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Eco-economic assessment of rice culture using pisces as alternative method of weed control in Southern Cross River State, Nigeria

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Abstract. This study investigated the ecology and economics of a rice/fish culture system in Calabar, Cross River State, Nigeria. Swamp water rice was cultivated normally as practiced in the study area; in plots of 100 m^2 each in which sumps of one tenth of surface area were dug to serve as refuge areas for fish. Four treatments comprised of control (rice cultivation only without any form of weed control), rice only but using Butachlor as chemical weed control method, rice + *Oreochromis niloticus* and rice + *O. niloticus* + *Heterobranchus longifilis.* This experiment had three replicates. Observation showed that there were no significant differences between treatments in some water qualities as temperature, phosphate concentration, alkalinity and total hardness. Ph was higher in control compared to other treatments. Significant differences occurred in nitrates concentration and dissolved oxygen concentration. Plankton count was lower in plots with fish, possibly because of the fish's grazing actions. The culture system recommended for small scale farmers is the rice + *O. niloticus* + *H. longifilis* due to the fact that it could provide higher varieties of food stuff with an increased income to the farmers.

Key Words: Ecology, economics, herbicides, weeds management, fish and rice production, Calabar.

Introduction. Weed control has been a major problem in food production (De Datta & Baltazar 1996; Labrada 1996). Several methods of weed control have been practiced. Water depth regulation is an effective and important method of controlling weeds in rice and fish ponds, because weeds find it difficult to germinate in flooded conditions. Weed densities decrease as water depth increases. But continuous flooding usually results in establishment of aquatic species. So flooding can not totally eradicate the problem and could become impracticable in non swamp rice species.

Since herbicides are able to destroy weeds on a large scale before or on emergence without interfering with the crops and without heavy dependence on human labor, their importance has been and will continue to be felt. Their rate of use is expected to increase in the tropics in the nearest future, especially as crop that are genetically modified to tolerate herbicides are continuing to emerge (Cox 2004; Asogwa & Dongo 2009). Cengiz et al (2001) showed that herbicides work at extremely low concentrations. At wrong or too high, or accumulated concentrations, these chemicals act as poisons. Some techniques used in agricultural mechanization are difficult as many African villages have little arable land space per farmer (Offem et al 2010). The use of herbicide in such subsistence farming has been possible due to some herbicide selectivity. Because of subsistence farming, mixed cropping has been possible for it is more difficult to practice mechanized farming system using mixed cropping (Taylor et al 1988).

However, pesticides directly or indirectly influence the wellbeing of some aquatic ecosystem as well as man. The residues of these chemicals including soaps and detergents end up in the aquatic ecosystems (Ogundele et al 2004). In the aquatic environment, these chemicals may adversely affect many none target organisms such as fish (Svoboda et al 2001; Ada et al 2011, 2012).

The uses of herbicides have become particularly relevant only in the past five decades, yet it is becoming progressively difficult in rice fields (Stanley Alliance Info-Tech Limited 2011). Reports of reduced efficacy in weed management have started emerging. In fields where Atrazine has been repeatedly used, there are microbes that use it as substrate, thereby reducing the herbicide effectiveness in subsequent applications (Krutz et al 2008). Some other herbicides that are not easily degraded example DDT can be transferred from one location to the other through water flow or by bioaccumulation along food chains (Shallangwa & Auta 2008; USEPA 2000).

Other methods of weed control include biological methods that involve transplanting seedlings which give the crop a period of growth advantage over the weeds. Some cultivars are important in this method because they have competitive ability against weeds. Cultivars with greater seedling vigor, greater leaf area development, greater early height, growth rates, and greater tillering ability are probably more competitive. Important also is the plant density because the closer the plants are sown, the more competitive they are against weeds. Greater plant densities may allow the crop canopy to close sooner, reducing weed germination and growth. The use of plants or fish to control weeds and to serve the function of fertilizer has been going on in Asia but has not been well investigated in Nigeria (Sollows & Tongpan 1986; FAO Corporate Document Repository 2012). Investigations into alternative methods of weed control that are environment friendly are needed.

Material and Method

Study area. The study was carried out in Cross River State of Nigeria. Cross River State is located in South-Eastern Nigeria between latitude 4° - 7° N and longitude 7°15 - 9°30 E, and has boundaries in the south by the Atlantic Ocean, east by the Republic of Cameroon and the Nigerian states of Benue in the north, Ebonyi and Abia in the west and Akwa Ibom in the south-west. The climate of the study area comprises a wet season (April - October) characterized by high rainfall (3050 ± 230 mm) and a dry season (November - March) marked with low rainfall (300 ± 23 mm) (Offem et al 2011). Temperatures range from 15.5 °C ± 7.6 °C in the wet season to 32.6 °C ± 5.4 °C in the dry season.

Experimental design. The experiment was made of (1) control, in which only rice was cultivated, (2) only rice treated with Butachlor herbicide to control weed, (3) rice + *Oreochromis niloticus* and (4) rice + *O. niloticus* + *Heterobranchus longifilis*. These treatments were assigned to plots randomly with three replications. Site preparation was the normal method used by the traditional rice farmers in the area. Construction of plots took place in 1995. Rice lasted for 30 ± 2 days in the nursery. Bonds were built round each plot of 100 m^2 as described by Subramanian (1988). Trenches of average depth of 1 m covering one tenth of a pond area were dug in plots where fish were stocked only. Trenches were removed 60 cm away from the bonds to prevent collapse of dykes (bunds). Transplanting of rice occurred in first week of April, 1995 after urea was applied two days earlier at the rate of 1 kg/plot (Delacruz 1988). Spacing was 40 cm by 40 cm and two seedlings per stand.

Fish were stocked in plots 30 days after rice transplantation to allow rice establish roots. *O. niloticus* fingerlings at weight of 20.18 ± 2.12 g and length of 10.23 ± 1.03 cm; and *H. longifilis* at weight of 1.34 ± 0.22 and length of 6.01 ± 1.87 cm were stocked at the ratio of 3:1 where rice and fish were cultured. Stocking density was 50 fish/plot of one acre (100 m^2 = 5000 fish/ha). Butachlor, a pre-emergence (PRE), translocated, and selective herbicide, was applied at 1 kg/plot before planting rice.

Plankton was sampled every fortnight. Each sample ready for analysis was a composite of four samples from different locations within the same paddy field. Bottom mud was sampled using screw top polythene bottle. Quantitative and qualitative analysis of samples were carried out using an inverted microscope within six hours. Plankton was identified with at magnification of x100 using keys given by APHA (1980), Kadiri (1988), and Kemdirim (2001).

pH, temperature and oxygen concentration were measured electronically with the help of pH meter model number WTH PH 90 and WTH OXI 196. Nitrate, total hardness, alkalinity and orthophosphate were analyzed using standard methods (APHA, 1980).

Rice and fish yield estimation. Rice yield was estimated using Ito & Hayashi (1969) method of rice yield estimation. A quadrate of size 1 m^2 was cast in five different locations at random in each plot. The number of pinnacle per cast was counted. Thirty pinnacles per cast were considered for grain number per plot. The weight of 1000 grains was measure and the yield given by the weight of one grain multiplied by estimated number of grain per plot.

Due to differences in cash value of *O. niloticus* and *H. longifilis*, they were converted to money value as at the time of harvest obtained at the Institute of Oceanography, University of Calabar, Nigeria.

Statistical analysis. Factorial analysis was carried out using a computer programme SPSS (statistics for social sciences) version 17 in a one way analysis of variance (ANOVA) for analysis of interactions between the different environmental factors, time and culture techniques (rice, Butachlor and fish). Fish and rice yields as well as mean plankton count and water quality parameters were analyzed using one way (ANAOVA) at 0.05 % level of significance. Means were separated in a post hoc analysis by Duncan's multiple range tests.

Results and Discussion. The present phytoplankton included *Chlorella, Closterium, Ankistrodesmus, Euglena, Nitzschia, Spirogyra*, *Navicula, Lepocinclis and Chlamydomonas* species, *Gymnodinium aeruginosa, Cryptomonas splendida, Tetraedron regulare, Selenastrum gracile and Oscillatoria rubescens* as shown in figure 1.

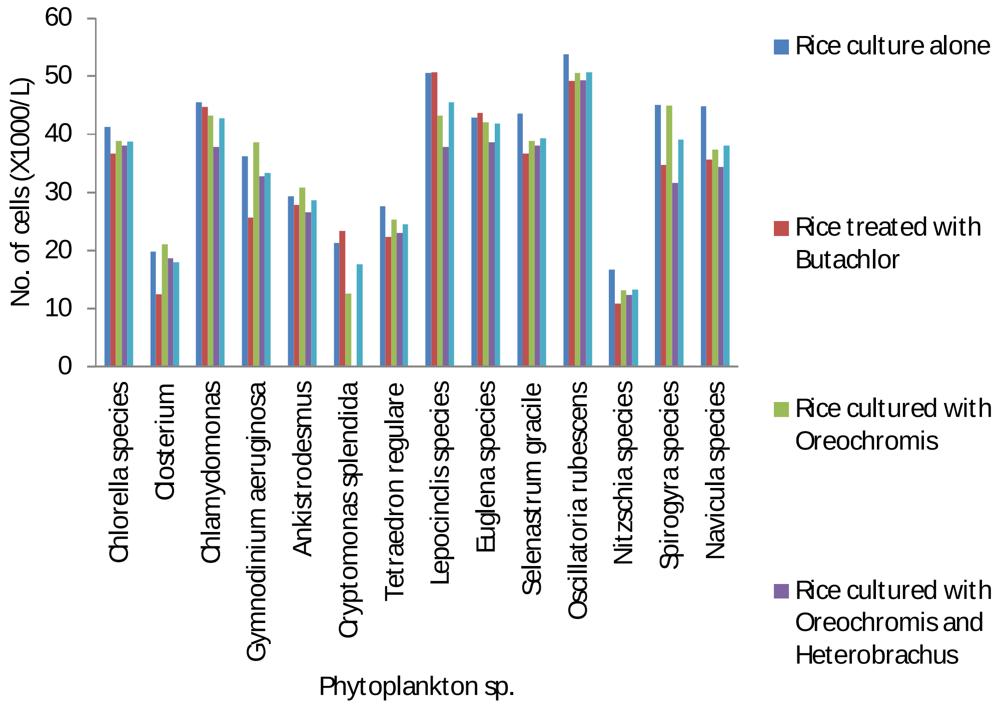

Figure 1. The species of phytoplankton present in the various treatments and their quantities. Population of plankton is in thousand per liter.

The zooplankton present included Proales, Colpoda, Didinium, Paramecium, Tintinnopsis species and Trachelomonas volvocina (Figure 2). Crustacean, worm and larvae population is displayed in figure 3, while figures 4 to 10 show water quality parameters such as pH, temperature, dissolved oxygen, nitrates, total hardness, alkalinity and phosphorus concentration in that order.

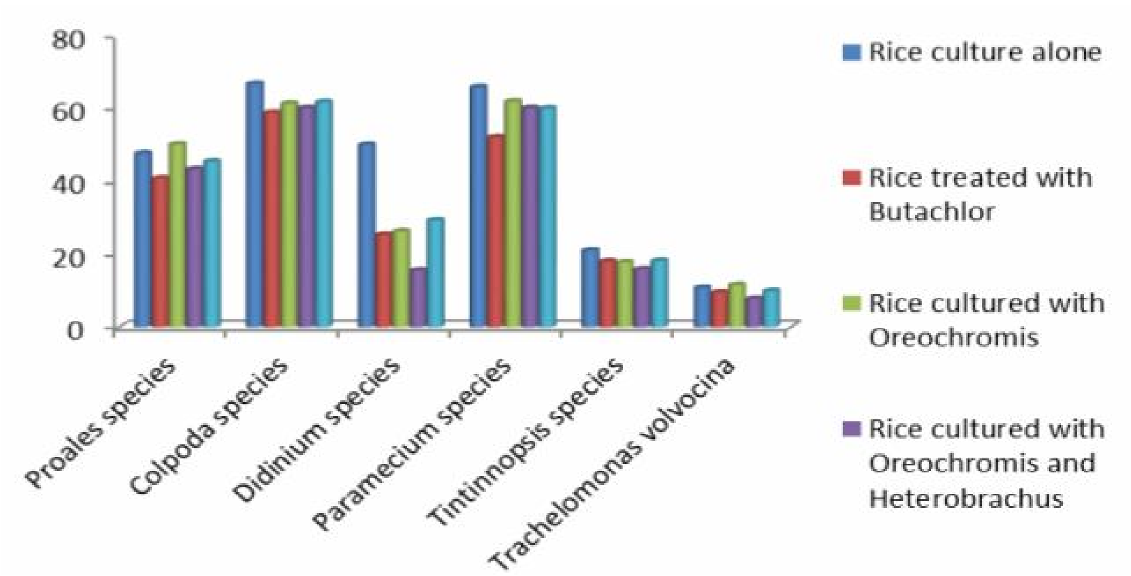

Figure 2. Zooplankton species present and their quantities. Population is in thousand per liter.

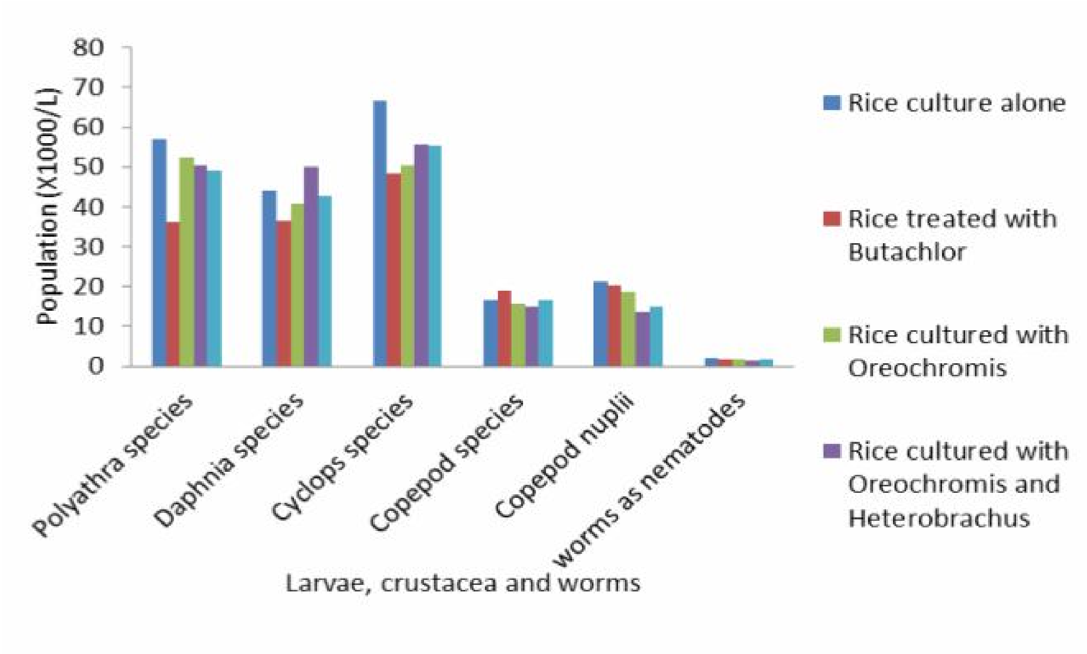

Figure 3. Quantities of crustaceans, larvae and worms in different treatment plots. Quantities are expressed as number of thousand per liter of water or bottom mud.

Butachlor application has however, resulted in fewer population of plankton possibly due to direct poisoning (Offem et al 2010). Fewer numbers of worms in treatments with *H. longifilis* could be due to its benthic feeding habits, which is equally helpful in soil aeration.

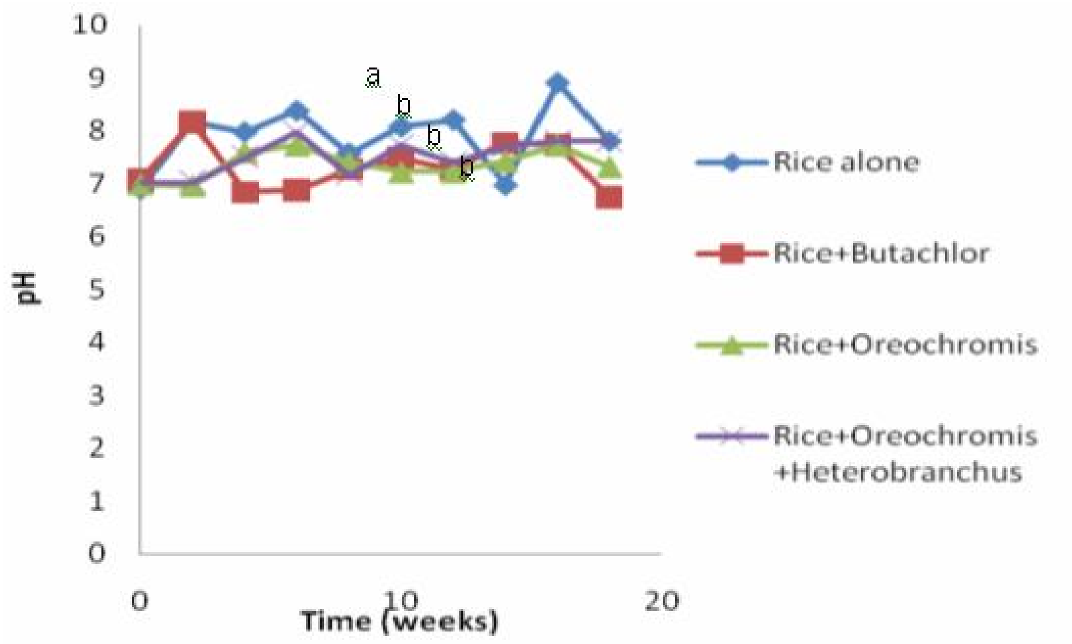

Figure 4. Hydrogen ion concentrations in the various treatments. There were significant differences in pH of plots with rice alone while other treatments were the same statistically. Graphs with the same letters show that there were no significant differences among the pH mean.

Water quality parameter such as temperature was the same in all the treatments because the treatments could not have thermal effects on the water. But all the graphs showed downward slopping with time towards the wet season. The reduction in temperature with time is therefore due to season (Figure 5).

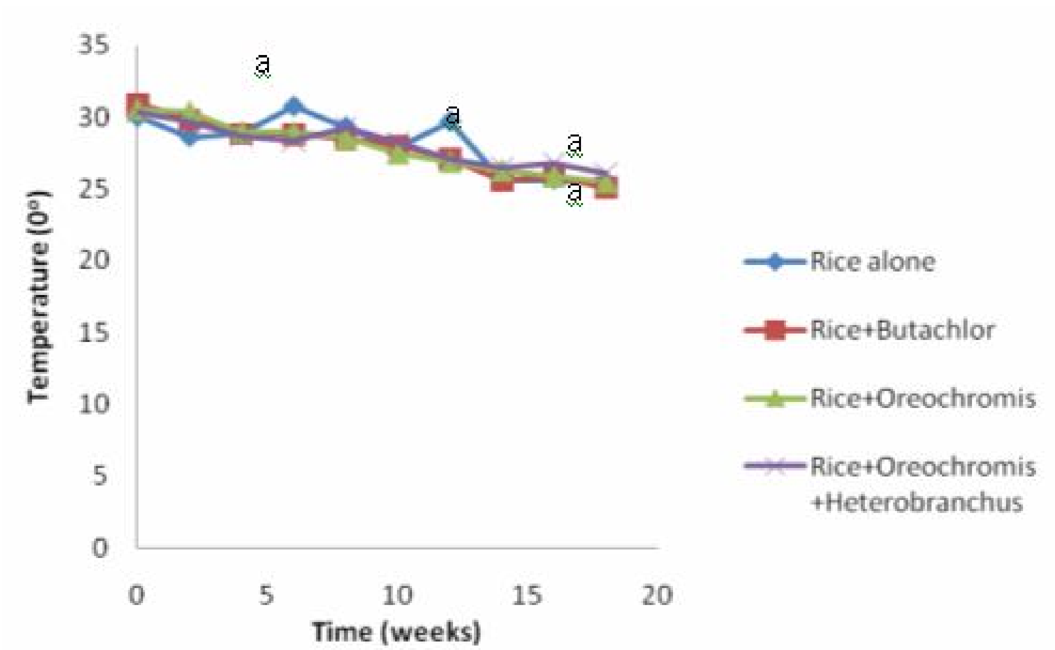

Figure 5. Temperature (^{o}C) in the various treatments. There were no significant differences in temperature between treatments.

Dissolved oxygen was lowest in treatment with rice + Butachlor and highest in treatment with control (rice alone). Plankton may have been responsible for enhanced oxygen production. Treatments with fish did not hinder oxygen production as dissolved oxygen concentration was still within optimal values for plankton production (Figure 6).

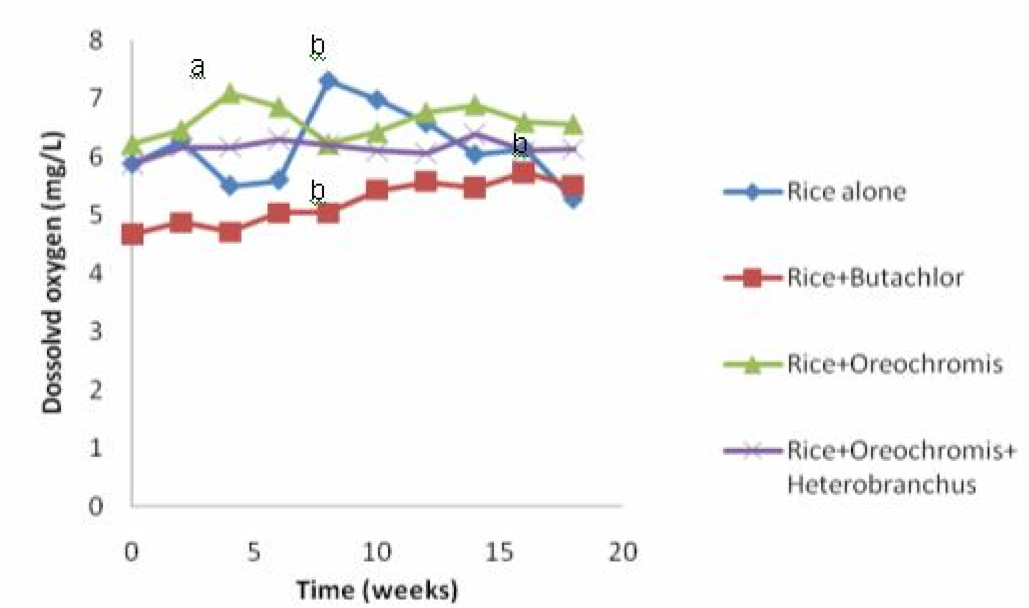

Figure 6. Dissolved oxygen concentration in various treatments. Rice alone has the highest concentration of dissolved oxygen. Rice + Butachlor have the lowest dissolved oxygen. Similar letters signify statistically similar means.

The higher concentration of nitrates in plots with rice + fish could be due to the tumbling action of *H. longifilis* to raise the bottom nutrients. These nutrients were expected to enhance the growth of plankton. Instead, plankton population in these plots was observed to be lower. This may be due to the grazing action of the fish (*O. niloticus).* The culture system is therefore an optimal one (Figure 7).

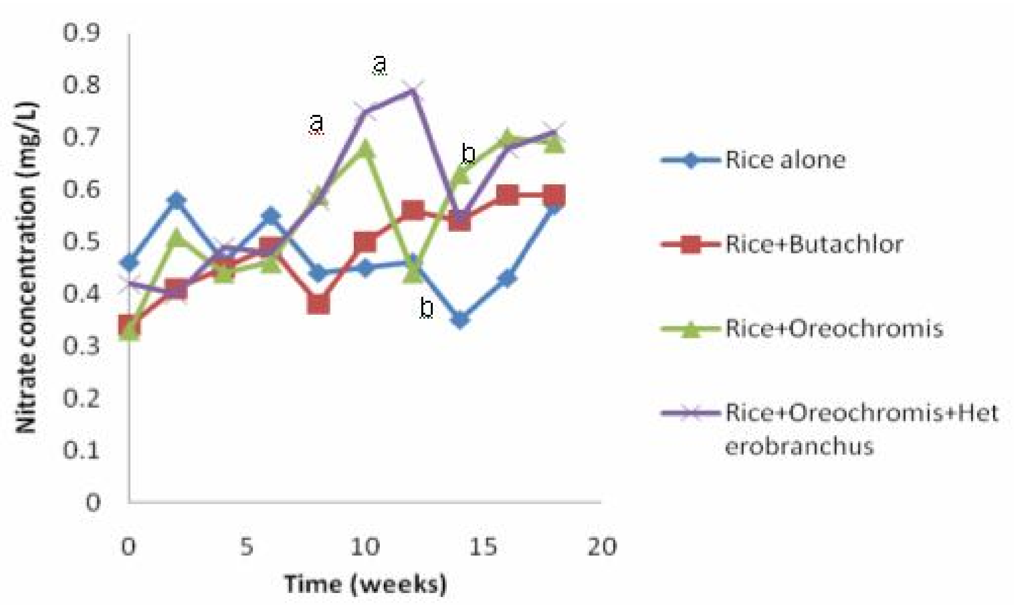

Figure 7. Nitrate concentrations in the various treatments. Graphs carrying the same letters signify that the nitrate concentrations were the same while those carrying different letters show that the nitrate concentrations were different.

Total hardness, alkalinity and phosphate concentration were also not significantly different between treatments. This could be explained on the basis that treatments did not influence these parameters. Similar concentration of phosphate could be due fertilizer applied and which probably was not differentially absorbed by fish nor degraded by Butachlor (Figure 8-10).

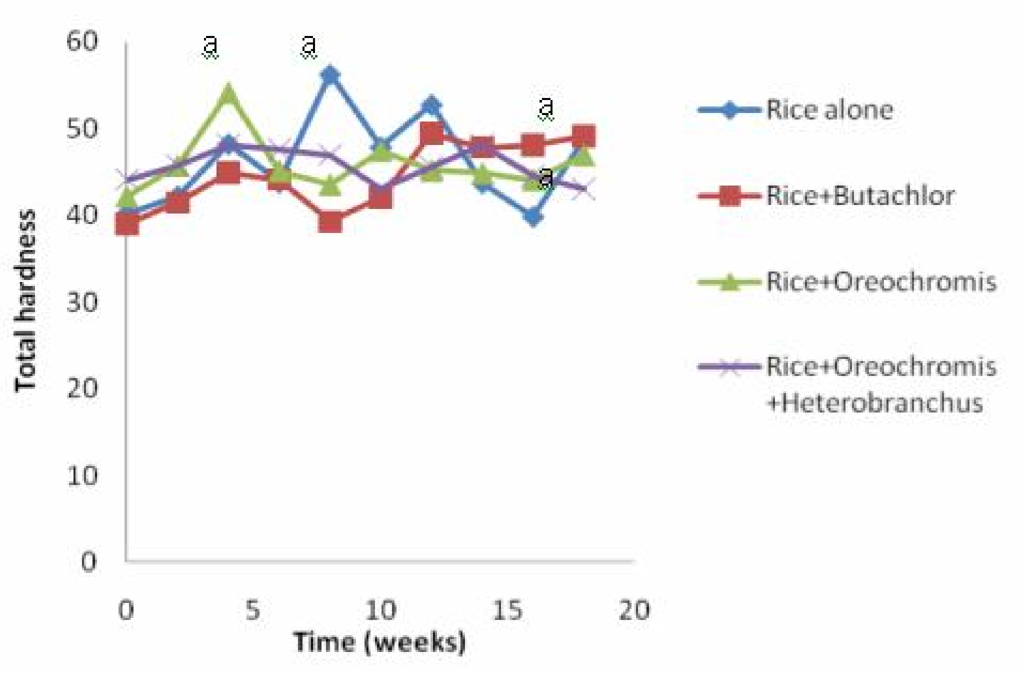

Figure 8. Mean of total hardness among treatments. There were no significant differences among the mean total hardness as it shown. Graph bearing the same letters do not differ from one another.

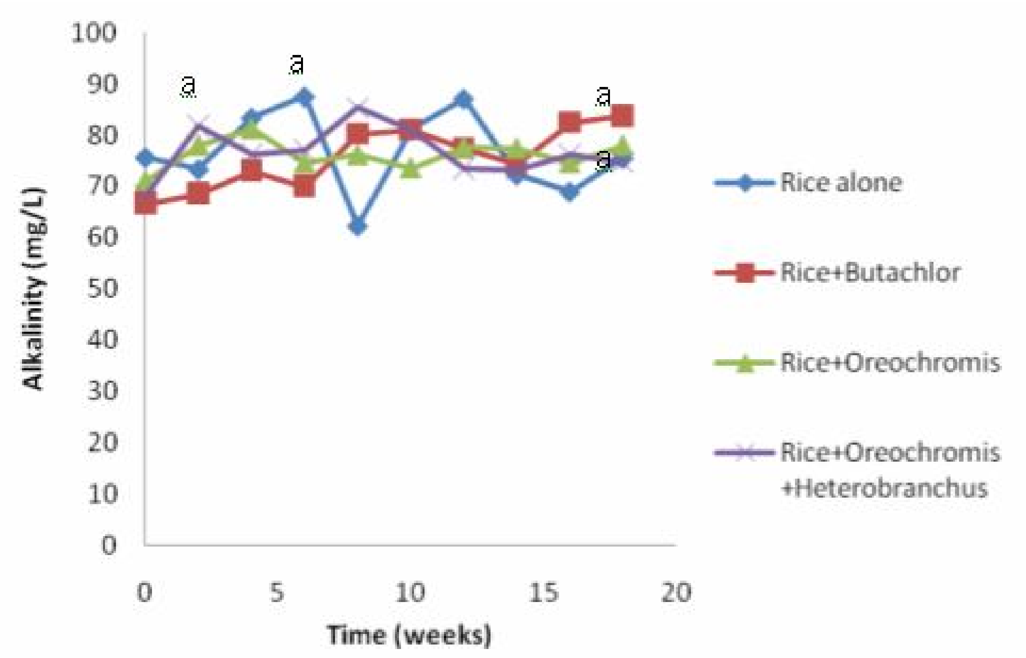

Figure 9. Alkalinity in the various treatments. There were no significant differencs in alkalinity among the treatments.

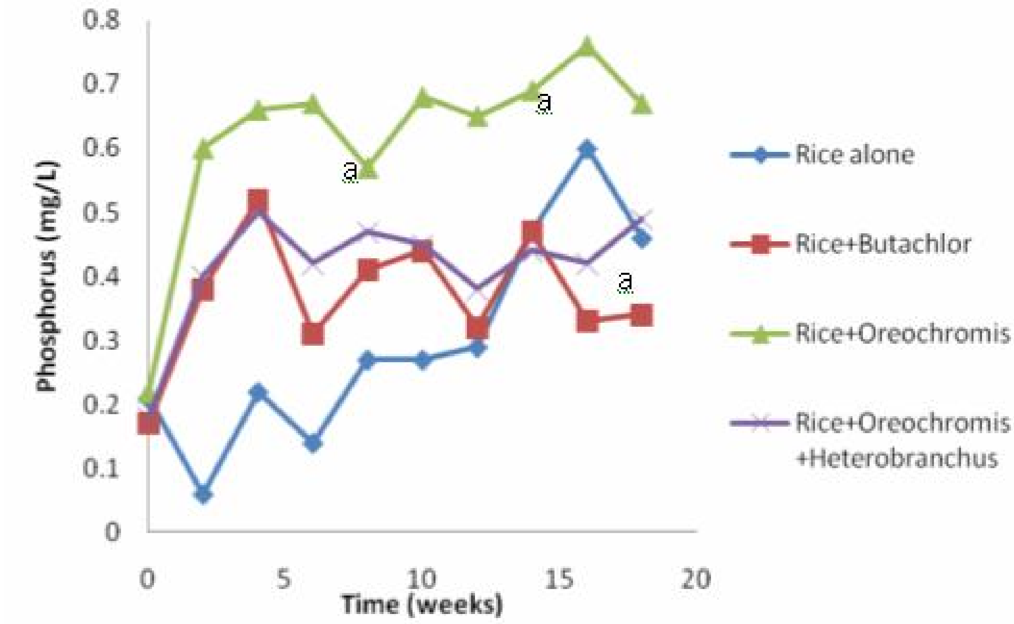

Figure 10. The concentration of phosphate in various treatments. There were no statistical significant differences among the mean concentrations. However, the magnitudes of phosphate concentrations were not the same.

There were no significant differences in the yield of rice between treatments, despite the higher absolute values in output from treatment with rice + *O. niloticus* + *H. longifilis*. Fish yield in terms of cash realized was also not statistically different. The total output of rice and fish together was observed to be significantly different. The income realized was higher in treatment with rice, *O. niloticus* + *H. longifilis*. This was followed by culture system involving rice + *O. niloticus* and rice + herbicide. Least value was obtained from system with rice alone without any form of weed control (Table 1).

Table 1

Yield of rice from various culture systems of pest control. Current price of husk rice = 200.00 N; Tilapia = 1500.00 N/Kg and mudfish = 2400.00 N/Kg

Treatment	*Plot no.*	*Average yield of rice (Kg/ha)*	*Average yield of Tilapia (Kg/ha)*	*Average yield of mudfish (Kg/ha)*	*Money value of all farm produce (N/ha)*
Rice with no weed control	8	7.80	-	-	1,560.00
	9	8.11	-	-	1,622.00
	1	6.90	-	-	1,380.00
Rice + Butachlor (1 – 2 kg/ha) as herbicide and no fish and no weeding	11	7.79	-	-	1,558.00
	12	8.98	-	-	1,796.00
	2	11.01	-	-	2,202.00
Rice + *Oreochromis niloticus* and no herbicide	3	10.76	8.67	-	15,156.00
	5	10.97	10.29	-	17,554.00
	10	11.46	9.86	-	17,082.00
Rice + Tilapia + Catfish and no weeding, no herbicide	4	10.85	5.88	6.22	23,518.00
	6	12.01	6.10	7.01	28,376.00
	7	11.99	5.79	6.33	26,275.00

N – Naira (currency of Nigeria).

The use of pesticides is beneficial for the growth of agriculture especially in the developing countries where land tenure system leaves very little land area for a particular farmer (Arua & Okorji 1998; Mabogunje 2007). Mechanical agriculture or aquaculture is difficult and farmers have to take to mixed cropping to provide their households with virtually all kinds of food classes. These pesticides though targeting some unwanted organisms (weeds), turn out to be hazardous to man preferred or cultured organisms. They therefore become pollutants.

Giving the small average size of land per farmer in Nigeria especially as the population is increasing, new farming systems such as rice with fish cultures are encouraged. The ecological components of the environments are fully utilized similar to what Sinha (1986) described in Asia. The fish while controlling the excessive growth of weeds, they are also able to reduce zooplankton, insects and mollusks that compete and destroy rice. The fish are also able to fertilize the field by their droppings, while the benthic activities of cat fish causes aeration of the soil. The growth of phytophagous tilapia is correlated to primary production and primary production is dependent on inorganic nutrients and carbon dioxide (Teichert-Coddington & Phelps 1989). Primary production is directly linked with the qualitative and quantitative nature of plankton present in water. Plankton abundance is in turn linked with important environmental parameters such as changes in temperature, radiation, hydrology and nutrient availability (Payne 1986). The concentration of Zooplankton is regulated by the presence of their food, which is principally the phytoplankton as well as the presence of their predators such as fish. Zooplankton species such as rotifers, branchiopods and copepods could be regarded as indicators of trophic status of a water body (Duggan et al 2003; Ekpenyong 2000; Ekpenyong et al 2012). So Offem et al (2011) noted that zooplankton richness appear to be largely controlled by factors related to productivity, water quality and fish production levels.

Pollutants act negatively on the growth of the fishery industry. Jauncey & Ross (1982) pointed that apart from the mortality of adult fish, they affect egg hatchability and fingerling survival and growth. According to APHA (1980) the 48 – 96 hour LC_{50} values are useful values of relative acute lethal toxicity to organisms under specific conditions. These values do not represent the safe concentration in the natural habitats, because long term contact with much lower concentrations may be lethal to fish and may cause a lethal impairment of their functions. So, long term effect of herbicide could cause endocrine disruption. By disrupting the hormonal system, a wide range of biological processes such as control of blood sugar, growth and function of reproductive system, regulation of metabolism, brain and nervous system development and development of an organism from conception to adulthood may become impossible (USEPA 2000).

Accumulation of residues, as stated by Tilak et al (2007) is a responsible factor for changes either in biochemical or pathological disturbance of overall biochemical cyclic reactions which are cumulative, causing lethality even at sub lethal concentrations. Some of the pesticides may influence some changes in environmental factors, as Issa et al (2004) had observed to affect the fecundity of cichlid in New Bussa, Nigeria. It is the influence of these pesticides on none target organisms that is used for the determination of ecotoxicological risks of the pesticides. Herbicides could be absorbed through gills and the digestive tract of the fish thereby resulting in histological alterations Cengiz et al (2001).

Gramozone has been described as a free radical generator in organisms (Asada & Barba 2004). All amino acid residues are susceptible for –OH attack. The reactive oxygen species (ROS) may cause aggregation fragmentation, amino acid modification and change in proteolytic susceptibility (Stadtman 1992, 1993).

Conclusions. Several methods of weed control in rice fields are available and have their various advantages. Among these methods are hand pooling, chemical control and cultural method. Cultural method involving the use of fish was observed to be economically preferred due to the fact that it is able to provide a variety of food items for the farmer. It is also able to improve the water quality of the paddy as there were more nutrients available in water column that could be used by plankton. However, it is recommended for small scale farmers only.

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