing serious ecological and health concerns. However, most empirical studies on mitigation measure have proposed utilization of integrated pest management methods to control use of pesticides and minimize the effects of these pesticides as others examined the viability of integrating fish into rice farming and the rest revealed a sustainable rice agro-ecosystem. Related studies conducted locally have scantly addressed the rice-fish integrated farming approach as an economic alternative mechanism to chemical pesticides, denying Kenyan rice farmers at Mwea irrigation scheme important information for propagating a healthy environment. This study sought to lock this gap by assessing the economic viability of integration of fish into rice farming as substitute to chemical pesticides at farms in Mwea Irrigation Scheme. The present study adopted experimental design using completely randomized block design undertaken in the rice field of Mwea irrigation scheme. The experiment comprised of three separate treatments, each replicated three times with the; first treatment having rice, stocked with fish and fertilized with regular urea fertilization; second treatment had rice, stocked with fish, partial fertilization and supplementary feeding, and the third treatment was kept as control (rice without fish). Pishori variety of rice plants was be transplanted in the paddy field and after 14 days of transplantation of rice plants, fingerlings of Nile Tilapia were released in on two plots. Rearing was done at two levels: fish present (rice-fish culture) and fish absent (rice-monoculture). Data on rice and fish growth was collected at intervals after three months of the project initiation. The study concludes that integrating Nile tilapia fish into rice farming increases rice yields and increase fish produce. Accordingly, there is increased net returns from rice and fish, reduction of chemical pesticides utilization (eliminate the use pesticides), increase of the farmers' income, diversified productivity of the soil, soil protection, increased nutrients uptake and biological control of pests.

Key words: *Economic Viability. Chemical Pesticides, Fish Produce, Integrating Tilapia Fish Into Rice Farming, Rice Yields.*

INTRODUCTION

As is the case in many other developing countries, agriculture in Kenya plays a very vital role in food security, economic growth, employment creation, Gross Domestic Product (GDP) and development (Abong'o, Wandiga, Jumba, Madadi & Henrikkylin, 2014; Chebai, 2014). However, achieving sustainable agriculture is under threat of disastrous pests, which might destroy the crops and reduce the expected yield (Pretty & Bharucha, 2015). Eradication of these pests is therefore becoming a major concern to the farmers and the country at large. As a remedy, farmers have resulted into using chemical pesticide for purpose of eradicating these pests and increasing food production for sustainable agriculture (Tam, 2016). More precisely, the utilization of pesticides has become an integral part of rice farming in Kenya (Chebai, 2014).

However, increasing evidence suggests that pesticides have intrinsic health and environmental risks depending on their use, storage and disposal (Stadlinger, Mmochi & Kumbilad, 2013). Thus, intensive and indiscriminate use of pesticides may pose serious ecological and health concerns to the environment and population where it is used (Abong'o *et al*., 2014). In an effort to avoid the perceived dangers of pesticides, biological and ecological methods such as Integrated Pest Management (IPM) approach) have been devised as environmentally friendly technological approaches to pest management intended to minimize negative impacts of pests on the environment (Alam, Haque, Islam, Hossain, Hasan, Hasan & Hossain, 2016). Among these, integrating fish into rice farming has emerged as a viable traditional pest control mechanism for irrigation systems (Saikia, Abujam, Das & Prasad, 2015). Although integrating fish into rice farming has been widely practiced in developed as well as developing countries, it has received a mild attention in the Africa region. While a few African countries have actively adopted it, irrigation agencies in the east African region such as Kenyan irrigation systems have paid very little attention to integrating fish into rice farming approach (Ja'afaruBadejo, Ghumdia & Ali, 2015).

Adoption of integrating fish into rice farming requires introduction of fish culture, such as Nile Tilapia (*Oreochromis niloticus*), into in the rice paddy fields (Desta, Devi,. Sreenivasa & Amede , 2014). Thus, the mechanism involves stocking fish fingerlings into rice paddy fields, obtaining fish in addition to the main crop, rice. On integrating fish into rice farming, the rice farmer is expected to attain; increased rice production, yield more fish, socio-economic benefits, biological and ecological affects (Saikia *et al*., 2015). Further, the approach promotes species diversification and nutrient recycling as it maximizes the efficient utilization of water and contributes to a drastic reduction in the use of chemical pesticides (Allahyari & Noorhosseini, 2014). Economically, the integrating fish into rice farming might be used as tool for hunger eradication, fighting poverty and eliminating malnutrition (Saikia & Das,2008).

RESEARCH METHODOLOGY

Study Area

The study was carried out in Mwea irrigation scheme on the Embu-Nairobi Highway in Kirinyaga County, approximately 100 kilometers from Nairobi. It is located at an elevation of 1,175 meters above sea level. This is predominantly a rice-growing area although other crops such as beans, maize and green vegetables are grown for subsistence. Rice farming is the main economic activity in the region, grown across 900 hectares. The region produces over 50% of all rice grown in the country. Although the main rice growing season June to December, rice is grown all-year-round. For this reason, many people have migrated to the region from different parts of the country to cultivate and trade in rice.

Research Design

Experimental research design was adopted because it offers the best method to study randomly selected groups due to the high degree of control. The subjects were both randomly allocated (Randomization) into the different groups and randomly selected (sampled), a significant feature of experimental research design (Beaumont, 2009). The study used true experimental design, completely randomized block design (Campbell, Stanley & Gage, 1963). The experiment comprised of three (3) separate treatments, each replicated three times with the; first treatment having rice stocked with fish and fertilized with regular urea (Treatment I, T1); second treatment had rice stocked with fish, partial fertilization and supplementary feeding (Treatment II, T2), and the third treatment was kept as control i.e., rice without fish (Treatment III, T3).

Rice was harvested 2 weeks prior to rice harvesting in Treatments I and II. During the study, 0.5 kg pishori seedlings variety of high yield rice plants were transplanted in the paddy field after growing for a period of 1 month in the nursery, each treatment receiving 500g of rice seedlings. Fourteen (14) days after transplantation (DAT) of rice plants, advance fingerlings of Nile Tilapia (*Oreochromisniloticus*) were released in the central ditches at a stocking density of 3 fish per m^2.There were six treatments which were stocked with 50 fingerlings each. The water levels in the rice paddies were maintained at 5cm and two weeks later water was raised to 10cm in the treatments.

Sample size and Sampling Procedure

The experiment comprised of three (3) separate treatments, each replicated three times. The experiment was carried out during 2017-2018 planting season. Each of the nine experimental plots occupied an average $18m^2$ area, with a ditch of 0.5m in depth and covering an area of $1m^2$ excavated at the middle for providing shelter to fish especially when the water levels are low or when the temperatures are high. The researcher constructed water channels for supplying water to the experimental plots, each having a width of 70 cm and a depth of 30 cm. The research also constructed embankments of 0.5m high and 0.50 m wide, surrounding these plots, for protecting the ponds from flood water . Each of the dykes had water depth regulated by having a common inlet and outlet.

The study used nylon nets, fixed with sticks around each plot that had fish, to help prevent the entry of unwanted animals into the plot. The experiment comprised of 3 separate treatments, each replicated three times and each treatment laid out in a randomized complete block design

(RCBD). Two out-lets were provided to drain out the excess rain water from the rearing plot area and it was guarded by 5mm mesh size screen at the field water inlet and a 10.0 mm mesh size screen at the main water gate of the rearing plot to prevent wild fish and aquatic predators from entering fish rearing paddy fields. The trenches and paddy plots were filled with irrigation water.

Pishori seedlings variety of high yield rice plants was transplanted in the paddy field after growing for a period of 1 month in the nursery. Fourteen (14) days after transplantation (DAT) of rice plants, advance fingerlings of Nile Tilapia (Oreochromis niloticus) were released in the central ditches at a stocking density of 3 fish per m^2. The average weight of fish was taken and recorded; two weeks later water was raised to 10cm. The fish was supplied by Kenya Marine & Fisheries Research Institute of Sagana, Kenya.

Data Collection

The study collected data from primary sources. The researcher collected data about fish in terms of weight of fish at harvest, quantity of fish and survival of fish for each plot (T1 and T2). Data on rice production on each plot (T1, T2 and T3) was collected after harvesting and recorded. Researcher designed tool was used to collect data on income generated from sales of fish as well as expenses on fish culturing. Rice was cultured for 128 days while the Fish was cultured for 90 days upon which it was harvested 2 weeks prior to rice harvesting in Treatments I and II.

3.5 Data Analysis

The study sought to assess the economic viability of integrating fish into rice farming by first measuring the fish growth harvested from the rice paddies. The study established the; fish weight, survival rate and net production. At harvest, fish was weighed and the population density was recorded. Then the study obtained the total profit from fish farming using the formula

Total profit from fish farming (Kshs) = Total return (Kshs.) – Total cost (Kshs)………...(i)

Next, the study calculated economic viability on paddy rice yield to establish the production of rice based on rice yields and income from rice farming (total income/net return). The study compared the average rice yields from experimental to that from control plot.

The income from the experimental and control plots was calculated by applying the formulae:

Total profit (Kshs) = Total return (Kshs.) – Total cost (Kshs) ……………………….….(ii)

$$\text{Percent profit to investment} = \frac{\text{Total Profit (Kshs)}}{\text{Total Cost (Kshs)}} \times 100 \quad \text{.........(iii)}$$

The study compared the rice yield income from the experimental to that from the control plots

Statistical analysis was carried out by using t-test at 5% level of significance.

RESULTS AND DISCUSSIONS

The data for analysis was collected from three main sources namely; Treatment I, Treatment II and Treatment III. Treatment III, which was used for planting rice the way the famers usually do, was used as the control plot. As treatment I was used for culturing fish and plating rice, Treatment II was used for culturing fish and rice where the fish was fed using fish feeds. The study analyzed data using quantitative analysis approach to produce descriptive statistics explaining the properties and characteristics of the study variables. The key descriptive statistics used in the study include; Mean (M), Standard deviation (SD), Maximum (MAX) and Minimum (MIN).

Fish in Treatment II were fed using fish feeds which cost 400/= per kg at a rate of 60g per day which totalled at 5.4kg for the whole period of the study. The following are the total costs of production breakdown:

- Labour for clearing bush and digging cost Kes.700.00 for all treatments
- Construction of paddies Kes.700.00 for all treatments
- Rice for seedlings (1/2kg) rice @ Kes.150 per Kg
- Planting cost Kes.400 for all treatments
- Fertilizer, 663g of DAP per treatment @ Kes140 per kg
- Urea, 663g per treatment@ Kes.160 per treatment
- Fertilizer, MP, 663g per treatment @ Kes.140 per treatment
- Fish fingerings, 300 pieces @ Kes.10 per pieces totaling Kes.3000
- Fish feeds, 60g per day
- Labour for harvesting Kes.300

Table 4.1: Cost - Benefit analysis of integrating fish into rice paddies

Item	Rice fields with fish	Rice fields with fish on feed	Rice fields without fish (Control)
Stocking data			
Stocking rate	150	150	-
Average size at stocking	14.4g	14.4g	-
Average size at harvesting	44.2g	65g	-
Survival percentage	83%	90%	-
Production (Total Kgs harvested)			
Rice	14kg	16.8kg	16.2
Fish	5.5kg	8.8kg	-
Operating costs			
1. Fish fingerlings (Kshs)	1500.00	1500.00	-
2. Rice seeds (Kshs)	25.00	25.00	25.00
3. Fertilization			
DAP& MP (Kshs)	185.00	185.00	185.00
Urea (Kshs)	106.00	-	106.00
4. Fish Feeds (Kshs)	-	810.00	-
5. Labour(Kshs)	2100.00	2100.00	1,850.00
Total costs	3916.00	4,620.00	2,166.00
Returns			
Rice (Kshs)	1,960.00	2,352.00	2,268.00
Fish(Kshs)	2,200.00	3,520.00	-
Total returns	4,160.00	5,872.00	2,268.00
Net returns	244.00	1,252.00	102.00
% Net returns to operating costs	6.2%	27.1%	4.7%

Analysis by rice yield in fish integrated treatments

The table above shows that, the total production was i.e. 14Kg, 16.8Kg and 16.2Kg for treatments I, II and III respectively. In treatment I there was a slight lowering of rice yield from the fields with rice-fish culture as compared to Treatment III. However, when the fish yield was taken into account, it was noted that there was a difference in net returns between the systems with Treatment I having more net returns than the control. .The studies by Zira et al. (2014), Kumar, Chari and Vardia (2012) found that adoption of fish into rice farming increase rice production which agrees to the findings in the present study.

There was a substantial increase in rice yields in treatment II. The increase in Treatment II was attributed to improved aeration of soil and water due to fish movement, increased soil fertility as a result of fish excreta and reduced insect populations. The study by Alam et al. (2016) found that the use of IPM effectively; protects the environment, leads to high rice yields and it also creates a more sustainable agro-ecosystem. The study by Alam et al. (2016) suggests for further research biological methods for creation of a sustainable rice agro-ecosystem. The findings in the present study agree to those in the study by Alam *et al.* (2016). Balogun, Aliyu and Musa (2014) conducted a study which also showed that the use of IPM for pest control results into sustainable environment, increased economic income and ensures food security

The study found that presence of fish in the rice field boosts rice field fertility and as accordingly lowers the need for fertilizer needs. Regardless of application of fertilizer or not, the rice will have high yields. However, application of urea increases the ammonia concentration and additional fertilizer is necessary for supporting phytoplankton production. In this study it was demonstrated that rice and fish can be harvested from the same field with minimal additional expenditure. That is using fish fingerlings and feeds increases the net returns while also providing an affordable source of protein to the farmers.

Analysis by Growth of fish in both treatments

Fourteen (14) days after transplantation (DAT) of rice plants, advance fingerlings of Nile Tilapia (*Oreochromisniloticus)* were released in the central ditches at a stocking density of 3 fish per m^2. Each treatment was 3m by 6m in size. The performance of the fish, in different treatments and in terms of length and weight are captured in Table 4.2.

The fish were seen to have a growth rate of 0.46g per day in treatment I while Treatment II had fish which had a growth rate of 0.67g per day. This was attributed to feeding the fish in treatment II with artificial feeds while the ones in treatment I had to depend on phytoplankton and zooplankton. The study by Halwart *et al*. (2014) established that stocking carp fish in rice paddy highly reduced the snail densities regardless of carp stocking density, and the rate of predation of the carp increased with increased level of snail infestation. The study found that Nile tilapia significantly reduced the densities of snail and particularly during the dry season and when the fish stocking density was high.

The market price for fish is 400/= per kg while rice is sold at 140/= per kg. The highest cost of production was observed to be labour which accounted for more than 65% of the total cost in all the treatments.

The total fish production from treatments I and II was 5.5kg and 8.8kg respectively. The average fish size attained in the experiment was 65.g, which is considered undersized by the local people who are used to larger fish of over 150 g. 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. Fish yields vary widely from 50 kg/ha to 2.25 tons/ha depending on various factors such as country, fish species, density, fish diets, culture tenure and a variety of other factors.

The total fish yields were 5.5kg for 18m^2 for Treatment I and 8.8kg for 18m^2 for treatment II. Fish yields vary widely from 50 kg/ha to 2.25 tons/ha depending on various factors such as country, fish species, density, fish diets, culture tenure and a variety of other factors (Leelapatra *et al.*, 1992; Li, 1992). In our study we noted that our catch was around 50kg/ha due to the stocking density of 3fingerling per m^2 and period of study which was 90 days.

Based on the results, application of urea results in an increase of ammonia concentration in the water up to 20 ppm. Early speculations indicated that rice-fish farming might use from 50% to 100% more fertilizers than rice farming without fish (Chen 1954) where the additional fertilizer was deemed necessary to support phytoplankton production as the base of the fish culture food chain. Recent reports indicate that the presence of fish in the rice field may actually boost rice field fertility and lower fertilizer needs as evidenced by the fact that no additional fertilizer was required in the Treatment I.

The survival rate was 83 and 90% for in treatment I and II respectively both culture systems indicating good management and suitability of Nile tilapia for rice integration system.

As shown in the table above the net returns Treatment III had the highest percentage of net returns compared to production costs followed by Treatment I. Treatment II had the lowest percentage of net returns compared to production cost. Treatment II however had the largest net returns sh.5872 compared to treatment Ish.4160 and treatment III sh.2268. The fish in treatment II attained market size of 65g as a result of the use of feeds. These findings agrees to studies by Desta *et al.* (2014) and Saikia *et al*. (2015) which conclude that taking up culture of native fish in the wet rice-field would boost the rural economy through community participation. Pengseng (2013) study found that adoption of fish into rice farming increase fish yield and increases farmers' income, which was true in this study.

When fish is integrated into rice paddies, they feed on the phytoplankton and zooplankton present in the irrigated water. Additional feeding of the fish with artificial feeds increases the size and weight of the fish. However, the growth of the fish is dependent on the; size of the fish at stocking, culture period in the rice fields and the amount and quality of supplementary feed. Notably, the survival rate of fish is approximately 90% for culture systems indicating good management and suitability of Nile tilapia for rice integration system. The net returns from fish harvest are higher where fish in integrated into rice paddies than where the fish are not stocked in rice paddies. This is attributed to culture of fish which results in higher net returns.

Table 4.15: Comparison fish growth parameter between the treatments

Time of sampling	**Treatments**			
	Treatment 1		Treatment 2	
	Length(cm)	Weight (gms)	Length(cm)	Weight(gms)
July 2018	8.60±0.17[b]	14.4±0.84[a]	8.6±0.17[a]	14.4±0.84[a]
September 2018	9.84±0.20 [b]	19.35±0.60[a]	10.2±0.18[a]	26.5±0.95[b]
October 2018	11.7± 0.37 [b]	34.0±0.69[b]	12.8±0.25[b]	46±1.31[c]
November 2018	12.2±.18[b]	44.2±0.61[b]	16.4±0.15[d]	65±1.52[d]
P-value	<0.001	<0.001	<0.001	<0.001

Mean±SE followed by the same small letter within the same column do not differ significantly from one another (SNK-test,α=0.05)

The growth rate parameter of the fish showed a significant variation across the treatment groups (p<0.001,α =0.05,One-way ANOVA).The length of the fish was higher in treatment group 2 (16.40±0.15cm) while the lowest length of fish was in treatment 1 (9.84±0.22cm).The lowest weight of fish was recorded in treatment group 1 (19.35±0.60g) while treatment group 2 contained fish with the highest weight (65±1.52g).

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The study concludes that integrating Nile tilapia fish into rice farming increases rice yields. The yields from the rice paddies was slightly higher than when using the normal method. Thus, it is economical to use fish instead of pesticides in rice field. In fact on introducing fish into rice paddies eliminate the use pesticides. Growing fish in paddies has been shown to lead to a reduction of these diseases as the fish feed on the vectors. Thus, integrating fish into rice paddies leads to high rice yields and it also creates a more sustainable agro-ecosystem. This approach increases rice and fish harvest from the same field at minimal additional expenditure and with increased net returns while also providing an affordable source of protein to the farmers. Further, it has a complimentary health benefit in that water since rice paddies are kept in a continuous flow. As it leads to high rice yields, it also creates a more sustainable agro-ecosystem. It was revealed that integrated fish- rice farming ensures water use efficiency maximization and contributes to drastically reducing chemical pesticides utilization.

The study concludes that integrated rice-fish farming increase fish yield as it also increases the farmers' income. It, provides for additional income from fish yield in the land where rice is harvested, delivering a wide range of economic benefits. 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. However, the study revealed that fish in rice paddies act as control on the organisms in the water since they feed on these organisms and drastically reducing them. Integrating fish into rice farming allows the fish to feed on these pests, drastically reducing chemical pesticides utilization. This approach significantly reduces the densities of these pests, hence protecting the rice against infestation by these snails and other worms. Thus, it results into sustainable environment, increased economic income and ensures food security to the local community.

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