Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.5, No.4, 2015

Performance and Trace Element Uptake of Rice Varieties under Different Fertilizer Application

Mutari Abubakari Wilson Dogbe Baba I.Y Inusah Askia M. Mohammed Fulera Tahiru
CSIR - Savanna Agricultural Research Institute. P.O.Box TL 52, Tamale. Ghana
Corresponding author : amutari74@gmail.com.

Abstract
This paper underscores the influence of different fertilizers application on the growth, yield and some trace elements uptake of two released local rice varieties widely cultivated and consumed in northern Ghana. Field experiments were conducted at the Council for Scientific and Industrial Research – Savanna Agricultural Research Institute at Nyankpala in the Northern Region of Ghana, to compare the performance of the rice varieties, *viz*. Digan and Nabogu. They were treated with three different inorganic fertilizers – NPK 15-15-15 (NPK), Sulphate of Ammonia (SA) and Triple Super Phosphate (TSP) and a control plot with no fertilizer treatment. The variety, Digan, showed shorter number of days (95) to 50% flowering than the Nabogu variety (107 days). The Digan variety yielded more under NPK and SA treatments than the Nabogu variety. The trace elements, Cd and Pb uptake by the two rice varieties were also assessed and found to be below detection limits. Fe and Mn were detected at an average of 2.540 and 0.419 mg/l respectively (within acceptable levels by FAO/WHO guidelines).
Keywords: heavy metal, bioavailability, inorganic fertilizer, split plot, iron, manganese

1.0 Introduction

Rice (Oryza sativa L.) is one of the most popular staples and widely consumed crop in Ghana, being second to maize. The rice sector employs about 10% of farming households and about 80% of national production is concentrated in the Northern, Upper East and Volta regions (MoFA, 2009, Boadu 2012). With the estimated rice production of 485,500 metric tons, the Northern Region produces about 35% of the national rice production figures (MoFA 2012).

In 2000 and 2002, the CSIR - Savanna Agricultural Research Institute released the 'Nabogu' and 'Digan' rice varieties, respectively, to meet the demand for an ecologically adaptable and consumer acceptable rice in the three northern regions of Ghana. . The Nabogu variety matures between 122-128 days and can be grown under both irrigation and rain-fed conditions. The Digan variety matures between 110 -115 days and can be cultivated under both upland and lowland conditions either irrigated or rain-fed with satisfactory results. These two varieties have become popular since their release and have been cultivated and consumed widely in northern Ghana. The grains are mostly consumed during important occasions such as naming ceremonies, festivals and funerals in the northern part of Ghana.

The Northern region of Ghana has been the larger producer of cereal grains where the bulk of cheap and readily available labour for rice production is dominated mostly by women. However, due to inadequate and inappropriate fertilizer applications by farmers, yields are often far lower than the promising results obtained from researcher-managed fields. An essential element for increasing yields and sustainability of agriculture depends on appropriate fertilizer managements (Rao et al., 2005). Although the content of the major elements vary widely in soils, rice in all ecologies must receive fertilizer applications to produce satisfactory grain yield (Fairhust, 2012. WARDA, 2001 and Dogbe, 1996). Recommended application rate for lowland rice cultivation in northern Ghana is 60-60-30 kg NPK/ha.

Although commercial fertilizers provide the essential elements required for plant growth, they also contain trace elements or heavy metals known to be hazardous to human health at certain threshold. Therefore, inappropriate fertilization could lead to heavy metal accumulation and fractional composition changes in the soil (Łukowski, and Wiater, 2009; Nwachukwu, 2010) as some soils are already rich with trace elements. For instance, cadmium (Cd) is naturally present in soils, but can also be introduced into soil through atmospheric deposition, industrial contamination, sewage sludge, irrigation water, and agricultural inputs such as manure and inorganic fertilizers, (Alloway and Steinnes, 1999; Sheppard *et al*., 2009 as in Grant, 2011). The major loss of Cd from soil occurs through crop removal.

In order to assess the elemental risk associated with any fertilizer application, Chaney (2012) recommends that the levels of trace elements should be considered when selecting fertilizers for use as well as the soil and plant elemental load.

Phosphorus fertilizers contain cadmium (Cd) as a contaminant at levels varying from trace amounts to as much as 300 mg Cd kg of dry product, and therefore represent a major source of Cd input into agricultural systems. Cadmium will accumulate in soils if the amount of Cd introduced through fertilizer application exceeds that removed by crop harvest or erosion, bioturbation, and leaching (Grant, 2011). Generally about 12-18 % of the cadmium in cereal plant tops is translocated to the grain which has lower cadmium content than any other part of the plant. The addition of cadmium to soil, either as cadmium chloride or in superphosphate, always increase the cadmium content of the grain of cereals or the edible portion of vegetables (David and William 1973, cited in Reuss,Dooley and Griffis, 1976; Kabir *et al*., 2010). Accordingly, Rahimi and Rokai (2008) cited Baldini et al. (2000) having identified cereals and vegetables as the major sources of Cd in animal diet because of their high consumption rates.

Long term exposure to Cd is associated with renal dysfunction. Because cadmium is biopersistent, once absorbed remains resident for many years. High exposure can lead to obstructive lung diseases and has been linked to lung cancer. Cadmium may also cause bone defects in humans and animals (ATSDR, 2014).

Exposure to lead (Pb) can occur from many sources but usually arises from industrial use. Generally, lead exposure to humans is through the use of tobacco and proximity to sources such as motorways and lead smelters. However, exposure to non-smoking adult population and children is through food, air, soil and water.

The rate of absorption of lead after ingestion ranges from 3% to 80%. It is heavily influenced by food intake, much more occurring after fasting than when lead is ingested with a meal. Its accumulation in the body can result in health problems such as hematological effects, neurological and behavioral effects, renal effects, cardiovascular effects, and effects on the reproductive system. (FAO/WHO, 2011).

Iron (Fe) is an essential trace element required by all forms of life and it's useful in the synthesis of haem proteins and in many enzyme systems. Iron requirements vary by age, gender and health condition. Its deficiency is one of the most common nutritional deficiencies in children, in women of child bearing age, and pregnant women.

Iron occurs as a natural constituent of all foods of plant and animal origin, and may also be present in drinking water. In food it occurs as iron oxides, inorganic and organic salts or organic complexes. Meat and grain contribute to a great part of diet-derived iron. According to the FAO/WHO (20110The average daily intake of iron is estimated to be 17 mg/day for males and 9-12 mg/day for females.

Toxic doses of iron in animal studies are characterized by initial depression, coma, convulsion, respiratory failure and cardiac arrest.

In human, acute toxicity of iron ingested from normal dietary sources has not been reported. However, subjects with impaired ability to regulate iron absorption will be at risk from excessive exposure to iron.

Manganese (Mn) is one of the most abundant metals in Earth's crust, usually occurring with iron and is required for the proper functioning of many cellular enzymes. It is found in the atmosphere as suspended particles from industrial emissions, soil erosion and volcanic eruptions. Naturally, Mn is present in grain and grain products at a range of 0.40 – 40.70mg/kg (WHO,2011).

In order to evaluate whether trace elements in specific fertilizers or soil amendments might compromise risk, it is prudent to assess the concentrations in the major pathway to the organisms. This study therefore sought to investigate the influence of three different fertilizers commonly used in the production of Digan and Nabogu rice varieties.

1.1 Objectives

The specific objectives of this study were:

- To compare the growth and yields of Digan and Nabogu rice varieties.
- To determine the presence of some heavy metal residues in rice fertilised with different inorganic fertilisers.
- To determine the levels of these metals under different fertiliser treatments.
- To determine the relative accumulation of heavy metals in the two rice varieties.

2.0 Materials and method

2.1 The experimental site

On station experiments were carried out during the 2012 and 2013 cropping seasons (from early June to late November) at the uplands fields of the CSIR-Savannah Agricultural Research Institute, at Nyankpala on the Nyanpkala – Tamale road near Changnaayili (latitude 90° 25"/ N, longitude 00° 58"/ W, and altitude 183 m above sea level)..

The main soils of the upland fields of the CSIR-SARI at Nyankpala are *Ferric luvisols* (FAO-UNESCO, 2002). They are reported to have been derived from concretionary ground water laterite soil described as Kpalsawgu series (A1) and Changnayili series (A2) which are both sandy loam soils that are slightly acidic with pH of 5.8. The type A soil which is widely found in many parts of the Guinea Savanna Zone is suitable for cereal production e.g. maize, millet, rice and sorghum (NAES 1993, Brammer, 1962).

A one acre (0.40ha) fallow field was ploughed and harrowed to obtain a fine tilth. The trial plot comprising a total of 225.5 m^2 was marked out from the prepared acre and used for the study.

Three fertilizer types- compound fertilizer (NPK), triple superphosphate (TSP) and sulphate of ammonia (SA) were imposed on the two local varieties of rice at a rate of 250 kg/ha, 45kg/ha and 125kg/ha respectively.
,
Thus, the experiment was a 2 x 3 factorial treatments conducted in a split plot design arranged in a RCBD with four replications. Each block had a control rice variety plot without fertilizer. Thus, a total of 32 experimental units were established (Figure 1).

The main plot factor was the variety (Digan and Nabogu) and the sub-plot (size, 2 m^2) factor was the fertilizer (NPK, SA and TSP). All necessary agronomic practices and data collection were observed. Pre and post emergence herbicide were sprayed two days after planting and two weeks after germination respectively.

2.2 Data collection

A quadrate of 1 m x 1 m was used to sample the plants for the data collection. In each unit, a total of five plants that fell within the quadrate were marked out and used for the data collected.
Data collected were per cent germination, days to 50% flowering, effective tiller count, plant height and grain yield.

2.3 Sampling for heavy metal analysis

The rice was harvested manually with sickles onto a tarpaulin spread in the field, threshed and winnowed. Samples were then taken from the processed paddies by coning and quartering as described by Hodges and Stathers (2012) to obtain a representative sample. They were then milled to obtain grains that were used for the analysis of heavy metals.

2.4 Sample preparation

The samples were taken to the analytical laboratory of the CSIR- Water Research Institute, Tamale. They were acid digested and analysed for cadmium (Cd), lead (Pb) manganese (Mn) and iron (Fe) using the Atomic Absorption Spectrophotometer (AAS) Shimadzu model AA-6300 (Shimadzu Corporation, Tokyo).

2.5 Statistical analysis

Where appropriate, the data was subjected to Analysis of Variance (ANOVA) using the Genstat Discovery statistical package version 9.2. (Lawes Agricultural Trust, Rothamsted Experimental Station, 2007). Fisher's least significant difference (LSD) test at 0.05 level of significance was used to separate means.

3.0 Results and discussions

3.1 Germination and days to 50% flowering

After a week of planting, the plots were assessed for germinated seeds. Germination was generally good in both years for the two varieties with Digan recording a higher germination percentage (Figure 2) than Nabogu. . This was not statistically significant ($p< 0.05$) and could be related to varietal differences rather than treatment as there was no treatment imposed at that level.

For the number of days to 50% flowering, the analysis in both experiments 1 and 2 showed that all the treatments were significantly different ($p<0.05$) between the two varieties with Digan having an earlier days (95) to reach 50% flowering while Nabogu had much later (107) days to reach 50% flowering.

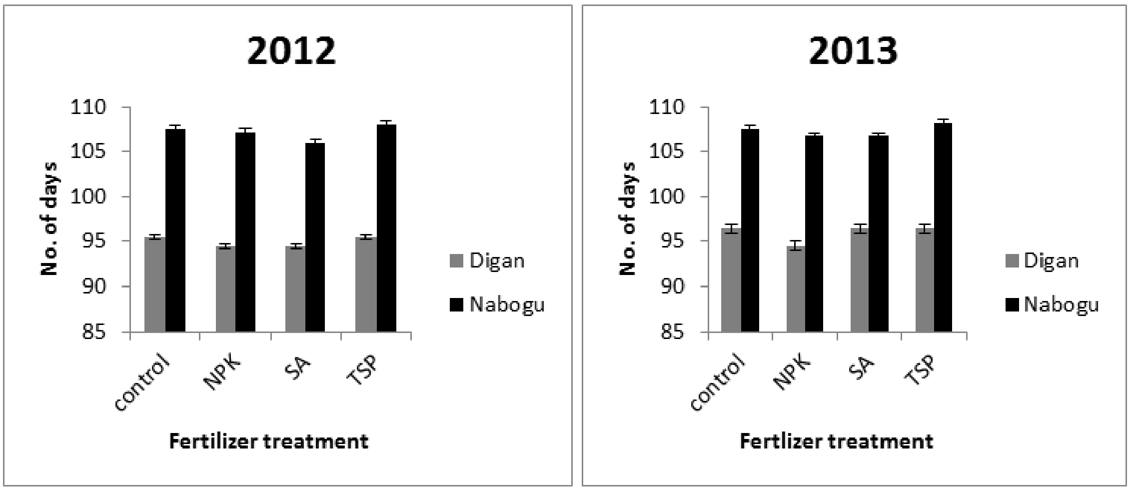

Figure 1. Graphs showing no of days to 50% flowering for the two cropping season

3.2 Plant height (cm) and tiller count

Plant height between the two varieties was significantly affected by NPK with means (Figure 3) of 82.40cm for Digan and 77.40cm for Nabogu. Law –Ogbomo and Law – Ogbomo (2009) indicated in a related study plant height increased significantly with NPK fertilizer application. Also, TSP treatment significantly affected plant height but in this case, Nabogu had a mean of 85.95cm while Digan had a mean of 74.20cm. However, the control and SA treatment did not affect the plant height significantly.

For the tiller count, only the control showed a significant difference between the varieties with means of 37.25 for Digan and 30.25 for Nabogu.

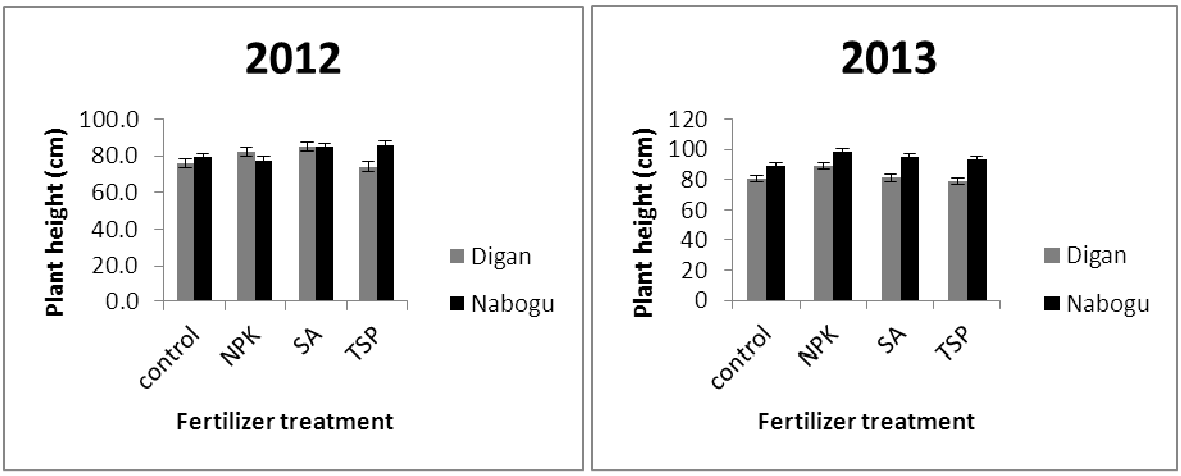

Figure 2. Graphs showing average plant height for the two cropping season

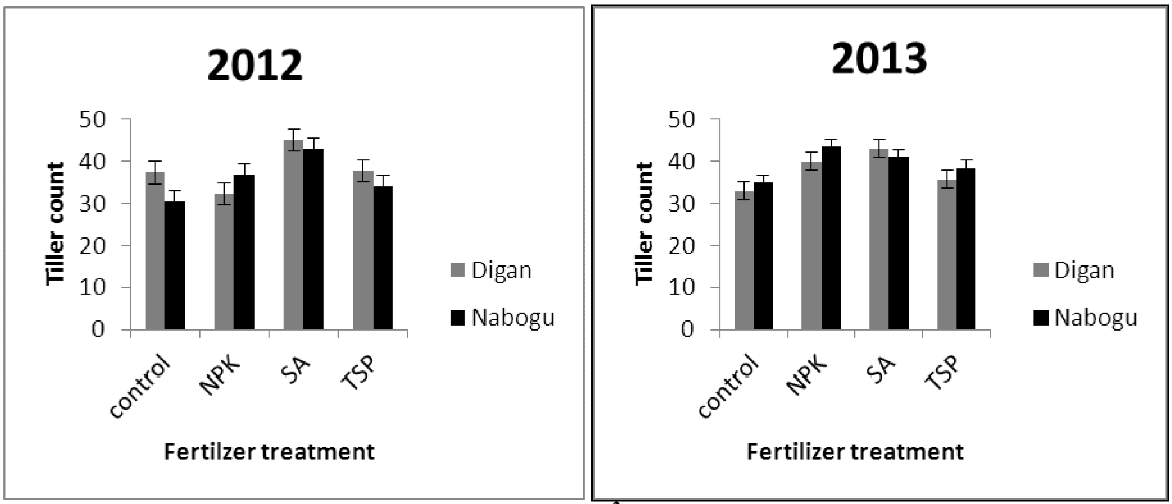

Figure 3. Graphs showing effective tiller count per m^2 for the two cropping seasons

3.3 Effect of treatment on paddy yield (kg/ha) for the two varieties

The analysis of variance showed that NPK and SA had a statistically significant effect on yield, with Digan yielding (Figure 4) about 1,900kg and 2000kg/ ha while Nabogu yielded about 400kg and 700 kg/ha respectively.

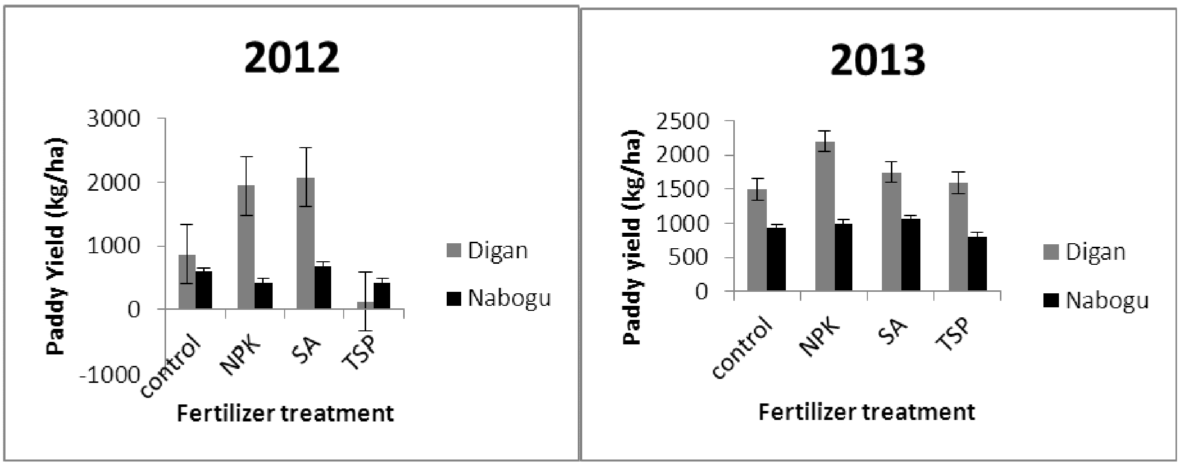

Figure 4. Graphs showing paddy yields for the two cropping seasons

3.4 Maturity period (days)

Data collected showed that Digan matures earlier than Nabogu. It was harvested (Figure 6) at 115 days after planting while Nabogu was harvested at 134 days. This figure corresponds with the variety information (CSIR – SARI, 2002) which indicated the maturity period for Digan as 110-115 days but that of Nabogu went a little above the information (122-128 days). Within each variety, the fertilizer treatments did not show any statistical difference ($p < 0.05$)

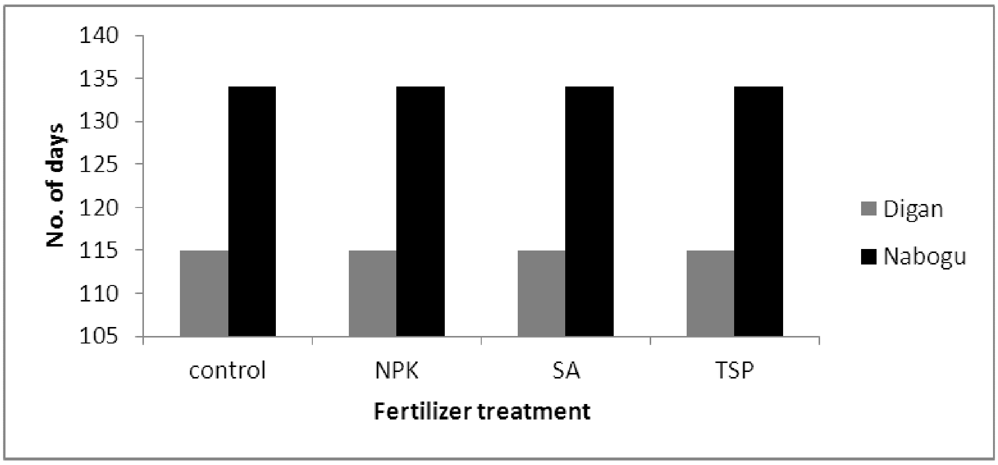

Figure 5. Graphs showing maturity periods for the two rice varieties

3.5 Trace elements

Four heavy metals were analysed for, i.e., lead (Pb), cadmium (Cd), iron (Fe) and manganese (Mn). Lead and cadmium could not be detected by the AAS but Fe and Mn were detected at appreciable quantities. The presence of these two elements (Fe and Mn) in the samples has some implication. The presence of both elements in the commodity makes one unavailable leading to its deficiency. Rossander - Hulten et al. (1991) showed that manganese inhibits the absorption of iron as they have similar physicochemical properties and absorption pathways. Similarly, Roomizadc and Karimian (2008) also indicated that application of manganese interferes with iron uptake by soybean plants.

Table 1. Levels of manganese and iron found in the two rice varieties

Treatment	0D	0N	NPK-D	NPK-N	SA-D	SA-N	TSP-D	TSP-N	Mean	Se
Mn (mg/l)	0.07	0.35	0.48	0.70	0.34	0.46	0.44	0.51	**0.42**	**0.06**
Fe (mg/l)	3.32	3.55	3.01	2.18	3.65	0.53	2.45	1.63	**2.54**	**0.38**

NB: O – control, D – digan, N – nabogu, NPK – nitrogen,phosphorous,potassium, SA – sulphate of ammonia and TSP – triple super phosphate.

4.0 Conclusion and recommendation

Owing to the results obtained, it could be concluded from the two cropping seasons that the Digan variety reaches full bloom earlier and thus has a shorter growing period than the Nabogu variety irrespective of the type of fertilizer applied. It was also observed from the results that overall, the Digan variety performed relatively better in terms of paddy yield though with slight variations with respect to fertilizer type.

In terms of trace element uptake, the Nabogu variety showed an overall higher uptake of Mn across the different fertilizer applications but lower in Fe uptake in the TSP, SA and NPK but not in the control.

It could be recommended for future experiments the rates of fertilizer application to ascertain the relative trace element uptake with respect to the different rates.

Acknowledgement

The authors wish to acknowledge the effort put up by Mr. Alidu Mahama, a technician of the rice improvement of CSIR – SARI and Master Jamal Abdulai, a student intern of Tamale Polytechnic for their assistance during the experimental layout and field data collection. Also, our gratitude goes to the management and laboratory staff of the Water Research Institute of the CSIR in Tamale for assisting with their facilities for the heavy metal analysis.

References

Agency for Toxic Substances and Disease Registry (ATSDR) (2011). Toxic substances portal – Cadmium. ATSDR, 4770 Buford Hwy NE, Atlanta, GA 30341.

Boadu, V.A. (2012). Rice price trends in Ghana (2006 -2011). USAID – GHANA. Monitoring, evaluation and technical support services. Ghana research and issue paper series. No 02-2012.

Chaney, R.L. (2012). Food safety issues for mineral and organic fertilizers. *Advances in Agronomy*, *117*, 51-116.

Chaney, R.L. (2012). Food Safety Issues for Mineral and Organic Fertilizers. *Advances in Agronomy*, Volume 117, Elsevier Inc. ISSN 0065-2113,
CSIR-SARI (2009). CSIR – SARI released high yielding rice varieties. Annual report.
Dogbe, W (1996). Characterization of inland valleys of Ghana. Annual report to the Savanna Agricultural Research Institute, Tamale, GHANA
Fairhurst, T. (2012). Handbook for integrated soil fertility management. *Africa Soil Health Consortium: Wallingford, UK.*
FAO/WHO (2011**).** Joint FAO/WHO food standards programme. Codex committee on contaminants in foods. Fifth session. The Hague, the Netherlands, 21 - 25 March.
Hodges, R. and Stathers, T. (2012). Training manual for improving grain postharvest handling and storage. 246pp. UN World Food Programme – University of Greenwich (Natural Resources Institute).
Kabir, M., Iqbal, M.Z., Shafiq,M., and Farooqi, Z.R. (2010). Effects of lead on seedling growth of *Thespesia populnea* L. *Plant soil environment*. Vol. 56 (4). Pp 194-199.
Lawes Agricultural Trust (Rothamsted Experimental Station) (2007) GenStat 9th Ed. *GenStat*Procedure Library. Release PL17.1
Law – Ogbomo, K.E., and Law – Ogbomo, J.E. (2009). The performance of Zea mays as influenced by NPK fertilizer application. *Notulae scientia biologicae*, 1(1):59-62
Łukowski, A., and Wiater, J. (2009). The influence of mineral fertilization on heavy metal fraction contents in soil. Part II: copper and nickel. *Pol J Environ Stud*, *18*(4), 645-650.
MoFA (2009). National rice development strategy (Draft). Republic of Ghana.
MoFA (2012). Provisional production estimates for 2012.
NAES (1993). Report 9. Farm Household Systems in Northern Ghana. Edited by Artur Runge-Metzeger and Lothar Diehl. Research Approach at the Nyankpala Agricultural Research Station (NAES). (G. Schimidt & H.Mercer-Quarshie).Verlag Josef Margraf, Hohenloher, Str no. 2, Weikersheim, Germany. 3-8; 36-38.
Nwachukwu MA, Feng H, Alinnor J. (2010). Assessment of trace metal pollution in soil and their implications within and around mechanic villages. Int. J. Environ. Sci. Tech. 7(2):347-358.
Rahimi, E., and Rokai, N. (2008). Measurement of cadmium residues in muscle, liver and kidney of cattle slaughtered in Isfahan abbatoir using grafite furnace atomic absorption spectrometry (GFAAS): a preliminary study. Iranial Journal of Vetenary Research. Vol.9 (2). Pp 174 – 177.
Roomizadch, S., and Karimian, N., (2008). Manganese - iron relationship in soybean grown in calcareous soils. Vol.19 (2). pp 397-406
Rossander-Hulten, L., Brune, M., Sandstrom, B., Lonnerdal, B., and Hallberg, L. (1991). Competitive inhibition of iron absorption by manganese and zinc in humans. American Society of Clinical Nutrition, Inc. Vol. 54 (1). Pp 152 -156.
Reuss, J., Dooley, H.L., and Griffis, W. (1976). Plant uptake of cadmium from phosphate fertilizer. Environmental Research Laboratory. Office of Research and Development. US – EPA. Corvallis, Oregon 97330. EPA – 600/3-76-053
WARDA, (2001). NERICA, rice for life. Bouake 01, Cote d'Ivoire. 6 – 13pp.
WHO (2011). Manganese in drinking water. Background document for development of WHO guidelines for drinking-water quality.
Wiater (2009). The Influence of Mineral Fertilization on Heavy Metal Fraction Contents in Soil. Part II: Copper and Nickel. *Polish Journal of environmental studies*. Vol. 18 (4). Pp 645 - 650

Appendix 1: Total Monthly Precipitation during Experimental Years

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Mean**	**Total**
2012	0.0	41.7	1.7	108.9	88.0	148.9	198.8	77.0	209.1	151.3	0.0	4.8	**85.9**	**1030.2**
2013	0.0	2.4	89.6	66.8	30.0	161.9	203.8	217.4	164.1	119.7	23.3	0.0	**89.9**	**1079.0**