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Effects of Low pH and Iron Toxicity on survival of *Oreochromis niloticus* and Lowland NERICA Rice Seedlings

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Abstract

An assessment of the effects of water acidity and iron toxicity on *Oreochromis niloticus* fingerlings and NERICA L-19 rice seedlings cultured in a low lying land area of Badore Research Centre, NIOMR – Lagos was done. The experimental units were designed as rice units, rice cum fish units and fish units. Each unit was replicated four times. The average pH and iron levels in the rice units ranged from 5.0 – 6.2 and 7.5 – 8.0 ppm respectively. The rice cum fish units had average pH and iron levels of 5.2 – 6.0 and 7.5 – 8.0 ppm respectively, while the lowest pH levels were found in the pond units and ranged from 3.5 – 6.95, the iron content in the pond water ranged from 3.0 – 8.0 ppm. The experimental units with the lowest pH resulted in high fish mortality. Adverse effects of low pH and high iron content on the rice seedlings were observed to be minimal. The implication of the combined effects of low pH and high iron content in soil and water for tilapia fingerlings and rice seedlings is discussed.

Keywords: low pH, iron toxicity, tilapia, rice

INTRODUCTION

Rice (*Oryza sativa* L.) is increasingly becoming important in Africa, both as a food and cash crop, especially as the African population is reported to have reached one billion (Haub and Kaneda, 2013; FARA, 2013; World Population Data Sheet, 2009) . In Nigeria, rice is the sixth major crop in cultivable area after sorghum (*Sorghum bicolor*), millet (*Pennisetum spp.*), cowpea (*Vigna unguiculata*), maize (*Zea mays*) and cassava (*Manihot spp.*) (Ukwungwu, 2000) and fourth in sub-Saharan Africa (WARDA, 2006). According to Ajayi *et al.*, (2010); Danbaba *et al.*, (2013); Okonji *et al.*, (2013). It is estimated that about 4.6 million hectares of potential farmland abound in Nigeria. This great rice potential notwithstanding, production of rice has not kept pace with the rapid growth in population.

Millions of smallholder farmers in the wetlands of Africa are grappling with natural vulnerability and poor adaptive capacity which impact negatively on agriculture. Rice production in the region is affected by such environmental stresses such as iron toxicity and acidity especially in lowlands with its unique geological feature of iron presence and acidity (Balasubramanian *et al*., 2007; Fageria *et al*., 2008).

Iron toxicity in lowland rice has been reported to be widespread in several countries, especially in the humid tropical regions of Asia, South America, and West and Central Africa (Sahrawat, 2010). According to Genon *et al.* (1994), iron toxicity was suspected to be a major nutritional disorder in rice cropping systems established on flooded organic soils that contain reductible iron. Ferrous iron toxicity is an important constraint affecting primarily lowland rice grown on acid flooded soils that are rich in reducible iron. Negative effects of iron toxicity on rice plants bronzes the rice leaves. Iron is a trace element that is essential for rice plants and aids in normal growth and development, however, at high concentrations it becomes toxic to the plants.

Gross *et al.*, (2007) stated that under anaerobic conditions, the ferric iron is reduced into its ferrous form which is soluble in water and readily taken up by plants. High iron content in soils is usually in the ferric (nonsoluble) form which is not accessible to rice plants. Under prolonged flooded conditions without drainage, the ferric iron converts into ferrous (soluble) iron and becomes available for uptake by rice plants. The soluble iron is then absorbed by the roots of the rice plants and accumulates in the shoots.

Lowlands are often affected by iron toxicity. It is particularly common in acid soils, especially those with a very low pH (less than 5.0), as acidity increases the availability of ferrous iron to the plants. In sub-Saharan Africa, where lowland rice ecologies represent about 53% of the total rice area in the region, iron toxicity is a serious problem for smallholder rice farmers.

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Iron toxicity presents in rice plants as bronze spots, beginning at the tip and spreading toward the base of the rice leaves. Other effects include stunted plant growth, decreased tillering, and high spikelet sterility (leading to reduced yield). Iron also damages the root structure of the rice plant and reduces its capacity to absorb soil nutrients. As such, iron toxicity is generally associated with a deficiency of phosphorus, potassium, and zinc (Sahrawat, 2010).

In Africa, Nigeria is by far a large fish consuming nation with a demand of 2.66 million metric tons per annum and an internal production of 0.7 million metric tons per annum (Atanda, 2012). As capture fisheries is dwindling, aquaculture is rising to bridge the gap. However, according to Nwachukwu (2012), the problem is that Nigerian aquaculture has generally shifted from a greatly diversified polyculture to a monoculture of catfish that feed high on the food chain thereby requiring higher crude protein levels in their feed. The choice of tilapia in this study is because it is cheaper to culture (Megbowon, 2012) as it utilizes lower crude protein to grow and also the rice cum fish models adapted from Asia utilize tilapia for this integrated form of fish farming. There is a dearth of information on the dual effects of iron toxicity and acidity on the survival and growth of rice and tilapia in Nigerian wetlands.

MATERIALS AND METHODS

The experiment was conducted at Badore Research Centre (N06 30.598’ E003 37.073’), Nigerian Institute for Oceanography and Marine Research in Lagos State.

Experimental design

The experimental design had three treatments and they were designed as rice units, rice cum fish units, and fish units. Each treatment was replicated four times, making a total of 12 replications. Each replicate was carried out on a plot size of 5 m x 10 m (50 m^2). The rice plots were marked out, ploughed, puddled and leveled. There was a bund height of about 15 cm constructed around each rice plot. The rice-cum-fish units had trenches of 1 m x 1 m all around the inner perimeter of the unit leaving out 3 m x 8 m for rice planting. The fish ponds were dug to a depth of 1 m also and were 5 m x 10 m (50 m^2) in dimension.

Culture of rice and fish

Eighteen day old seedlings of the rice variety NERICA L-19 were transplanted to the field at the rate of 2 plants per hill at 25 cm by 25 cm spacing, while tilapia species, *Oreochromis niloticus* were stocked in the trenches and ponds at the rate of 20 per m^3, and this was carried out four weeks after transplanting the rice seedlings. Flooding of the experimental units was both tidal and rain-fed. Data was collected on seedling height (SH) (cm), and length at harvest (cm) for the rice plants while weight (g) and total length (cm) were collected for the tilapia at stocking and at harvest. At harvest of both the rice and tilapia, the percentage survival relative to initial transplanted seedlings and stocked fingerlings were also calculated.

Soil and water analysis

pH of the water in the plots (Treatment 1), trenches (Treatment 2) and ponds (Treatment 3) were determined using Pondcare® Master Liquid Test Kit and confirmed with YSI pH meter (Model pH 10: SN JC003754; Code 08F1). Iron level was measured using LaMotte iron kit (Code 4447-01), while soil samples from all replicates were gotten using soil auger and analysed for both pH and iron levels.

RESULTS AND DISCUSSION

The pH throughout the study period was acidic. The pH and iron levels from the study are presented in Table 1. The average pH and iron levels in the rice units ranged from 5.0 – 6.2 and 7.5 – 8.0 ppm respectively. The rice cum fish units had pH and iron levels of 5.2 – 6.0 and 7.5 – 8.0 ppm respectively, while the lowest pH levels were found in the pond units and ranged from 3.5 – 6.9, the iron content in the pond water ranged from 3.0 – 8.0 ppm. The pond with the lowest pH resulted in high fish mortality. Adverse effects of low pH and high iron content on the rice seedlings were observed to affect 21.28% of the plants on the average and are captured in Plate I. The pond with the highest level of iron, and lowest pH level resulted in high fish mortality. These are depicted in Plate II and Plate III.

Patches of rice plots affected most by iron toxicity had reduced plant height, and no grain yield. Overall, rice grain yield from replicates affected by the bronzing disease were lower than those unaffected. This agrees with the findings of Sahrawat (2010) in Asia. Reduction in rice yield as a result of iron toxicity had been reported earlier as a major problem in the inland valleys of Nigeria which can cause a loss of up to 60% in rice yield (Abifarin, 1984; Carsky, 1992; Osunde *et al.*, 2001). However, the percentage survival and rice yield loss were not as poor as the foregoing probably due to the improved rice species used for the field trials.

Table 1: Effects of pH and Iron levels on the growth and survival of NERICA L-19 and *Oreochromis niloticus*

S/N	Replicates	pH	Iron (ppm)	Seedling height SH (cm)	Length at harvest (cm)	Fish weight at stocking (g)	Fish weight at harvest (g)	Fish length at stocking (cm)	Fish length at harvest (cm)	Survival (%)
1	R1	5.5	7.5	11.2	150.0	Nil	Nil	Nil	Nil	87.6
2	R2	5.0	7.6	11.5	148.6	Nil	Nil	Nil	Nil	88.7
3	R3	6.0	7.5	12.3	143.5	Nil	Nil	Nil	Nil	69.7
4	R4	6.2	8.0	12.4	144.8	Nil	Nil	Nil	Nil	68.9
5	T1	5.2	7.5	13.1	161.1	5.3	46.28	3.5	13.8	88.2
6	T2	5.5	7.6	12.8	156.8	5.0	72.29	3.7	15.9	81.5
7	T3	5.8	7.7	12.4	139.9	5.1	48.22	3.8	14.3	83.3
8	T4	6.0	8.0	12.3	146.8	5.2	52.05	3.8	15.0	88.6
9	F1	6.9	3.0	Nil	Nil	5.4	38.62	3.6	13.8	43.6
10	F2	5.6	4.1	Nil	Nil	4.9	40.01	3.7	14.1	32.3
11	F3	4.2	7.4	Nil	Nil	4.7	39.58	3.6	13.8	24.1
12	F4	3.5	8.0	Nil	Nil	4.8	0	3.6	0	0

Key: R – Rice only
T – Trench (Rice and Fish)
F – Fish only

Plate I shows Iron toxicity symptoms on the stems and leaves during experimental trials at Badore Research Centre however, this bronzing affected very small portions of the rice fields, while Plate II shows iron film on pond water surface and Plate III depicts total fish kill with replicate with the lowest pH and highest iron level (F4).

Plate I: Bronzing of rice seedlings

Plate II: Iron film on pond water surface

Plate III: Total fish kill in pond F4

CONCLUSION

Heavy presence of iron and low pH as is naturally found in wetlands may affect rice plants and tilapia grown in such environments. However, the inevitability of making use of iron toxic and acidic wetlands for food production, such as is found in Badore Research Centre, is inescapable as the human population grows. The outcome of this study demonstrates that the effects of iron toxicity can be kept to a minimum with the use of iron tolerant species such as NERICA L-19 which is an improved and hardy rice variety developed by AfricaRice. To improve water chemistry for tilapia culture, it is recommended that the intervention approach of heavy and sustained liming of acidic ponds be employed to reduce fish mortality.

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