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Integrated Production of Rice and Fish: Toward a Sustainable Agricultural Approach

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Authors' contributions

This work was carried out in collaboration between all authors. Author FTU designed the study, carried out the field experiment and wrote a report. Author FU performed the statistical analysis and wrote the first draft of the manuscript. Author IK managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To improve the knowledge and practice of integrated agriculture (specifically rice-cum-fish) in the face of declining land availability and increasing food demand.
Study Design: Experimental study design.
Place and Duration of Study: Akperan Orshi College of Agriculture, Yandev, Nigeria, between June 1 and November 30, 2014.
Methodology: The research methodology was that of an experimental design with three plots comprising of rice mono-cropping, fish mono-culture and rice-cum-fish culture in an integrated production plot. Three plots of land were used totaling an area of 0.04025 ha (402.5 M^2). Fish was reared in an earthen pond with a total area of 0.0100 ha (100 M^2) and 1.5 M deep. Also, integrated production plot of rice-cum-fish with an area of 0.02025 ha (202.5 M^2) where the area for rice was centralized and measuring 0.0100 ha (100 M^2), leaving the remaining area of land bordering the rice plot at 0.0100 ha (100 M^2) and 1.5 m deep for rearing fish. Zero tillage was adopted for both areas allotted for the cultivation of rice to enhance sustainable agricultural practice. The research lasted for a period of 183 days. Fish in the various ponds were harvested on the same day with the

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aid of fishing gears, weighed and recorded. Rice was also harvested on the same day, trashed, winnowed weighed and recorded.
Results: The parameters considered for rice were plant height (PH), number of tillerings produced by rice and rice yield. Fish parameters include fish mean length gain (MLG), total number of fish harvested and survival rate. The average PH, number of tillers and rice yield for Rice Mono-Culture (RMC) and Integrated Production Plot (IPP) were 70.9 cm & 78.8 cm, 16 & 20, 1456 Kg/ha & 1625 kg/ha respectively. Similarly, the Fish Mean Length Gain (MLG), total number of fish harvested and the survival rate for Fish Mono-Culture (FMC) and Integrated Production Plot were 40 cm & 47 cm, 1237 & 1250 and 95% & 96% respectively.
Conclusion: Integrated farming system have a tendency of positively influencing, improving and increasing the community's rice and fish production in the face of the threatening increase in population and food demand from the results obtained. Further research could also be conduction within and outside the research area to ascertain the trends and dynamism of this system of agriculture taking into consideration global climate change.

Keywords: Fish-cum-rice; integrated farming; sustainable agriculture; Yandev.

1. INTRODUCTION

The effectiveness of any farming system can be compared with a similar practice but with varied inputs and its respective output. Integrated farming is considered to have taken its origin over 2,400 years from China [1], and it involves a dynamic system of fish poly-culture (a systematic way of rearing fish), production of poultry, livestock and crops, and the "integrated" (combined) use of manure, grass and other crops as feeds and fertilizers [2]. Integrated fish farming refers to the coordinated growing of crops as well as rearing of fish in the same plot. This could also involve the rearing of animals and fish. The most commonly known integrated systems of farming are expressed in terms of "Fish-Cum"; meaning "Fish and" others as the case may be [3,4].

In Nigeria, over 1.5 million hectares of swamp areas in Niger Delta as well as in the Niger flood plain between Yauri and Lokoja (Kebbi and Kogi States respectively) as well as the Benue flood plains show good prospects for rice-cum-fish culture. It could also be noted that potential land areas that would be put under rice production in Nigeria is estimated at about 4-6 million hectares. However, only 40% (a total of about 2 million hectares) of these lands are currently cultivated [5]. A 2003 report on potentials of rice production in Nigeria revealed that virtually all the states in Nigeria have records of rice production. However, Adamawa, Benue, Borno, Kaduna, Kano, Niger and Taraba states (just about seven states out of the thirty-three) make up 50% of the total area of rice cultivation in the country. In Nigeria, Integrated farming is practiced either as capture or traditional method or as culture method [6].

1.1 Traditional or Capture Method

Traditional method refers to a practice whereby wild fish species mainly, catfish; *Clarias* and *Hetrobranchus* which enter the flooded rice paddies from streams or irrigation canals are trapped and allowed to grow along with the rice. When the rice is harvested, fish are captured for sales or consumption. The catfish species (*Clarias* and *Hetrobranchus*) are mostly caught in this type of system since they have the ability to move 169m from one environment to another with or without water [7]. Also, these leads to abundant silt deterioration of the flood water and on the other hand, pond silt is high in terms of quality manure for the crops cultivated. More also, the crops in turn could be used as fish feeds [8].

About 2.6 million hectares of seasonal flood plains, where water remains for 4-6 months is effectively utilized for integrated farming in India [6]. These are traditionally rice farming zones and owned mostly by small scale farmers. Trapping fish in such rice fields is a traditional practice [9]. Most of the farmers have small ponds, measuring 25-30M^2 in their rice fields which are used to harvest rain water for irrigating land during puddling and to trap fish which has entered after rice has been transplanted with flooded water. This rice flood offers an additional area for producing fish and increasing farm income by employing appropriate technology. It is hereby pertinent to note that only a limited number of farmers with high access to technology and extension have adopted Rice-cum-fish farming in the Nigeria as a part of developmental schemes of various agencies. The regular adoption of this technology is yet insignificant [6]. Presently rice-cum-fish farming

is not practiced in Nigeria as a culture system. The common practice is the capture method. It is also the first method initially adopted by the Asian countries before the concurrent or rotational methods.

1.2 Culture Method

Most of the rice-cum-fish culture methods in Nigeria have been on experimental basis [9]. The cost-benefit analysis of rice monoculture, fish monoculture and rice-cum-fish culture and that rice-cum-fish culture system gives an increase in rice yield and increase in revenue due to inclusion of fish in the culture system has been a means for justification. According to [10], rice-cum-fish farming started in Nigeria at New Bussa on a farmer's plot at Karabande, New Bussa, where a farmer used the run-off from water running through the power generation turbines at Kainji dam to grow rice and fish twice in a year. They further noted that the trials, however, did not last long as the farmer lost his source of water in the later years [11]. This attempt paved way for a series of studies with National Cereals Research Institute (NCRI) at their Rice Experimental Farm, Badeggi (Niger State) and at Iddo and Gwagwalada farms of Abuja in the FCT through the Agricultural Development Projects (ADPs) and at the Dadin-Kowa (Gombe State) sub-station of the institution and their results were encouraging [10]. The research was however, based on the study of the growth performance of the fish species and the yields as well as On-farm adaptive nature of both rice and fish [5]. Presently, conscious efforts by NSPFS to sensitize and create awareness of the rice-cum-fish Technology through farmer participatory demonstrations are in place. All the efforts are research work to demonstrate and show rural farmers the technical and economic viability of rice-cum-fish farming in Nigeria [5].

1.3 Water Recycling in Integrated Farming System

The most difficult challenge with fresh water aquaculture is the fact that it requires a huge volume of water per annum (about 1 million gallons of water per acre) ($1M^3$ of water per M^2) [12]. This calls for extended water purification system for reuse and recycling of local water. Water recycling refers to the treatment of used water in the pond either naturally or artificially for further fish culture [13]. The use of hydroponic beds has been an effective means of recycling in fish culture over the years. This is basically carried out in such a way that, large plastic fish tanks are placed in a green house. A hydroponic bed is also placed near them above or between the tanks. When the fish is raised in the tanks, they are able to eat algae, which naturally grow in the tanks when the tanks are properly fertilized. This however, is the natural way of recycling the water in the pond for fish culture [14]. Artificially, the water in the tank is slowly circulated in the hydroponic beds where the fish waste feeds a commercial plant crops. Carefully cultured micro organisms in the hydroponic beds converts ammonia into nitrates and the plants are fertilized by the nitrates and phosphates. Other wastes are strained out by the hydroponic media which bubbles as an aerated pebble-bed filter [15]. A wild variety of plant organisms can grow well in the hydroponic beds. The advantage of using the hydroponic beds is that, since the system is place in a green house, its adaptability to all regions and climates both temperate and tropical regions is sure [15]. The main environmental impact of water recycling in ponds is that it frequently discharges the water that could increase the salinity of water and it maintains the fish's electrolytic balances [16]. Recent growers make use of discretional measures to maintain the fish health, reducing their salt and waste water discharge permits. A common means of purification is the use of calcium compounds which will reduce the turbidity rate in ponds. However, limestone also known as agricultural lime ($Caco_3$) has been effective means of treating ponds in fish culture. However, some veterinary authorities speculate that ultraviolet ozone disinfectant systems (widely used for ornamental fish) plays prominent role in keeping the fish healthy with recycled water [16]. Experience from this research also show that sodium chloride (table salt) could also be used for treatment in fish culture especially when infected by fungi (Field work, 2014).

2. EXPERIMENTAL DETAILS AND METHODOLOGY

2.1 Study Area

AkperanOrshi College of Agriculture, Yandev (AOCAY), the study area, is located in Gboko LGA. Gboko LGA is located between Latitudes 07°08' 16" and 07°31' 58" and Longitudes 08°37' 46" and 09°10' 31"and is bounded to the north and north-east by Tarka and Buruku LGAs, to the south by Ushongo LGA, to the south-west and west by Konshisha and Gwer-East LGAs, respectively. The central location of AOCAY is at

Latitude 07°22' 08"N and Longitude 09°03' 01"E, at about 728 feet above sea level (Figs. 1 & 2).

The study area is located within the general area of the Benue trough, which is largely covered by Cretaceous continental (to the North) and marine (to the South) sediments [17]. The Benue floodplain is filled with Quaternary heterogeneous sediments [18], while its geology is a combination of the pre-Cambrian basement comprising the lower and upper Cretaceous sediments in addition to some volcanic deposits [19]. Generally, the soils of the Benue floodplains are alluvial although, heterogeneous and the soils are superior agriculturally to the adjoining upland soils derived from sandstones. The soils of this region in which the study area is found are classified as Acrisols (Ortic and Feric subgroups) Dystric Cambisols [20]. The well drained soils of the study area have pre-dominantly low activity clay fractions (Kandic property), low to medium base status and nutrient retaining capacities like most other upland soils of the sub-humid region [18]. The soils dominated by southern guinea savanna vegetation, although at present, extensive cultivation, annual bush-burning and several other anthropogenic activities have transformed the vegetation into shrubs and bushes [21].

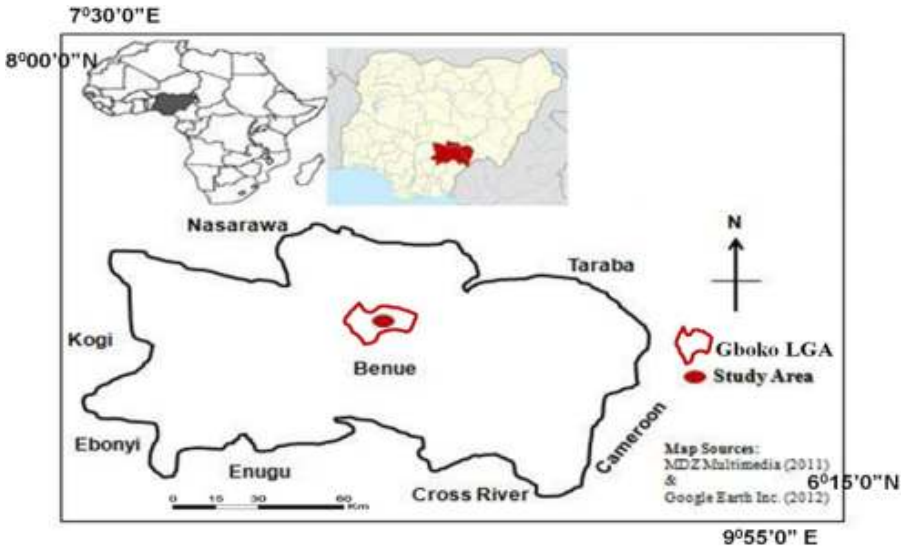

Fig. 1. Contextual location of the study area

Fig. 2. Google earth image (2012) of AOCAY

2.2 Experimental Details

2.2.1 Experimental layout

The experiment was conducted on a field located North-East of the institution (AOCAY). The amount of rainfall for that period was recorded as 1146.50 mm while the average rainfall for the period was recorded as 286.63 mm. The average minimum and maximum temperature for the period were recorded as 25.57℃ and 30.93℃, respectively. The experimental design is one with rice mono-cropping, fish mono-culture and rice-cum-fish in an integrated production plot (see Fig. 3). Three plots of lands were used totaling an area of 0.04025 ha. Fish was reared in an earthen pond with a total area of 0.0100 ha as well. Also, integrated production plot of rice-cum-fish with an area of 0.02025 ha where the portion for rice was centralized and with an area of 0.0100 ha, leaving the remaining area of land bordering the rice plot at 0.0100 ha and 1.5m deep for rearing fish. Zero tillage was adopted for both areas designed for the cultivation of rice. This was also an attempt to ensure optimal seed bed preparation, effective weed control, controlled evaporation and enhanced water infiltration, erosion control, less or no soil disturbance, conforming to the contemporary cultural practice as well as to have less effect on the ecosystem as suggested by [22]. The research lasted for a period of 183 days (between June 1 and November 30, 2014). Fish was harvested on this date from both ponds using fishing gears (drag and scoop nets). Rice also, was harvested, trashed and winnowed and seeds were collected.

2.2.2 Equipment and materials

In the course of this field experiment, the study utilized several simple farm implement, inputs, equipment and organic compounds. These include:

i. 0.0100 ha area of land for rice mono cropping.
ii. Treated paddy rice (FARO 52).
iii. Earthen pond with an area 0.0100 ha and 1.5 m deep.
iv. 0.02025 plot of land designed for integrated production of rice and fish.
v. Fish feeds (Vital feed and Multi feed).
vi. Juveniles of average length of 25 cm (2, 600).
vii. Measuring tape (Fiber glass type).
viii. Lines for measurement.
ix. Shovel.
x. Suspended/muddy water for pond sealing.
xi. Fishing gear (net and others).
xii. Recording materials (pen, paper, drawing paper, straight edge, etc).
xiii. Tank for Harvesting and storage of fish.
xiv. Weighing scale.
xv. Threshing stick.
xvi. Sacks.
xvii. Sickle.
xviii. Buckets.

2.2.3 Planting

20 kgs of treated paddy rice (FARO-52) was raised on two separate beds weighing 10 kgs each. They were transplanted to the plot after 2weeks of nursery to their various experimental plots (see Fig. 3 for experimental plot layout). Zero tillage was adopted for uniformity of the experimental treatment since the integrated plot could not be tilled.

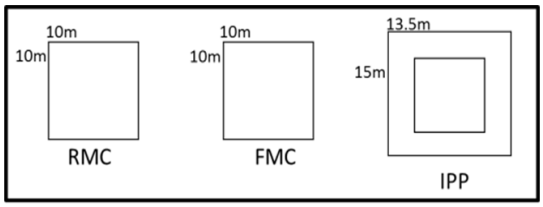

Fig. 3. Experimental layout for the study [RMC (Rice); FMC (fish) and IPP (fish-cum-rice)]

2.2.4 Weed control

The weed control measures adapted was the manual method by uprooting the weeds on both plots of cultivated rice and it was carried out twice within the duration of experiment. Chemical means of weed control was excluded to ensure that elements or agents capable of causing pollution to the ponds and/or mortality of fish were avoided.

2.2.5 Harvest

After the period of 4 months, the cultivated rice reached its maturity and ready for harvest. The matured rice was harvested using sickle. The harvested rice was hand-threshed and winnowed to separate the grains from the chaff and weighed to determine its weight.

3. RESULTS

The results shown below indicate that rice and fish yields in the integrated production plot were better with respect to the parameters under evaluation. Given that the method of planting, tillage operation and the experimental research period was same, the basis for comparison was established. Generally, the results show that average plant height, number of tillers produced and the yield of rice under mono-culture were 93 cm, 16 and 112 kg (1344 kg/ha) respectively whereas, the average plant height, number of tillers produced and the yield of rice in an integrated production plot were 96 cm, 20 and 125 kg (1500 kg/ha), respectively. Specific analyses are shown under subsequent sections.

3.1 Plant Performance Analysis

Specifically, plant performance analysis was considered under plant height (measured in centimeters) at four different intervals as shown in Table 1. Number of tillers produced by rice was another parameter considered under plant performance. The number of tillerings produced was recorded at four different intervals within the period of research. Table 2 shows the details of performance of rice recorded during the research period.

3.2 Crop Yield Analysis

This research considered Crop yield as the most important parameter for comparing the performance of rice in a mono-cropped plot on the one hand, and in the integrated plot on the other hand. Table 3 presents the results of crop yield from the research work carried out.

3.3 Fish Performance Analysis

Fish (Catfish; *Clarias*) performance analysis in both cultured pond and integrated production plot was based on the average mean length gain, total number of fish harvested after the research period of four (4) months and the survival rate. Table 4 represents the results and the summary of the comparative performance of fish both in the normal cultured pond and that of the integrated production plot.

Table 1. Rice performance under plant height

Treatment	Observed plant height				
	1st	2nd	3rd	4th	Mean
RMC	31.8	54.2	90.0	107.5	70.9
IPP	44.3	75.0	85.3	110.7	78.8

Source: Fieldwork, 2014

Table 2. Rice performance under number of tillers produced

Treatment	Observed plant height				
	1st	2nd	3rd	4th	Mean
RMC	5	12	16	16	16
IPP	7	12	20	20	20

Source: Fieldwork, 2014; RMC= rice mono-culture; IPP= integrated production plot

Table 3. Crop yield

Treatment	Crop yield (kg)	Yield rate (kg/ha)	Total
RMC	112	1344	1456
IPP	125	1500	1625

Table 4. Fish yield

Treatment	Comparative factors	
	Normal fish culture	Integrated production plot
No. of fish stocked	1300	1300
Initial mean length (cm)	25	25
Final mean length (cm)	63	70
Mean length gain (cm)	40	47
Total No. of fish harvested	1237	1250
Survival rate (%)	95	96

4. DISCUSSION

Integrated farming is justified to be significant in diverse measures. In an integrated production plot, Micro-biological activities are higher, the ecosystem is gradually boosted which improves and enhances the micro- biological activities in the pond for both fish and rice growth. This is practical as the oxygen gas expelled by the plant is absorbed by the fish and the carbon II oxide gas expelled by the fish is used up by the crop in the pond [23]. Fish-cum-crop integration increases the number of feed and fertilizer sources is relatively stable; the cost could be reduced by one third and the quality of feed and fertilizer is very high. In addition, the energy consumed in transporting and purchasing feeds and fertilizer could be reduced [24]. A well-managed fish-cum-crop integration is a self-sufficient system. Pond silt is used to fertilize the fodder crops that in turn are used to feed the fish. As the fish grows, pond silt accumulates. This cycle fully utilizes sunlight, land, pond silt and fertile pond water and these improves the ecological condition of the pond; it has been reported that planting grass on the pond dykes reduces the soul erosion by 57%. Fish farming is a seasonal work. The input of labour varies greatly. In the slack season, excess labour can be used for crop production. This provides more job and increases income [8]. Also, Pond silt can be directly used as base manure for fodder crops. Pond silt is safe manure. The amount applied is not necessarily limited. This method is beneficial to the release and diffusion of nutritional elements. It also improves the dissolved oxygen content of the base layer of water [4].

It is evident that integrated system of farming is on a low scale in Nigeria. However, the research was aimed at; encouraging and determining the symbiotic ecological relationship between the rice and the fish within the same pond for maximum yield, farming system approaches such as the development of participatory extension methods, biological processes such as the effect of feeding and maturing rates on fish growth, ecological systems capable of encouraging maximum micro-biological activities in the ponds and the Studies of production economics and financial elements of farm operation [25]. This research is also geared towards proving the viability of integrated farming within the research area and in Nigeria at large. More to that, it is an attempt to work in line with the Federal Government of Nigeria`s agricultural transformation agenda hence through improved agricultural practices. From the results of the experiment carried out, the two factors rice and fish under comparative study were considered on the mono cropping as to the former and sole rearing as to the latter. However, their integration was also considered in an integrated production plot.

Considering the above mentioned factors and relating them with the results, it is paramount and evident to express the comparative nature of this research as the average plant height (PH) of rice in the integrated production plot to be seven (7) points better than that of the mono cultured plot; also that, the number of Tillers produced were in a differential value of six (6) points; the yield on the other hand is what appreciated the research work to produce more in the integrated plot than in the other plot. Careful examination of the fish performance also relates the fact that, the Final Mean length (FML), the Mean Length Gain(MLG), the total number of fish harvested and the survival rate from the integrated production plot and the mono cultured plot were 70 cm as against 63 cm, 47 cm as against 40 cm, 1250 as against 1237 and 96% as against 95% respectively.

5. CONCLUSION

From the results of the research, it can be deduced on a final note and with the conclusion that, integrated farming is viable at Yandev the study area and also has the tendencies of positively influencing, improving and increasing the community`s rice and fish yield. However, the conventional way of both capture and culture methods of fish management as well as the usual tillage operation of rice cultivation may have to be contended with the advent of this system of farming.

With the increasing demand of Rice, both as a major cash and stable crop for the teeming population of the study area and Nigeria at large, there is indeed the need for an efficient way of Rice production in reasonably large quantities to meet up with increasing food demand. Fish on the other hand is very essential due to its high nutritional, medicinal and industrial value. This also calls for an improved way of growing Fish to meet such high demand. In addition, the current decline in international oil prices have resulted in increasing decline in Nigeria’s foreign reserve.

The need to diversify Nigeria's economy calls for an inward approach to self-sufficiency in rice production. This is more so as huge foreign reserves, estimated at over USD2 billion annually, is expended on the importation of rice for local consumption. This approach is expected to boost local rice sufficiency while also scaling down dependence on foreign rice imports, which ultimately saves the Nigerian Government billions of dollars in foreign reserves.

Therefore, from the results of the study, it is suggested that;

i. Integration of Rice and Fish should be fully adopted at Yandev for better yield and results;
ii. The Government at all tiers and through their Agencies should encourage farmers in embarking on this system of agriculture for better results and to ensure maximum food security. Specifically, the approach should be incorporated into the current Central Bank of Nigeria's agricultural improvement policy;
iii. Similar studies should be embarked upon periodically to further ascertain the trends and dynamism in this system of agriculture taking into consideration the consistently changing global climate systems and improved seed technologies and fish species.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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