# DIVERSITY AND ETHNOBOTANICAL STUDIES OF THE AFRICAN RICE (*Oryza glaberrima*) AND ITS WILD RELATIVES IN THE VOLTA REGION OF GHANA

**BY**

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**DECLARATION**

I hereby declare that this thesis is original, and that no part of this thesis has been presented for another degree in this University or elsewhere except for references to works of other researchers which have been duly acknowledged.

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## ABSTRACT

The study aimed at collecting, characterizing, storing and assessing the ethnobotanical uses of the African rice and its wild relatives collected from the Volta Region of Ghana. It also aimed at detecting the concentrations of mineral elements namely: nitrogen (N), phosphorus (P), potassium (K), iron (Fe), zinc (Zn), copper (Cu), lead (Pb), cadmium (Cd) and arsenic (As) in soils of the different accessions collected. Seven accessions of rice were collected from paddy fields in fourteen locations in five districts of the Volta Region. The study revealed that wild rice accessions were not present in the paddy fields. Newer and more productive rice varieties (*O. sativa*) were more commonly cultivated in farmers' fields, while the African rice was hardly cultivated. On the very few farms where the African rice was found, only a small portion of the land was allocated for its cultivation. The wild rice species were not found on farmers fields because they are seen as weeds. In Adaklu-Waya, where the wild rice was found, sections of the plants had been destroyed by a heavy duty truck which accesses water from the river where the wild rice grows. This provides evidence that the African rice and its wild relatives are severely threatened in the Volta region of Ghana. Agro-morphological characterization was carried out to verify the authenticity of the *O. glaberrima* accessions collected. Cluster analysis separated the different varieties collected into two groups based on the agro-morphological traits examined. Cluster 1 had three varieties belonging to the *O. glaberrima* species, namely; Kamugbaa, Kawomor (black) and Kawomor (red) while Cluster 2 had four varieties belonging to the *O. sativa* species, namely; Mansa, Viwotor, Ewe Moli (Wegbe) and Ewe Moli (Worawora). There were variations seen for most of the agronomical traits examined which could be used in breeding programmes. The herbarium voucher of wild rice in the Ghana herbarium aided in determining the wild rice collected. It was determined to be *O. barthii* because of features such as spongy roots, very long awns and its bunch growth. It was found amidst other grasses and grew by the bank of a river. Ethnobotanical studies were carried out only for the local rice varieties because the wild rice was found growing in the wild. The results showed that 62% of the farmers encountered were women, suggesting that women dominate rice cropping in the Volta Region and are very knowledgeable at selecting seeds. The ethnobotanical studies further revealed that the decline in the cultivation of the African rice in the Volta Region was due to its low yield, difficulty in de-husking seeds and poor consumer demands. The few farmers who still cultivate it do so because of its good taste, drought tolerance, good grain quality, pest and disease resistance and its good cooking quality. The desirable traits mentioned by farmers indicate that the African rice possesses useful genes which could be used to improve cultivated rice and breed new rice varieties. At $P \leq 0.05$, the soil analyses showed significant differences in pH, EC, particle sizes, N, P, K, Fe and Zn concentrations. Cu and Pb were not significantly different while Cd and As were below detection in soils of the different accessions. Based on these results, the soils were characterized as acidic ($4.68 \pm 0.14$ to $6.71 \pm 0.16$), with low salinity concentrations ($98.00 \pm 16.64$ to $222.33 \pm 21.39$ $\mu Scm^{-1}$) and higher percentage of sand ($68.15 \pm 7.88\%$) as compared to silt ($17.78 \pm 4.05$ %) and clay ($18.91 \pm 4.71\%$). Furthermore, despite the significant differences in N, P, K, Fe and Zn concentrations in soils of the various accessions, it was obvious that the wild rice has the ability to tolerate very low concentrations of N ($0.05 \pm 0.01\%$), P ($0.02 \pm 0.00$ %) and K ($0.03 \pm 0.01$ %) as compared to the other rice accessions, hence may possess genes that can adapt to nutrient - deficient soils.

# DEDICATION

I dedicate this work to Almighty God for granting mankind a world full of diversity, the bedrock of an extraordinary world; who makes all things possible and beautiful in His time.

Secondly, to my Parents (Mr. and Mrs. Opuni Sekyere) for their unfailing love, support, prayers and encouragement; who deemed it right to give me the best legacy I could ever have.

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| | |
|---|---|
| % | Percentage/ percent |
| µg/g | Microgram per gram |
| µg/l | Microgram per liter |
| $\mu Scm^{-1}$ | Microsiemens per centimeter |
| µm | Micrometer |
| AAS | Atomic Absorption Spectrophotometer |
| A. Chev. | Auguste Jean Baptiste Chevalier |
| ANOVA | Analysis of Variance |
| AP | Awn presence |
| As | Arsenic |
| BC | Before Christ |
| BCE | Before the Common/Current/Christian Era |
| Cd | Cadmium |
| CE | Common Era |
| CERSGIS | Center for Remote Sensing and Geographic Information Services |

| | |
|---|---|
| CL | Culm length |
| cm | Centimeter |
| CN | Culm number |
| CS | Culm strength |
| Cu | Copper |
| CWR | Crop Wild Relatives |
| Cycle | Mean days to 80% maturity |
| DAS | Days after sowing |
| DNA | Deoxyribonucleic Acid |
| EC | Electrical Conductivity |
| FAO | Food and Agriculture Organization |
| Fe | Iron |
| FH | Mean days to 50% first heading |
| FLL | Flag leaf length |
| FLW | Flag leaf width |
| g | Grams |
| GDP | Gross Domestic Product |

| | |
|---|---|
| GL | Grain length |
| GPS | Global Positioning System |
| GW | Grain width |
| HCl | Hydrogen chloride |
| $HClO_4$ | Perchloric acid |
| HGW | 100-grain weight |
| $HNO_3$ | Nitric acid |
| $H_2S0_4$ | Sulphuric acid |
| IBPGR | International Board for Plant Genetic Resources |
| IESS | Institute of Environment and Sanitation Studies |
| IPGRI | International Plant Genetic Resources Institute |
| IRRI | International Rice Research Institute |
| K | Potassium |
| kg | Kilogram |
| L | Linnaeus |
| LBL | Leaf blade length |
| LBW | Leaf blade width |

| | |
|---|---|
| LL | Ligule length |
| LSD | Least Significant Difference |
| LS | Ligule shape |
| m | Meters |
| mg/kg | Milligram per kilogram |
| mg/l | Milligram per liter |
| ml | Mililiter |
| mm | Millimeter |
| MH | Mean days to 80% main heading |
| M | Moles |
| nm | Nanometer |
| N | Nitrogen |
| NaOH | Sodium hydroxide |
| NERICA | New Rice for Africa |
| NPP | Number of panicles per plant |
| NTSYS | Numerical Taxonomy System |
| P | Phosphorus |

| | |
|---|---|
| PAB | Panicle attitude of branches |
| Pb | Lead |
| PGR | Plant Genetic Resources |
| PGRFA | Plant Genetic Resources for Food and Agriculture |
| PGRRI | Plant Genetic Resources Research Institute |
| $PNO_3$ | Potassium Nitrate |
| ppm | Parts per million |
| RYMV | Rice Yellow Mottle Virus |
| SIREC | Soil and Irrigation Research Center |
| Steud. | Steudel |
| UPGMA | Unweighted Pair Group Method using Arithmetic Averages |
| USDA | United States Department of Agriculture |
| Zn | Zinc |

# CHAPTER ONE

## 1.0 INTRODUCTION AND LITERATURE REVIEW

### 1.1 Importance of plant genetic resources

Global food security is vulnerable to the changing climatic conditions and environmental degradation which has caused reductions in crop yields, increase in food prices, economic crises and food shortages (Jansky *et al*., 2013). Plant genetic resources for food and agriculture (PGRFA) are important in tackling the issues of food security (FAO, 2015). They are useful in the provision of food as well as medicine; provision of industrial products which help in generating income; facilitating pollination services and soil processes in peculiar situations; carbon sequestration and in protecting the soil against erosion (Hajjar, Jarvis, & Gemmill-Herren, 2008). Therefore, they are the major building blocks of sustainability, resilience and adaptability in food production systems and provision of environmental services ( FAO, 2015).

Plant Genetic Resources for Food and Agriculture are ―any genetic material of plant origin of actual or potential value for food and agriculture” (ITPGRFA, 2009). Conserved PGRFA represent a measure in safeguarding against future adverse changes in agricultural environments. Their genetic diversity enables them resist new diseases and adapt to the changing climatic conditions. PGRFA include breeding lines and genetic stocks, obsolete cultivars and landraces, and traditional or heritage varieties of crops. Particularly, they include crop wild relatives (CWR) (Ford-Lloyd *et al*., 2011) .

CWR ~~a~~re wild plant taxa closely related to crops to which they may contribute beneficial genes, they constitute an enormous reservoir of genetic variation for crop improvement and are an important socio-economic resource" (Hunter *et al*., 2012). The Russian Plant Geneticist Nicolai Vavilov in the 1920s and 1930s recognized their importance as gene donors for crop improvement (Ford-Lloyd *et al*., 2011). For example, *Aegilops tauschii*, the relative of wheat is resistant to the Hessian fly which is a pest of cereal crops (Espuing, 2014). Genes introduced from *A. tauschii* have provided the wheat crop with tolerance to drought, heat, salinity and water logging. The nutritional quality of durum wheat has been improved with genes from its wild relative *Triticum dococcoides*. *Saccharum arundinaceum* a relative of sugar cane can survive under very low temperatures and *Prunus ferganensis* the wild version of peach is resistant to drought (Espuing, 2014).

The CWR of potatoes (*Solanum demissum*) were used in the 1900s to improve cultivated varieties of potatoes against the fungus that caused potato blight. In the 1970s, blight damaged almost about US$ 1billion worth of maize in the United States which was remedied through the use of blight resistant genes from wild varieties of Mexican maize (Stolton, Maxted, Ford-Lloyd, Kell, & Dudley, 2006). Also, when the grassy stunt virus, (a plant pathogenic virus transmitted by the brown plant hopper *Nilaparvata lugens* and by two other *Nilaparvata species*, *N. bakeri* and *N. muiri )* caused poor yield of rice across Asia in the 1970s, *Oryza nivara* was found to have genes resistant to the grassy-stunt virus; hence resistant rice hybrids are now grown across Asia. Genes from a wild relative of tomato have brought about a 2.4 % increase to the commercial yield of tomatoes. This is estimated to be worth US$250 million in California (Stolton *et al*., 2006). Clearly, the importance of CWR cannot be over emphasized.

Wild plants were domesticated by man through natural selection (nature chose phenotypes appropriate for cultivation on man-made lands and in gardens through cross pollination) and artificial selection (the phenotypes and genotypes of the wild plants gradually changed as humans chose plants with certain desirable characters through hybridization). These combined actions for some crops resulted in populations called landraces, and these desirable plants were preserved and multiplied. They are considered as endemic to a particular area (Zeven, 1998). For example, the two cultivated species of rice, *Oryza sativa and Oryza glaberrima*, were domesticated independently from their wild relatives. Asian rice (*O. sativa*) appears to have been domesticated approximately 9,000 years BC in the Yangtze River basin in China, from the wild annual ancestor of *O. nivara*, which evolved from the wild perennial rice *O. rufipogon.* In a parallel evolutionary pathway, domestication of the African rice (*O. glaberrima)* occurred, around 3,000 BC, which evolved from its wild annual ancestor, *O. barthii* in the Inland Niger River delta, Mali (Linares, 2002; Molina *et al*., 2011; Vaughan *et al*., 2008a, b). There are five wild rice species represented in Africa, namely *O. barthii, O. brachyantha, O. eichingeri, O. longistaminata and O. punctata* (Nayar, 2012). In Ghana, three of these wild species are represented, namely *O. barthii*, *O. longistaminata* and *O. punctata.*

The wild relatives of rice are closely related progenitors of the two cultivated rice species (*Oryza sativa* and *Oryza glaberrima*), but they possess greater genetic variation due to the fact that their genetic diversity has not been hindered as a result of domestication. Hence, they represent a ‗reservoir of useful traits for crop improvement' (Maxted *et al*., 2012). According to Harlan (1975 as reported in Zeven, 1998), landraces have a certain degree of genetic stability. Farmers have names for them and diverse landraces are understood to vary in adaptation to soil type, time of seeding, date of maturity, height, nutritive value and other properties (Zeven, 1998). In Africa, crop diversity is found in areas such as the Ethiopian highlands, the Sahelian transition Zone, the delta of the Niger River and the humid forest zone of West and Central Africa (Nnadozie & Kameri-mbote, 2002). The highlands of Ethiopia are a center of origin for coffee and diversity for sorghum, lentils, wheat and barley. The delta of the Niger River, is a center of origin for African rice and a center of diversity for oil palm, yams and cowpea (Nnadozie & Kameri-mbote, 2002).

Many of the CWR grow in conflict zones where their conservation is threatened (Espuing, 2014). CWR also face the threat of genetic erosion due to land use change, climate change, nitrogen deposition and biotic exchange including alien invasive species (Ford-Lloyd *et al*., 2011). Furthermore, they are poorly represented in germplasm collections due to financial and political constraints. Increasing threats to natural habitats and farming systems make it urgent to collect, conserve and characterize landraces and wild relatives in order to have them available to reduce the effects of biotic and abiotic stresses caused by climate change (FAO , 2015). Improvements to *in situ* and *ex situ* conservation programmes for domesticated species, their wild relatives and other wild genetic resources important for food and agriculture, along with policies that promote their sustainable use are therefore urgently needed (Jarvis *et al*., 2008).

**1.2 Why conserve rice germplasm**

Rice is one of the leading food crops in the world today, along with wheat and maize. An area of 214 million hectares of wheat is harvested yearly followed by rice with 154 million hectares and maize with 140 million hectares, making wheat the most cultivated cereal. However, in terms of their consumption rate, rice ranks higher with a percentage of about 85 as compared to wheat (72%) and maize (18%) (Maclean, Dawe, Hardy, & Hettel, 2002). In fact, in some countries such as Bangladesh, Cambodia, Lao PDR, Myanmar and Vietnam, the consumption rate is more than 150 kg/capita/year (Hay *et al*., 2013), while in Ghana rice consumption accounts for more than 28 kg/capital/year with urban areas accounting for the highest rice consumption. This is because in the urban areas, rice is preferred over other staples, the reason being that it is easy and convenient to cook and it allows for a wide variety of dishes. Its per capita rate of consumption is estimated to increase to about 63 kg in 2018 due to increase in population and urbanization (Angelucci *et al*., 2013; MoFA, 2009). Other factors responsible for its high consumption rates are its nutritional and medicinal values - rice lowers the problem of bowel disorder and protects the body against constipation. This is possible because it is rich in insoluble fiber. It is also rich in carbohydrates, low in fat, contains some protein and plenty of vitamin B (Olembo, M‘mboyi & Oyugi, 2010). Rice also provides the global human population with 21% per capita energy and 15% per capita protein (Maclean *et al*., 2002). Furthermore, it possesses socio-cultural values because it forms part of religious rites, festivals and ceremonies in some countries like Ghana

(Norman & Kebe, 2006). It also has a paramount role in the ritual life of farming communities and is recognized as being of deep cultural significance among some Africans in the diaspora in South America (Teeken *et al*., 2012).

Rice is also used in the fight against poverty due to its wide range of uses as outlined below:

1) Rice starch- It is an important constituent used for ice cream, custard powder, puddings, gel and alcohol among others (Olembo *et al*., 2010);
2) Broken rice- It is used for baby foods, soups and for brewing purposes (Olembo *et al*., 2010);
3) Rice bran- It is a feed concentrate for livestock and fish. Bran oil is used for pharmaceutical products and for human consumption (used for confectionery products like bread, snacks, cookies and biscuits) (Olembo *et al*., 2010; Verhey, 2010);
4) Defatted rice bran- It is used for cattle feed, organic fertilizers, medicinal purposes and in making wax (Olembo *et al*., 2010);
5) Rice straw- It is used to make coarse paper and also a source of cellulose for ruminant livestock. It is also used for composting and for building materials and as an ultra-pure source of silica and for making footwear and headwear. Rice marbles are used to add decorative effects on book covers, which is a unique use of rice. (Verhey, 2010);
6) Rice husk- It is used as fuel, in board and paper manufacturing, building materials and as an insulator. It is also used for compost making and as chemical derivatives (Olembo *et al*., 2010).

The leading producers of rice in the world are China and India. Thailand, India and Vietnam are the major rice exporting countries (Kam, 2011). According to FAOSTAT (2014), with respect to global cereal production, rice production accounted for 34.1% in 2011/2012 (about 485.9 million tonnes), 35.7% in 2012/2013 (about 490.1 million tonnes) and 36.3% in 2013/2014 (about 496.6 million tonnes). This shows that there is an increase in demand as a result of increase in population.

In Africa, rice consumption is third after maize and sorghum, yet Africa produces only about 3.6% of the world‘s paddy rice. Rice production ranks fifth with respect to area cultivated (alongside wheat) after millet (*Pennisetum glacum*; 21% area), sorghum (*Sorghum bicolor* (L.) Monench; 19% area), maize (*Zea mays* L.; 12% area) and cassava (*Manihot esculenta* Cranz; 9% area) (Nayar, 2012). Therefore, rice production in Africa is relatively low; hence, African countries depend on large imports of rice. In fact, Africa is the second-largest rice importing continent in the world after Asia (Kam, 2011). According to Samado, Guei, and Keya (2008) the cost of rice imports into West and Central Africa sub-regions, accounts for over US$1billion in scarce foreign exchange each year. This is a tremendous loss of foreign exchange especially for countries that are already in debt. In Ghana, for example, rice import bills account for US$ 450 million annually (Angelucci, Asante-Poku & Anaadumba, 2013).

In Ghana, rice is the second most important food crop after maize and its consumption keeps increasing due to increase in population, urbanization and change in consumer habits (MoFA, 2009). It accounts for nearly 15% of the gross domestic product (GDP) making it important to the economy and agriculture. An area of about 45% is allocated to rice production and it is a source of employment to the rural communities (Kranjac-Berisavljevic, 2000). Although rice production takes place in all the ten regions of the country, the main rice producing regions are Northern, Volta and Upper East regions, which together produce between 45000 – 60000 tonnes per year each. Rice production is mostly done by small holder farmers, having farms less than one hectare in size (Angelucci *et al.,* 2013). Local rice production, therefore, falls far below consumption resulting in a high dependence on imported rice which accounts for 400,000 tonnes yearly (MoFA, 2009).

Although Ghanaian rice farmers grow varieties of both the Asian rice (*O. sativa*) and African rice (*O. glaberrima*), rice imports into Ghana consist solely of the Asian rice which is one of the world‘s largest food crops and is grown almost worldwide. The African rice is mainly grown in tropical West Africa and differs in many quantitative and qualitative traits as compared to the Asian rice (Li, Zheng, & Ge, 2011). Africa is the only continent where the two cultivated species co-exist (Sié *et al*., 2012). *O. glaberrima* possesses many important traits namely; weed competitiveness, drought tolerance and ability to respond to low input conditions. It is able to compete with weeds due to its early vigor, low extinction coefficient; high light use efficiency and high specific leaf area leading to high canopy growth for a given amount of assimilates. The weed competitiveness of *O. glaberrima* is also due to its high root biomass accumulation and thin roots with better soil penetration ability which helps to compete with weeds for nutrients. It also has the ability to produce extra tillers between 40 and 80 days after germination and can compensate for any loss in tillering suffered due to weeds. It has the ability to resist pests and diseases. It can survive a wide range of difficult ecosystems and has the ability to tolerate phosphate, iron and aluminum toxicity (Sarla & Swamy, 2005). Other useful qualitative traits of *O. glaberrima* proposed by West African farmers are faster cooking rate, keeps well, possesses good taste with salt and pepper and is suitable for feeding weaning babies. Hence it possesses genes which could improve milling, cooking and eating qualities of Asian rice (Sarla & Swamy, 2005).

Rice production in Africa is faced with several challenges. Firstly, about 80% of rice production is done mostly by local farmers who have limited access to equipment and finances. Secondly, rice yield is impacted by a variety of environmental factors including drought, problems related to minerals (such as acidity, alkalinity, phosphorus deficiency and iron toxicity), unavailability of suitable and improved varieties for diverse environments, weeds, pests and diseases (Kam, 2011). To remedy these problems, one of the options is the development of high yielding varieties adapted to environmental conditions in the region, hence the need to collect germplasm of the African rice and its wild relatives.

Already, some of the useful genes of the African rice have been combined with the high yield of Asian rice by rice breeders to develop rice plants that are high yielding, drought and pest-resistant and adapted to the growing conditions of West Africa. The hybrid crop is called NERICA (New Rice for Africa) (Li *et al.,* 2011). According to Nayar (2010) only about 7% of the genetic makeup of *O. glaberrima* is in NERICA. There is still the, issue of weed competitiveness which is a major problem for farmers in West Africa. Therefore, it is important that the genetic makeup of NERICA is improved. It is therefore important to conserve the biodiversity of the African rice for sustainable use of its valuable genetic resources. Sadly, the African rice is now sparsely grown in pure stands, while in some areas, it is completely replaced with the Asian rice (Nayar, 2012).

If collections are not promptly undertaken, there is a high risk of losing these very important genetic resources. According to Vaughan, Yoshida, Takeya & Tomooka (2013) the African rice and its wild relatives are gradually disappearing due to certain causes of genetic erosion such as urbanization and agricultural intensification. For example, the wild relatives of rice have been located along roadsides where there is much anthropogenic activity taking place. It is therefore important to identify areas where the African rice and its wild relatives are located in order to:

a) Create access to germplasm for taxonomy, phylogenetics and biosystematics;
b) Conserve germplasm so that it can be characterized and evaluated;
c) Present quality germplasm to plant breeders.

In addition to this, farmers are the ‗motivators' behind the adoption of new local seed technologies. It is therefore important to assess the socio-cultural factors alongside the ecological factors associated with the cultivation of the African rice and protection of its wild relatives because they stand as models for local preferences and seed technologies (Teeken *et al*., 2012).

## 1.3 Botanical description of rice

The rice plant belongs to the genus *Oryza* and the tribe Oryzeae of the family Gramineae (Poaceae). It may typically be considered as an annual grass adapted to the aquatic environment (Chang, 1965). It consists of about 20-25 species of which only two are cultivated: *Oryza sativa* L., the universally cultivated Asian rice and *Oryza glaberrima* Steud., the African rice (Nayar, 2012). The cultivated rice plant normally grows to a height of between half a meter and two meters, but there are some varieties which attain a height of about 6-9 meters. The rice plant is divided into two main parts: root and shoot systems (Chang, 1965).

### 1.3.1 Root

The rice plant has a relatively low and dense root system as compared to other upland cereal crops like maize and wheat probably because it grows under flooded conditions (Morita & Nemoto, 1995). The rice root system consists of two major types; crown roots and nodal roots. They both develop from the nodes. The crown roots develop from nodes below the soil surface while the nodal roots develop from nodes above the soil surface. The nodal roots are mostly found in rice cultivars growing at water depths above 80 cm. In flooded soils, rice roots occasionally surpass a depth of 40 cm. This is as a result of limited oxygen diffusion through the aerenchyma cells of roots to supply the growing root tips (Maclean *et al*., 2002).

### 1.3.2 Culm

The culm is also known as the jointed stem of rice. It is made up of the nodes and internodes. Each node bears a leaf and a bud. Tillers arise from the main culm in an alternate pattern. The primary tillers originate from the lowermost nodes which in turn give rise to the secondary tillers. The secondary tillers also give rise to tertiary tillers (Chang, 1965).

### 1.3.3 Leaves

The leaves are borne on the culm in two ranks, one at each node. The leaves consist of the sheath and the blade. The leaf sheath is connected to the leaf blade (Chang, 1965). It encircles the culm above the node in varying length, form and tightness. The blades are usually flat and sessile. Varieties vary in blade length, width, area, shape, color, angle and pubescence. The topmost leaf below the panicle is the flag leaf. The flag leaf differs from others in shape, size and angle (Chang, 1965).

At the junction between the leaf blade and the leaf sheath is a pair of claw-like appendages, called the auricles. Coarse hairs cover the surface of the auricles (Maclean *et al*., 2002). In between the leaf sheath and the blade is a membranous, glabrous or ciliate ligule. It varies in length, color and shape from variety to variety (Chang, 1965). The junction of the sheath and the blade is called the collar or juncture. The collar appears as a raised region found at the back of the leaf (Chang, 1965).

### 1.3.4 Floral organs

The floral organs are modified shoots. They consist of the panicle, spikelet and the flowers.

#### 1.3.4.1 Panicle

The culm bears the panicle on the topmost internodes. The panicle axis is the central axis of the inflorescence, which extends from the panicle base to the apex. The panicle has a racemose pattern of branching. Each node on the main axis gives rise to the primary branches which also bear the secondary branches (Chang, 1965).

#### 1.3.4.2 Spikelet

The spikelet bears the pedicel, a short stalk that is an extension of the panicle axis and the primary or secondary branch. At the upper end of the pedicel are two short rudimentary glumes. A pair of sterile lemmas and rachilla located between the rudimentary glume and the spikelet (Yoshida, 1981). The flower is enclosed by the lemma and palea, which may either be awned or awnless (a fibrous bristle present in some cultivars, formed as an extension of the midrib of the lemma) (Yoshida, 1981).

#### 1.3.4.3 Flower

The flower consists of six stamens which are composed of 2-celled anthers borne on slender filaments and the pistil contains one ovule. There are two wale-like, transparent, fleshy structures located at the base of the flower, adnate to the palea (Chang, 1965). The rice fruit is called a caryopsis which has a single seed fused with the wall of the ripened ovary (pericarp). The grain is the ripened ovary with the lemma, palea, rachilla, sterile lemmas and the awn, if present, firmly attached to it. The lemma, palea, sterile lemmas, rachilla and the awn, if present, constitute the hull or husk (Chang, 1965).

## 1.4 Growth and development of the rice plant

Rice is an annual grass with a life cycle which ranges from 80 to more than 200 days, from germination to maturity (Verhey, 2010). There are three agronomic stages associated with the growth and development of rice, they are:

a) Vegetative phase;
b) Reproductive phase;
c) Ripening phase.

### 1.4.1 Vegetative phase

The seed imbibes water and becomes elastic. The coleorhiza (sheath covering the radicle) elongates slightly, emerging through the seed coat, allowing the radicle to break through the coleorhiza and become anchored in the soil. This occurs within two days when temperatures are between 70 to 90°F/ 21 to 32°C (Moldenhauer & Slaton, 2013). Below or above this temperature, germination requires more time. Generally, germination occurs within the temperature range of 50 to 107°F/ 10 to 42° C with an optimum temperature of about 87° F / 31°C (Moldenhauer & Slaton, 2013). This involves active tillering, increase in plant height and leaf emergence at regular intervals. The primary leaf acts as a protective covering for the next developing leaf. As the seedling grows, the next leaf elongates and differentiates into three distinct parts; the sheath, collar and blade (Olembo *et al*., 2004). The development of the primary and secondary leaf is called the pre-tillering phase. Tillering occurs when a sprout is produced from the crown, which forms just below the soil surface or from the axils of the lower leaf. This usually begins three weeks after emergence (Verhey, 2010).The vegetative lag phase occurs as tillering ends and the reproductive phase of the plant begins to unveil. During this time the rate of formation of new tillers decreases while the plant height and stem diameter increase slowly (Verhey, 2010).

### 1.4.2 Reproductive phase

This phase is characterized by culm elongation, a decline in tiller number, booting, emergence of the flag leaf, heading and flowering (Moldenhauer & Slaton,2013). This stage differs based on cultivar and weather conditions. Anthesis or flowering refers to the events between the opening and closing of the spikelet and this lasts for 1-2 hours. Fertilization of the ovary by the pollen grain is completed within 5-6 hours after pollination (Moldenhauer & Slaton,2013).

### 1.4.3 Ripening phase

According to Olembo *et al*., (2010), the ripening phase follows ovary fertilization and may be divided into three phases, viz:

1) Milk stage – During this stage, the developing starch grains in the kernel are soft and the innermost part of the kernel is full with white liquid similar to milk;
2) Soft dough stage – The starch in the grain starts becoming rigid though still soft;
3) Hard dough stage – The whole grain is rigid during this stage and almost ready for harvest. The moisture content is still above 22 %. The whole grains start to mature, such that they turn out to be hard and ready for harvest. This stage is reached at approximately 20 to 22 % moisture content. Ripening is described by leaf senescence and grain growth (Maclean *et al*., 2002).

## 1.5 Origin of the African rice

Rice history dates back to 130 million years ago when the seven continents, which were originally joined, gradually started drifting apart. Since then, rice has been growing everywhere apart from Antarctica (Shamar, 1991). Interestingly, the Latin word for rice, ―Oryza" and the English ―Rice" are both derived from the ancient Tamil word ―Arisi". Arab traders took arisi with them and called it ‗Al-ruz" in Arabic. This became ―Arroz" in Spanish and ―Oriza" in Greek. In Italian, it is called ―rizo" in French ―riz" and in German ―reis" (Shamar, 1991).

Historically, the first account of rice in Africa appears to be that of Alexander the Great (in the fourth century BCE). He introduced rice into Egypt after his invasion of India. In Egypt, rice cultivation started in 639 CE. The Greek philosopher and historian, Strabo, earlier noticed the growing of rice in Cyrinaica (Libya) in about 12 CE (Nayar, 2012). The Islamic scholar, Al-Bakri, gave the first account of rice cultivation in West Africa along the Niger River in 1068 CE. Ibn Batuta, a well-known Moroccan traveler also gave account of the abundance of rice in the Inland Niger Delta. Several early travelers also noticed the cultivation of rice in West Africa, before the first Europeans arrived in the early 15$^{th}$ century (Nayar, 2012).

The main center of diversification of the African rice (*O. glaberrima*) is the swampy basin of the upper Niger river in West Africa, which was apparently formed around 3000 BC (Linares, 2002). Poteres (1970, cited by Sweeney and McCouch, 2007) reported that *O. glaberrima* was first cultivated in flood waters using floating rice cultivars. Rice cultivation then spread to the brackish waters using non-floating cultivars and later cultivars were chosen and planted on upland fields which were watered by rainfall. Two secondary centers were formed 500 years later in the South West near the Guinean Coast. The first on the coast of Gambia, Casamance and Guinea Bissau and the second in the Guinea forest between Sierra Leone and Western Ivory coast around 100 BC (Agnoun, Biaou, Sié, Vodouhè, & Ahanchédé, 2012). The major rice growing countries outside West Africa are Congo DR, Egypt, Madagascar, Mozambique and Tanzania (Nayar, 2012).

According to Richards (1996) *O. glaberrima* was selected at several different localities within the vast forest and savanna areas, where the wild species *O. barthii* was harvested by the ancient hunting and gathering human population. Therefore they concluded that African rice was first cultivated many centuries before the first Europeans arrived in the West African coast. The African rice (*O. glaberrima*) is grown in a zone extending from the Delta of River Senegal in the West to Lake Chad in the East. To the Southeast, its range is bordered by the river basins of the Benue, Logone and Chari. The floodplains of Northern Nigeria, the Inland Delta of the Niger River in Mali, parts of Sierra Leone and the hills on the Ghana-Togo border are areas where it is intensively cultivated (Agnoun *et al*., 2012). There are few erratic reports of its occurrence in the Americas (Central America, the Carribbean, Eastern USA) and East Africa (Pemba and Zanzibar Islands (Tanzania) and Mozambique) till about the 1920s. This was as a result of the slave trade during the 16$^{th}$ and 18$^{th}$ Centuries. It has since disappeared from cultivation in most of these regions (Nayar, 2010).

**1.6 History of rice cultivation in Ghana**

In the Gold Coast (Modern day Ghana), rice was one of the major food crops in the 17$^{th}$ and 18$^{th}$ centuries. Its significance was next to millet and maize and it was cultivated more than yam and sweet potatoes, the two chief root crops in the country (Kranjac- Berisavljevic, Blench & Chapman, 2003). Rice cultivation was mostly done by small scale subsistence farmers, who used the bush/ fallow system and shifting cultivation in which rice was cultivated from two to four years until the fertility of the soil diminished. A fresh piece of land was obtained and the cycle was repeated. The original piece of land was allowed to gain fertility for about 10–15 years

(Kranjac-Berisavljevic *et al*., 2003). Though this practice was wasteful in its use of land and labor, it was capable of sustaining the population without noticeable adverse effects on the land. Due to increase in population, the system is no longer effective and the fallow periods have been reduced to 2 - 4 years with subsequent reduction in yields ( Kranjac-Berisavljevic *et al*., 2003).

Until the 1920s, most of the rice was produced in the Volta and Western Regions of Ghana by traditional farmers. It was not until the 1960s that rice became an important crop in Ghana and now, the bulk of Ghana‘s rice comes from the Northern Region of the country. In the Volta Region, rice cultivation is frequently carried out by women while the men focus on the cultivation of crops such as coffee, cocoa and rubber. Most of the rice varieties were grown without any improvement as they were inherited from ancestors and some of these varieties are still in cultivation (Kranjac-Berisavljevic *et al*., 2003). *O. glaberrima* plants are grown on the mountains as upland hill rice. In the Inland valley, mixtures of *O. glaberrima* and improved types, mostly of *O. sativa* origin are grown in water flooded fields. Traditional rice varieties are of great importance to the people in the Volta Region of Ghana. For example, they are used for rituals, festivals, as staple food, etc. ( Kranjac- Berisavljevic, 2000).

## 1.7 Characteristic features of the African rice and its wild relatives

### 1.7.1 *Oryza glaberrima* Steud.

It is often called the African rice, red rice or rice of Casamance. It grows to a height of about 120 cm or more in upland or irrigated conditions. In floating conditions, it grows up to 5 m in height. It possesses fibrous roots and the stems are without ramifications. The inflorescence is a terminal, ellipsoid, stiff and compact panicle which is erect at maturity with ascendant racemose branches (Agnoun *et al*., 2012). Spikelets are ellipsoid, more or less persistent with reduced to sterile lemmas (glumes absent or strongly rudimentary) separated from the fertile lemmas. Caryopsis (grain) is often reddish and tightly enveloped by lemma (glume inferior) and palea (glume superior) which is usually without apical awn and can be colored (Agnoun *et al*., 2012).

In paddy fields, *O. glaberrima* can be differentiated from *O. sativa* by differences in ligule shape and panicle branching. Also lodging and seed dormancy occurs during maturity within the African rice genotypes and this can also be a differentiation factor between the two cultivated rice species (Agnoun *et al*., 2012). According to Linares (2002) *O. glaberrima* seeds shatter easily, the grains are brittle and difficult to mill and most importantly, yields are low. Some varieties of *O. glaberrima* mature faster than *O. sativa*, making them important as emergency food.

### 1.7.2 *Oryza longistaminata* A. Chev. And Roehr

It is distinct from other wild rice due to its very long and pointed ligule. It grows to about 2.5 m in height. The seeds easily shatter. It possesses rhizomes which are branched and reproduction is carried out by these rhizomes (Agnoun *et al*., 2012). It is the prototype of the perennial wild rice initially known as *O. perennis* by Moench in (1794) which was the ancestor of *O. sativa* in Asia (Dania & Williams, 1978). It is found in shallow or deep water, pools, swamps, flood plains and river banks and occurs at about 1800 m in altitude. It often occurs in pure stands. It is a source of resistance to diseases affecting *O. sativa* such as bacterial leaf blight (*Xanthomonas oryzae pv. Oryzae*). It is a harmful weed in rice cultivation areas because it subdues the growth of cultivated rice and forms hybrids with it. *O. longistaminata* is an important source of genes for the development of perennial types of *O. sativa* which would provide a permanent ground cover and reduce erosion (Brink & Belay, 2006).

### 1.7.3 *O. barthii* (*O. breviligulata* A. Chev. Roehr)

It is an annual of about 150 cm tall, growing in a bunch (Agnoun *et al*., 2012). The stem is erect and roots formed from the lower nodes are spongy, striate and glabrous. It is found in shallow water, in ponds and marshes and often occurs as weeds in rice cultivation areas. It occurs at about 1500 m in altitude. It may form pure stands but often found scattered with other aquatic grasses (Brink & Belay, 2006). The grains shatter very easily and the panicles are usually collected before they mature. It is not normally cultivated but collected from the wild. It is a source of resistance to diseases affecting *O. sativa* such as bacterial leaf blight (*Xanthomonas* *oryza pv. Oryzae*), rice yellow mottle virus (RYMV) and sheath blight (*Thanatephorus cucumeris, anamorph: Rhizoctonia salani*) (Brink & Belay, 2006).

### 1.8 Rice production systems in sub-Saharan Africa

Rice is a semi-aquatic grass and grows in varied soil types and water regimes (Verhey, 2010). It is also described by its plasticity which aids its growth in any biophysical environment in West and Central Africa (Defoer *et al*., 2004). Rice is grown in a whole range of agro-ecological zones from humid forests to Sahel within which five major rice systems can be distinguished with respect to water supply and topography in sub-Saharan Africa (Dofoer *et al*., 2004) viz:

1) Rainfed upland rice on plateaus and slopes;
2) Lowland rainfed rice in valleys and flood plains with varying degrees of water control;
3) Irrigated rice with relatively good water control in deltas and flood plains;
4) Deep water floating rice along river beds/ banks;
5) Mangrove swamp rice in lagoons and deltas in coastal areas.

The three main rice ecologies in West and Central Africa are rainfed uplands, rainfed lowlands and irrigated systems (Dofoer *et al*., 2004).

1) Rainfed upland rice on plateaus and slopes - It covers the largest area of about 44% mainly in coastal areas in the humid and sub-humid agro-ecological zone. Main water supply is rainfall but the water recedes after sometime (Dofoer *et al*., 2004). This ecology is characterized by unpredictable rainfall patterns. Rice varieties suitable for this ecology

are short duration and drought tolerant types (MoFA, 2009). Rice varieties are grown on free draining soils where the water table is permanently below the root zone of the rice plant. In some parts of West Africa, bimodal rainy season permits two crops of rice per year, while ratooning is also practiced in areas with approximately 1600 mm of rainfall per annum (Kranjac-Berisavljevic *et al*., 2003).

2) Lowland rainfed rice in valley bottoms and flood plains with varying degrees of water control- It covers an area of about 31% of the rice cultivation area (Dofoer *et al*., 2004). This ecology has water management problems due to regular flooding from ground water and precipitation (MoFA, 2009).

3) Irrigated rice with relatively good water control in deltas and floodplains - It covers 12% of the rice cultivation area. This involves the use of dam-based irrigation systems, water diversions from rivers and pump irrigation from surface water or tube wells (Dofoer *et al*., 2004). It may also be appropriate for rice-fish culture (MoFA, 2009).

**1.9 Role of soil quality in rice production**

Soil quality as defined by Doran and Parkin (1994, cited in Lungmuana and Colney, 2011) is the ―capacity of soil to function within ecosystem and land use boundaries, to sustain productivity and maintain environmental quality and promote plant and animal health". Soil health has to do with the integration of the physical, chemical and biological components of the soil. To assess soil health, soil testing is the only tool used to measure the physical, chemical and biological health of the soil (Lungmuana and Colney, 2011). The essence of soil testing is to ascertain the capability and suitability of land for agriculture and allied activities, and to identify and quantify the soil constraints such as: acidity, alkalinity, toxicity of nutrients, deficiencies and chemical fixation of nutrients, etc. Soil is a dynamic body and undergoes changes, hence the need to ascertain its quality (Lungmuana and Colney, 2011).

The soils on which rice plants grow differ as much as the climatic regimes to which the crop is exposed. Soil texture ranges from sand to clay, pH from 3-10, organic matter content from 1-50 %, salt content from 0-1% and nutrient availability from surplus to acute deficiency (Talpur, Changying, Junejo & Tagar, 2013). Intensive agriculture involving high yielding varieties of rice and other crops, has led to serious removal of nutrients from the soil. Similarly excessive and indiscriminate use of chemical fertilizers has resulted in the decline of soil health (Talpur *et al*., 2013). The micro nutrients needed by rice plants in small quantities are copper, zinc, iron, manganese etc. while the essential nutrients in rice production needed in large quantities are nitrogen, potassium and phosphorus. In fact, the demand of the rice plant for other macro nutrients mainly depends on nitrogen supply because it affects photosynthesis, dry matter production and yield supply (Hamaoka *et al*., 2013).

Poor soil is one major reason for the inability of many West African countries to reach self-sufficiency in rice production. Therefore, it is important that the soils in which the African rice and its wild relatives grow are analyzed to assess their ability for continuous survival in the face of excesses and/or deficiencies in soil nutrients.

### 1.10 Rice conservation efforts

It is imperative that germplasm are collected, conserved, characterized and utilized because it underpins global food security for continuous sustainability, especially now that threats to food security is largely attributed to climate change (Wambugu, Furtado, Waters, Nyamongo, & Henry, 2013) . Collection efforts began in the 1950s and later years (1980s and 1990s) when the International Board for Plant Genetic Resources (IBPGR, which became known as IPGRI and now Bioversity International), was formed in collaboration with both international and national partners, who funded most of the African wild rice germplasm collection efforts (Wambugu *et al*., 2013). Similarly, between 2000 and 2008, collections were also made through various missions by AfricaRice scientists and partners in Burkina Faso, Côte d'Ivoire, Niger, Sierra Leone and Togo (Sanni *et al*., 2013). Due to these relentless efforts made at collection of rice germplasm, the International Rice Research Institute (IRRI) for example, has approximately 3,601 accessions of African rice species, which is the highest collection as compared to other gene banks in the world (Wambugu *et al*., 2013). In Ghana, the International Rice Research Institute (IRRI) funded rice collections in 1985. In 1992 as well, the Ministry of Food and Agriculture organized the collecting of rice germplasm in the Western Region of the country (Bennett-Lartey, Ayensu, Monma & Ito 1997; Howes, 1981). Though data obtained from the national gene bank of Ghana (PGRRI, Bunso) and the Ghana Herbarium show that efforts were made in the past at collecting wild and domesticated rice species from various parts of the country, no collections have been made in the past twenty or more years prompting the urgency to check the current status of these very useful genetic resources in the Volta Region of Ghana, hence, the basic purpose of the current study.

Although there are more than 1750 gene banks in the world today, of which more than 10% hold some rice germplasm, the proportion of the rice germplasm that are wild is less than 3% (Hay *et al*., 2013). This indicates the need to find and collect them urgently, so as to take proper measures in conserving them either *in situ* or *ex situ*. *In situ* conservation is done by establishing reserves to allow natural evolutionary processes to be maintained, thus providing a continuous source of novel genetic variation for crop improvement (Hunter *et al*., 2012). However, *ex situ* conservation is the more common germplasm conservation method and can take the form of seed banks, field gene banks or botanic gardens (Bennett-Lartey, Ayensu, Monma & Ito 1997; Howes, 1981). DNA storage in DNA banks represents another option for the conservation of genetic materials. For example, the conservation facilities for PGR in Ghana can be classified into three categories. First, there are facilities for conserving orthodox seeds, which comprise cold storage and seed drying facilities. Then there are plants with recalcitrant seeds and vegetatively-propagated crops. These are conserved in field gene banks as living plants. Thirdly, there are *in vitro* facilities that can be used to conserve and rapidly multiply PGR. A major constraint has been storage facilities (Bennett-Lartey, Ayensu, Monma & Ito 1997; Howes, 1981). Therefore most of the seeds are now non-viable. This gap also prompted the urgency to collect African rice accessions in the current study.

One of the components for conservation of plant genetic resources to ensure proper management is characterization. "Characterization" means to describe a character or quality of an individual. The word "characterize" also means to "distinguish", that is to differentiate or to separate into kinds, classes or categories. Therefore characterization of genetic resources involves the differentiation of accessions (De Vincente *et al*., 2005). Morphological characterization of plant species is important in identification of duplicate accessions, detection of unique traits and also the structure of the population to be conserved (De Vincente *et al*., 2005). Morphological diversity is assessed by measuring variations in phenotypic traits such as growth cycle, color of leaves, among others (Machoene, 2009). Morphological markers are also referred to as 'traditional markers'. The level of analysis of these markers is phenotypic. There are certain demerits of morphological markers, namely: they are controlled by environmental conditions, they are labor demanding and require large populations of plants in performing breeding experiments. They also require large plots of land and/or green house for their growth, but they are still very useful and are of high recommendation before more in-depth biochemical or molecular studies are carried out (Smith & Smith, 1992). The main advantage of conducting morphological characterization is that published descriptors are readily available for most major crop species. Therefore, characterization of the agro-morphological characters of the rice accessions collected in this study and subsequent comparison of their diversity or relatedness, using the rice descriptors suggested by Bioversity *et al*., (2007), will provide useful information for future breeding purposes.

Another method useful in conservation of plant genetic resources is the study of their ethno-botanical uses. This is because ethno-botany entails not only the traditional knowledge of plants for food and medicine which exists for hundreds or even thousands of years but also strategies for sustainable utilization of plant genetic resources. Therefore ethnobotany has an important role in the conservation of nature, in particular biodiversity (Gary, 1995). For example, Teeken *et al*., (2012) conducted a study to analyze why farmers in different parts of the West African coastal zone either continue to grow or have abandoned the African rice. They found that farmers' varieties are the outcome of long breeding processes shaped by ecological and social factors, but this legacy tends to be neglected in existing participatory seed improvement approaches. Linares (2002) also embarked on a research to explore the reasons for the demise of the African rice and has documented the contexts within which it still survives. This is a very important approach in conservation because farmers are stewards of these important genetic resources and therefore very knowledgeable. Besides, although these genetic resources are gradually being replaced by improved varieties, some farmers continue to cultivate them because of certain socio-cultural reasons such as their use in marriage ceremonies, funerals and other customary rites. These farmers are able to pinpoint the useful traits of these genetic resources which allow for their continued cultivation (Linares, 2002; Teeken et al., 2012).

## 1.11 Objectives of the Study

The current study was, therefore, conducted with the following objectives:

- To ascertain the geographic locations of *O. glaberrima* and its wild relatives in the Volta region;
- To assess the ethno-botanical uses of *O. glaberrima* and its wild relatives in the communities in which they occur;
- To determine the mineral composition of the soils in which they are found;
- To conduct phenotypic studies to document variations among collected accessions;
- To collect and store the seeds of *O. glaberrima* and its wild relatives.

# CHAPTER TWO

## 2.0 MATERIALS AND METHODS

## 2.1 The Volta Region

### 2.1.2 Why the Volta Region was chosen for the study

In Ghana, though rice cultivation is practiced in the ten regions, it is chiefly carried out in the Northern, Upper East and the Volta Regions of Ghana. Due to challenges such as time factor and financial constraints, the Volta Region was chosen for the study. Secondly, the herbarium vouchers in the Ghana herbarium show that, in the past, efforts have been made at collecting rice germplasm in the Volta Region. Therefore it was important to check the status of these very vital genetic resources in the Volta Region, especially now when genetic erosion is at its peak.

### 2.1.3 Geographic description of the Volta Region

#### 2.1.3.1 Location and districts of the Volta Region

The Volta Region is bounded by latitudes $8^{o}$ 45 ' N and $5^{o}$ 45' N and longitude $0^{o}$ 45'E. It covers a total land area of 20,572 $km^2$ and stretches from the coast (the Gulf of Guinea) running through all the vegetation zones found in the country. The region is one of the ten (10) regions of the Republic of Ghana (MoFA, 2015). Geographically, Volta Region lies at the eastern side of Ghana. Volta Region shares common boundaries with four (4) major regions of Ghana namely, Greater Accra, Eastern, Brong Ahafo and Northern Regions. The Volta Region is divided into 18 administrative districts namely: Adaklu -Anyigbe, South Dayi (Kpeve), North Dayi (Kpando), South Tongu (Sogakope), North Tongu (Adidome), South Ketu, North Ketu, South Nkwanta, North Nkwanta, Ho Municipal, Hohoe Municipal, Jasikan, Kadjebi, Krachi East, Krachi West, Biakoye and Keta (MoFA, 2015).

#### 2.1.3.2 Vegetation

The region has a length of about 500 km stretching from the south to the north and its vegetation can be grouped into: the Coastal strand and Mangrove; Guinea savanna and Dry semi-deciduous forest (MoFA, 2015).

#### 2.1.3.3 Relief and drainage

The region has topography from less than 15 meters above sea level at the coast and up to 855 meters above sea level, with mountain Afadzato being the highest point (MoFA, 2015). More than half of the region falls within the Volta River Basin with the Volta Lake draining a substantial portion of the region. The region has the world‘s largest man-made lake (Lake Volta) (MoFA, 2015).

#### 2.1.3.4 Soils

The major soils are savanna ochrosols, sandy coastal soils, tropical grey earth, regolithic groundwater laterites, topohydric and luthochronic earth. The soil types range from heavy clay loams to sandy loams to alluvial soils (MoFA, 2015).

#### 2.1.3.5 Climate

The Volta Region has tropical climate, characterized by moderate temperature, 12$^{o}$C – 32$^{o}$C for most of the year. It also has a bi-modal rainfall pattern; i.e. it has two rainfall regimes in the year, the first from March to July and the second from mid-August to October (MoFA, 2015). Rainfall figures, which vary greatly throughout the region, are highest in the central highland areas and in the forest zone and are lowest in the Sahel-savannah zone in the northern parts of the region. The annual rainfall ranges between 513.9 mm and 1099.88 mm (MoFA, 2015).

### 2.1.4 Agricultural practices in the Volta Region

Agriculture plays a very important role in the socio-economic development of the region. This has been so since the Gold Coast era to the present day Ghana. The rural people play a vital role in the region‘s economy since they dominate the economically active population engaged in agriculture (about 74%). The main sub-sectors include crops, livestock, fisheries, agro forestry and the Non-Traditional Commodities (MoFA, 2015).

Averagely, each household owns 0.46 hectares of land for farming. The region cultivates industrial and food crops such as cereals, legumes, vegetables, oil palm root and tubers, pulses and plantation crops. Nonetheless, the region is endowed with rich vegetation that supports rearing of livestock of many species. The common farming practices include mono cropping, mixed cropping and mixed farming. Commercial rice production is chiefly done in Aveyime in the North Tongu district (MoFA, 2015).

## 2.2 Field survey of the districts

The collection mission was conducted between November 2014 and January 2015.The selection of districts visited was based on information gathered from the herbarium as well as personal communication with some members of staff of both the Department of Botany (Mr. Roger K. Ofori) and the University of Ghana‘s Soil and Irrigation Research Center (SIREC), Kpong (Mr. Timothy Osakpa and Mr. Seyram Fiati). This provided useful information on where the species have been recorded in the past. New locations were discovered in the course of the collection mission. Generally, collection was done along the major roads but in several instances the routes diverged from the major roads by either driving or walking. The location coordinates of each site where species were collected were recorded using a Global Positioning System (GPS) (GPSMAP® 60CSx).

## 2.3 Collection procedure for rice samples

Five out of the 18 districts were visited namely: Hohoe District (Likpe Bakwa, Santrokofi, Akpafu Mempeasem and Have Ando No. 1); Jasikan District (Apesokubi, Worawora); Ho Municipal District (Wegbe); Biakoye District (Kwame krom) and Adaklu-Anyigbe District (Adaklu-Waya). In some of the locations visited, no rice samples were collected because the African rice was not present. Panicle bearing seeds of cultivated rice were collected from mature rice plants and were placed in well-labeled brown envelopes. The local names of the varieties collected were: Mansa, Viwotor, Kawomor (red), Kawomor (black), Kamugbaa and Ewe Moli. At Adaklu-Waya, a wild relative of the African rice was found growing along a river bank without human interventions, but most of the seeds had shattered. The vegetative part of the wild plant was collected and placed in a sampling bag with a little water in it. It was taken to the greenhouse in the Department of Botany, University of Ghana and transplanted in pots. There was no local name for it.

## 2.4 Interview techniques

The farmers were selected on the basis of years of experience in rice farming as well as the presence of African rice accessions on their farms. The interviews were conducted mostly in Ewe, a local dialect mostly spoken throughout the Volta Region. Semi structured questionnaires were used during the interviews (Appendix 1).

Approximately 10 farmers per town visited were interviewed. The individual interviews first focused on personal information of the interviewee. The semi-structured questionnaire addressed the issue of their preference for the African rice and why very few farmers cultivate it.

**2.5 Collection procedure for soil samples and its preparation for analysis**

Wherever rice samples were collected, soil samples were also collected at a depth of 0-10cm using a soil auger. Soils were kept in soil sampling bags and labeled according to the name of the rice variety. Three samples of the soil were collected for each rice variety. The soils were air-dried for 5 days, pulverized and passed through a 2 mm diameter sieve to obtain the fine earth fraction after which they were stored in sealable plastic bags.

The soil samples were analyzed in the Ecological Laboratory of the Institute of Environment and Sanitation Studies (IESS) in the University of Ghana, Legon. The soil particle size, pH, electrical conductivity (EC) as well as the concentrations of nutrient elements such as nitrogen (N), potassium (K), phosphorus (P), iron (Fe), zinc (Zn), copper (Cu), lead (Pb), cadmium (Cd) and arsenic (As) were determined.

#### 2.5.1 Laboratory analysis of soil samples

#### 2.5.1.1 Particle size analysis

#### 2.5.1.1.1 Materials used for grain size analysis

Balance, sieves, 152H hydrometer, 1000-ml measuring cylinders, 10-ml micro beaker, timing device, bottles, plunger and a mechanical shaker.

#### 2.5.1.1.2 Procedure for grain size analysis

This test is used to determine the percentage of different grain sizes in the soil. The mechanical or sieve analysis is used to determine the distribution of the coarser, larger-sized particles and the hydrometer method is used to determine the distribution of the finer particles. The essence of the grain size analysis is to determine the grain size distribution which is used in classifying the soil. Furthermore, it helps in determining the level of water retention in the soil. 40 g of the soil was weighed into clean plastic bottles and 100 ml of 5% calgon (Sodium hexametaphosphate) solution was added. The content of each bottle was then shaken on a mechanical shaker for 2 hours after which it was transferred into 1000-ml measuring cylinder and topped up to the mark. The suspension was then agitated using a plunger and 5 minutes thereafter the density of the suspension (clay and silt) was taken using a hydrometer. The second hydrometer reading of the suspension was taken after 4 hours (clay). After the 4 hour reading, the content was emptied onto a 47 µm sieve. The sand retained on the sieve was then washed off until clear water was seen passing through the sieve. An empty beaker was weighed and recorded and the washed soil was poured into the beaker gently. It was dried at 105 $^{O}$C for 24 hours in a soil drying oven (Model SD0225). The dry weight of the sand was recorded. The empty beaker weight was subtracted from the full beaker weight of the sand. The particle size was determined using the formulae below;

$$\% \text{ Clay and Silt} = \frac{Hydrometer\ reading\ @\ 5\ minutes\ x\ 100}{Total}$$

$$\% \text{ Clay} = \frac{hydrometer\ reading\ at\ 4\ hours\ x\ 100}{Total}$$

% Silt = % (Clay and Silt) - % Clay

$$\% \text{ Sand} = \frac{Oven\ dry\ weight\ of\ the\ particles\ retained\ on\ the\ 47\quad m\ sieve\ x\ 100}{Oven\ dry\ mass\ of\ sample}$$

Total= (Sand + Clay+ Silt) g

The USDA soil texture diagram was used to classify the soil using the calculated values of sand, silt and clay.

#### 2.5.1.2 Soil pH

The soil pH readings were measured using a pH meter (Hanna Instrument Conductivity Meter, Model HI 98130) in a 1:1 soil to distilled water ratio. 20 g of each soil sample was weighed into a 100-ml beaker and 20 ml of distilled water was added. It was vigorously stirred using a glass rod and allowed to stand for 20 minutes. The electrode of the pH meter was inserted into the supernatant of the soil solution and the pH was measured. The electrode of the pH was rinsed with distilled water before each reading. The pH of each soil suspension was displayed digitally by the pH meter and these values were recorded (Page *et al.,* 1982; Klute, 1986).

#### 2.5.1.3 Electrical Conductivity (EC)

Electrical conductivity was determined by electrical conductivity meter (Hanna Instrument Conductivity Meter, Model HI 98130) in 1:1 soil water ratios. Twenty gram of soil sample was weighed into a 100- ml beaker and 20 ml of distilled water was added and stirred intermittently for 20 minutes. The conductivity electrodes were then washed and dipped into the soil extract and the digital display was recorded as the salt content in the extract, to indicate salinity of the soil sample (Page *et al.,* 1982; Klute, 1986).

#### 2.5.1.4 Detection of trace elements and heavy metals

##### 2.5.1.4.1 Reagents

1. Perchloric acid (60-62%)
2. Concentrated $HNO_3$
3. Concentrated $H_2SO_4$

##### 2.5.1.4.2 Procedure

1.0 g of each soil sample was weighed into a digestion tube, which was washed thoroughly with distilled water and a brush. 10 ml of Ternary mixture (20 ml $HClO_4$, 500 ml $HNO_3$, and 50 ml $H_2SO_4$) was added under a fume hood. The contents were heated gently at low to medium heat under a perchloric acid fume hood until dense white fumes appeared (i.e. fumes of sulphur). It was allowed to cool and then diluted with distilled water. The solution was filtered (using a filter paper and a funnel) into a washed 100-ml pyrex volumetric flask. Distilled water was added to make up to the mark. The solution was used to determine the concentrations of Zn, Fe, Mn, Cu, Pb, As and Cd using an atomic absorption spectrometer (AAS). The AAS unit has four parts: interchangeable lamps that emit light with element-specific wavelengths, a sample aspirator, a flame or furnace apparatus for volatilization of the sample and a photo detector ( Perkins, 1970).

In order to analyze a given sample using AAS, a lamp was chosen that produced a wavelength of light that was absorbed by the element. Sample solutions were aspirated into flame. If any ion of the given element was present in the flame, they would absorb light produced by the lamp before it reached the detector. The amount of light absorbed depended on the amount of the element present in the sample. Absorbance values for unknown samples were compared to calibration curves prepared by running known samples.

Calculations of concentration of the trace elements and heavy metals were done using:

$$\text{Final Concentration } (\mu g/l) = \frac{Concentration\ (analytical\ measurement) x\ Nominal\ value}{Weightof\ soil\ (g)}$$

Where:

Concentration (analytical measurement) = instrumental measurement

Nominal volume = final volume of digestate sample solution

Microgram per liter of each mineral element was then converted to milligram per kilogram (mg/kg) using the formula: mg/kg = $\frac{value}{1000}$

**2.5.1.5 Detection of total phosphorus**

1-ml aliquot of the digested solution was measured into a 25-ml volumetric flask. A drop of potassium nitrate and ammonia was added respectively to the mixture to turn yellow. 5 ml of L-Ascorbic acid was added for the blue colour development and thereafter, 5 ml of stock solution was added. A standard solution was also prepared (25 ppm). It was then read using a spectrophotometer at a wavelength of 712 nm. From the readings the percentage of phosphorus was deduced as follows:

$$\% \text{ P} = \frac{spectron\ readings}{weight\ of\ sample\ (g)} x \frac{volume\ of\ extract}{aliquot} x \frac{100}{10^6}$$

**2.5.1.6 Detection of total potassium**

A flame photometer (Model 18 Perkin-Elmer Photometer 2) was used to detect potassium. The instrument was first calibrated using standard K solutions with concentrations of 2 ppm, 5 ppm and 10 ppm. This gave the range of the concentrations to be expected in the sample solutions while the amount of light emitted at a particular wavelength was measured by a null galvanometer and recorded (Jackson, 1962). All the samples were taken through this process to determine the concentration of K. Percentage K was calculated using the formula below:

$$\% \text{ K} = \frac{flame\ reading}{1000} x \frac{volume\ of\ extract}{1000} x \frac{100}{weight\ of\ sample\ (g)}$$

**2.5.1.7 Detection of total nitrogen**

Nitrogen was determined using the Kjeldahl procedure. The method involves three major procedures: digestion, distillation and titration.

**2.5.1.7.1 Digestion procedure**

1.0 g of the soil sample was weighed into a digestion tube. 10- ml of sulphuric acid was added. 9 g of copper sulphate (catalyst) was also added. The mixture was heated at low heat on a digestion block for 30 minutes where by the soil would have been clear or straw coloured. It was allowed to cool and diluted with distilled water. The solution was filtered (using a filter paper and a funnel) into a clean 100-ml Pyrex volumetric flask. Distilled water was added to make up to the mark (Jackson, 1962).

**2.5.1.7.2 Distillation procedure**

A 250-ml titration flask containing 5 ml of boric acid and two drops of methyl red indicator were placed on the receiving platform in a steam distillation unit with tube from the condenser extending below the surface of the trapping solution. A digestion tube was also attached to the steam distillation unit containing 5 ml aliquot followed by 5 ml of aqueous NaOH. The titration flask was removed when the color changed to bluish green.

**2.5.1.7.3 Titrimetric procedure**

The distillate was titrated against 0.01 M HCl solutions to an orange end point.

The percent total nitrogen was calculated using the following formula below:

$$\% \text{ N} = \frac{titre\ x\ 14\ x\ 0.01\ x\ 100\ x\ 100}{sample\ weight\ (g)\ x\ aliquot\ x\ 1000}$$

### 2.5.2 Quality control

Reagent blanks and certified reference materials were obtained from the Ecological laboratory of the University of Ghana. They were used as standards against each batch of sample to ensure accuracy.

### 2.5.3 Green house studies

The African rice can be identified in the field based on their straight panicles and short ligule, while the wild rice species possess long awns and exhibit severe shattering as seen in the Ghana herbarium and literature (Agnoun *et al*., 2012; Linares, 2002; Brink and Belay, 2006). In the field, some of the characteristic features of the African rice seen were contrary to that from the Ghana Herbarium and literature but the farmers insisted that they were the local rice and they even called it Ewe Moli (local rice). The accessions were, however, collected and agro-morphological studies were carried out to ascertain whether indeed they were African rice varieties. All of the 7 accessions were sown in 5.0 kg of soil. The experimental design was a randomized block with three replicates. The experiment was conducted in the greenhouse at the Department of Botany, University of Ghana, Legon, between January 2015 to May 2015. The plants were watered on a daily basis with equal volume of water. After direct sowing, thinning to one plant was carried out 20 days after sowing (DAS). The temperature of the green house was between 27 $^{o}$C and 30 $^{o}$C during the day. Five grams per pot (5g/pot) of NPK fertilizer (15-15-15) was applied 20 days after sowing. At tillering, 1.5g/pot of urea was applied. There were a total of 21 pots, with each accession having 3 replicates. Agro-morphological evaluation was conducted in the green house using rice descriptors in accordance with the method described by Bioversity International *et al*., (2007). A total of 3 representative plants per accession were recorded and averaged. Agro-morphological characterization was not carried out on the wild rice because it was clearly identified in the field on the basis of the information gathered from the Ghana Herbarium. Due to its bunch growth, spongy roots and very long awns as well as the fact that it was found growing by the bank of a river among other aquatic plants, it was identified as *Oryza barthii*.

**2.5.3.1 Variables measured**

Data was collected on morphological traits including both quantitative and qualitative parameters. The venier caliper, 12 inches ruler and precision balance scale were used to measure some quantitative parameters of the rice accessions.

**2.5.3.1.1 Quantitative Traits**

**2.5.3.1.1.1 Mean days to 50% first heading**

Number of days from effective seeding date to when 50% of the plants had the first flush of flowers was observed and recorded.

**2.5.3.1.1.2 Mean days to 80% main heading**

Number of days from effective seeding date to when eighty percent of the plants were heading was recorded.

**2.5.3.1.1.3 Mean days to 80% maturity**

Number of days from effective seeding date to when eighty percent of the grains on the panicle were ripened was recorded.

**2.5.3.1.1.4 Mean ligule length (mm)**

The length of the ligule was measured from the base of the collar to the tip of the ligule of the penultimate leaf, i.e. leaf below the flag leaf. This was done after anthesis.

**2.5.3.1.1.5 Mean leaf blade length (mm)**

This was measured from the ligule of the penultimate leaf to the tip of the blade.

**2.5.3.1.1.6 Mean leaf blade width (mm)**

The widest portion of the penultimate leaf on the main culm was measured at early reproductive stage.

**2.5.3.1.1.7 Mean flag leaf length (mm)**

The length of the flag leaf from the ligule to the tip of the blade was measured.

**2.5.3.1.1.8 Mean flag leaf width (mm)**

The width at the widest portion was measured.

**2.5.3.1.1.9 Mean culm length (mm)**

This was measured from ground level to the base of the panicle of three representative plants.

**2.5.3.1.1.10 Mean grain length (mm)**

This was measured at the distance from the base of the lowermost glume to the tip (apiculus) of the fertile lemma or palea.

**2.5.3.1.1.11 Mean grain width (mm)**

This was measured at the distance across the fertile lemma and palea at the widest point. An average of 10 representative grains was measured.

**2.5.3.1.1.12 Mean 100-grain weight (g)**

Random sample of 100 well -developed, whole grains, were dried to 13% moisture content and weighed on a balance.

#### 2.5.3.1.2 Qualitative trait

##### 2.5.3.1.2.1 Ligule shape

The shape of the ligule was observed and categorized based on four character states: Absent (0), Truncate (1), Acute to acuminate (2) or 2-cleft (3)

##### 2.5.3.1.2.2 Culm strength

Culms were assessed by gently pushing the tillers back and forth. This test gives some indication of stiffness and resilience. This was categorized into five character states: very weak (1), weak (3), intermediate (5), strong (7) or very strong (9).

##### 2.5.3.1.2.3 Awn presence

The presence or absence of awns was observed and categorized into three character states: absent (0), partly awned (1) or fully awned (2)

##### 2.5.3.1.2.4 Panicle attitude of branches

The panicle attitude of the main axis was observed and categorized into four character states: upright (1), semi-upright (2), slightly drooping (3) or strongly drooping (4).

## 2.6 Data Analysis

### 2.6.1 Mineral elements

Gen-Stat statistical package version 12 was used to undertake one-way analysis of variance (ANOVA) at a significant level of $p \leq 0.05$. Post Hoc tests were carried out for values with $p \leq 0.05$ using Fisher‘s Least Significant Difference.

### 2.6.2 Agro-morphological diversity

The data were statistically analyzed using Gen-Stat package version 12. The package helped to calculate the minimum, maximum, mean and standard deviation values as well as the coefficient of variation. One-way analysis of variance (ANOVA) at a significant level of $p \leq 0.05$ was computed and a Post Hoc test for values with $p \leq 0.05$ using Fisher‘s Least Significant Difference was carried out as well.

Numerical Taxonomy System (NTSYS) version 2.1 (Rohlf, 2000) was used to determine variations among the different accessions. A dissimilarity matrix (DIST coefficient) based on all traits was created for each group from the transformed data using average taxonomic distance. (Sneath & Sokal, 1973). The product moment correlation (CORR. Coefficient), for each group was also calculated for all possible pairs. The DIST and CORR coefficient were calculated for all possible pairs to obtain the respective matrices and create the dendograms. The cophenetic correlation for each dendogram was computed as a measure of goodness of fit (Mantel t-test) for the method of clustering used. Distance matrix was constructed by means of Jaccard coefficient. Data transformation matrices and dendograms were calculated and visualized by applying the widely used unweighted pair group method using arithmetic average (UPGMA) in NTSYS software programe (Rohlf, 2000).

### 2.6.3 Questionnaires

Data obtained from the questionnaire administration were analyzed using Microsoft Excel 2007. Percentages of responses were computed. Desirable and undesirable traits were ranked to highlight farmers‘ perception.

# CHAPTER THREE

## 3.0 RESULTS

### 3.1 The distribution of cultivated and wild rice in fields visited

The coordinates of the locations for sites visited are listed in Table 1. These coordinates were presented to staff of the Center for Remote Sensing and Geographic Information Services (CERSGIS) who assisted in creating the distribution map of rice fields in the study area (Plate 1).

**Table 1: Coordinates showing the distribution of cultivated and wild rice in fields visited**

| District | Town | Latitude | Longitude | Accessions collected |
|---|---|---|---|---|
| Adaklu | Adaklu - waya | N06.44272 | E000.62962 | Wild rice |
| Adaklu | Adaklu - waya | N06.44243 | E000.62998 | Wild rice |
| Adaklu | Adaklu - waya | N06.44232 | E000.63003 | Wild rice |
| Adaklu | Adaklu - waya | N06.44224 | E000.63013 | Wild rice |
| Biakoye | Kwame Krom | N07.27169 | E000.32638 | No sample collected |
| Hohoe | Likpe Bakwa | N07.13830 | E000.54255 | Kamugbaa/Mansa/Viwotor |
| Hohoe | Santrokofi | N07.18572 | E000.47737 | No sample collected |
| Hohoe | Santrokofi | N07.24989 | E000.46794 | No sample collected |
| Hohoe | Akpafu Mempeasem | N07.24457 | E000.46929 | Kawomor(red and black) |
| Hohoe | Haver Ando No. 1 | N06.79601 | E000.34019 | No sample collected |
| Ho municipal | Wegbe | N06.64898 | E000.37498 | Ewe Moli (Wegbe) |
| Jasikan | Akpesokubi | N07.59023 | E000.39513 | No sample collected |
| Jasikan | Worawora | N07.53436 | E000.37987 | Ewe Moli (Worawora) |
| Jasikan | Worawora | N07.53572 | E000.37498 | No sample collected |

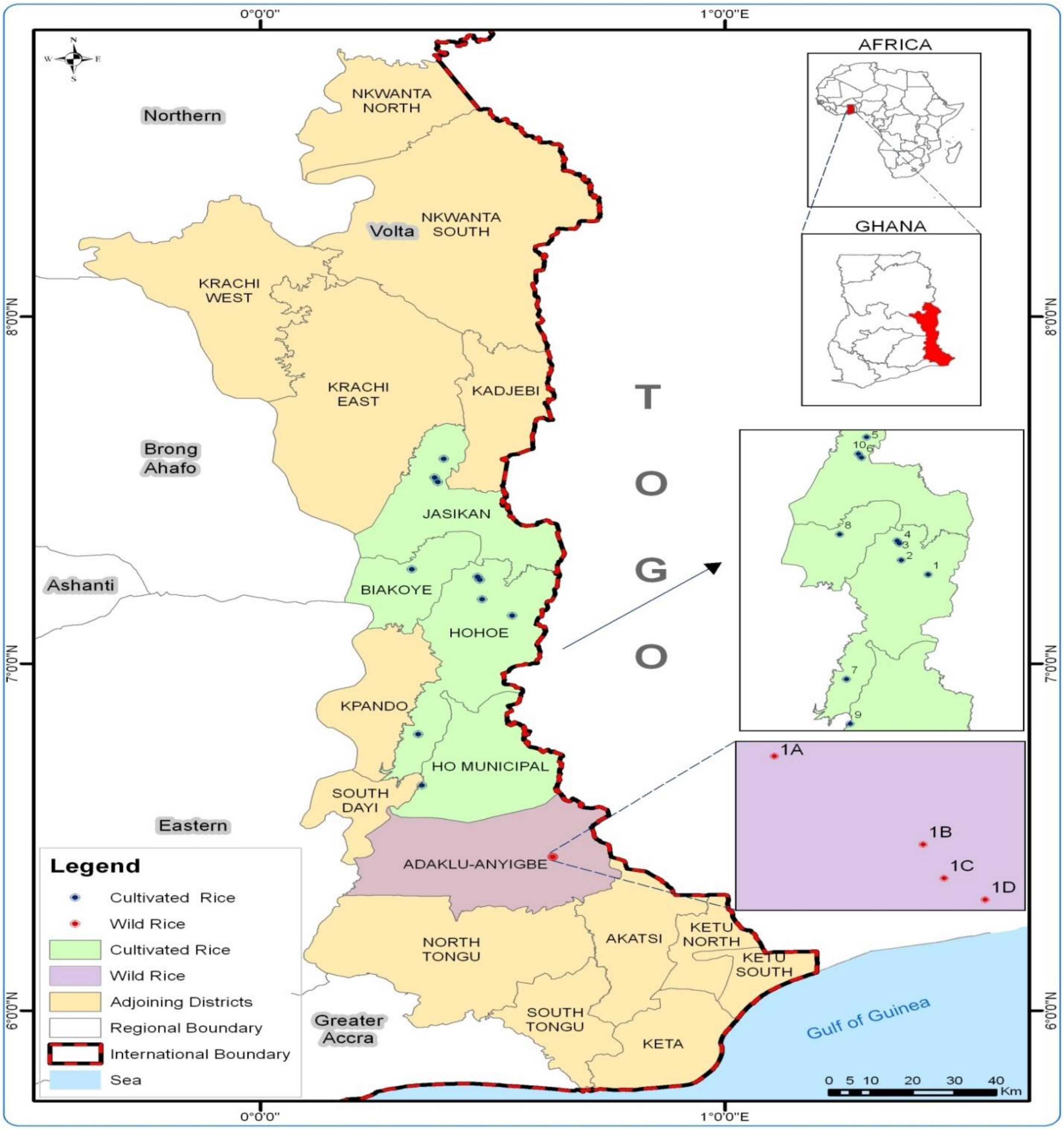


**Plate 1: A map of the study area showing the distribution of cultivated and wild rice in fields visited**

### 3.2 Vegetation of the collection sites

**3.2.1 Likpe Bakwa-** Rice farms here were mainly upland rainfed. As a result of agricultural practices, the vegetation has been transformed from forest vegetation to savanna vegetation. Here three rice varieties were collected namely: Mansa, Viwotor and Kamugbaa. The predominant tree species encountered were *Ceiba pentandra*, *Triplochiton scleroxylon*, *Elaeis guineensis* and *Khaya senegalensis*. The ecosystem of rice farming here is upland rainfed.

**3.2.2 Akpafu Mempeasem -** Due to anthropogenic activities, the vegetation has been changed from forest vegetation to savanna vegetation. The rice varieties collected here were namely: Kawomor (red and black). The major tree species found were *Elaeis guineensis*, *Cocos nucifera* and *Musa sapientum.* Farmers practice upland rice farming and intercrop the rice with other crops such as *Saccharum officinarum*.

**3.2.3 Worawora-** The original vegetation (forest vegetation) is gradually being altered. This could be mostly attributed to the logging activities taking place. A river flows through the farm but recedes after sometime. A rice variety identified as Ewe Moli by the farmers was collected. Upland rice farming is the common practice. The main tree species encountered were *Elaeis guineensis*, *Cocos nucifera* and *Musa sapientum.*

**3.2.4 Wegbe** – The vegetation here is forest ecosystem, but due to human activities such as farming and logging, the vegetation is gradually changing to a savanna ecosystem. Thickets were also found close to the collection sites. The rice variety collected was also called Ewe Moli. The predominant trees species found were *Elaeis guineensis* , *Ceiba pentandra,* and *Musa sapientum.*

**3.2.5 Adaklu-Waya -**The vegetation is derived savanna. The wild rice was found here amidst grasses like *Panicum minimum* and *Panicum maximum*. It was growing along the bank of a river called River Tedzitsor. The trees which were predominant were *Ceiba pentandra*, *Elaeis guineensis*, *Musa paradisiaca, Cocos nucifera*, *Tectona grandis* and *Theobroma cacao*.

### 3.3 Evidence of threats to diversity in the fields visited

In most farms (80%) visited there was no evidence of African rice cultivation taking place. Few farms (20%) cultivated the African rice, and even on such farms the African rice varieties were only grown in pure stands on very small portions of the land while the Asian rice was actively cultivated on a larger portion of the land. Similarly, wild rice was not found on farmers fields because the farmers see them as weeds. This informed the administration of questionnaires to assess reasons why the cultivation of the African rice was gradually diminishing. In the case of the wild rice, questionnaires were not administered because as earlier stated it was growing without any human intervention.

**Plate 2: Sections of the wild rice destroyed by a heavy duty vehicle**

The research team was, however, informed by the local field guide that a heavy duty vehicle was used to access the water from River Tedzitsor for building purposes. This had led to the destruction of sections of the wild rice as shown in plate. 2.

### 3.4 Questionnaires

Table 2 gives an overview of the farmer‘s interviewed. In all, 60 farmers were interviewed including 37 females and 23 males.

**Table 2: Number of farmers interviewed in the Volta Region of Ghana**

| District | Female | Male | Total |
|---|---|---|---|
| Hohoe | 18 | 5 | 23 |
| Jasikan | 5 | 9 | 14 |
| Ho | 8 | 4 | 12 |
| Biakoye | 6 | 5 | 11 |
| **Total** | **37** | **23** | **60** |

The information gathered from the interviews is presented in the ensuing sub-sections.

#### 3.4.1 Demography of respondents

In the Volta Region, rice farming is gender related. Most of the rice farmers encountered were women and accounted for 62% of the sample group. The interviewees were mostly small scale farmers. The average age of the interviewed farmers across the four districts was 35 years. Half of the farmers interviewed had attended primary school while the other half constituted secondary school certificate holders, illiterates and vocational apprentices. Majority of the farmers interviewed cultivated their rice on rain fed upland areas.

### 3.4.2 Reasons why few farmers still cultivate the African rice

Some of the desirable traits influencing the continuity of African rice cultivation by farmers in the Volta Region are: good taste, grain expansion after cooking, good grain quality, drought tolerance and diseases/ pest resistance. However, low yield, lodging and shattering of seeds, difficult de-husking the grains were cited by most farmers as the reasons why they had abandoned the cultivation of the African rice. This information is presented in Table 3.

**Table 3: Desirable and undesirable traits of the African rice in the Volta Region of Ghana**

| **Desirable traits in the African rice** | **% of respondent** | **Undesirable traits in the African rice** | **% of respondent** |
|---|---|---|---|
| Good taste | 100.00% | Low yield | 100.00% |
| Good grain quality | 87.00% | Difficult de-husking | 100.00% |
| Cooking quality | 100.00% | Lodges and shatters easily | 100.00% |
| Disease / pest resistance | 100.00% | | |
| Drought tolerance | 100.00% | | |

### 3.5 Physicochemical properties of the soils

#### 3.5.1 Soil pH

The pH of the soils from the sites of the different rice accessions ranged from 4.68 ± 0.14 to 6.71 ± 0.16 as shown in Table 4. The minimum pH of 4.68 ± 0.14 was recorded in soils of the accession Ewe Moli (Worawora) while the maximum pH of 6.71 ± 0.16 was recorded in soils of the accession Ewe Moli (Wegbe).

#### 3.5.2 Electrical conductivity

The EC of the soils of the different rice varieties ranged from 98.00 ± 16.64 to 222.33 ± 21.39 $\mu Scm^{-1}$ as shown in Table 4. The level of salinity varied from 98 ± 16.64 $\mu Scm^{-1}$ {in soils of the accession Ewe Moli (Worawora)} to 222.33 ± 21.39 $\mu Scm^{-1}$ {in soils of the accession Ewe Moli (Wegbe)}.

#### 3.5.3 Soil particle size

The particle sizes of soils of the different rice accessions are presented in Table 4. The percentage silt content ranged from 4.84 ± 2.91 % in soils of the accessions Ewe Moli (Wegbe) to 19.86 ± 1.72 % in soils of the accession Viwotor. The clay content varied from 8.35 ± 2.59 % (in soils of accession *O. barthii*) to 28.84 ± 6.13 % (in soils of the accession Kawomor). The soils of the accession Mansa had a minimum sand content of 53.51 ± 9.08 % while Ewe Moli (Wegbe) had a maximum sand content of 85.48 ± 8.72 %.

Based on the analysis of variance carried out, there were significant differences among the soils of the various accessions in soil pH, EC and particle size.

**Table 4: pH, EC and particle size of soils of each accession**

| **Accessions** | **pH** | **EC(μScm$^{-1}$)** | **Silt (%)** | **Clay (%)** | **Sand (%)** | **Textural class** |
|---|---|---|---|---|---|---|
| Kawomor | $5.69 \pm 0.07^{c}$ | $128.67 \pm 23.18^{a,b,c}$ | $16.35 \pm 7.03^{b,c}$ | $28.84 \pm 6.13^{c}$ | $54.81 \pm 12.03^{a}$ | Sandy clay |
| Ewe Moli (Worawora) | $4.68 \pm 0.14^{a}$ | $98.00 \pm 16.64^{a}$ | $15.53 \pm 4.56^{b,c}$ | $21.66 \pm 2.29^{b,c}$ | $62.80 \pm 6.83^{a,b}$ | Sandy clay loam |
| Kamugbaa | $6.08 \pm 0.28^{d}$ | $165.33 \pm 63.41^{c}$ | $9.08 \pm 5.38^{a,b}$ | $16.42 \pm 9.16^{a,b}$ | $76.50 \pm 11.90^{b,c}$ | Sandy loam |
| Viwotor | $5.83 \pm 0.24^{c,d}$ | $117.33 \pm 23.24^{a,b,c}$ | $19.86 \pm 1.72^{c}$ | $19.86 \pm 1.72^{b,c}$ | $60.27 \pm 3.43^{a}$ | Sandy clay loam |
| Mansa | $5.31 \pm 0.17^{b}$ | $109.00 \pm 32.51^{a,b}$ | $18.93 \pm 6.02^{c}$ | $27.56 \pm 5.30^{c}$ | $53.51 \pm 9.08^{a}$ | Sandy clay loam |
| Ewe moli (Wegbe) | $6.71 \pm 0.16^{e}$ | $222.33 \pm 21.39^{d}$ | $4.84 \pm 2.91^{a}$ | $9.68 \pm 5.81^{a}$ | $85.48 \pm 8.72^{c}$ | Loamy sand |
| *O. barthii* | $6.45 \pm 0.05^{e}$ | $163.33 \pm 5.77^{b,c}$ | $7.96 \pm 0.75^{a}$ | $8.35 \pm 2.59^{a}$ | $83.70 \pm 3.17^{c}$ | Loamy sand |
| **P value** | **< 0.001** | **0.004** | **0.003** | **0.002** | **0.001** | |

Means in the same column with the same superscript are not significantly different ($p \leq 0.05$)

### 3.6 Mineral elements in the soil

The mean concentration of mineral elements (N, P, K, Fe and Zn) in the soils of the various rice accessions are presented in Table 5 while that of (Cu, Pb, Cd and As) are presented in Table 6. The total N concentration of soils of the different rice varieties ranged from a minimum concentration of 0.05 ± 0.01% (in soils of the accession *O. barthii*) to a maximum concentration of 0.30 ± 0.16% (in soils of the accession Viwotor).

The minimum total P concentration of 0.02 ± 0.00 % was recorded in soils of the accession *O. barthii* while a maximum concentration of 0.17 ± 0.01% was recorded in soils of the accession Kawomor.

The mean total K concentration of soils of the 7 rice accessions varied from a minimum concentration of 0.03 ± 0.01% (in soils of the accession *O. barthii*) to a maximum concentration of 0.22 ± 0.04 % (in soils of the accession Kawomor).

The minimum Fe concentration of 0.11 ± 0.04 mg/kg was recorded in soils of the accession Ewe Moli (Worawora) while a maximum concentration of 0.43 ± 0.10 mg/kg was recorded in soils of the accession Kawomor.

The soils of both accessions Kawomor and Ewe Moli (Wegbe) had same minimum Zn concentrations of 0.04 ± 0.01 and 0.04 ± 0.02 mg/kg respectively while soils of the accession *O. barthii* had a maximum concentration of 0.12 ± 0.02 mg/kg.

Cu concentration was lowest in soils of the accessions Ewe Moli (Wegbe) (2.84 ± 0.66 mg/kg) and highest in soils of the accession *O. barthii* (6.02 ± 0.57 mg/kg).

Mean Pb concentration in soils of the 7 rice accessions indicated that soils of the accession Kawomor had a minimum concentration of 0.02 ± 0.01 mg/kg while soils of the accession Ewe Moli (Wegbe) had a maximum concentration of 0.26 ± 0.16 mg/kg.

Cd and As concentrations were below detection in all the 7 soils of the different accessions of rice.

One way analysis of variance showed that there were significant differences among soils of the different rice accessions in N, P, K, Fe and Zn concentrations, which was contrary to concentrations in Cu and Pb.

**Table 5: Concentrations of N, P, K, Fe and Zn in soils of the various rice accessions.**

| Accessions | TN (%) | TP (%) | TK (%) | Fe (mg/kg) | Zn (mg/kg) |
|---|---|---|---|---|---|
| Kawomor | $0.26 \pm 0.01^{b,c}$ | $0.17 \pm 0.01^{c}$ | $0.22 \pm 0.04^{c}$ | $0.43 \pm 0.10^{b}$ | $0.04 \pm 0.02^{a}$ |
| EweMoli(Worawora) | $0.21 \pm 0.01^{b,c}$ | $0.16 \pm 0.01^{b}$ | $0.13 \pm 0.01^{b,c}$ | $0.11 \pm 0.04^{a}$ | $0.05 \pm 0.02^{a}$ |
| Kamugbaa | $0.23 \pm 0.04^{b,c}$ | $0.16 \pm 0.01^{b}$ | $0.17 \pm 0.04^{c,d}$ | $0.36 \pm 0.21^{b}$ | $0.08 \pm 0.03^{a,b}$ |
| Viwotor | $0.30 \pm 0.16^{c}$ | $0.16 \pm 0.00^{b}$ | $0.16 \pm 0.02^{c}$ | $0.25 \pm 0.16^{a,b}$ | $0.05 \pm 0.01^{a}$ |
| Mansa | $0.17 \pm 0.04^{b}$ | $0.16 \pm 0.01^{b}$ | $0.18 \pm 0.03^{a,b}$ | $0.16 \pm 0.07^{a}$ | $0.08 \pm 0.05^{a,b}$ |
| Ewe Moli (Wegbe) | $0.15 \pm 0.03^{a,b}$ | $0.16 \pm 0.01^{b}$ | $0.08 \pm 0.06^{c,d}$ | $0.28 \pm 0.04^{a,b}$ | $0.04 \pm 0.01^{a}$ |
| *O. barthii* | $0.05 \pm 0.01^{a}$ | $0.02 \pm 0.00^{a}$ | $0.03 \pm 0.01^{a}$ | $0.12 \pm 0.02^{a}$ | $0.12 \pm 0.02^{b}$ |
| **P Value** | **0.006** | **< 0.001** | **< 0.001** | **0.022** | **0.023** |

Means in the same column with the same superscript are not significantly different ($p \leq 0.05$)

**Table 6: Concentrations of Cu, Pb and Cd in soils of the various rice accessions.**

| **Accessions** | **Cu (mg/kg)** | **Pb (mg/kg)** | **Cd (mg/kg)** | **As (mg/kg)** |
|---|---|---|---|---|
| Kawomor | 4.29 ± 1.68 | 0.02±0.01 | BD | BD |
| Ewe Moli (Worawora) | 3.20 ± 1.21 | 0.26± 0.16 | BD | BD |
| Kamugbaa | 3.30 ± 1.77 | 0.18 ± 0.13 | BD | BD |
| Viwotor | 4.02 ± 1.09 | 0.11± 0.06 | BD | BD |
| Mansa | 3.77 ± 1.19 | 0.07±0.04 | BD | BD |
| Ewe Moli (Wegbe) | 2.84 ± 0.66 | 0.10 ± 0.08 | BD | BD |
| *O. barthii* | 6.02 ± 0.57 | 0.12 ± 0.03 | BD | BD |
| **P Value** | **0.112** | **0.098** | | |

Means in the same column with the same superscript are not significantly different ($p \leq 0.05$)

### 3.7 Agro-morphological characterization of rice accessions

Summary statistics on agro-morphological variables highlighted the diversity of the accessions collected. The minimum, maximum, mean, standard deviation and coefficient of variation values showed the range of variability of 12 quantitative variables for seven rice accessions (Table 7). From the total variables examined, only 7 exhibited significant differences ($p \leq 0.05$) (Table 8).

Association among the 7 accessions revealed by UPGMA cluster analysis is presented in Fig 3. The dendograms classified varieties into two main clusters. The larger cluster which was assigned as cluster 2 consisted of 4 varieties, namely; Ewe Moli (Worawora), Mansa, Viwotor and Ewe Moli (Wegbe). Kamugbaa, Kawomor (black) and Kawomor (red) belonged to cluster 1. Traits that were distinct in the formation of the two groups were; number of days to first heading, number of days to main heading, number of days to maturity, ligule length, ligule shape, leaf blade width, flag leaf width, culm length, grain width, hundred grain weight, awn presence, culm strength and panicle attitude of branches. Cluster 1 had varieties with short and truncated ligules, weak culms, presence of short awns, erect to semi-erect panicles. They were also early maturing, had heavier hundred grain weight, wider flag leaf width and leaf blade width. Drooping panicles, strong culms, long ligules which are 2-cleft in shape, absence of awns, narrower leaf blade width and flag leaf width and longer crop cycle were characteristics of cluster2.

**Table 7: Summary statistics of 12 quantitative variables showing the diversity of 7 rice accessions**

| Quantitative variable | Min | Max | Mean ± S.D | CV (%) |
|---|---|---|---|---|
| Number of days from seedling to first heading : FH | 46 | 66 | 56.71 ± 9.55 | 16.84 |
| Number of days from seedling to main heading : MH | 61 | 87 | 75.29 ± 12.80 | 17.00 |
| Number of days from seedling to maturity: Cycle | 84 | 109 | 97.71 ± 12.08 | 12.36 |
| Ligule length : LL (mm) | 0.30 | 1.60 | 0.94 ± 0.60 | 63.83 |
| Leaf blade length : LBL (mm) | 26.73 | 44.10 | 37.04 ± 6.06 | 16.36 |
| Leaf blade width: LBW (mm) | 0.70 | 1.13 | 0.93 ± 0.19 | 20.43 |
| Flag leaf length: FLL (mm) | 29.50 | 38.57 | 32.91±3.11 | 9.45 |
| Flag leaf width: FLW (mm) | 0.53 | 1.60 | 1.14 ± 0.41 | 35.96 |
| Culm length: CL (mm) | 31.50 | 82.27 | 47.83 ± 17.84 | 37.30 |
| Grain length: GL (mm) | 9.16 | 10.26 | 9.80 ± 0.43 | 4.39 |
| Grain width: GW (mm) | 1.17 | 2.60 | 1.71 ± 0.61 | 58.48 |
| 100-grains weight:HGW (g) | 2.46 | 2.94 | 2.68 ± 0.18 | 6.72 |

Min: minimum, Max: maximum, SD: standard deviation and CV: Coefficient of Variation

**Table 8: Ranking of the quantitative variables that are significantly different**

| Accessions | FH | MH | Cycle | LL | LBW | FLW | CL | GW | HGW |
|---|---|---|---|---|---|---|---|---|---|
| Kamugbaa | $47.00^{b}$ | $61.00^{b}$ | $84.00^{b}$ | $0.33^{b}$ | $1.13^{a}$ | $1.57^{a}$ | $56.97^{b}$ | $1.40^{b}$ | $2.73^{b}$ |
| Kawomor (black) | $47.00^{b}$ | $62.00^{b}$ | $86.00^{b}$ | $0.30^{b}$ | $1.13^{a}$ | $1.47^{a}$ | $37.17^{c}$ | $1.17^{b}$ | $2.84^{a,b}$ |
| Kawomor (red) | $46.00^{b}$ | $62.00^{b}$ | $85.00^{b}$ | $0.30^{b}$ | $1.10^{a}$ | $1.60^{a}$ | $46.43^{b,c}$ | $1.32^{b}$ | $2.94^{a}$ |
| Ewe Moli (Wora wora) | $65.00^{a}$ | $86.00^{a}$ | $109.00^{a}$ | $1.47^{a}$ | $0.77^{b}$ | $0.53^{c}$ | $48.63^{b,c}$ | $1.52^{b}$ | $2.46^{d}$ |
| Mansa | $66.00^{a}$ | $87.00^{a}$ | $109.00^{a}$ | $1.30^{a}$ | $0.80^{b}$ | $0.93^{b}$ | $31.83^{c}$ | $2.60^{a}$ | $2.47^{d}$ |
| Viwotor | $63.00^{a}$ | $86.00^{a}$ | $108.00^{a}$ | $1.30^{a}$ | $0.70^{b}$ | $0.93^{b}$ | $31.50^{c}$ | $1.40^{b}$ | $2.60^{c}$ |
| Ewe Moli (Wegbe) | $63.00^{a}$ | $83.00^{a}$ | $103.00^{a}$ | $1.60^{a}$ | $0.87^{a,b}$ | $0.97^{b}$ | $82.27^{a}$ | $2.58^{a}$ | $2.73^{b}$ |
| **P Value** | **< 0.001** | **< 0.001** | **< 0.001** | **< 0.001** | **0.012** | **< 0.001** | **< 0.001** | **0.002** | **< 0.001** |

Means in the same column with the same superscript are not significantly different ($p \leq 0.005$)

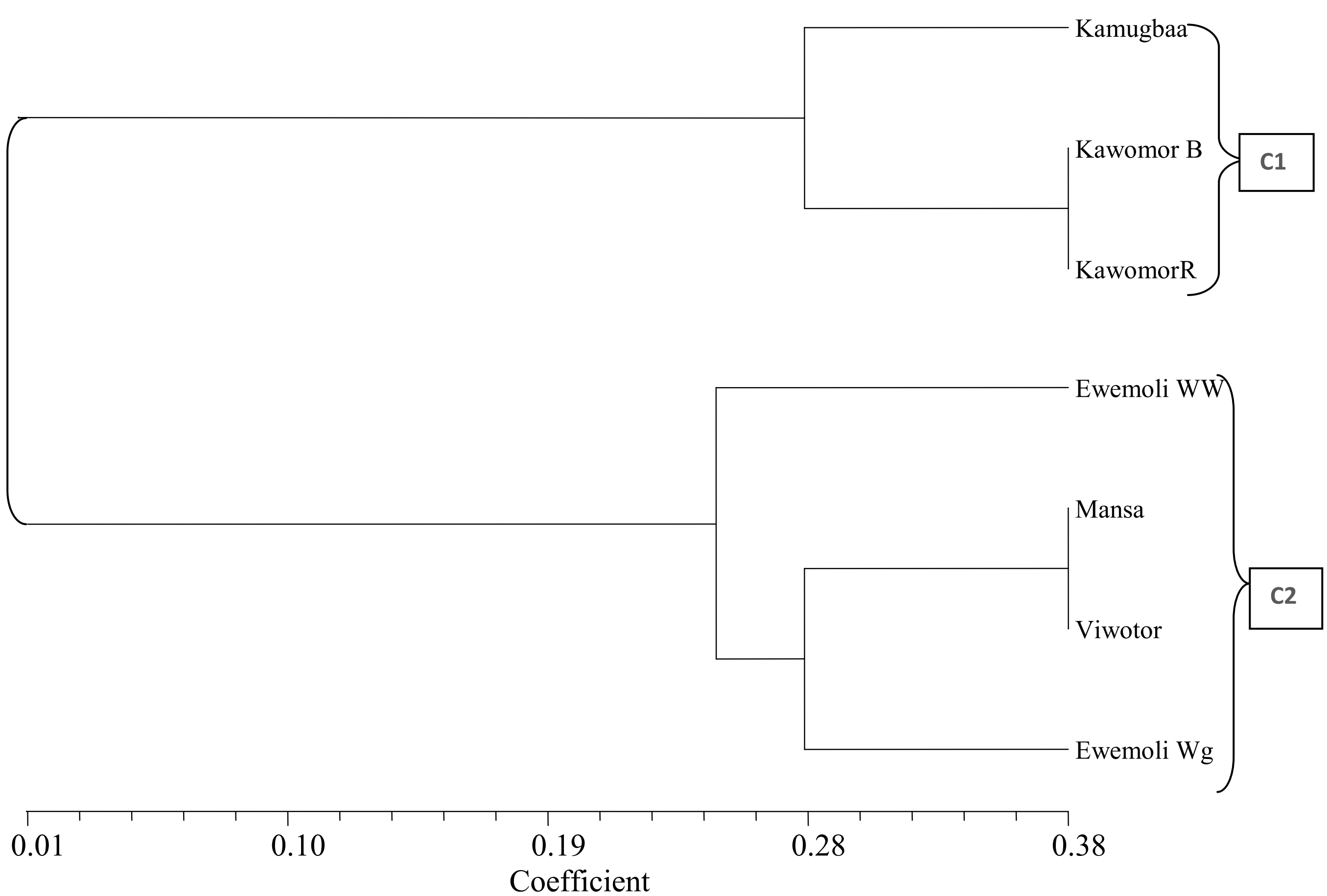


Plate 3: Dendogram based on 16 agro-morphological characters for seven rice accessions generated by UPGMA clustering using Jacquard‘s coefficient of similarity

# CHAPTER FOUR

## 4.0 DISCUSSION

### 4.1 Threats to diversity in the field

Based on the evidence from the field, the cultivation of *O. glaberrima* is gradually declining in favor of *O. sativa.* Farmers in the Volta Region prefer varieties which are more productive and therefore tend to grow more of the *O. sativa* varieties. Evidence from previous studies has shown that the cultivation of *O. glaberrima* is gradually diminishing as a result of the introduction of *O. sativa* (Nayar, 2012). The wild rice was not found in farmers‘ fields, because the farmers see them as weeds, therefore are severely threatened. The level of threat where the wild rice was found (Adaklu-Waya) is lower probably due to lack of agricultural activities taking place except for the heavy duty truck which comes occasionally to take up water for construction purposes. Similar studies in the Northern part of Ghana, Mali and Tanzania showed that the wild rice found on farmers‘ fields were seen as weeds and therefore efforts were made by the farmers to reduce their population or eradicate them totally (Johnson, 2000).

### 4.2 Questionnaires

#### 4.2.1 Rice cropping practices

Based on the survey carried out in the Volta Region of Ghana, women dominated rice cropping while the men were involved in cultivating sugar cane, maize, millet and coffee. This finding is not different from previous studies carried out in other African countries. According to Huvio (1998) as stated by Agboh-Noameshie, Kabore and Misiko (2013) women are more involved in rice farming in The Gambia and Liberia. Similarly, in earlier studies conducted in Burkina Faso and Ghana, it was also concluded that the number of women in rice farming is higher as compared to the number of men (Kam, 2011; Norman & Kebe, 2006). In the Volta region of Ghana, women play a significant role in rice cropping because they are able to bring up new varieties of rice which they have carefully experimented on. They also practice agro-biodiversity and are better at selecting and storing seeds. These findings were not different from earlier studies, in Guinea and Democratic Republic of Congo (Agboh-Noameshie *et al*., 2013).

### 4.2.2 Preferred rice traits

In the Volta Region, both farmers and consumers indicated that in spite of the relatively low cultivation, they still cherished their local varieties because of the good taste, expansion of grains when cooked and the good grain quality. The Jola women of Senegal also liked their local varieties due to the above mentioned traits (Linares, 2002). During special occasions (marriage ceremonies), it is used to fulfill ceremonial rites. In the current study, about 80% of the farmers were not cultivating the African rice while 20% of the farmers grew it in small quantity. The reasons given were that it has low yield, it is difficult to de-husk and it lodges easily. They prefer varieties which they find commercially profitable.

## 4.3 Physicochemical properties of soil

### 4.3.1 Soil pH

The current study showed that the pH of the soils of the 7 rice accessions were acidic. The variations may be due to their geographic locations. Similar works by Ilagan *et al*., (2014) and Fo *et al*., (2012) showed that the paddy soils were acidic. Intensive crop production, rainfall and water percolation and organic matter decay are factors which lead to soil acidity. In sandy soils, water percolates quickly and the bases reservoir is rather small (buffer capacity) due to the low clay and organic matter content (Talpur *et al*., 2013). According to Fageria *et al*., (2011), soil pH is an essential chemical property due to its impact on soil micro organisms and the accessibility of nutrients to plants. The most favorable pH for rice ranges from 5.5 – 7.0; however, rice is known to grow under a pH of 4.2 – 8.5 (Fo *et al*., 2012). Therefore the pH of the soils of the various rice accessions fall within acceptable limits. The rice varieties encountered seem to be more tolerant of acid soils.

### 4.3.2 Electrical Conductivity

The electrical conductivity of the soils in the study showed that there were significant differences in soils of the different accessions. These variations could be due to the source of water irrigation in paddy fields and/or could be geographical. In a study carried out by Ndaeyo, Iboko, Harry and Edem (2008), a salinity level of 0.06 dS/m (60 $\mu Scm^{-1}$) was recorded in a Teaching and Research farm in the University of Uyo, Nigeria which is lower than of the current study. Soils with EC of 4 ds/m (4000 $\mu Scm^{-1}$) or more are classified as saline (Munns & Tester, 2008). The low levels of salinity in soils of the various accessions may be due to the fact that the farms are not close to coastal areas. Soils with high levels of salt reduce the ability of plants to take up water which inhibits plant growth (Munns & Tester, 2008). Hence, the findings in the current study show that the soils of the different accessions fall within the acceptable limits of salt concentration.

### 4.3.3 Soil particle size

Averagely, the soils in the current study had 17.78 ± 4.05 % silt, 18.91 ± 4.71 % clay and 68.15 ± 7.88 % sand. The texture of the soil ranged from sandy clay to sandy clay loam to sandy loam to loamy sand. According to Bell and Seng (2005), a soil is termed ‗sandy' if it contains <18 % clay and > 65 % sand, therefore the soils in the current study could be described as sandy. The high percentage of sand observed could be as a result of high weathering of the parent material. Similar outcomes were obtained in soils of upland rice production in the Northern Guinea Savanna of Nigeria (Odunze *et al*., 2010). The problem with sandy soils is leaching; water percolates through soils easily, carrying away nutrients and bringing in toxic materials (Bell & Seng, 2005). Effective water control is difficult because sandy soils do not retain water. Sandy soils may be improved by adding organic matter and mineral fertilizers (Bell & Seng, 2005). The African rice varieties studied seem to be well adapted to sandy soils.

#### 4.3.4 Mineral elements in the soil

The N concentration in the soils studied varied across accessions (0.05 ± 0.01 to 0.30 ± 0.16 %). The variations may be geographical. Nitrogen is a mobile nutrient in the soil and therefore a limiting factor for plant growth. It occupies a unique position as a plant nutrient, therefore high amounts are required as compared to the other essential nutrients (Hofman & Oswald 2004; Akenga *et al*., 2014 ). The concentrations of total N among the soils of the various accessions seem to be low. This could be as a result of leaching, since the soils are sandy. Sandy soils retain only about one inch of water per foot of soil, therefore relatively small amount of rain or irrigation water readily move nitrate below the root zone (Lamb, Fernandez & Daniel, 2014). Total N concentration in the soils of *O. barthii* was the lowest as compared to soils of the other accessions. It is possible that the wild rice accession has genetic traits that are able to adapt to low nitrogen conditions (Hamaoka *et al*., 2013). Oriola and Olabode (2013) recorded a total N ranging from 0.28 to 32.56 % in irrigated rice fields in Kwara state, Nigeria which were higher than that observed in the current study. Nitrogen is a constituent of the building block of all plant structures and the most important plant nutrient for crop production and also the most limiting nutrients for rice production in many countries like Ghana (Akenga *et al*., 2014).

There were significant differences in total P concentration across the various soils of the rice accessions (0.02 ± 0.00 to 0.17 ± 0.01 %). This may be geographical and also may be as a result of the parent material. According to Fo *et al*., (2012), phosphorus is generally limiting in paddy fields due to its low content in parent material and its high ability of sorption on mineral surfaces. Low concentrations of total P was also recorded in paddy soils in Southern Lake Tai area, China (Zhou & Zhu, 2003). It seems from the results that *O. barthii* is able to tolerate low concentrations of P as compared to the other accessions. It may possess certain genetic traits that allow it cope in P deficient soils. Agricultural soils usually cannot meet demand for phosphate and application of fertilizer is therefore necessary (Akenga *et al*., 2014). The accessions studied currently would be able to survive in soils low in P concentration but would do better if fertilizer is added.

Significant differences were found in the total K concentrations of soils of the different accessions. It is possible that the differences could be due to the effect of weathering on the parent material, soil temperature and the differences between the pH of the soils (Rehm & Schmitt, 1997). Ethan, Odunze, Abu and Iwuafor (2011) detected total K in lowland paddy fields in Niger state, Nigeria which was lower than that of the present study. K helps to stimulate growth, increases protein production, improves the efficiency of water use and also improves the resistance of plants to diseases (Rehm & Schmitt, 1997). Soils of *O. barthii* recorded a total K concentration lower than the rest of the accessions, yet it was able to tolerate the deficiency. This may be as a result of its ability to adapt to soils with low K concentrations.

Iron concentration in soils of the different rice accessions showed significant differences. This may be attributed to factors such as: excessively low or high temperatures, the presence of certain organisms (e.g. nematodes) and soil oxygen deficiency. Sandy soils which form the textural class of the present study are considered to have the lowest overall iron concentrations

(EPA, 2005). According to FAO/WHO (2002), the level of iron concentration in the soil should not exceed 50000 mg/l (50000 mg/kg). Hence, the concentration of iron in the current study is within the permissible level. Ethan *et al*., (2011) recorded iron concentration in waterlogged low land soil in Niger state, Nigeria of 342 mg/kg which was higher than that of the current study. Iron is important for plant growth; helps in the formation of chlorophyll (EPA, 2005) and is generally considered to be a micronutrient, therefore needed in small amounts.

The concentration of Zn in soils of the different accessions had significant differences with values ranging from 0.04 ± 0.01 to 0.12 ± 0.02 mg/kg. These variations may be geographical. According to Carolyn & Aquila (2014), Zn concentration in paddy fields in Kompipinam, Malaysia averaged 11.36 ± 15.82 mg/kg which is higher than that of the present study. Zn is an essential microelement and plays a very essential catalytic role in enzyme reactions (Hägnesten, 2006). The baseline for the concentration of Zn in soils is 300 mg/l (300mg/kg) (FAO/WHO, 2002). Hägnesten (2006) suggested that soils with less than 0.83 mg/kg Zn concentration are deficient. The soils in the current study are therefore deficient in Zn. This deficiency may be attributed to factors such as organic matter content, pH, and soil moisture (Hägnesten, 2006).

The soils of the different accessions had Cu concentration ranging from 2.84 ± 0.66 to 6.02 ± 0.57 mg/kg; however, there were no significant differences among the soils of the different accessions. According to FAO/WHO (2002) the level of Cu should not exceed 100 mg/l (100 mg/kg). Therefore Cu concentrations among the soils of the accessions fall within the acceptable limits. Evidence from previous studies in China and India showed that Cu concentrations did not exceed the recommended limit, although higher than that of the current study (Wu, Luo, & Zhang 2010; Satpathy, Reddy & Prakash Dhal 2014). Cu is a microelement needed in small quantity.

The mean Pb concentration was not statistically different among soils of various accessions. Absence of mining activities , cement factories or fossil fuel-fired electrical power plant in the collection sites could be reasons why Pb concentration was low (Angima & Sullivan, 2008). According to FAO/ WHO (2002), the level of Pb in the soil should not exceed 100 mg/l (100 mg/kg). Studies show that Pb concentrations are low in paddy fields not close to mining sites (Carolyn & Aquilah, 2014; Machiwa, 2007). Pb is a poisonous heavy metal and therefore not needed in high amount in agricultural soils.

The cadmium concentration found in the soils of the various rice accessions were below detection. Previous works indicate that the level of Cd concentrations in paddy fields were quite low for fields not close to mining sites (Mwegoha & Kihampa, 2010; Machiwa, 2010). According to FAO/WHO (2002), Cd concentration in soils should not exceed 3 mg/l (3 mg/kg), since it is a poisonous mineral element. Therefore, based on the result from the current study, the concentration of cadmium does not exceed the acceptable limits.

In the current study, As concentration in the soils of the various accessions were below detection. This may be largely due to lack of intense weathering processes , anthropogenic activities such as mining , pesticide use, fertilizer application and irrigation with As contaminated water (Sahoo & Mukherjee, 2014) and/or the inability of the AAS machine to detect As levels in the soil. Similar results were obtained by Anyakora, Ehianeta, & Umukoro, (2013) on ‗Heavy metal levels in soil samples from highly industrialized Lagos environment' in which As levels were not detected. In a study carried out by Adomako, Deacon, and Meharg (2010), As concentration in paddy soils from the Anum valley in Ghana was up to 103 mg/kg which was very high as compared to the current study. This is because the paddy field was close to an old mining site. According to FAO/WHO (2002) the level of As in the soils should not exceed 20 mg/l (20 mg/kg). Hence the concentration of As in the current study falls within acceptable levels.

### 4.4 Diversity of the accessions collected

The cluster analysis using Jaccard's coefficient of similarity classified the seven accessions into two major groups. Cluster 1 comprises of Kamugbaa, Kawomor (black) and Kawomor (red) while Cluster 2 consists of Mansa, Viwotor, Ewe Moli (Wora wora) and Ewe Moli (Wegbe).

The accessions in Cluster 1 had short and truncated ligules, erect panicles, had heavier grain weight and were early maturing. These are characteristics exhibited by *O. glaberrima* species. From earlier studies, similar characteristics were exhibited by *O. glaberrima* species (Linares, 2002; Agnoun, 2012). According to Linares (2002), because *O. glaberrima* were early maturing, they were used as emergency foods in Senegal. Cluster 2 accessions had drooping panicles, long ligules which were 2-cleft in shape, longer crop cycle, these traits indicate that the accessions belong to the *O. sativa* species. These traits were also noted in studies carried out by Rabara, Ferrer, Diaz, Newingham and Romero, (2014); Nayar, (2012). From the cluster analysis, the diversity of the accessions collected from the Volta Region, highlighted the predominance of *O. sativa* in comparison to *O. glaberrima* accessions. The dominance of *O. sativa* was noted in Burkina Faso, where 86 % of the rice accessions collected were *O. sativa* and only 14% were *O. glaberrima* (Kam, 2011). Evaluations of these germplasms should be conducted to assess their potential as donor parents for the breeding of new varieties with improved responses to various biotic and abiotic stresses. Information was also gathered from some farmers on the low starch and high fiber content of the African rice, therefore best suited for diabetic patients. Another farmer also mentioned the medicinal benefits of the water from the cooked African rice.

The findings from the cluster analysis raise an important concern about the reliability of the traditional knowledge gathered during the ethnobotanical studies. It is worth noting, that all 7 accessions collected from the field were identified as ‗local' rice varieties by the farmers. This highlights the importance of the agro-morphological characterization conducted as a means of validating the information obtained from the field.

# CHAPTER FIVE

## 5.0 CONCLUSION AND RECOMMENDATIONS

### 5.1 Conclusion

The study showed that the African rice is gradually disappearing from farmers' fields in the Volta Region of Ghana as a result of the introduction of newer and more productive rice varieties (*O. sativa*). The wild rice species was absent in farmers fields because they were seen as weeds. In Adaklu-Waya, where the wild rice species was found, sections of the plants had been destroyed as a result of a heavy duty truck which accesses water from the river where the wild rice grows. It is therefore obvious from the current study that the African rice and its wild relatives are threatened in the Volta Region.

The study showed that at a depth of 0-10 cm, the micro-elements (Fe, Zn, Cu) and heavy metals (Pb, Cd and As) concentrations in soils of the rice accessions collected were within the acceptable limits of FAO/WHO (2002). The macro-elements concentrations (N, P and K) were lowest in soils of the accessions *O. barthii* as compared to soils of the other accessions. These suggest that the wild rice possesses certain genetic traits that enable it tolerate deficiency in N, P and K.

The ethnobotanical studies carried out for the African rice show that farmers have a history in conserving and utilizing biological diversity. Women especially play significant roles in rice cultivation in the Volta Region. Due to low yield, difficulty in de-husking and poor consumer demands, the cultivation of the African rice in the Volta region has declined except for few farmers who still cultivate it because of its good taste, drought tolerance, good grain quality, pest/ disease resistance and its good cooking quality.

Out of the five districts surveyed in the Volta Region, wild rice species was found growing in only one location in one district (Adaklu-Waya), highlighting the threat of genetic erosion. The agro-morphological studies carried out show that only three out of the seven accessions collected from farmers‘ fields belong to the *O. glaberrima* species. They are: Kamugbaa, Kawomor (black) and Kawomor (red). Agro-morphological characterization was not carried out for the wild rice, but based on the herbarium voucher in the Ghana herbarium and its phenotypic features; it was determined to be *O. barthii*. Due to time factor, the study was carried out during the dry season, but it would be interesting to also find out if the growing conditions of the wild rice are different during the raining season.

## 5.2 Recommendations

- Conservation measures (*both in situ* and *ex-situ*) are necessary to avoid losing this very important rice germplasm to genetic erosion. Furthermore it is important that the people in the communities in which the indigenous rice species were found are educated on the importance of conservation.
- High molecular approaches such as genome sequencing could be employed to precisely study their genetic diversity and value, thereby enhancing their use.

- Rice is mainly composed of starch, hence an analysis of the starch characteristics of the African rice varieties and its wild relatives and the diversity of genes encoding these starches would be particularly important.
- The consumption of the African rice should be encouraged by the Ministry of Health and the Food and Drugs Board because of its nutritional qualities.
- Women are more involved in rice farming and therefore should be empowered through practical training as they are highly knowledgeable in seed selection, seed storage, genetic conservation and seed health.
- Research should be carried out on the nutritional and medicinal composition of the African rice.
- Further research should be carried out on cross breeding the wild rice species with other local rice varieties to produce varieties able to withstand the changing climatic conditions affecting rice production.

# REFERENCES

Adomako, E.E., Deacon, C. & Meharg, A.A. (2010). Variations in Concentrations of Arsenic and Other Potentially Toxic Elements in Mine and Paddy Soils and Irrigation Waters from Southern Ghana. *Water Quality Exposure and Health*, 2, 115-124. doi.org/10.1007/s12403-010-0029.

Agboh-Noameshie, A., Kabore, A., & Misiko, M. (2013). Integrating Gender Considerations in Rice Research for Development in Africa. In M.C.S.J. Wopereis, D.E. Ahmadi, N. Tollens & A. Jalloh (Eds.), *Realizing Africa's Rice promise* (pp 343-354). Wallington, United Kingdom: CAB International.

Agnoun, Y., Biaou, S. S. H., Sié, M., Vodouhè, R. S., & Ahanchédé, A. (2012). The African Rice *Oryza glaberrima* Steud : Knowledge Distribution and Prospects. *International Journal of Biology*. *4*(3), 158–180. doi:10.5539/ijb.v4.3.158.

Akenga, P., Salim, A., Onditi, A., Yusuf, A., & Waudo, W. (2014). Determination of selected micro and macronutrients in sugarcane growing soils at Kakamega North District , Kenya, *Journal of Applied Chemistry* *7*(7), 34–41. Retrieved from http://www.iosrjournal.org.

Angelucci, F., Asante-Poku A., & Anaadumba, P. (2013). Analysis of incentives and disincentives for rice in Ghana. *Technical notes series. Rome: Monitoring African Food and Agricultural Policies*, FAO.

Angima, S. D., & Sullivan, D. M. (2008). *Evaluating and Reducing Lead Hazard in Gardens and Landscapes*. *Extension guide*. Oregon State University Extension Service. http://ir. library.oregonstate.edu/xmlui/bitstream/handle/1957/19844/ec1616-e.pdf (accessed 20 April 2015).

Anyakora, C., Ehianeta, T., & Umukoro, O. (2013). Heavy metal levels in soil samples from highly industrialized Lagos environment. *African Journal of Environmental Science and Technology. 7*(9), 917– 924. doi:10.5897/AJEST2013.1543.

Bell, R.W., & Seng, V. (2005). The management of the agro-ecosystems associated with sandy soils. In K. Kaen (Ed.), *Proceedings of FAO workshop on management of tropical sandy soils for sustainable agriculture* (pp 19-25). Thailand: FAO

Bennett-Lartey, S. O., Ayensu, F. K., Monma, S., & Ito, K. (1997). Vegetable germplasm collecting in Ghana. *Plant Genetic Resources Newsletter*, 111(1): 69-71.

Bioversity-International, IRRI, WARDA. (2007). *Descriptors for wild and cultivated rice (Oryza spp.)*, Rome, Italy; Los Baños , Phillipines; Cotonou Benin.

Brink, M., & Belay, G. (2006). *Plant Resources of Tropical Africa 1*. Cereal and Pulses. PROTA Foundation. (p 298). Wagenigen, Netherlands: Backhuys Publishers, Leiden, Netherlands/CTA.

Carolyn, P., & Aqilah, F. A. T. (2014). Assessment of heavy metals accumulation in paddy rice (*Oryza sativa*). *African Journal of Agricultural Research*, *9*(41), 3082–3090. doi:10.5897/AJAR2014.8760.

Chang, T. (1965). The morphology and varietal characteristics of the rice plant. *Technical Bulletin* 4:1-31.

Dania, O. F. M., & Williams, J.T. (1978). Evolution in Indigenous West Africa Rice. *Economic Botany* 32(1): 59-64. doi 10.1007/BF02906730.

Defoer, T., Wopereis, M.C.S., Jones, M.P., Lancon, F., Erenstein, O., & Guei, R.G. (2004). *Challenges and technical opportunities for rice-based production systems for food security and poverty alleviation in Sub-Saharan Africa*. Rome, Italy : FAO.

De Vicente, M. C., Guzmán, F. A., Engels, J., & Ramanatha, R.V. (2005). Genetic characterization and its use in decision making for the conservation of crop germplasm. In R.J.A. Sonnino, (Ed.), *The role of biotechnology in exploiting and protecting agricultural genetic resources* (pp. 121-128) Villa Gualino, Turin, Italy. FAO, Rome.

Doran, J.W., & Parkin, T.B. (1994). Defining and assessing soil quality. In J.W.Doran, Coleman, D.F. Bezdicek & B.A. Stewart (Eds.), *Defining Soil Quality for Sustainable Environment* (pp. 3-21). Madison WI. Soil Science Society of America Special Publication no.35.

Environmental Proection Agency (EPA) (2005). *Ecological Soil Screening Levels for Lead*: *Interim Final OSWER Directive* 9285.7-69. Washington, DC.

Ethan, S., Odunze, S., Abu, S.T., & Iwuafor, E.N.O. (2011). Effect of water management and nitrogen rates on iron concentration and yield in lowland rice. *Agriculture and Biology Journal of North America*, *2*, 622–629. doi:10.5251/abjna.2011.2.4.622.629.

Espuing, D.M. (2014). *Food crops wild relatives endangered*. BBC Retrieved from http://www.bbc.com/news/

Fageria, N. K., Carvalho, G. D., Santos, A. B., Ferreira, E.P.B., & Knupp, A.M. (2011). Chemistry of lowland rice soils and Nutrient availability. *Communication in Soil Science and Plant Analysis, 43: 1913-1933* doi: 10.1080/00103624.2011.591467.

FAO/WHO, (2002). *Schedule 1 maximum and guidelines for contaminants and toxins in food. Codex Alimentarius- General standards for contaminants and toxins in food.* Joint FAO/WHO food standards programme codex committee, Rotterdam.

FAOSTAT, (2014) http://faostat3.fao.org.

FAO, (2015). Coping with climate change – the roles of genetic resources for food and agriculture. Rome.

Fo, T., Omoko, M., Boukong, A., Ad, M. Z., Bitondo, D., & Fuh, C.C. (2012). Evaluation of lowland rice ( *Oryza sativa* ) production system and management recommendations for Logone and Chari flood plain – Republic of Cameroon, *Agricultural Science Research Journal. 2*(May), 261–273. Retrieved from http://resjournals.com/arj.

Ford-Lloyd, B. V., Schmidt, M., Armstrong, S. J., Barazani, O., Engels, J., Hadas, R., Hammer, K., Kell, S. P., Kang, D., Khoshbakht, K., Li, Y., Long, C., Lu, B., Ma, K., Viet Tung Nguyen, V.T., Qiu, L., Ge, S.,Wei,W., Zhang, Z., & Maxted, N. (2011). Crop Wild Relatives—Undervalued, Underutilized and under Threat? *BioScience*, *61*(7), 559–565. doi:10.1525/bio.2011.61.7.10.

Gary, J.M. (1995). *Ethnobotany, A people and plants conservation manual*. United Kingdom. Royal Botanic Gardens, Kew

Hägnesten, H. (2006). *Zinc deficiency and iron toxicity in rice soils of office du Niger , Mali*. (pp1-37). *Gunnar Jacks* , KTH Stockholm.

Hajjar, R., Jarvis, D. I., & Gemmill-Herren, B. (2008). The utility of crop genetic diversity in maintaining ecosystem services. *Agriculture, Ecosystems and Environment*, *123*: 261–270. doi:10.1016/j.agee.2007.08.003.

Hamaoka, N., Uchida, Y., Tomita, M., Kumagai, E., Araki, T., & Ueno, O. (2013). Genetic Variations in Dry Matter Production , Nitrogen Uptake , and Nitrogen Use Efficiency in the AA Genome *Oryza* Species Grown under Different Nitrogen Conditions, *Plant production science*. *16*(3), 107–116. (Retrieved from http://www.jstage.jst.go.jp/browse.pps).

Hay, F.R., Sackville H.N.R., Furman, B.J., Upadhyaya, H.D., Reddy, K.N., & Singh, S.K. (2013). Cereals. In: Normah, M.N., Chin, H.F., & Reed, B.M. (Eds.), *Conservation of Tropical Plant Species* (pp 293-315). New York. Springer.

Hofman, G., & Oswald, V.C. (2004). *Soil and Plant Nitrogen*. Paris: International Fertilizer Industry Association.

Howes, C. (1981). Guidelines for developing descriptor lists. *FAO/IBPGR Plant Genetic Resources Newsletter*, 45:26-32.

Hunter, D., Maxted, N., Heywood, V., Kell, S., & Borelli, T. (2012). Protected Areas and the challenge of conserving crop wild relatives. T*he International Journal of Protected Areas and Conservation. 18.1:*.87-98. Retrieved from http://www.iucn.org/parks.

Huvio, T. (1998). *Women's role in rice farming*. http://www.fao.org/sd/wpdirect/wpan0027.htm.

Ilagan, A., Tablizo, R. P., Barba, R. P. & Marquez, N.A.(2014). Soil Fertility Evaluation For Rice Production In Catanduanes Province , Philippines. *International Journal of Scientific and Technology Research 3*(12), 81–87. Retrieved from http://www.ijstr.org.

ITPGRFA, (2009). *International Treaty on Plant Genetic Resources for Food and Agriculture.* Rome, FAO. Retrieved from http://www.planttreaty.org/texts_en.htm.

Jansky, S. H., Dempewolf, H., Camadro, E. L., Simon, R., Bisognin, D. A., & Bonierbale, M. (2013). A Case for Crop Wild Relative Preservation and Use in Potato. *Crop Science Society of America*, 53:746-754. doi:10.2135/cropsci2012.11.0627.

Jarvis, A., Upadhyaya, H., Gowda, C.L.L., Aggarwal, P. K. & Fujisaka S, A. B. (2008). *Climate Change and its Effect on Conservation and Use of Plant Genetic Resources for Food and Agriculture and Associated Biodiversity for Food Security.*ejournal.icrisat.org (pg 6-26). Wallingford, UK: CAB International.

Jackson, M.L., (1962). *Soil Chemical Analysis* . Prentice Hall, Englewood Cliff, New York.

Johnson, D.E., Riches, C.R., Kayeke, J., Sarra, S. & Tuor, F.A. (2000). *Wild rice in sub-Saharan Africa: its incidence and scope for improved management.* FAO Global Workshop on Red rice Control, pp 87-94. Cuba, FAO.

Kam, H. (2011). *A study of the Diversity of Burkina Faso Rice Landraces and Identification of Source of Resistance to Rice yellow mottle virus* (RYMV). (PhD thesis), School of Agricultural, Earth and Environmental Sciences (SAEES), College of Agriculture, Engineering and Science, University of KwaZulu-Natal, Republic of South Africa.

Klute, A. (1986). Methods of Soil Analysis Part II. *American Society of Agronomist*. Madison, Wisconsin, USA.

Kranjac-Berisavljevic, G., Blench, R. M., & Chapman, R. (2003). *Rice production and livelihoods in Ghana. Multi-agency Parternerships for technical change in west african agriculture* (pp 1–86). National Workshop on rice production in Ghana ODI/UDS .

Kranjac-Berisavljevic, G. (2000). Paper 1: *Some Features of Rice Production In Ghana. Multi-Agency Partnerships for Technical Change in West African Agriculture*. National Workshop on Rice Production In Ghana.

Lamb, J.A., Fernandez, F.G., & Kaiser, D.E. (2014). *Understanding nitrogen in soils*. University of Minnesota cooperative extension service.

Lungmuana, & Colney, L. (2011). Soil testing- an important tool for assessing soil health and quality. *Science vision* (4), 214-217. Retrieved from http://www.sciencevision.org.

Linares, O.F. (2002). African rice (*Oryza glaberrima*): History and future potential. *Proccedings of the National Academy of Science.* USA 99:16360-16365. doi: 10.1073/pnas.252604599.

Li, Z.M., Zheng, X.-M., & Ge, S. (2011). Genetic diversity and domestication history of African rice (*Oryza glaberrima*) as inferred from multiple gene sequences. *Theoretical and Applied Genetics*, *123*(1), 21–31. doi:10.1007/s00122-011-1563-2.

Machiwa, J. F. (2007). Heavy metal levels in paddy soils and rice (*Oryza sativa* L. ) from wetlands of lake victoria basin, Tanzania. *Tanzania Journal of Science*. 36, 60-70. Retrieved from http://www. ajol.info/index.php/tjs/.

Machoene, T.M. (2009). *Morphological characterization and cryopreservation of sweet potato, Ipomea batatas (L.)., accessions of the NPGRC of South Africa.* (Msc. Thesis), International Masters Programme at the Swedish Biodiversity Center.

Maclean, J.L., Dawe, D. C., Hardy, B., & Hettel, G. P. (Eds.). (2002). *Source Book for the Most Important Economic Activity on Earth*. Wallington, United Kingdom: CAB International.

Maxted, N., & K. (2012). *Toward the Systematic Conservation of Global Crop Wild Relative Diversity*, 52:774-785 doi:10.2135/cropsci2011.08.0415.

Ministry of Food and Agriculture (2015). Volta region of Ghana. Republic of Ghana. Retrieved from http://mofa.gov.gh/site/?page_id=658.

MoFA. (2009). National Rice Development Strategy (NRDS) (DRAFT). Ministry of Food and Agriculture. Accra, Ghana.

Moldenhauer, K., & Slaton, N. (2013). Rice Growth and Development. In T.K Hardke (Ed.), *Arkansas production handbook* (pp 7–14). Arkansas,University of Arkansas, Press.

Molina, J., Sikora, M., Garud, N., Flowers, F.M., Rubinstein, S., Reynolds, A., Huang, P., Jackson, S., Schaal, B.A., Bustamante, C.D, Boyko, A.R., & Purugganan, M.D. (2011). Molecular evidence for a single evolutionary origin of domesticated rice. *Proceedings of the National Academy of Science* USA.doi:10.1073/pnas.1104686108.

Morita, S., & Nemoto, K. (1995). *Morphology and anatomy of rice roots with special reference to coordination in organo and histogenesis*. Netherlands: Kluwer Academic publishers.

Munns, R., & Tester, M. (2008). Mechanisms of salinity tolerance. *The Annual review of plant biology* 59:651-681. doi 10.1146/annurev.arplant.59.032607.092911.

Mwegoha, W. J. S., & Kihampa, C. (2010). Heavy metal contamination in agricultural soils and water in Dar es Salaam city , Tanzania. *African journal of environmental science and technology 4*(11), 763–769. Retrieved from http://www.academicjournals.org/AJEST.

Nayar, N. M. (2012). Evolution of the African Rice: A Historical and Biological Perspective. *Crop Science*, *52*(2), 505 doi:10.2135/2010.10.0605.

Nayar, N.M. (2010). The history and genetic transformation of the African rice, *Oryza glaberrima* Steud (Gramineae). *Current science* 12 (99) 1681-1689 Retreived from http://www.currentscience.ac.in/.../article_id_099_12_1681_1689_0.

Ndaeyo, N.U., Iboko, K.U., Harry, G.I & Edem, S. (2008). Growth and yield performances of some upland rice ( *Oryza Sativa* L.) cultivars as influenced by varied rates of NPK (15:15:15) fertilizer on an ultisol *Agro-Science Journal of Tropical Agriculture , Food , Environment and Extension*, *7*(3) ,249255 .http://www.agrosciencejournal.com/public/agro703-713.

Nnadozie, K. C., & Kameri-mbote, P. (2002). Plant genetic resources in africa's renewal policy , legal and programmatic issues under the new partnership for Africa's development. Michigan: International Plant Genetic Resource Institute.

Norman, J. C., & Kebe, B. (2006). African smallholder farmers : rice production and sustainable livelihoods (pp 33–64). *International Rice Commission Newsletter* (FAO).

Odunze, A. C., Kudi, T. M., Daudu, C., Adeosun, J., Ayoola, G., Amapu, I. Y., & Constance, D. (2010). Soil moisture stress mitigation for sustainable upland rice production in the Northern Guinea Savanna of Nigeria. *Agriculture and Biology Journal of North America*. 1193–1198. doi:10.5251/abjna.2010.1.6.1193.1198.

Olembo, N., Mmboyi, F., & Oyugi, K. (2010). Success Stories in Crop Improvement in Africa (pp 1-44). *African Biotechnology Stakeholders Forum*. Nairobi, Kenya.

Oriola, E.O., & Olabode, A.D. (2013). Assessing the physico-chemical properties of irrigated soils for sustainable rice production in Patigi Kwara state. *Asian Journal of Empirical Research* 3(7): 860-869. Retrieved from http://www.academia.edu/

Page, A.L., Miller, R.H., and Keeney, D.R. (1982). Methods of Soil Analysis II. *American Society of Agronomist*, Madison, Wisconsin, USA.

Perkins, H.F. (1970). A Rapid Method of Evaluating the Zinc Status of Coastal Plain. *Community of Soil Science and Plant Analysis*. 1, 35-42

Poteres, R. (1970). Primary Cradles of Agriculture in the African Continent . In: J. Fage & R. Olivier (Eds.), *Papers in African Prehistory* ( pp 409-452). Cambridge: Cambridge University Press.

Rabara, R.C., Ferrer, M.C., Diaz, C.L., Newingham, C.V., Romero, G.O. (2014). Phenotypic Diversity of Framers' Traditional Rice Varieties in the Phillipines. *Agronomy* 4, 217 - 241; doi 10.3390/agronomy4020217

Rehm, G., & Schmitt, M. (1997). *Potassium for crop production*. Minnesota: Minnesota Extension Service. Retrieved from http://www.mes.umn.edu/.

Richards, P. (1996). ‗Agrarian creolization: the ethnobiology, history, culture and politics of West African rice'. In R. Ellen & F. Katsuyoshi (Eds.), *Redefining Nature: Ecology, Culture and Domestication* (pp 291-318). Oxford: Berg.

Rohlf, F. J. (2000). Numerical Taxonomy and Multivariate Analysis System. *NTSYS-pc. Version 2.1*, Exeter Software, New York,USA.

Sahoo, P. K., & Mukherjee, A. (2014). Arsenic fate and transport in the groundwater-soil-plant: An understanding of suitable rice paddy cultivation in arsenic enriched areas. In D. Sengupta (Ed.), *Recent trends in modelling of environmental contaminats* (pp 28-30). India: Springer.

Sanni, K.A., Tia, D. D., Ojo, D.K., Ayoni S. Ogunbayo, S.A., Sikirou, M., & Hamilton, N.R.S. (2013). Diversity of rice and related wild species in Africa. In M.C.S. Wopereis, D.E.Johnson, N. Amadi, E. Tollens & A. Jalloh (Eds.), *Realizing Africa's Rice Promise* (pp.87-94). Wallingford, UK: CAB International.

Sarla, N., & Swamy, B. P. M. (2005). *Oryza glaberrima* : A source for the improvement of *Oryza sativa*. *Current science*. 89 (6) 955-963. Retreived from http://www.researchgate.net/.

Satpathy, D., Reddy, M. V., & Dhal, S. P. (2014). Risk Assessment of Heavy Metals Contamination in Paddy Soil , Plants , and Grains (*Oryza sativa* L .) at the East Coast of India. *Bio Medical Research International*, pp 1–11. doi.org/10.1155/2014/545473.

Shamar, R.D. (1991). The story of rice. India: National book trust.

Sié, M., Sanni, K., Futakuchi, K., Manneh, B., Mandé, S., Vodouhé, R., Dougbe, S., Drame, K.N., Ogunbayo, A., Ndjiondjop, M.N., Traore, K.(2012). Towards a Rational Use of African Rice (*Oryza glaberrima* Steud .) for Breeding in Sub-Saharan Africa.*Global* *science books*. 6 (1) 1-7 Retreived from http://www.globalsciencebooks.info/JournalsSup/.

Smith, J.S.C. and Smith, O.S. (1992). Finger printing crop varieties. *Advanced Agronomy*. 47: 85- 140.

Sneath, P. H. A. & Sokal, R. R. (1973). *Numerical Taxonomy: The Principles and Practice of Numerical Classification.* San Francisco, california, USA: W. H.Freeman and Co.

Somado, E.A., Guei, R.G., & Keya, S.O. (Eds.). (2008). *NERICA : the New Rice for Africa – a Compendium* (pp 4-210). Cotonou, Benin: Africa Rice Center (WARDA); Rome, Italy: FAO; Tokyo, Japan. Sasakawa Africa Association..

Stolton, S., Maxted, N., Ford-Lloyd, B., Kell, S., & Dudley, N. (2006). *Food stores: Using protected areas to secure crop genetic diversity*. United Kingdom: World wide fund for Nature.

Sweeney, M., & McCouch, S., (2007). The Complex History of the Domestication of Rice. *Annals of Botany*, 951–957. doi:10.1093/aob/mcm128.

Talpur, M.A., Changying, J.I., Junejo,S.A., Tagar, A. A. (2013). Impact of Rice Crop on Soil Quality and Fertility. *Bulgarian Journal of Agricultural Science* ,*19*(6), 1287–1291. Retrieved from http:// www.agrojournal.org/.

Teeken, B., Nuijten, E., Temudo, M. P., Okry, F., Mokuwa, A., Struik, P. C., & Richards, P. (2012). Maintaining or Abandoning African Rice: Lessons for Understanding Processes of Seed Innovation. *Human Ecology*, *40*(6), 879–892. doi:10.1007/s10745-012-9528-x.

Vaughan, D.A., Lu, B-R., Tomooka, N. (2008a). The evolving story of rice evolution. *Plant Science*.174:394–408. doi**:** 10.1016/j.plantsci.2008.01.016.

Vaughan, D.A., Lu, B-R., Romooka, N. (2008b). Was Asian rice ( *Oryza sativa* ) domesticated more than once? *Rice* 1:16–24. doi 10.1007/s12284-008-9000-0.

Vaughan, D., Yoshida, Y., Takeya, M., & Tomooka, N. (2013). Collecting the Wild Relatives of Crops in the Tropics. In Normah, M.N., Chin, H.F., & Reed , B. M. (Eds.). *Conservation of tropical species* (pp.27–42). New York: Springer-Verlag.

Verhey, W.H. (Ed.) (2010). Soils, plant growth and crop production. In *Encyclopedia of Life Support System* (Vol. 2, pp.1-11). EOLSS Publishers Co Ltd.

Wambugu, P. W., Furtado, A., Waters, D. L. E., Nyamongo, D. O., & Henry, R. J. (2013). Conservation and utilization of African *Oryza* genetic resources. *The rice journal .com 6*(1), 1. doi:10.1186/1939-8433-6-29.

Wu, C., Luo, Y., & Zhang, L. (2010). Variability of copper availability in paddy fields in relation to selected soil properties in South East China. *Geoderma* 156:200-206. doi:10.1016/j.geoderma.2010.02.018.

Yoshida, S. (1981). *Fundamentals of rice crop science*. Phillipines. International Rice Research Institute.

Zeven, A. C. (1998). Landraces: A review of definitions and classifications. *Euphytica*, 104 (183643), 127–139. doi:10.1023/A:1018683119237.

Zhou, Q., & Zhu, Y. (2003). Potential pollution and recommended critical levels of phosphorus in paddy soils of the southern Lake Tai area, China. *Geoderma*, *156*(3-4), 200–206. doi:10.1016/j.geoderma.2010.02.018.

**Appendix 1**

**QUESTIONNAIRE ON THE ETHNO-BOTANICAL USES OF THE AFRICAN RICE (*Oryza glaberrima*)**

**A) Demography of respondents**

**(Please tick where appropriate)**

1: Name: ____________________________________________

2: Gender:

a) Male (   )

b) Female (   )

3: Age:

a) Below 20 (   )

b) 21-30 (   )

c) 31-40 (   )

d) 41- 50 (   )

e) 51- 60(   )

f) 61 and above (   )

4: Occupation: ____________________________________________

5: Education:

a) Primary school (   ),

b) Secondary school (   )

c) Vocational studies (   )

d) Tertiary (   )

**Appendix 1 cont'd**

e) None (   )

6: Location/ residence: ____________________________________________

**B) Details on *O. glaberrima* and its characteristics**

7: List the varieties of *O. glaberrima* you have in your locality.

a) ______________________________________
b) ______________________________________
c) ______________________________________

8: Do you cultivate it?

a) Yes (   )
b) No (   )

9: If yes, how often do you cultivate it? (Please tick where appropriate).

a) Annually (   )

b) Biannual (   )

c) Others specify

10: At what stage can it be distinguished from other rice plants?

a) Vegetative stage(   )
b) Reproductive stage(   )

11: What parts is used for medicinal purposes and for what ailment?

a) Leaves for______________________________________
b) Stems for ______________________________________
c) Roots for ______________________________________

**Appendix 1 cont'd**

d) Others specify________________________________________

12: List reasons why you prefer *O. glaberrima* to other rice species

a)____________________________________________________

b) ____________________________________________________

c) _____________________________________________________

13: What percentage of consumers demand for *O. glaberrima*?

a) 25% ( )
b) 50% ( )
c) 75% ( )
d) 100% ( )

14: How would you rate its cooking and nutritional qualities?

a) Excellent ( )

b) Very good ( )

c) Good ( )

d) Fair ( )

15: How would you rate its taste?

a) 25% ( )
b) 50% ( )
c) 75% ( )
d) 100% ( )

16: Do you cook it on special occasions?

a) Yes ( )
b) No ( )

**Appendix 1 cont'd**

17: If yes, please tick where appropriate

a) Lekoyi festival ( )
b) Marriage Ceremony( )
c) Christmas( )
d) Sallah ( )
e) Easter ( )
f) Others specify

18: List the challenges *O. sativa* is prone to despite its high yield that *O. glaberrima* are resistant to.

a)______________________________________________________________

b) _____________________________________________________________

c) _____________________________________________________________

**Appendix 2**

Analysis of variance table for pH, EC, and particle size

Variate: pH

| Source of variation | Degree of Freedom | Sum of Squares | Means of Squares | Variance ratio | Fpr. |
|---|---|---|---|---|---|
| Accessions | 6 | 8.50731 | 1.41789 | 45.67 | <0.001 |
| Residual | 14 | 0.43467 | 0.03105 | | |
| Total | 20 | 8.94198 | | | |

Variate: EC

| Source of Variation | Degree of Freedom | Sum of Squares | Means of Squares | Variance ratio | F pr. |
|---|---|---|---|---|---|
| Accessions | 6 | 33749.8 | 5625.0 | 5.69 | 0.004 |
| Residual | 14 | 13845.3 | 989.0 | | |
| Total | 20 | 47595.1 | | | |

**Appendix 2 cont'd**

Variate: Silt

| Source of variation | Degree of freedom | Sum of squares | Mean of squares | Variance ratio | F pr. |
|---|---|---|---|---|---|
| Accessions | 6 | 620.81 | 103.47 | 5.92 | 0.003 |
| Residual | 14 | 244.67 | 17.48 | | |
| Total | 20 | 865.48 | | | |

Variate: Clay

| Source of variation | Degree of freedom | Sum of squares | Mean of squares | Variance ratio | F pr. |
|---|---|---|---|---|---|
| Accessions | 6 | 1153.95 | 192.33 | 6.34 | 0.002 |
| Residual | 14 | 424.87 | 30.35 | | |
| Total | 20 | 1578.82 | | | |

Variate: Sand

| Source of variation | Degree of freedom | Sum of squares | Means of squares | Variance ratio | F pr. |
|---|---|---|---|---|---|
| Accessions | 6 | 3283.66 | 547.28 | 7.25 | 0.001 |
| Residual | 14 | 1056.47 | 75.46 | | |
| Total | 20 | 4340.13 | | | |

**Appendix 3: Analysis of variance table for mineral elements**

Variate: N

| Source of Variation | Degree of freedom | Sum of squares | Mean of squares | Variance ratio | F pr. |
|---|---|---|---|---|---|
| Accessions | 6 | 0.12131 | 0.020219 | 4.98 | 0.006 |
| Residual | 14 | 0.05680 | 0.004057 | | |
| Total | 20 | 0.17811 | | | |

Variate: P

| Source of variation | Degree of freedom | Sum of squares | Mean of square | Variance ratio | F pr. |
|---|---|---|---|---|---|
| Accessions | 6 | 0.05396190 | 0.00899365 | 377.73 | <0.001 |
| Residual | 14 | 0.00033333 | 0.00002381 | | |
| Total | 20 | 0.05429524 | | | |

Variate: K

| Source of variation | Degree of freedom | Sum of squares | Mean of squares | Variance ratio | F pr. |
|---|---|---|---|---|---|
| Accessions | 6 | 0.081448 | 0.013575 | 12.08 | <0.001 |
| Residual | 14 | 0.015733 | 0.001124 | | |
| Total | 20 | 0.097181 | | | |

**Appendix 3 cont'd**

Variate: Fe

| Source of variation | Degree of freedom | Sum of squares | Mean of squares | Variance ratio | F pr. |
|---|---|---|---|---|---|
| Accessions | 6 | 0.27167 | 0.04528 | 3.63 | 0.022 |
| Residual | 14 | 0.17440 | 0.01246 | | |
| Total | 20 | 0.44607 | | | |

Variate: Cu

| Source of variation | Degree of freedom | Sum of squares | Mean of squares | Variance ratio | F pr. |
|---|---|---|---|---|---|
| Accessions | 6 | 19.912 | 3.319 | 2.15 | 0.112 |
| Residual | 14 | 21.602 | 1.543 | | |
| Total | 20 | 41.513 | | | |

Variate: Pb

| Source of variation | Degree of freedom | Sum of squares | Means of squares | Variance ratio | F pr. |
|---|---|---|---|---|---|
| Accessions | 6 | 0.109333 | 0.018222 | 2.26 | 0.098 |
| Residual | 14 | 0.112933 | 0.008067 | | |
| Total | 20 | 0.222267 | | | |

**Appendix 3 cont'd**

Variate: Zn

| Source of variation | Degree of Freedom | Sum of Squares | Means of Squares | Variance ratio | Fpr. |
|---|---|---|---|---|---|
| Accessions | 6 | 0.013467 | 0.002244 | 3.57 | 0.023 |
| Residual | 14 | 0.008800 | 0.000629 | | |
| Total | 20 | 0.022267 | | | |

**Appendix 4: Analysis of variance table for agro-morphological variables**

Variate: FH

| Source of variation | Degree of freedom | Sum of squares | Means of squares | Variance ratio | F pr. |
|---|---|---|---|---|---|
| Accessions | 6 | 1618.571 | 269.762 | 62.94 | <0.001 |
| Residual | 14 | 60.000 | 4.286 | | |
| Total | 20 | 1678.571 | | | |

Variate: MH

| Source of variation | Degree of freedom | Sum of Squares | Mean of Squares | Variance ratio | F pr. |
|---|---|---|---|---|---|
| Accessions | 6 | 2997.619 | 499.603 | 88.17 | <0.001 |
| Residual | 14 | 79.333 | 5.667 | | |
| Total | 20 | 3076.952 | | | |

Variate: Cycle

| Source of variation | Degree of Freedom | Sum of Squares | Means of Squares | Variance ratio | F pr. |
|---|---|---|---|---|---|
| Accessions | 6 | 2724.95 | 454.16 | 15.51 | <0.001 |
| Residual | 14 | 410.00 | 29.29 | | |
| Total | 20 | 3134.95 | | | |

**Appendix 4 cont'd**

Variate: LL

| Source of variation | Degree of freedom | Sum of squares | Means of squares | Variance ratio | F pr. |
|---|---|---|---|---|---|
| Accessions | 6 | 6.47810 | 1.07968 | 21.80 | <0.001 |
| Residual | 14 | 0.69333 | 0.04952 | | |
| Total | 20 | 7.17143 | | | |

Variate: LBL

| Source of variation | Degree of freedom | Sum of squares | Means of squares | Variance ratio | F pr. |
|---|---|---|---|---|---|
| Accessions | 6 | 659.66 | 109.94 | 2.32 | 0.092 |
| Residual | 14 | 664.31 | 47.45 | | |
| Total | 20 | 1323.97 | | | |

Variate: LBW

| Source of variation | Degree of freedom | Sum of squares | Means of squares | Variance ratio | F pr. |
|---|---|---|---|---|---|
| Accessions | 6 | 0.63619 | 0.10603 | 4.28 | 0.012 |
| Residual | 14 | 0.34667 | 0.02476 | | |
| Total | 20 | 0.98286 | | | |

**Appendix 4 cont'd**

Variate: FLL

| Source of variation | Degree of freedom | Sum of squares | Means of squares | Variance ratio | F pr. |
|---|---|---|---|---|---|
| Accessions | 6 | 174.46 | 29.08 | 0.66 | 0.684 |
| Residual | 14 | 618.07 | 44.15 | | |
| Total | 20 | 792.53 | | | |

Variate: FLW

| Source of variation | Degree of freedom | Sum of squares | Means of squares | Variance ratio | F pr. |
|---|---|---|---|---|---|
| Accessions | 6 | 2.95143 | 0.49190 | 21.52 | <0.001 |
| Residual | 14 | 0.32000 | 0.02286 | | |
| Total | 20 | 3.27143 | | | |

Variate: CL

| Source of variation | Degree of freedom | Sum of squares | Means of squares | Variance ratio | F pr. |
|---|---|---|---|---|---|
| Accessions | 6 | 5724.7 | 954.1 | 9.02 | <0.001 |
| Residual | 14 | 1480.2 | 105.7 | | |
| Total | 20 | 7204.9 | | | |

**Appendix 4 cont'd**

Variate: GL

| Source of variation | Degree of freedom | Sum of squares | Means of squares | Variance ratio | F pr. |
|---|---|---|---|---|---|
| Accessions | 6 | 3.3416 | 0.5569 | 1.60 | 0.219 |
| Residual | 14 | 4.8723 | 0.3480 | | |
| Total | 20 | 8.2140 | | | |

Variate: GW

| Source of variation | Degree of freedom | Sum of squares | Means of squares | Variance ratio | F pr. |
|---|---|---|---|---|---|
| Accessions | 6 | 6.6996 | 1.1166 | 6.51 | 0.002 |
| Residual | 14 | 2.4007 | 0.1715 | | |
| Total | 20 | 9.1003 | | | |

Variate: HGW

| Source of variation | Degree of freedom | Sum of squares | Means of squares | Variance of ratio | F pr. |
|---|---|---|---|---|---|
| Accessions | 6 | 0.602095 | 0.100349 | 24.06 | <0.001 |
| Residual | 14 | 0.058400 | 0.004171 | | |
| Total | 20 | 0.660495 | | | |

**Appendix 5 cont'd**

Fig 5: Roots of the wild rice. Evidence to show that the wild rice is *0.barthii*

Fig 6: Shattered seeds of the wild rice germinating

Fig 7: Shattered panicle of the wild rice

**Appendix 5 cont'd**


Fig 8: Mature seeds of the wild rice