KWAME NKRUMAH UNIVERSITY OF SCEINCE AND TECHNOLOGY
COLLEGE OF AGRICULTURE AND NATURAL RESOURCES FACULTY OF AGRICULTURE DEPARTMENT OF CROP AND SOIL SCIENCES

MORPHO-AGRONOMIC CHARACTERIZATION OF NEWLY DEVELOPED UPLAND RICE GERMPLASM (*ORZYA SATIVA* L., *ORZYA GLABERRIMA* STEUDEL) FROM THE AFRICA RICE CENTER AND GHANA

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE IN PLANT BREEDING (AGRONOMY)

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DECLARATION

I do exceptionally declare that this work is a direct result based on original field research undertakings and is supportive of cited references in relations to other Researchers' previous and similar work performed, and therefore this thesis has not been presented in parts or whole in any form or manner for a degree wheresoever.

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DEDICATION

I hereby make this special dedication in this thesis to my wife, Mrs. Josephine Toweh Newmah and mother, Ma Kpannah Hillue Denkialoe. This is in remembrance of their numerous financial sacrifices, prayers and moral support shined or rained to ensure the realization of academic achievements in my personal life.

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ABSTRACT

A total of eighty-four rice accessions collected from the Africa Rice Center and Ghana were characterized and evaluated for phenotypic diversity. The phenotypic diversity among accessions was determined based on morphological and physiological traits. Thirteen quantitative and eleven qualitative characteristics were measured based on the genotypes, using the randomized complete block experimental design with three replications in a rice growing community of Nobewam (Ashanti region), Ghana. The data collections were based on the internationally acceptable standard evaluation system (ses) for rice (*O.sativa, O.glaberrima*). GenStat package was used to analyze quantitative parameters. A dendrogram (using the Ntsys pc) showed nitrogen regime and its relationship among 3 groups of accessions based on binary data scored on the present and absent of the morpho-agronomic characteristics. The identified accessions consisted of 49 as high and 33 low nitrogen responders belonging to different clusters. A third cluster consisted of 2 accessions suggesting their distinctiveness from the others. Correlations between quantitative traits and associated yield components were found at the least significant difference of ($P < 0.05$). The results revealed a strong genetic relationship between days to flowering and grain maturity character. The coefficient of variation was more than 10 % and standard deviation less than 10 % for many of the characters observed.

There was wide genetic variability in the rice germplasm for days to flowering (5883days) and grain maturity (85-105 days). Majority (60%) of the rice accessions possessed erect leaves and moderately strong sturdy culms, classified as high nitrogen responders and the rest, as low responders with droopy leaves and weak stem based on the "plant type"

concept; 35% erect and 46 intermediate flag leaf angle; 67% showed awnlessness; 75% found with well exserted panicle, 55% with compact and 26% intermediate panicle types respectively.

Regardless of the accessions response to Nitrogen uptake, there were significant variations in the grain yield and grain characteristics. The long grain and translucent types could be used in quality grain development. Generally, average grain yield for high nitrogen responders showed low value of 2.2 t/ha as compared to low nitrogen responders of 2.4 t/ha.

In order to exploit the genetic potential and distinctiveness of the rice accessions as observed in this study, application of molecular investigations may further provide basis for these genotypes to be beneficially useful in the breeding programmes.

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WARDA	-	West Africa Rice Development Association
CRI	-	Crops Research Institute
RCBD	-	Randomized Complete Block Design
IRRI	-	International Rice Research Institute
IRTP	-	International Rice Testing Program
ANON	-	Anonymous

CHAPTER ONE

INTRODUCTION

Rice (*Oryza* sativa, L; *Oryza* glaberrima, Steudel) is vital to more than half of the world's growing human populations. Its values lie in food grain in the diets of millions of Asians, Sub Sahara Africa and Latin Americans living in the tropics and subtropics. It is likely that rice will continue to remain a major source of their daily food since population growth in these areas is reportedly at high increasing rate (Sasaki, 1999, 2002). Rice contributes towards achieving food security, employment and income for the poor rural dwellers, thus drives towards reducing poverty.

Due to the significant role the rice crop plays as a food to about half of the world population, the UN dedicated honour to this single commodity. Also, in 2002 world rice production began to increase once again, following three consecutive years of declining production: world production in 2005 stood at around 614 million tonnes of paddy rice (FAOSTAT, 2005). Third, world average yield in 2005 was projected to break the 4 tonnes/ha barrier. An average yield of 4 tonnes/ha may not appear to be a major accomplishment. However, considering that rice is grown on over 150 million ha under a wide variety of conditions from irrigated to dryland to floating, an average yield of 4 tonnes/ha is indeed a significant achievement. Only the contrary, rice production in sub-Saharan Africa continues to be outpaced by consumption; imported rice accounts for 50 percent of sub-Saharan Africa's rice requirement (FAO, 2006).

Rice is rapidly becoming a staple food in the African diet, low and stagnant rice production accentuates the food security problem confronting much of sub-Saharan Africa. No wonder food shortage in Africa is becoming synonymous with rice deficit. Although excessive water usage, environmental degradation due to pesticide and nutrient contamination, methane emission and ammonia volatilization are a few of the adverse effects of rice production requiring urgent attention. Land and water resources for rice production are diminishing and global climate changes may have a major effect on rice production. However, a wide range of technologies available for reducing these adverse consequences of rice production are not extended to majority of rice growers or farmers (FAO, 2006).

Nguyen and Ferrero (2006), reported rice is second most widely grown crop, and about 3 billion people consume more rice per year. In the near future, the possibility for rice expanding areas will remain very limited because scarcity of global water resources for agriculture, the expansion of urban and industrial sectors in Asia where land is already limited along with high costs of developing new lands suited for rice production in SubSaharan Africa and Latin America where rice is cultivated on 155.5 million ha in areas, an average growth rate of 0.39% a year, in the last 30 years. Emphasis should, therefore be placed on increasing productivity per unit area by enhancing growth requirements and developing new cultivars that are efficient in making use of available resources for increased yields. The latter goal can be achieved by evaluating new and adapted germplasm for specific growth and yield traits.

The average growth rate of rice yield was 3.68% per year in the early 1980s, but it decreased to 0.74% per year in the late 1990s (Nguyen and Ferrero, 2006). Several factors may contribute to the decline of the area under cultivation and in yield. The most important of these factors are: limited returns in its approach to yield potential of the high yielding varieties, declining productivity in intensive rice production systems, pressures from abiotic and biotic stresses, low returns in developing countries, increasing production costs in industrialized countries, and increasing public concern for the protection of environmental resources. One of the most effective means of addressing the issues in rice cultivation and raising the average yields at the farm level is through research and subsequent dissemination of the resulting data (Nguyen and Ferrero, 2006).

In view of the aforementioned, genetic characterization of morphological and physiological traits and evaluation will enable rice breeders to exploit a wide range of genotypic diversities to further crop improvement practices. A careful consideration of some morpho-agronomic characters that are associated with the yielding ability of the crop (Yoshida, 1981) led to the "plant type" concept based on low and high yielding varieties of rice in Japan. Tsunoda, (1964) compared and summarized morphological characteristics of low and high yielding varieties of rice and then deduced a concept known as "plant type" concept as:

- Low nitrogen responders possess long, broad, thin, drooping, pale-green leaves and tall, weak stems.
- High nitrogen responders have erect, short, narrow, thick, dark-green leaves, and sturdy stems.

Therefore, it is meaningful to systematically evaluate germplasm within countries of Africa in order to select superior lines of early and advanced breeding materials as strategy for rice improvement. The strategy should combine specific agro-ecological adaptations of local rice varieties to identify high yielding rice varieties for local introduction and varietal improvement.

Yoon *et al*. (2000) commented molecular techniques as a fundamental tool should be exploited to complement morphoagronomic evaluation because it provides better diversity clarity in plant populations at DNA level. It should include taxonomic groupings of accessions to establish their phylogenetic relationship (Fatokun *et al*., 1993) and (Kaga, 1996).

Padulosi (1993) revealed successful breeding programme should consider genetic diversity of a crop for achieving the goals of improving the crop, producing high yielding and better resistant varieties. This will probably refocus the effective utilization of a number of landraces being cultivated locally and rapidly replaced by improved cultivars thus narrowing genetic base of rice agriculture. Similarly Singh (1989) reported reduced genetic variability underscores the need to collect landraces for *ex situ* conservation and to characterize them for future rice breeding programs at morphological and molecular levels because the evaluation of phenotypic diversity usually reveals important traits of interest to plant breeders. The field results on rice accessions will help create useful genetic database for future breeding programs, geared towards genetic improvement of local varieties for increased food production at household level.

Characterization and evaluation of agro-morphological characters of rice accessions collected from the Africa Rice Center and Ghana and compare their genetic diversities and relatedness, using the rice descriptor suggested by Anon (2007), will be very vital for improving the rice germplasm in Ghana and Africa. The Africa rice successfully obtained hybrids from the interspecific between *Oryza sativa* and *O. glaberrima* were given to the National Agriculture and Research Systems and Crops Research Institute, Ghana for evaluation. The varieties differ in many characteristics, but have not been characterized. Therefore, knowledge of these varieties' morpho-agronomic characteristics will further contribute towards creating genetic data base for improved breeding programmes in the sub region of West Africa.

1.0 General Objective

The general objective of the study was to characterize and evaluate the morphoagronomic parameters of rice germplasm from the Africa Rice Center and Ghana, and select promising genotypes for further crop improvement.

1.1 Specific objectives

- to evaluate vegetative growth performance of the rice accessions from the Africa Rice Center and Ghana.
- to evaluate yield performance of rice accessions from the Africa Rice Center and Ghana.

- to evaluate the potential nitrogen response of rice accessions from the Africa Rice Center and Ghana.

CHAPTER TWO

LITERATURE REVIEW

2.1 Rice Description and Its Global Significance

Rice (*Oryza sativa*, *O. glaberrima*) is the seed of a monocot plant and belongs to the family Gramineae. Morphologically, rice is an annual grass and one of the most important crops. Although it can grow in diverse environments, it grows faster and more vigorously in wet and warm conditions. This plant develops a main stem and many tillers and may range from 0.6 to 6 meters (floating rice) in height (Anon, 2004).The tiller bears a ramified panicle that measure between 20 and 30 centimeters wide. Each panicle has 50 to 300 flowers (floret or spikelet), which form the grains. The fruit obtained is a caryopsis and has great food security potentials.

The significant role the rice crop plays in the environments led Fageria *et al.* (2003) described rice as a main source of 35-60% dietary calories consumed by more than 3 billion people and probably the most versatile crop. The two species of domestic rice Oryza sativa, grown throughout the world and Oryza glaberrima, cultivated mostly in West Africa.

Calpe (2002) described rice as a major staple food for the rural population, and mainly cultivated by small farmers in holdings of less than 1 ha. Rice served as a "wage" commodity for workers in the cash crop and non-agricultural sectors. Its duality gave rise to conflicting policy objectives, with policy-makers to save farmers when prices drop, and or defended consumer purchasing power when sudden price increases.

Additionally, rice crop vitality can be seen in its nutrition to much of the population in Asia, Latin America and the Caribbean and Africa. It is central to the food security of over half the world population, not to mention to the culture of many communities. Rice is therefore considered a "strategic" commodity in many countries and is, consequently, subject to a wide range of government controls and interventions (Calpe, 2002).

At the African continent level, Jones *et al.* (1998) considered rice crop as the main staple food in at least 8 of the 17 countries of West Africa and rapidly gaining popularity as a major food among other crops. However, self-sufficiency in West African rice production is declining because demand is increasing faster (5.9% annual growth since

1970) than its production (4% annual growth over the period). They also indicated that rice growth environments in West Africa are extremely diverse, varying as a function of agro-ecological, geo-morphological, hydrological, and socio-economic factors. Upland rice occupies 80% of rice area and accounts for 75% of regional production (Jones *et al*., 1998). In spite of exact non available statistics, it is estimated that over 80% of the resource poor rice farmers in West Africa grow rice as a subsistence crop. Most rice farmers in West Africa grow landraces which are generally tolerant to environmental stresses but whose yield potential is lower than that of improved varieties. On the other hand, improved varieties bred for improved management conditions generally are not well adapted to traditional farming systems.

New improved rice varieties better adapted to the resource-poor farmers conditions are required and must draw on existing germplasm or be developed by combining desired characters from various germplasm sources.

Rice, a genetic resource, can be morphologically and physiologically characterized and evaluated in order to enable breeders to understand and appreciate its wide range of genotypic diversities for relevant crop improvement practices. It is therefore important to consider some morpho-agronomic characters that are associated with the yielding ability of the crop as provided by Yoshida (1981). Based on the evolutionary theory of "plant type" concept with regard to low and high yielding varieties of rice in Japan, Tsunoda (1964) compared and summarized their morphological characteristics as outlined:

- Low nitrogen responders possess long, broad, thin, drooping, pale-green leaves, and tall, weak stems.

- High nitrogen responders have erect, short, narrow, thick, dark-green leaves, and sturdy stems.

Rice is grown extensively in tropical and sub-tropical regions of the world. More than half of the people on the globe depend on rice as their basic diet and, generally extensively consumed in the producing countries (Jamal *et al.*, 2009). It is estimated that the world population will increase by about 2 billion in the next two decades, and half of this increase will be in Asia where rice is the staple food (Gregory *et al*., 2000), and other continents of the world particularly Asia, Africa and Latin America, where the demand for rice is a top priority as reported by Sasaki, (1999, 2002). To feed this increasing population, 35% more rice will be required than the present level of rice production globally (Duwayrie and Nguyen, 1999).

During the past three decades, the crop has seen a steady increase in demand and its growing importance is evident given its important place in the strategic food security planning policies of many countries and governments to maintain minimum food reserves to ensure food security. In addition, countries engaged in rice distribution schemes and producer price support usually keep large rice inventories in public storage facilities (Calpe, 2002). Its adoption as a principal staple food is increasing in Africa every day whereas self sufficiency in rice production declines as demand increases.

Vaughan *et al*. (2003) considered rice crop as a major source of nutrition for about twothird of mankind. This phenomenon involuntarily provides an avenue for an increased production in order to keep pace with the growing population in spite of its productivity seriously being affected by biotic and abiotic stresses (Zafar *et al*., 2004).

In 1996, Africa consumed a total of 11.6 million tonnes (Mt) of milled rice per year, of which 3.3 Mt were imported (i.e. 33.6%), and 21 of the 39 rice- producing countries in Africa imported between 50 and 99 percent of their rice requirements (Norman and Otoo, 2002). The distribution of rice imports on a regional basis varies enormously, with the North and Central African regions setting the lower (1.7%) and upper (71.7%) limits, respectively (Norman and Otoo, 2002). Other information shows that the volume of rice imports between 1990 and 1992 was highest in West Africa (2550, 000 tonnes) and lowest in Central Africa (219, 000 tonnes) (Norman and Otoo, 2002).

Africa's inability to produce rice to self-sufficiency levels is indicative of the presence of major constraints in the rice industry requiring urgent attention. It is necessary to stem the trend of over-reliance on imports to meet the increasing demand for rice. Local potential resources for production should be exploited with sustainable strategies at all levels of the rice industry. This creates an urgent need to increase and improve the production of rice in Africa in order to meet the high demand (Ogunbayo *et al*., 2005). The need for expansion of rice cultivation does not only depend on cultural practices and management, it also depends on the suitability of rice varieties, which must be drawn from existing germplasm that has been collected and conserved by genetic resources centers (Ng *et al.,* 1988).

In Ghana, rice is becoming a major food crop and daily, its growing importance, demand and productivity is largely experienced in most local communities. According to the Millennium Development Authority on Economic Growth and Poverty Reduction (MOFA, 2005) reported rice accounts for nearly 13% of total cereal consumption in Ghana. As a growing diet and major staple, it is increasingly replacing other traditional staples of rural and urban dwellers. For instance, the per capita consumption of rice is estimated increased from 7 kg/year in 1988/89 to 18.7 kg/year during 1998-2000 as reported by the Ghana living standard survey. Current estimates put per capita consumption at 25 kg/year (MOFA, 2005). Besides, an IRRI/FAO report estimated domestic output of milled rice in 2004 at 14,000 MT against demand of 440,000 MT (MOFA, 2005) leaving a domestic deficit of supply.

With the foregoing estimates, MOFA, (2005) reported small scale farmers are primary producers, and they continue to contribute towards hunger reduction by cultivating rice crop over a wide range of environments; but yet still limited in terms of yields due to a number of factors ranging from poor agronomic practices to mainly lack of high yielding varieties.

The huge demand for rice productivity amidst associated environmental factors in developing countries coupled with its high populations is evident of these countries incapability to meet world-wide demand. This left the sub-region of West Africa to begin experiencing rice shortages and fluctuation in prices. Alternatively, it can be inferred that evaluating and characterizing landraces of rice germplasm will help plant breeders in the sub-region to better embark on specific selection to improve rice accessions based on agro-morphological traits and variations as a result of differences in their DNA sequences. It is likely to foster increased rice production and productivity if the trend is supported.

This generally agreed with Frankel *et al.* (1995) who reported that landraces are the most diverse populations of cultivated plants. Besides being adapted to their natural and man-made environments, landrace genotypes tend to be co-adapted. Hence, genetic variation within a landrace may be considerable, but is far from random (Qualset *et al*., 1997). The genetic diversity among and within landraces makes them a valuable resource as potential donors of genes for the development and maintenance of modern crop varieties, and for direct use by farmers (Soleri and Smith, 1995). The utilization of these rice genetic resources had been limited to only adaptable genotypes as reported by Caldo *et al*. (1996).

Guei and Traore (2001) described the rice to constitute a good source of unique genes for stress tolerance and genetically dynamic. Despite these positive attributes, little efforts have been made to characterize and evaluate landrace rice accessions of West Africa origin.

Ogunbayo *et al*. (2005) studied phylogenetic evaluation of forty rice accessions using morphological and molecular techniques within cluster similarities and between clusters morphological differences were observed. Landraces of rice accession differ from improved cultivars in adaptation to soil type, sowing and ripening periods and yield stability particularly, in regions where seasons are unpredictable. This re-enforced the importance of investigating local germplasm for breeding purposes. Therefore, accurate assessment of the levels and patterns of genetic diversity can be invaluable in crop breeding for diverse applications including (1) analysis of genetic variability in landrace genotype and cultivars (Cox *et al*., 1986), (2) identifying diverse parental combinations to create segregating progenies with maximum genetic variability for further selection (Barret & Kidwell, 1998), and (3) introgression of desirable genes from diverse germplasm into the available genetic base (Thompson *et al*., 1998).

2.2 Global Production of Rice

According to DARE and ICAR (2002) reported “of all staple food crops”, rice accounts for the dietary energy requirements of almost half the world population and with over 90 percent of it being produced and consumed in Asia. It is the second most important crop in the world (after wheat, which has an annual cultivation area of 213 million hectares [Mha]) and is grown annually on 151.54 Mha, with an annual production of 593 million tonnes (Mt) and an average productivity of 3.91 t/ha (FAOSTAT, 2002). The four decades since 1961 saw an increase in area, production and productivity of rice of 31.2, 174.9 and 109.7 percent, respectively. Besides Asia, rice is grown to very limited extent in Africa, Latin America, the United States and Australia and in the European Union.

In Asia, rice is grown on 136.07 Mha, Africa, 7.67 Mha and 5.09 Mha in Latin America. Annual rice production in the three continents is 539.84, 16.97 and 19.54 Mt, respectively, and average productivity 2.97, 2.21 and 2.84 t/ha. Asia and Latin America have similar rates of growth in area, production and productivity: production increased at a rate of 2.5 percent per year, and area and productivity by 0.4 and 2.1 percent per year. Growth in these regions was equal to the rate of growth globally. However, in Africa, production increased at a rate of 2.8 percent per year, due mainly to the increase in area (2.2%/year); the annual rate of increase in productivity was low (0.6%). The total world rice area during this period increased from 125 to 150 Mha, an increase of over 19 percent. In Africa, the area under rice more than doubled from 3.5 Mha to over 7.0 Mha. In Asia, the total rice area increased from 118 to 122 Mha, i.e. an increase of just 3.22 percent. In South America, area increased from 5.04 to 5.70 Mha, i.e. an increase of around 13 percent. The changes in area, production and productivity of rice in the three continents for each of the last four decades continued to remain steady as indicated.

2.3 Socio-Economic Importance of Rice

Rice is one of the cereals, comprises the most important food crop in the world. It is the most common cereal grain consumed, and offers considerable economic and agricultural importance. The global, annual rice production is 562, 260 thousand metric tons (tmt), a yield that is a close third to wheat (584, 874 tmt) and maize (576, 821tmt) as reported by Leviton & McMahon, (1996) and World Almanac, (1998). However, rice is the only cereal crop, almost entirely consumed by humans unlike wheat and corn.

Africa, as a one of the continents in the world, accounts for 32% of the global imports as a big international player in the rice marketing arena with a record level of 9 million tonnes in 2006 (WARDA, 1998). This concurred with Sohl (2005) reports of Africa’s emergence as a big rice importer is explained by the fact that in the last decade, rice became the most rapidly growing food source in sub-Saharan Africa. The trend of change was mainly due to 4% of growth increased in population annually, rising incomes and consumer preferences in favor of rice mainly experienced in urban area. Balasubramanian *et al*. (2007) documented the relative growth in demand for rice is faster in this region than anywhere in the world (WARDA, 2005) and is apparent throughout the sub-regions of sub-Saharan Africa (SSA). The period from 2001–2005, rice production expansion at the rate of 6% per annum, with 70% of the production increase due mainly to land expansion and only 30% being attributed t*o* an increase in productivity (Fagade, 2000; Falusi, 1997; Africa Rice Center, 2007).

Dingkuhn *et al*. (1997) described land expansion of the West and Central Africa (WCA) mainly seen in the rainfed systems (constituting 78% upland and rainfed lowland). Nonetheless, demand for rice in WCA has far outstripped the local production (Africa Rice Center, 2007).

According to OSIRIZ (CIRAD's Observatory of International Rice Statistics), Africa cultivated about 9 million hectares of rice in 2006, a production figure that surpassed 20 million tonnes for the first time but as well determined to 7% as an increment per annum in the future. There remains a critical event in West Africa, where the rice sector is by far the most important in South Sahara Africa (SSA). Despite the upward trends in international and domestic rice prices, domestic rice consumption is increasing at a rate of 8% per annum, surpassing domestic rice production growth rates of 6% per annum. The production-consumption gap in this region is being filled by imports, valued at over US$ 1.4 billion per year. The share of imports in consumption rose from an average of

43% from 1991 to 2000, to an average 57% by 2002-2004 (WARDA, 2005; FAOStat, 2002).

In 1991, rice production exceeded maize production by 41, 094 tmt (Leviton & McMahon, 1996); however by 1996 this trend was reversed, and maize production exceeded rice production by 14, 561 tmt (World Almanac, 1998). Moreover, maize production experienced a 12.3% greater increase than rice between the years 1991-1996 as also reported by Leviton & McMahon, (1996) and World Almanac, (1998). By the year 2050, the predicted African population will total 2,049,953, 000, an increase of 67.8% from the 2020 census, and 173.2% from the 1997 census (The World Almanac, 1998).

2.4 Principal Constraints to Rice Cultivation in Africa

Demand for rice in West Africa has been growing at the rate of 6% per year since 1973 (Nwanza, 1996). Increased consumption is due both to population growth and to the increased proportion of rice in the West African diet. In an attempt to keep pace with demands, production of rice in West Africa has been expanding rapidly, growing at 5.1% per year, faster than any of the other principal staple food crops. Despite the growth in regional production already achieved, imports of rice have grown at the alarming rate, averaging 9% a year for two decades. As a low-input system, upland ecosystems tend to not use fertilizer and rely solely on rain. Under these conditions, diseases are considered a major problem as well. Lowland systems use water from rainfall, subsurface water tables, and surface water. By using fertilizer and controlling pests, lowland areas have the potential to produce far greater yields than the upland ecosystem (WARDA, 1993).

Recently, breeding program for rice varieties are geared towards adapted plant mechanisms to meet some of the basic climatic and edaphic (drought, nutrient poor or toxic soils), which constrained continent of Africa. This has considerably reduced yield of rice per unit area of about only 49% of the global average. Unlike more developed regions of the world, insects and diseases result in a larger drain on yields and the problems may persist longer. The principal constraints dealing with rice cultivation in Africa can be categorized into biotic and non biotic constraints.

Johnson *(*1997) reported rice yield in rainfed-upland systems average about 1 ton per hectare, weed competition remains the most outstanding yield-reducing factor followed by blast, soil acidity and general soil infertility. Notwithstanding, farmers traditionally continue to manage these stresses through long periods of bush-fallow. Alongside these, increasing population growth has led to a dramatic reduction in the fallow periods thus encroaching on the extended periods of cropping in many areas in Africa.

According to Moormann and Veldkamp (1978), rice growth needs 600 mm of rain to complete its growth. Water is a limiting factor in upland/dryland rice cultivation areas but soil characteristics also play an important role in these areas. Varietal traits that can avoid drought are very important. Recent release of early maturing progenies from interspecific crosses between *O. glaberrima* and *O. sativa* named New Rice for Africa (NERICA) will give farmers the chance to grow rice in areas having limited rainfall.

Virmani (1979) reported iron toxicity exists in many West African countries, including Benin, Burkina Faso, Côte d'Ivoire, Liberia, Nigeria, Senegal and Sierra Leone where yield losses resulting from toxicity range from 12 to 88 percent. Where non-tolerant lines are grown in such conditions, total crop failure may result. The major physical constraint in this ecosystem is uncontrolled floodwater, which can inundate the crop or produce flash floods capable of carrying away the harvest. The ability to remove weeds and control diseases before seeding largely determines the area that can be grown by family labors and the efficiency of weeding after sowing greatly affects grain yield harvest.

2.5 Grain Yield

Africa holds a low average grain yield of (2.2 t/ha), which is believed to be below the world average (3.4 t/ha) by 49 percent (FAO, 2000). Its low average of grain yield may be due to several factors, including the poor standard of production technologies coupled with dominance of the upland ecosystem (55%), (FAO, 2000). The irrigated ecosystem represents only 11 percent of the total rice area in Africa, while in the world, it accounts for 53 percent (Kaung Zan *et al*., 1985). The average grain yield of Africa shows very little improvement with time. The north has the highest grain yield (4.9-5.7 t/ha) because of the high level of production technology and the dominance of the irrigated ecosystem. West Africa and East Africa have the lowest average grain yields in Africa (1.6 and 1.9 t/ha, respectively (Nyanteng, 1998). It should be noted that West Africa, which contributes 56.5 percent of the rice area, accounts for 42 percent of the total production, while North Africa, which is responsible for only 8.2 percent of the rice area, accounts for 32 percent of total production as a result of the higher grain yields, higher cropping intensities and the dominance of the irrigated ecosystem (Nyanteng, 1998).

2.6 Potentials for the Future

As the UN Millennium Development project seeks to spread global economic development to Africa, the "Green Revolution" is cited as the model for economic development. With the intent of replicating the successful Asian boom in agronomic productivity, groups like the Earth Institute doing research on African agricultural systems, hoping to increase productivity. An important way this may happen is through production of national accessions as in the case of the “New Rices for Africa” (NERICA). The landraces when selected have promising qualities to tolerate the low input and harsh growing conditions of African agriculture and would be billed as technology from Africa, for Africa. Just as NERICA appeared in *The New York Times* (October 10, 2007) and *International Herald Tribune* (October 9, 2007), these landraces would be trumpeted as miracle crops that will dramatically increase rice yield in Africa and enable an economic resurgence.

2.7 Genetic Erosion of Crop Germplasm

Among the natural resources, the germplasm or genetic resources of crop plants have a sharp depletion in both the number of crop species and the genetic diversity expressed by the amount of genetic variation within a species since the beginning of scientific breeding (Frankel, 1973; Harlan, 1975). Along with the rapid pace of development during the last three decades, the genetic resources of crop plants have been dwindling at an alarming pace. The genetic base of the major food crops suffered a sharp reduction when the farmers, consumers, crops suffered, and government demanded genetic uniformity among the new varieties. The rapid spread of improved varieties has intensified the displacement of the traditional unimproved cultivars (land races and accelerated their extinction. The trend toward greater uniformity has increased the genetic potential vulnerability of the major crops to epidemics of diseases and insects (National Academy of Sciences, 1972). Paradoxically, genetic erosion is a by-product of successful plant breeding (Paddock, 1970; Hawkes, 1983).

2.8 Morpho-agronomic Characterization

Characterization of morphological and physiological traits and evaluation is particularly useful in revealing economic importance of crop. It is needed for the sub region of West Africa since evaluation of germplasm accessions in any collections is essential to ensure the principles of conservation and utilization of germplasm (Riley *et al*., 1995). Qualset and Shands (2005) reported characterization was needed to handle the diversified genetic resources of plants to improve the nutritional value of foods, meet changing consumers demand, combat pest, and diseases and adapt to the environmental changes.

However, the amount of data related to agronomic traits on crop germplasm is limited. Due to reasons that include relatively high costs and difficulties of large scale experimental trials, the use of agronomic evaluation to characterize germplasm collections is far from the actual necessity of uncovering the phenotypes of agronomic interest in accessions of a collection. More should definitely be done in this area in order to stimulate a higher use of stored germplasm in breeding programs. A complete agronomic trait evaluation of crop germplasm remain to be achieved in the next few years, though, seems to be practically impossible (IRRI, 1996).

2.9 Importance of Characterization

Conservation of genetic resources entails several activities, many of which may greatly benefit from knowledge generated through applying characterization and evaluation of germplasm. This is the case for activities related to the acquisition of germplasm (locating and describing the diversity), its conservation (using effective procedures) and evaluation for useful traits. In all, the availability of sound genetic information ensures that decisions made on conservation will improve germplasm management. Of the activities related to genetic resources, those involving germplasm evaluations and the addition of value to genetic resources are particularly important as they help identify genes and traits, and thus provide the foundation on which to enhance use of collections.

Characterization' is the description of a character or quality of an individual (MerriamWebster, 1991). The word 'characterize' is also a synonym of 'distinguish', that is, to mark as separate or different, or to separate into kinds, classes or categories. Thus, characterization of genetic resources refers to the process by which accessions are identified or differentiated. This identification may, in broad terms, refer to any difference in the appearance or make-up of an accession.

De Vicente *et al*. (2005); Rubenstein and Heisey (2003), reported descriptors' lists are a vital tool for ensuring that those who are documenting the characteristics of conserved species are using the same language and standards. In the agreed terminology of gene banks and germplasm management, the term ‘characterization ‘stands for the description of characters that are usually highly heritable, easily seen by the eye and equally expressed in all environments (IPGRI/CIP, 2003). Similarly, Anon (2010) reported that quantitative traits are measurable characteristics which exhibit continuous variation (height, weight) and can be attributed to the interaction between two or many genes and their environment.

In genetic terms, characterization refers to the detection of variation as a result of differences in either DNA sequences or specific genes or modifying factors. Standard characterization and evaluation of accessions may be routinely carried out by using different methods, including traditional practices such as the use of descriptor lists of morphological characters.

They may also involve evaluation of agronomic performance under various environmental conditions. In contrast, genetic characterization refers to the description of attributes that follow a Mendelian inheritance or that involve specific DNA sequences. In this context, the application of biochemical assays such as those that detect differences between isozymes or protein profiles, the application of molecular markers.

2.10 Challenges of Germplasm Characterization

The lack of precise information about economic traits has been one of the reasons for the poor use of accessions in gene banks. The characterization and evaluation of conserved germplasm is the weakest link in many of the national, regional and global collections. For a crop like rice with a large gene pool, the development of core collections will facilitate easy accessibility to and effective use of the genetic diversity preserved. Without knowledge of the specific economic value of a genetic material, how can it be categorized as a genetic resource? Hence, greater effort is essentially needed to evaluate and optimize genetic resources in national, regional and global rice improvement programmes (FAO, 2002).

2.11 Future Trends for Germplasm Characterization

A core collection - i.e. a representative set of accessions covering maximum diversity with minimum repetition and consisting of ecologically and genetically distinct accessions - needs to be developed at national, regional and international centres for crop species with a large collection (such as rice). Besides reducing conservation costs and increasing management efficiency, it promotes effective and sustainable use of genetic diversity by facilitating rapid and precise identification of germplasm sources for improvement of desired traits. For delineation of a core collection, the extent of diversity to be covered and number of accessions to be included in the set must be established. A core collection can be made more dynamic with the integration of molecular techniques to increase the number of distinct alleles, remove duplicates and create scope for the addition of new accessions whenever identified as different from the present ones. Efforts should be made to develop attribute-based core collections, which will help reduce the sample size as well as facilitate rapid identification of donors for desired traits with increased precision. Genetic enhancement of significant economic traits needs particular attention.

Germplasm collection expeditions should be organized regularly to complete the gaps in germplasm collection from underexplored and unexplored centres of diversity. Systematic characterization of the collected germplasm is then vital. The genetic resources generated in research institutions/stations - i.e. released varieties, breeding lines, advanced material evaluated in coordinated trials, mutants, genetic stocks etc. - must be conserved. Many of the mutants developed, discarded and then lost may have been vital for functional genomics, crucial for future breeding with great velocity and precision (FAO, 2002).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of Experimental Site and Land Preparation

The experiment was conducted in the rice growing community of Nobewam (0 6° 38' 122 ″, W 001° 16 ' 54.7 ", 195 m above sea level), Ashanti region. The land was brushed, de-stumped and ploughed with assistance from the community members of Nobewam. Soils were sampled to a depth of 20 cm (prior to the land preparation) and analyzed (Appendix 4) at the Department of Soil Science laboratory, Kwame Nkrumah University of Science and Technology. Soils analyzed were based on the Walkley and Black method (Walkley *et al*.,1934) for organic C (%), total nitrogen by Soils analyzed were based on the Walkley and Black method (Walkley *et al*., 1934) for organic C (%), total nitrogen by Kjeldahl (Bremmer, 1965) and available phosphorus by the Bray methods (mg/kg) (Bray *et al.*, 1945).

The climate and vegetation of research site is similar to most of the middle belt in Ghana and with a tropical rainfall, i.e. bi-modal rainfall pattern and wet semi-equatorial climate The research area is generally undulated and drained by a number of rivers. Occasional flooding is experienced in the inland valleys along the river basins. It is characterized by double maxima rainfall lasting from March to July and again from September and normally ends in the late part of November with a mean annual rainfall of 1,200 mm being ideal for season cropping (Anon, 2002).

3.2 Cropping history of the Land

Prior to cultivating the land, it was reported by the landlord that crop rotational system was practiced. In previous year, land had been cropped to maize followed by plantains intercropped with cassava.

3.3 Experimental Design

A randomized complete block design (RCBD) was used with three (3) replications. The total area was 2040 m^2 (102 m x 20 m) with each accession planted on a plot size of 4.35 m^2, two-plants per hill at spacing of 20 cm x 20 cm. The observable traits data were collected when replicated accessions attained a 5-leaf seedling stage until crop maturity.

3.4 Origin of Planting Materials

A total of 84 accessions of rice germplasm received from the Crops Research Institute (CRI)-Ghana and Africa's Rice Center (Africa Rice) were investigated to determine their genetic diversity and variability based on agro-morphological characters. The Ghanaian rice accessions evaluated were 47, 1 Ivorian and 36 Africa Rice lines, (Appendix 1). The materials were direct-seeded on 27th July 2009. The basal fertilizer of 18.6 kg/ha (NPK 15-15-15) was topdressed days after sowing. The second 9.9 kg/ha and third 12.9 kg/ha (Urea) were also topdressed at tillerings and prior to the panicle initiation. Weeding was performed by hand and plots were maintained, pest and diseases free until harvest.

3.5 Field Evaluation of Rice Cultivars

Two main parameters of morphological and agronomic traits were measured to generate data for the eighty-four rice accessions studied.

3.5.1 Morphological traits

Morphological analysis was done using both quantitative and qualitative characters collected during the different growth stages of the accessions. Leaf pattern was determined at early vegetative while at late vegetative stage, leaf blade length, leaf blade width, ligule length, and days to heading, culm length, culm number after full heading were also recorded. Culm diameters at flowering period, 100-grain weight and one-meter quadrat square at harvest were measured as quantitative characters. At vegetative stage, characters like leaf blade pubescence, leaf blade color, basal sheath color, flag leaf angle, ligule shape, collar colour, auricle colour, were some of the qualitative traits determined. Other characters evaluated were awns, panicle type and panicle exsertion near maturity

3.5.2 Agronomic traits

The plant height, days to 50% effective heading and 80% mature grain ripened were the parameters measured. The venier caliper, 5-meter tape, 15 inches ruler and precision balance scale were used to measure some quantitative parameters of rice accessions.

3.5.3 Standard Evaluation System for Rice Data Collection

The sources of materials accessed and used as a guide for rice data collection included: IBPGR-IRRI (1980), IRTP (1988) and Bioversity International, IRRI and WARDA Rice Descriptor (2007). The parameters measured were as outlined:

3.5.3.1 Days to 50% heading

To obtain data, the date was recorded when rice accessions were sowed until 50% heading (flowering) during their vegetative growth at research site. The rain and other moisture were also factored into calculating effective seedling date when available to the seed for germination.

3.5.3.2 Days to 80% grain maturity

To obtain the data, 84 accessions effective days to maturity were recorded when 80% of the grains on the panicle were fully mature and ripened from the date of sowing of rice seeds. As a result, two groups of accessions were observed to possess early and late mature grain ripened.

3.5.3.3 Plant height

To obtain the plant height with regards to the evaluated accessions, the use of actual measurement in centimeter (cm) of 5 samples size, randomly selected per replicated plots and averaged. It was measured from the soil surface to the tip of the tallest leaf blade at the 5-leaf stage as outlined: 3 Short (<30 cm), 5 Intermediate (~45 cm) and 7 Tall (>60 cm).

3.5.3.4 Culm Length

To obtain the culm length, accessions were measured from ground level to the base of the panicle after rice effective days heading. 5 plants sample size randomly selected and averaged as per replicated accessions. Recording and averaging of five actual measurements, to the nearest centimeter after flowering to maturity. The culm length in centimeters was measured to have an idea whether replicated accessions attain stature coded as follows : 1 Very short (<50 cm, 2 Very short to short (51–70 cm), 3 Short (71–90 cm), 4 Short to intermediate (91–105 cm), 5 Intermediate (106–120 cm), 6

Intermediate to long (121–140 cm),7 Long (141–155 cm), 8 Long to very long (156– 180 cm) ,9 Very long (>180 cm).

3.5.3.5 100 Grain weight

100 well developed seeds weight counted were obtained from the 3 replicated accessions. The seeds were randomly selected from the harvested samples of accessions after harvest, dried at 13% moisture content and weighed on a balanced precision scale (METTER PM 400) at the Department of Soil Laboratory, Faculty of Agriculture- Kwame Nkrumah University of Science and Technology, Ghana.

3.5.3.6 Culm Diameter (mm)

Culm diameter found at the basal internode and measured in millimeters. It was measured as the outer diameter of the basal portion of the main Culm. A total of three representative plants per replicated accessions were recorded and averaged at the late productive stage.

3.5.3.7 Leaf Length (LL)

To obtain the actual measurement in centimeters, the leaf length of accessions was measured in centimeters from the topmost leaf blade below the flag leaf on the main culm. 5 plants leaf sample size were measured and averaged per replicated accessions.

3.5.3.8 Leaf Diameter (LD)

The actual measurement, in millimeters as per replicated accessions was taken at the widest portion of the blade on the leaf blade just below the flag leaf. Again 5 plant samples were measured and averaged at the late vegetative stage.

3.5.3.9 Ligule Length (LgL)

Ligule length of the replicated accessions was actually obtained when measured in millimeters from the base of the collar to the tip. A hand calibrated tape rule was used to take 5 plants sample size randomly selected per accession and averaged at the growth stage of 4-5.

3.5.3.10 Grain Length (mm)

The grain length was measured in millimeters as the distance from the base of the lowermost glume to the tip (apiculus) of the fertile lemma or palea, whichever is longer. For those accessions with awned, they were measured to a point comparable to the tip of the apiculus (exclude the awn). The venier caliper was used to record the averages of 10 representative grains per accession at 13% seed moisture after harvested and dried.

3.5.3.11 Grain Width (mm)

To obtain the grain width in millimeters, it was measured as the distance across the fertile lemma and palea at the widest point. The caliper was used to take the average of 10 representatives of grains, randomly selected per accession. This was done when harvested accessions were sun dried at seed moisture of 13%.

3.5.3.12 Culm Number (productive tillers)

The Culm number was obtained when 5 plants sample size, randomly selected of replicated accessions physically counted and averaged. This was done immediately after accessions days to effective heading.

3.5.3.13 Grain Yield

To obtain the grain yield per accession, one-meter quadrat was taken from the 2.9 m x 1.5 m plot size, replicated 3 times per accession. The samples per accession were collected and weighed on the precision balance scale at the Department of Soil Science laboratory, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology. The mean for the weighed samples per accession-plot size in grams was averaged and converted into tonnes/ha.

3.5.3.14 Flag Leaf Angle (FLA)

To obtain the data as required, the leaf angle of 5 plants sample size randomly selected per replicated accession was measured near the collar as the angle of attachment between the flag leaf blade and main panicle axis, scored at anthesis or growth stage 45. The accessions were scored for erect, intermediate, horizontal and descending angles.

3.5.3.15 Leaf Blade Pubescence (LBP)

To determine this qualitative trait, apart from the ocular inspection, the leaves of replicated accessions were fingers rubbed from the tip down on the leaf surface. The presence of hairs on the blade surfaces was classified as glabrous, intermediate and or pubescent. The data was recorded at late vegetative stage.

3.5.3.16 Ligule Shape

To obtain the qualitative trait, ligule shape per accession was determined at the late vegetative stage when 5 plants sample size were cross-checked. The check was to verify whether plants ligule shapes were: Truncate, Acute to acuminate and or 2-Cleft.

3.5.3.17 Basal Leaf Sheath (colour)

Another qualitative trait determined at the late vegetative stage of accessions growth based the presence of colour of the outer surface of the leaf sheath. Accessions were scored as Green, Green with purple lines, Light purple and Purple accordingly.

3.5.3.18 Panicle Exsertion

To determine this qualitative trait, panicle exsertions of rice accessions at the extent to which the panicle are exserted above the flag leaf sheath. The exsertions were determined near maturity based on the following as outlined: 1 Enclosed (panicle is partly or entirely enclosed within the leaf sheath of the flag leaf blade), 3 Partly exserted (panicle base is slightly beneath the collar of the flag leaf blade), 5 Just exserted (panicle base coincides with the collar of the flag leaf blade), 7 Moderately well exserted (panicle base is above the collar of the flag leaf blade) and 9 Well exserted (panicle base appears well above the collar of the flag leaf blade.

3.5.3.19 Panicle Type

To obtain data for panicle type, accessions were carefully cross examined to determine whether they have compact, intermediate and opened type. The sum total of the panicle type was determined and averaged at the end of the exercise.

3.5.4 Statistical Packages

The data were statistically analyzed using Gen-Stat package. The package helped to calculate the means, standard error, standard deviation and coefficient of variations. The Least significance difference (Lsd) test at 5% probability was used to separate means as described by Steel and Torrie (1980). Frequency distributions were computerized to categorize the accessions into classes. Correlations were also determined.

The clustering technique of Numerical and Taxonomy System (NTSYSpc software) (Rohlf, 2002) using the Unweighted Pair Group Method of Arithmetic means (UPGMA) was performed to develop a dendrogram for the 84 rice accessions.

a. Erect leaf pattern b. Droopy leaf pattern

Plate 1: Two groups of leaf architecture of rice varieties observed during growth of rice accessions.

CHAPTER FOUR

RESULTS

4.1 Morpho-agronomic Analysis of Quantitative Traits

The mean, standard error, range, coefficient of variation, standard deviation, F probability of the least significant difference at 5% were computerized for 13 quantitative traits as shown in the table below. Correlation matrix was also determined (Appendix 5).

Table 1: Mean ± S.E., Range, Coefficient of Variation (CV) %, Standard Deviation (SD) of 84 rice accessions

Traits	Mean + S.E	Range	CV (%)	SD	F Probability
Days to 50 % heading	71.6± 0.42	58-83	9.38	6.72	0.001
Days to 80 % maturity	93.43±0.64	85-105	10.77	10.09	0.001
Plant height (cm)	61.05±0.59	36-87	15.43	9.42	0.001
Culm length (cm)	79.78±0.73	54-122	14.51	0.49	0.001
leaf length (cm)	47.19±0.48	32-69	16.28	7.68	0.001
Culm diameter (mm)	4.07±0.03	2.80-5.50	12.22	0.49	0.001
Ligule length (cm)	1.18±0.03	0.30-3.20	21.83	0.40	0.001
Leaf diameter (mm)	1.47 ±0.20	0.08-2.40	21.83	0.32	0.001
Grain Width (mm)	2.85±0.41	2.48-3.37	6.69	7.68	0.001
Grain length (mm)	10.46±0.07	8.08-13.13	10.95	1.15	0.001
Prod.tillers # per plant	30.13±0.43	19-46	22.55	6.80	0.001
Grain yield (t/ha)	2.30±0.41	0.44-4.55	38.40	88.50	0.001
100 grain weight (t/ha)	3.28±0.41	2.30-4.40	13.17	1.29	0.009

4.2 Phenological Studies of some Morpho-agronomic traits among Rice Accessions

The results of phenological studies among the eighty-four rice accessions as revealed by number of days to headings (flowering), days to maturity, nitrogen plant-responders and variations in grain yield are as follows:

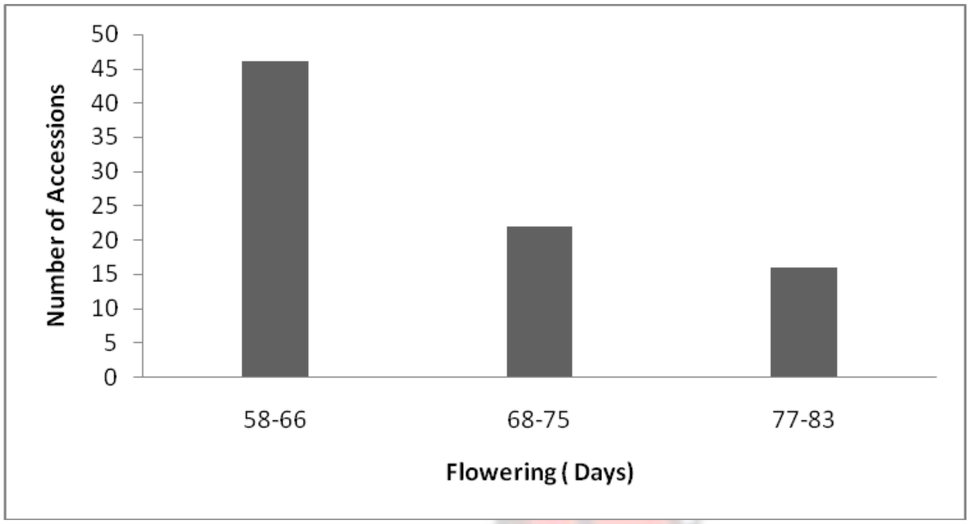

Figure 4.1: Variation in days to flowering among rice accessions.

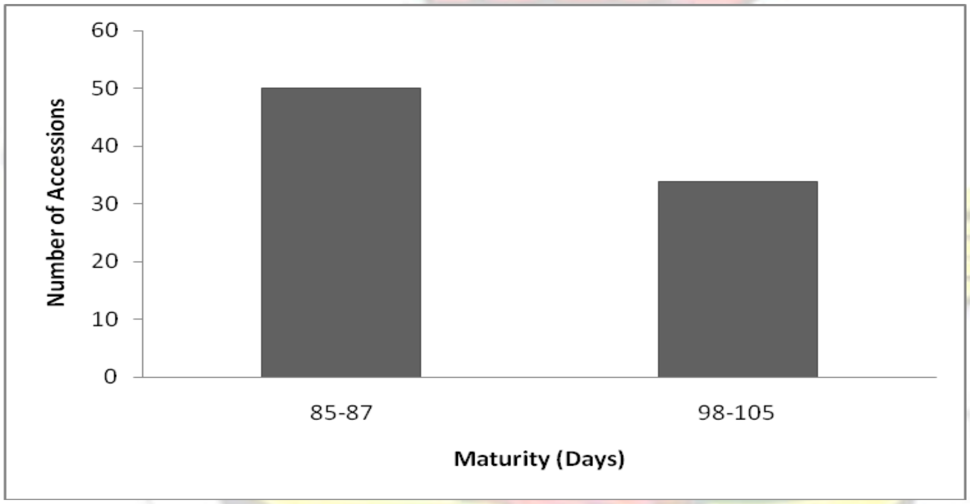

Figure 4.2: Variation in days to grain maturity among rice accessions.

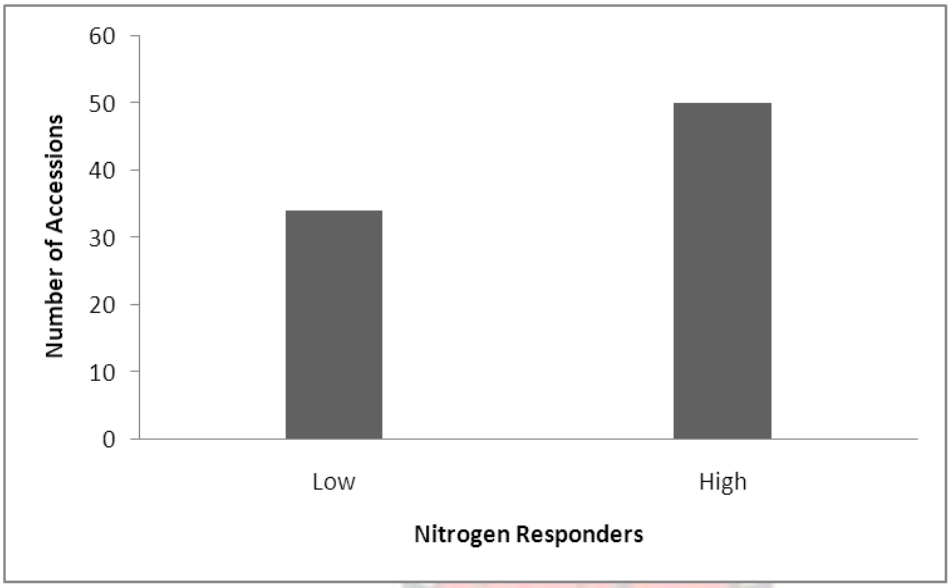

Figure 4.3: Low and high N-responders as observed among rice accessions based on the "plant type" concept

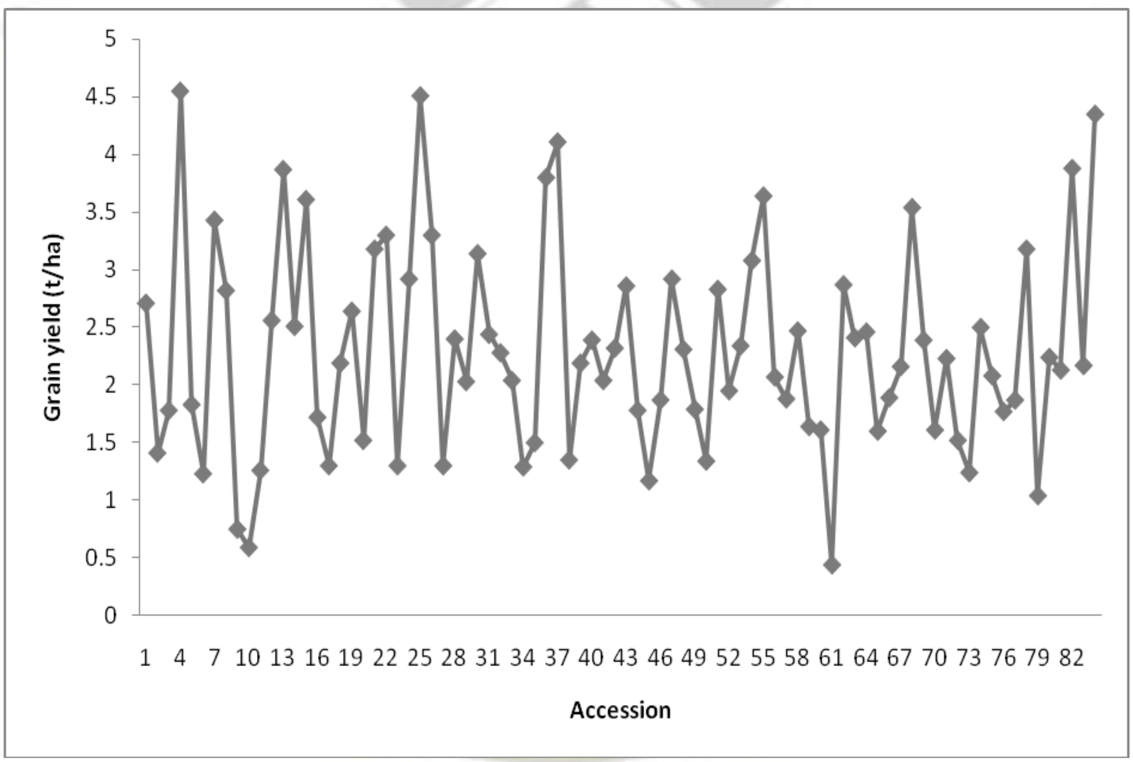

Figure 4.4: Variations in grain yield as observed among rice accessions after evaluation

Figure 4.5 Histogram showing variations in some Traits among Rice Accessions after 3 months field evaluation

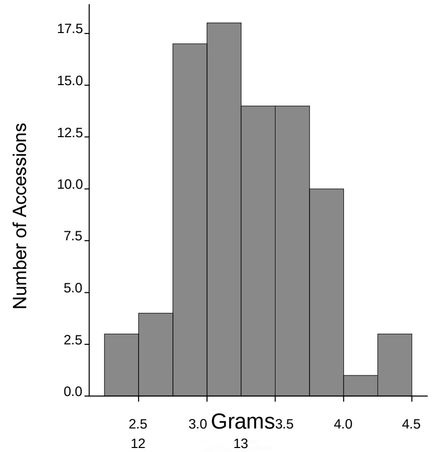

Figure 4.5.1: 100-Grain Weight

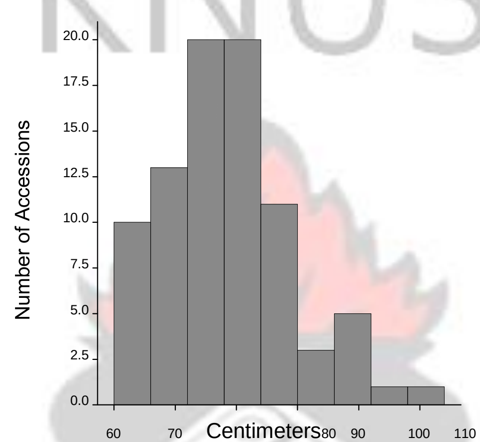

Figure 4.5.2: Culm Length

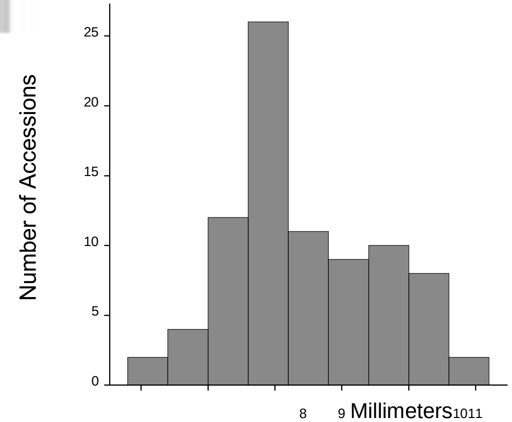

Figure 4.5.3: Grain Length

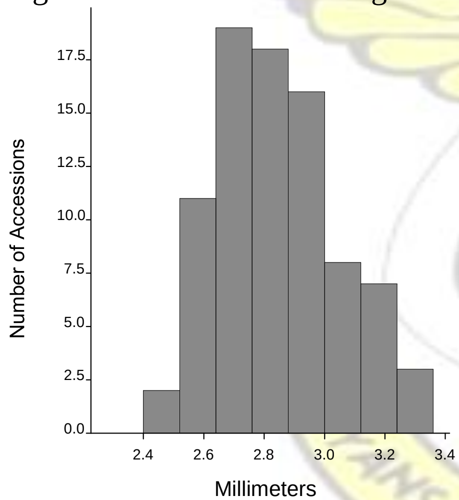

Figure 4.5.4: Grain Width

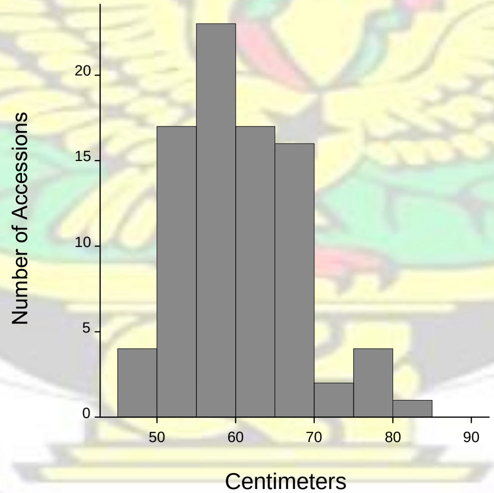

Figure 4.5.5: Plant Height

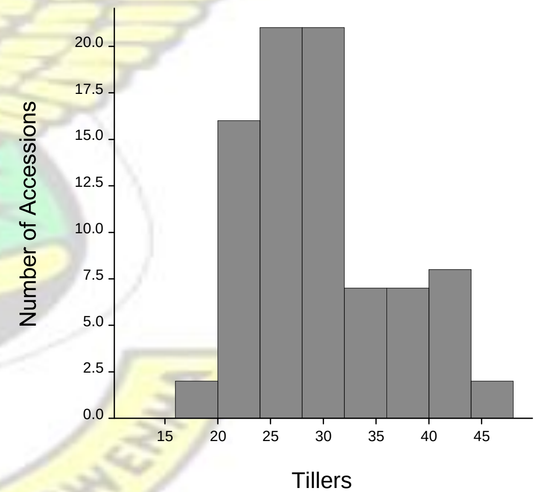

Figure 4.5.6: Productive Tillers

4.3 Cluster analysis using the UPGMA based on binary scores of growth parameters of rice accessions

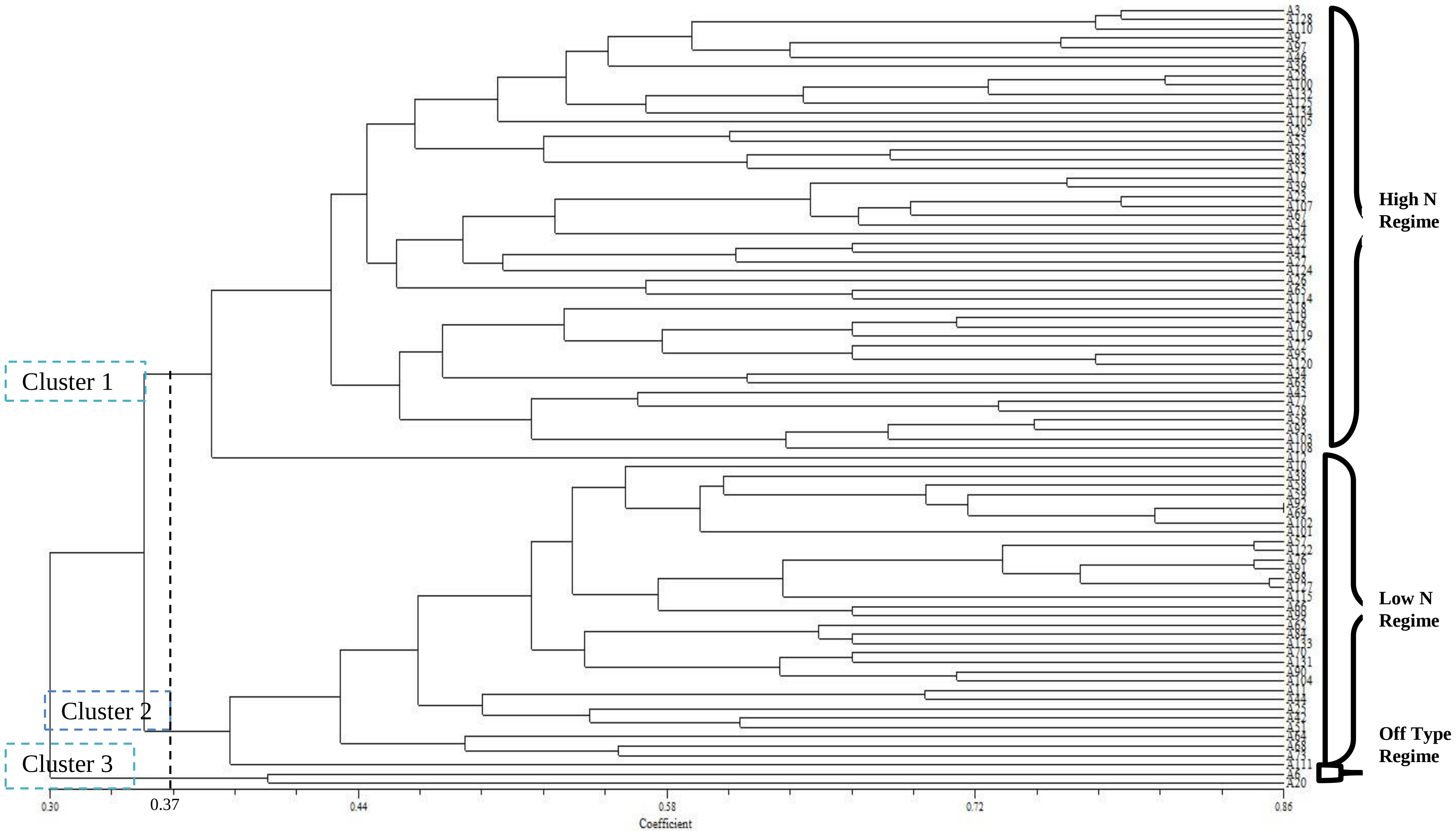

Figure 4.6: Dendrogram showed 3 clusters of N-regime of 84 rice accessions classified based on the "plant type" concept

CHAPTER FIVE

DISCUSSION

The present study was conducted to evaluate field performance of rice accessions from the Africa Rice Center and Ghana to assess the presence of variability for desired traits. A significant amount of variations did exist among the eighty-four accessions for all the twenty-four morpho-agronomic traits evaluated.

A cardinal objective of any breeding program is to produce high yielding and better quality lines for release as cultivars to farmers for increased food productivity. The prerequisite to achieve this goal is the presence of sufficient amount of variability, in which desired lines are selected for further manipulation that leads to achieving the target objectives. Therefore, the introduction of new populations can be easily made from one region to another and may be used for further manipulation to develop breeding lines.

The study results showed 50 accessions that could be classified as high nitrogen responders with erect dark-green leaf pattern and sturdy stems. On the other hand, 34 accessions were observed that could be classified as low nitrogen responders, with droopy pale-green leaf pattern and weak stems as postulated in the “plant type” concept by Tsunoda (1964) and therefore, present the detailed explanations as outlined:

5.1 Days to 50% Effective Heading (flowering)

The analysis of variance shows highly significant genetic variations ($P \leq 0.01$) among the genotypes for effective days to 50% heading (Table 4.1). Coefficient of variation (CV) showed 9.38% and standard deviation of 6.72 for days to flowering respectively. Number of days to flowering ranged from 58 to 83 (Table 4.1). Minimum days to 50 % flowering were observed in 46 genotypes (58-66 days) in contrast to 22 (68-75 days) as intermediate, while maximum of (77-83 days) for 16 genotypes. Similar results were reported by Tahir *et al.* (2002) in rice. This type of variability might be due to the genetic makeup of the landrace lines and genotypic environmental interactions. Early maturing genotypes exist in the collections and could be exploited for cultivar development (Fig 4.1).

5.2 Days to Grain Maturity

Analysis of data exhibited high range of 85-105 days along with coefficient of variation of 10.77%, (Table 4.1). Sixty percent of accessions showed shorter maturity period i.e. 87 days representing earliness (Fig 4.2). As indicated, minimum value for days to maturity genetically revealed that accessions have benefit of early seeds ripening, compared to 40 percent with late maturity. Early maturing plant types could be selected for areas with short rainy seasons in the rainfed ecologies. Such genotypes will also be suitable in areas where farmers grow a second crop to take advantage of residual water after harvesting the early rice crop.

5.3 Plant Height

Analysis of data revealed plant height mean value of 61.05 and a wide range of 36-87 cm, with coefficient of variation (15.43%) and standard deviation of 9.42, (Table 4.1). Plant height in rice is complex character and the end product of several genetically controlled factors called internodes (Cheema *et al*., 1987). Tall plant type is very typical of landrace genotypes which exceed in their capacity to support panicle growth by large stem reserve mobilization. Ali *et al*. (2000) observed relatively greater range in plant height than the other characters. The minimum plant height check was recorded for accession CRI-48 and ARCCU12Fal-L4P7-11-2-3 accession for the maximum value. A break-through was realized in plant breeding with speedy development of semi drawf cultivars with displayed characteristics of lodging resistance and nitrogen responsiveness in erect leaves pattern. This was why Hirano *et al*. (1992) confirmed the success of the "Green Revolution" to be directly related to intensive use of semi dwarf varieties. This was true because the semi dwarf plant type was extensively utilized in the rice (*Oryza sativa*) cultivars throughout the world. However depending on the part of the world where improvement farmers live, there is a growing desire to combine desirable characteristics of tall varieties' with yielding ability and a new type of architecture: intermediate plant height as stated by Zafar *et al*. (2004). A number of accessions possessing the short and intermediate stature plant-type were identified in the current study (Fig 4.5.5) that could be exploited for cultivar improvement.

5.4 Culm Length

The mean of 79.78 and a range of 54-122 cm were recorded. The $P < 0.001$ was highly significant at least significant difference of 5%, coefficient of variation (14.51%) and standard deviation (0.49), (Table 4.1). As a component of plant height, there were variations in the Culm length measured, with a significant portion of accessions of 54 being short to intermediate (91-90 cm), 16 very short to short (51-70 cm), 11 short to intermediate (91-105 cm), 2 intermediate (106-120 cm) and 1 intermediate to long (121140 cm). It was observed that a significant amount of the accessions possessed very short to intermediate culm architecture (Fig 4.5.2). Similarly, Akromah and BennettLartey (1986) reported such short sturdy culms could be exploited for breeding purposes because they minimize lodging, thus creating little yield or no yield loss with well developed panicles. These genetic attributes are essential when high yielding varieties for warm tropical environments where rice yields generally tend to be low due to high temperature that increases respiratory losses in carbohydrate reserves**.**

5.5 Productive Tillers per Plant type

It is one of the main attributing plant traits as indicated by Abbasi *et al.* (1995). Based on statistical data analyzed, there was high significant difference of P< 0.001 at LSD of 5 %. The coefficient of variation and standard deviation recorded 22.55% and 6.80 respectively. The accessions had a great variability with high range (19-46) for number of productive tillers (Table 4.1) and variation among accessions (Fig 4.5.6). The accessions that produced more productive tillers will contribute to increased yield in a breeding program and could be selected as base genotypes for further improvement.

5.6 100-Grains Weight

100 Grain weight is another yield-attributing trait as reported by Abbasi *et al*.

(1995).The mean of 3.28 was recorded for the genotypes with a range of 2.30 -4.40 g (Table 4.1) and some variations among accessions (Fig 4.5.1). The coefficient of variation was 13.17% and low standard deviation value 1.29. It was observed that CRI 74 had maximum grain weight of 4.40 g and the minimum genotype (ARCCU12FaIl4P7-2-2-1-1) recorded 2.30 g. These observations agreed with Ali *et al*. (2000) who noted similar maximum variation for 100-grain weight in rice ranging from 2.80 to 4.68 g. These differences were due to grain size and grain shape. It could be concluded that accessions or varieties observed possessing longer and slender grains generally have lower grain weight. The long grain and translucent types could be used in grain quality development to meet the consumers' preference.

5.7 Grain Length and Grain Width

Analysis of data revealed the mean grain length and width were 10.46 mm and 2.85 mm respectively. Coefficient of variations was recorded as 10.95 and 6.69 correspondently. In breeding applications, grain size is usually evaluated by the grain weight, which is positively correlated with several characters including grain length, grain width and grain thickness (Xu *et al.*, 2002). It is a major determinant of grain weight, one of the three components (number of panicles per plants, number of grain per panicle and grain weight of grain yield. The grain length ranged from 8.08-13.13 and width 2.48-3.37 (Table 4.1), thus inferring rice accessions were largely long-grain (with 78 accessions recorded as long-very long). Also, 68 accessions were recorded semi spherical and the rest, spherical. Although the preference for rice grain characteristics varies with consumer groups, long and slender grains is generally preferred and are good valuable attributes that could be exploited to improve the grain characteristics of local rice accessions (Table 4.1).

5.8 Grain yield per Plant-type (Accession)

Analysis of the data regarding number of grain yield per plant-type showed significant variability ($P < 0.001$) and 38.4% recorded as coefficient of variation, among evaluated genotypes (Table 4.1). Grain yield per plant-type ranged from 0.44- 4.55 t/ha (Fig 4.4). Minimum grain yield per plant-type was recorded 0.44 t/ha for CRI-43 and maximum recorded for genotype ARCC12FaIL4P7-8-2-1-1 was 4.55 t/ha. Similar variability were reported by Zahid *et al.* (2005) who studied twelve genotypes of coarse rice to check their yield performance in Kallar tract and reported highly significant variation for different traits. This variation in the grain yield might be due to the environment and genetic constitution of accessions (Mahpattra, 1993) or the correlation of grain yield per plant with various yield contributing characteristics like; fertility of soil, flag leaf area, number of grains per panicle and grain weight which showed positive correlations. Similarly, Mirza *et al*. (1992) reported positive correlation among number of panicles per plant, panicle length, number of grains per panicle, 100-grain weight and grain yield per plant-type.

5.9 Phenotypic Diversity based on Morph-agronomic characteristics of Rice Accessions

A dendrogram of the 84 rice accessions was constructed by the Unweighted Pairs Groups Method of Arithmetic Averages (UPGMA) based on morpho-agronomic similarity (Appendix 7). A dendrogram of the accessions also revealed the nitrogen regime and relationship among accessions used in the study (Fig 4.6). The clusters identified consisted of 49 high nitrogen responders and 33 potential low nitrogen responders belonging to different clusters. A third cluster consisted of 2 accessions suggesting their distinctiveness from the others.

The study agreed with Aliyu and Fawole (2000) description of cluster analysis as the singular efficacy and ability to identify crop accessions with highest level of similarity using the dendrogram. Evaluation of genetic diversity within rice accessions using the cluster in this study provided three clusters along with lot of variations in morphological properties. Also, the dendrogram generated from similarity matrices has provided an overall pattern of variation as well as the degree of relatedness among accessions. However because morphological characters are mostly subjected to environmental influences (Anon, 1990), there is the need to conduct molecular studies to gather more evidence on the distinctiveness of the accessions from each cluster.

5.10 Qualitative Characters

They are also important parameters for plant description and evaluation, and are greatly influenced by the consumers' preference. The computerized frequency distribution for 11 qualitative traits is depicted in (Appendix 2). For panicle exsertions, it was observed that a significant portion of 75 (89 %) were well-exserted and 9 (10.71%) moderately well-exserted. For panicle type, compact type was 55 (65.48%), intermediate 26 (30.95%) and opened 3 (3.57%). The blade pubescence constituted 37 (44.05%) accessions showed glabrous pubescence, 38 (45.24%) intermediate and 9 (10.71%)

pubescent. IIhamuddin *et al*. (1988) found panicle exsertion a conspicuous character for identification of the rice cultivars. Breeding for erect leaf angle has been suggested as a method of increasing grain yield in cereal crops. There are great possibilities of increasing light penetration into crop canopy, which is one of the ways of obtaining higher grain yield. Duncan, (1971) demonstrated increased penetration of light into canopy would increase photosynthetic rate and perhaps enhance grain yield. Also, Chang and Tagumpay (1970) realized erect leaf angle was associated with high yield in rice (*Oryza sativa* L).

5.11 Flag Leaf Angle

Leaf angle is measured near the collar as the angle of attachment between the flag leaf blade and the main panicle axis. It is believed to influence the degree of light saturation of the upper leaves of rice crop (Yoshida, 1981). Its distribution had 35 (41.67%) accessions with erect, 3 (3.57%) horizontal and bulk of the accessions, 46 (54.76%) were intermediate. IIhamuddin *et al*. (1988) did observe differences in the flag leaf angle, varying from erect to semi-erect. Also, there were two distinct categories of leaf patterns observed in current study with a significant portion (59.52 %) having erect leaf pattern and the rest of accession (40.48 %) with droopy leaf architecture. It is established facts that erect leaves allow the deeper penetration and more even distribution of light which results in crop photosynthesis (Yoshida, 1981). The crop photosynthesis of an erect-leaved canopy is about 20% higher than that of the droopyleaved canopy when the LAI is extremely high (Van Keulen, 1976). This model assumes that all the leaves are uniformly oriented at angles of 0^{o} or 90^{o} with respect to the horizontal plane.

5.12 Awning Characteristic

Awning characteristic is another trait recorded among accessions evaluated. Majority of the accessions 67 (79.76%) had absent of awns, short and partly, and short and fully awned were 5 (5.95 %) and 4 (4.76 %) and the rest, long and partly, and long and fully 5 (5.95 %) and 3 (3.57%) respectively (Appendix 2). Awning is considered a nuisance during milling by many farmers but it has been reported to play a role in preventing birds from sucking the milk-stage rice during grain filling. Breeders may therefore select the short-awned types as a compromise during cultivar development.

5.13 Ligule Shape

Ligule contains many silica phytoliths (hardening materials) and also, a membrane appendage of hairs that lies at the junction between the sheath and blade. It is believed to be involved in preventing water, or insects from penetrating into the sheath (Anon, 2009). Most of the accessions were observed to have 2-cleft ligule shape (86.91%). Ligule type can serve as a unique character for identifying genotypes and could be of great importance in sorting mixtures of important cultivars. The association of ligule shape with special genotypes should, therefore, be noted in every rice breeding program.

CHAPTER SIX

CONCLUSIONS

Morpho-agronomic characterization is an important prerequisite to evaluate phenotypic` diversity within germplasm collection. It fosters crops improvement and meets existing demand for food posed by growing human populations. It creates the basis to ensure effective utilization of conserved germplasm by both farmers and breeders otherwise unevaluated germplasm remain mere curiosities to the breeding programmes.

The studies of the eighty-four rice accessions revealed a significant amount of information for breeding programmes interventions as outlined:

- There was wide genetic variability in the rice germplasm for days to flowering and grain maturity. These materials could be used by farmers to evacuate crop for next cropping season, escape insect pest population and other adverse environmental factors.
- Differences among accessions were observed for characters like; flag leaf angle, awning, leaf blade pubescence and a low variability for those characteristics of leaf patterns, leaf blade color, panicle type and exsertions and basal leaf sheath color.
- About 60% of the rice accessions possessed erect leaves and moderately strong sturdy culms; 35% erect and 46 intermediate flag leaf angle; 67% showed awnlessness, 75% found with well exserted panicle, 55% with compact and 26%

intermediate panicle types respectively. These phenotypic traits of could be explored for the rice improvement.

- Majority (60%) of the accessions classified were associated with the dark green and erect leaf pattern with sturdy stems and the rest, pale green with droopy leaf pattern and weak stems. Based on the "plant type" concept, the latter group will be low nitrogen responders and will require improvements. Cluster analysis performed established accessions with regard to N response based on their morpho-agronomic characteristics.
- Regardless of the accessions response to N uptake, there were variations in their grain yield and grain characteristics. Average grain yield for high nitrogen plants showed low value of 2.2 t/ha as compared to low nitrogen plants of 2.4 t/ha. Additionally, variation in the grain length and width did exist as shown in their values obtained. The long grain and translucent types could be used in quality grain development.

RECOMMENDATIONS

- The accessions which flowered and matured early should be further evaluated and validated for future improvement of the crop.
- Based on the groupings from the dendrogram, accessions should be selected from each of the groups for molecular studies to gather additional information on their distinctiveness as expressed in the analysis.
- The accessions should be analyzed for their phylogenetic relationship and variation based on molecular markers, to complement the morpho-agronomic findings.

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APPENDICES

Appendix 1: Rice germplasm characterized in Ghana for phenotypic diversity

	Crops Research Institute		WARDA (Africa Rice Center)		IVORY COAST	
No	Code	Designation	Code	Designation	Code	Designation
1	58	CRI-1	3	ARCCU3Fa12-LIIP2-I-I	133	IDSA 85
2		60B	6	ARCCU3FaIL6P15-5-4-3		
3	62	CRI-5	9	ARCC12Fa12L4P7-6-2-1-1		
4	63	CRI-6	10	ARCCU12FaIL4P7-8-2-1-1		
5	64	CRI-7	11	ARCCU12L6P7-9-3-1-1		
6	65	CRI-8	12	ARCCU12FaL4P7-2-2-1-1		
7	66	CRI-9	17	ARCCU3Fa7-L14P8-B-B-1		
8	67	CRI-10	18	ARCCU3Fa9-LP5-B-B-2		
9	68	CRI-11	19	ARCCU3Fa9-L15P5-B-B-1		
10	70	CRI-13	20	ARCCU2Fa4-L7PI-B-B-2		
11	72	CRI-15	22	ARCCU3FaIL-LIPI-B-B-1		
12	73	CRI-16	23	ARCCU2Fa9-L3P3-B-B-4		
13	76	CRI-19	24	ARCCU3Fa7-LI6P5-B-B-4		

14	77	CRI-20	25	ARCCU3Fa7-L9P8-1-B-B-2
15	78	CRI-21	26	ARCCU3Fa12-L8PI-B-B-2
16	79	CRI-22	27	ARCCU3Fa7-L3P3-B-B-2
17	83	CRI-26	28	ARCCU3FaII-LIPI-B-B-2
18		88SEC	29	ARCCU3Fa-L13P2-2-B-B-1
19	90	CRI-33	34	ARCCU3Fa3L7PI-B-B-1
20	91	CRI-34	36	ARCCU12FaIL6P7-24-1-1-2
21	92	CRI-35	38	ARCCU12FaI-L4P7-11-2-3
22	93	CRI-36	39	ARCCU3Fa12L8P1-B-B-1
23	95	CRI-38	41	ARCCU3Fa9L6PI6P5-B-B-1
24	97	CRI-40	42	ARCCU3Fa7LI6P5-B-B-1
25	98	CRI-41	44	ARCCU3FaI0L7PI-B-B-I
26	99	CRI-42	45	WAB56-104
27	100	CRI-43	46	Nerica 1
28	101	CRI-44	51	Nerica14
29		101A	52	Nerica15
30	102	CRI-45		Nerica16
31	103	CRI-46	54	Nerica17
32	104	CRI-47	55	Nerica18
33	105	CRI-48	56	Nerica 8
34	107	CRI-50	57	Nerica 9
35	108	CRI-51	132	WAB450-5-1-BLI-DV6
36	110	CRI-53	134	TOX 3377
37	111	CRI-54		
38	114	CRI-57		
39	115	CRI-58		
40	119	CRI-62		
41	120	CRI-63		
42	122	CRI-65		
43	124	CRI-67		
44	125	CRI-68		
45	127	CRI-70		
46	128	CRI-71		
47	131	CRI-74		

Out of the 84 rice accessions evaluated: 47 Crops Research Institute-Ghana, 36 WARDA (Africa Rice Center) and 1 Ivorian.

Appendix 2: Computerized frequency distribution for 11 qualitative traits in rice accessions after 3 months field evaluation

Traits	No. Accessions	Proportion (%)
Leaf pattern		
Erect	50	59.52
Droopy	34	40.48
Basal leaf sheath color		
Green	78	92.86
Purple	6	7.14
Flag leaf angle		
Erect	35	41.67
Intermediate	46	54.76
Horizontal	3	3.57
Descending	0	0
Blade pubescence		
Glabrous	37	44.05
Intermediate	38	45.24
Pubescence	9	10.71
Awning characters		
Absent	67	79.76
short & partly awned	5	5.95
short & fully awned	4	4.76
long & partly awned	5	5.95
long & fully awned	3	3.57
Ligule shape		
Acute to culminate	11	13.09
2-Cleft	73	86.91
Collar color		
Green	42	50

Pale green	32	38.1
Pale	10	11.9
Blade color		
Pale green	34	40.48
dark green	50	59.52
Auricle color		
Pale green	81	96.43
whitish green	3	3.57
Panicle exsertion		
well exserted	75	89.29
moderately exserted	9	10.71
Panicle type		
Compact	55	65.48
Intermediate	26	30.95
Open	3	3.57

Appendix 3: Phenological studies showed rice accessions as potential Nitrogen responders

Accessions as High Nitrogen Responders with erect, dark green leaves and sturdy stem characters

No Code CRI	Code	WARDA
1	63 CRI-6	3 ARCCU3Fa12-LIIP2-I-I
2	3 CRI-8	4 ARCCU3FaIL6P15-5-4-3
3	67 CRI-10	9 ARCC12Fa12L4P7-6-2-1-1
4	72 CRI-15	12 ARCCU12FaL4P7-2-2-1-1
5	77 CRI-20	17 ARCCU3Fa7-L14P8-B-B-1

6	78 CRI-21	18 ARCCU3Fa9-LP5-B-B-2
7	79 CRI-22	19 ARCCU3Fa9-L15P5-B-B-1
8	83 CRI-26	22 ARCCU3FaIL-LIPI-B-B-1
9	93 CRI-36	23 ARCCU2Fa9-L3P3-B-B-4
10	95 CRI-38	24 ARCCU3Fa7-LI6P5-B-B-4
11	97 CRI-40	26 ARCCU3Fa12-L8PI-B-B-2
12	100 CRI-43	27 ARCCU3Fa7-L3P3-B-B-2
13	103 CRI-46	28 ARCCU3FaII-LIPI-B-B-2
14	105 CRI-48	29 ARCCU3Fa-L13P2-2-B-B-1
15	107 CRI-50	34 ARCCU3Fa3L7PI-B-B-1
16	108 CRI-51	36 ARCCU12FaIL6P7-24-1-1-2
17	110 CRI-53	39 ARCCU3Fa12L8P1-B-B-1
18	114 CRI-57	41 ARCCU3Fa9L6PI6P5-B-B-1
19	119 CRI-62	45 WAB56-104
20	120 CRI-63	46 Nerica 1
21	124 CRI-67	52 Nerica15
22	125 CRI-68	Nerica16
23	128 CRI-71	54 Nerica17
24	55 Nerica18	
25	56 Nerica 8	
26	132 WAB450-5-1-BLI-DV6	
27	134 TOX 3377	

Droopy pale-green leaves and weak stems characters

No	Code **CRI**	Code **WARDA**
1	58 CRI-1	10 ARCCU12FaIL4P7-8-2-1-1
2	60B	11 ARCCU12L6P7-9-3-1-1

3	62 CRI-5	20 ARCCU2Fa4-L7PI-B-B-2
4	64 CRI-7	25 ARCCU3Fa7-L9P8-1-B-B-2
5	66 CRI-9	38 ARCCU12FaI-L4P7-11-2-3
6	68 CRI-11	42 ARCCU3Fa7LI6P5-B-B-1
7	70 CRI-13	44 ARCCU3FaI0L7PI-B-B-I
8	73 CRI-16	51 Nerica 14
9	76 CRI-19	57 Nerica 9
10	88SEC	
11	90 CRI-33	**IVORY COAST**
12	91 CRI-34	133 IDSA 85
13	92 CRI-35	
14	98 CRI-41	
15	99 CRI-42	
16	101 CRI-44	
17	101A	
18	102 CRI-45	
19	104 CRI-47	
20	111 CRI-54	
21	115 CRI-58	
22	122 CRI-65	
23	127 CRI-70	
24	131 CRI-74	

Out of 84 rice accessions, 50 for high and 34 low were classified for possessing potential as nitrogen responders (27 WARDA and 23 CRI accessions showed characters for high responders and rest, 9 WARDA, 24 CRI and 1 IVORY COAST as low nitrogen responders.

Appendix 4: Results of analyzed soil samples at research site

Parameter	**Sample**		
	A, B & C	D,E& F	G,H & I
pH (1-2.5 H_20)	6.27	6.08	6.11
Organic C (%)	1.16	1.52	1.46
Organic matter (%)	2.00	2.62	2.52
Total N (%)	0.25	0.25	0.27
Available (mg/kg)	23.88	27.37	38.4

Exchangeable cation (cmol/kg)			
Ca	3.20	3.20	3.00
Mg	4.00	4.80	3.80
K	0.10	0.21	0.09
Na	0.17	0.18	0.21
Al	0.50	1.30	0.60
H	0.70	1.00	0.40
ECEC(cmol/kg)	8.67	10.71	8.1

Appendix 5: Correlation matrix (25 x 25) of thirteen traits used in characterizing eighty-four rice accessions

100-Grain weight (g) Grain yield (t/ha), Days to 50 % heading (DH) 80% Grain maturity (MGR), Culm length (cm), Culm diameter (mm), Grain length (mm), Grain width (mm), Leaf length (cm), Leaf diameter (mm), Ligule length (mm), Plant height (cm), Prod tiller

100_GW g	1												
G yield t/ha	0.085	1											
50 % DH	-0.107	0.202	1										
80 % MGR	-0.057	-0.023	*0.564	1									
Culm length	0.127	0.297	0.212	0.076	1								
Culm diameter	-0.155	0.102	0.230	0.017	0.244	1							
Grain length	0.339	0.004	-0.092	0.099	-0.019	-0.156	1						
Grain width	0.142	0.019	-0.0172	-0.013	0.202	-0.060	-0.389	1					
Leaf length	0.101	0.071	0.037	0.062	0.173	0.023	0.219	0.030	1				
Leaf diameter	0.085	0.072	0.209	0.215	0.164	0.047	0.064	0.141	0.236	1			
Ligule length	-0.037	0.093	0.074	0.053	-0.025	-0.023	0.081	-0.038	0.043	0.097	1		
Plant height	0.128	0.116	-0.085	-0.023	0.402	0.025	0.165	0.147	0.198	0.065	-0.048	1	
Prod_tiller	0.030	-0.102	-0.171	-0.028	0.026	-0.026	0.384	-0.331	-0.061	-0.124	-0.027	0.096	1

- Highly significant at ($P < 0.05$)

The Character 50% Days to effective heading is significantly correlated with 80% Days to grain maturity

Appendix 6: Chart showed some qualitative and quantitative traits for the eighty-four accessions

Code	Rice accession	Plant height (cm)	Days to heading	Days to grain maturity	Leaf Length (cm)	Culm Length (cm)	Prod. tillers per plant	Grain Length (mm)	Grain Weight (mm)	100 Grain weight (g)	Grain yield (t/ha)	Leaf pattern	Leaf blade color	Awn character	Panicle exsertion	Panicle type
3	ARCCU3Fa12-LIIP2-I-I	62	66	87	44.67	73.33	30	9.56	3	3.29	2.71	erect	D-green	0	Well exserted	Intermediate
6	ARCCU3FaIL6P15-5-4-3	46.33	83	105	46.33	65.67	20	8.08	3	2.46	1.41	erect	D-green	7	m-well exserted	Compact
9	ARCC12Fa12L4P7-6-2-1-1	59.33	66	87	54.33	73.67	34	9.32	2.8	2.81	1.78	erect	D-green	5	well exserted	Compact
10	ARCCU12FaIL4P7-8-2-1-1	54.67	83	105	48	80	27	9.62	2.8	2.82	4.55	droopy	P-green	0	m-well exserted	Open
11	ARCCU12L6P7-9-3-1-1	56.33	83	105	39.33	84.67	32	11.6	2.6	2.88	1.83	droopy	P-green	1	well exserted	Compact
12	ARCCU12FaL4P7-2-2-1-1	55.33	83	105	33.67	64	25	8.46	2.9	2.34	1.23	erect	D-green	5	well exserted	Intermediate
17	ARCCU3Fa7-L14P8-B-B-1	54.33	66	87	50	65.33	22	10.5	3.1	2.8	3.43	erect	D-green	0	well exserted	Open
18	ARCCU3Fa9-LP5-B-B-2	57.33	66	87	39.33	74	26	10	3	3.68	2.82	erect	D-green	0	well exserted	Compact
19	ARCCU3Fa9-L15P5-B-B-1	56	66	87	50.67	77.33	30	8.98	2.8	2.62	0.75	erect	D-green	0	well exserted	Compact
20	ARCCU2Fa4-L7PI-B-B-2	51	66	87	51	71.67	19	9.86	3	3.34	0.59	droopy	P-green	7	m-well exserted	Compact
22	ARCCU3FaIL-LIPI-B-B-1	55.67	66	87	37.67	78	40	10.1	3.2	3.58	1.26	erect	D-green	0	well exserted	Compact

23 ARCCU2Fa9-L3P3-B-B-4 82 83 105 38.67 92.33 30 9.65 2.9 3.08 2.56 erect D-green 0 well exserted
Intermediate

24 ARCCU3Fa7-LI6P5-B-B-4 60.67 66 87 52.33 102.7 26 9.59 3 3.34 3.87 erect D-green 0 m-well exserted Open

25 ARCCU3Fa7-L9P8-1-B-B-2 66 83 105 57 80.67 29 9.44 2.9 2.98 2.51 droopy P-green 1 m-well exserted
Compact

26 ARCCU3Fa12-L8PI-B-B-2 66.33 66 87 45 88.33 25 9.06 3 3.07 3.61 erect D-green 7 well exserted Intermediate 27 ARCCU3Fa7-L3P3-B-B-2 80 66 87 50.33 113.3 29 9.7 3.2 3.26 1.72 erect D-green 0 well exserted Intermediate 28 ARCCU3FaII-LIPI-B-B-2 61.67 66 87 38.67 82 43 9.97 3.1 2.91 1.3 erect D-green 0 well exserted Compact

29 ARCCU3Fa-L13P2-2-B-B-1 64 66 87 57.33 89 25 9.98 3 3 2.19 erect D-green 0 well exserted Intermediate

34 ARCCU3Fa3L7PI-B-B-1 63 66 87 48 81.33 27 9.88 2.9 2.87 2.64 erect D-green 0 well exserted Compact 36 ARCCU12FaIL6P7-24-1-1-2 64.33 66 87 46 80.33 30 9.73 2.7 3.07 1.52 erect D-green 5 well exserted Compact 38 ARCCU12FaI-L4P7-11-2-3 72.67 83 105 47.33 106.3 21 8.51 3.3 3.37 3.18 droopy P-green 9 well exserted Compact 39 ARCCU3Fa12L8P1-B-B-1 66.67 66 87 44 84.33 32 9.31 3 3.13 3.3 erect D-green 0 well exserted Compact

41 ARCCU3Fa9L6PI6P5-B-B-1 61 66 87 46.67 88 37 9.3 3 3.27 1.3 erect D-green 0 well exserted
Compact

42 ARCCU3Fa7LI6P5-B-B-1 67.67 66 87 52 87.33 28 9.97 3 4.12 2.92 droopy P-green 5 well exserted
Intermediate 44 ARCCU3FaI0L7PI-B-B-I 61.67 83 105 45.67 102 36 9.75 2.8 3.12 4.51 droopy P-green 0
well exserted Compact

45 WAB56-104 58 66 87 42.67 86.33 39 10.2 2.7 3.07 3.3 erect D-green 0 well exserted Intermediate 46 Nerica 1 49 83 105 43.67 82 23 9.47 2.8 3.14 1.3 erect D-green 1 well exserted Compact

51 Nerica14 57.67 75 105 45.33 71.67 10.1 2.9 2.77 3.24 droopy P-green 9 well exserted Intermediate

52 Nerica15 69 75 105 48.33 86.67 24 10.1 2.9 3.43 2.3 erect D-green 0 m-well exserted Intermediate

Nerica16 70.33 66 87 39.67 88 30 10.1 2.8 4.28 3.14 erect D-green 0 m-well exserted Intermediate 54 Nerica17 57 66 87 47 81 22 10.7 3.3 3.95 2.44 erect D-green 0 well exserted Intermediate 55 Nerica18 68.67 66 87 39.33 81.67 25 9.83 2.9 3.15 2.28 erect D-green 0 well exserted *Intermediate*

56 Nerica 8 62.33 66 87 45 68.67 28 10.8 2.6 3.18 2.04 erect D-green 0 well exserted Compact

57 Nerica 9 62.67 66 87 47.67 78 30 10 3.1 2.88 1.29 droopy P-green 0 well exserted Compact

58 CRI-1 55.33 75 105 47 66.67 29 11 2.5 3.57 1.5 droopy P-green 1 well exserted Compact

60B 60 75 105 50 80.67 29 10.2 3 3.46 3.8 droopy P-green 7 well exserted Compact

3.17 4.11 droopy P-green 0 well exserted Compact

62 CRI-5 49 83 105 43.67 88.67 22 10.7 2.6

63 CRI-6 53 66 87 48.67 80.67 39 11.6 2.7 3.08 1.35 erect D-green 0 well exserted Compact

64 CRI-7 56.67 66 87 50.67 77.33 41 10.1 2.6 2.51 2.19 droopy P-green 0 well exserted Intermediate

65 CRI-8 52.67 75 105 43 63.67 27 9.19 2.7 3 2.39 erect D-green 0 well exserted Intermediate 66 CRI-9 64.67 66 87 43.33 74.67 33 11.7 2.8 3.97 2.04 droopy D-green 0 well exserted Intermediate

67 CRI-10 52 83 105 44 85.67 32 8.49 2.7 3.06 2.32 erect D-green 7 well exserted Intermediate

2.82 2.86 droopy P-green 0 well exserted Intermediate

68 CRI-11 71.33 66 87 43.33 76.67 41 9.13 2.9

70 CRI-13 77.67 75 105 59.33 99.33 32 11.2 3.2 3.95 1.78 droopy P-green 0 well exserted Compact 72 CRI-15 50.67 66 87 37 67 31 10.1 3.2 3.45 1.17 erect D-green 0 well exserted Compact 73 CRI-16 63.67 66 87 47.67 72.67 29 11.3 2.8 3.64 1.87 droopy P-green 0 well exserted Compact

76 CRI-19 80 66 87 64.33 89 43 13.1 2.7 3.4 2.92 droopy P-green 0 well exserted Compact 77 CRI-20 65.67 75 87 54.33 83.67 30 11.6 2.7 3.28 2.31 erect D-green 0 well exserted Compact

78 CRI-21 54.67 66 87 36.67 73.67 31 9.48 2.7 3.85 1.79 erect D-green 0 well exserted Intermediate 79 CRI-22 57.33 66 87 47.67 75.67 28 10.5 2.7 2.99 1.34 erect D-green 0 well exserted Compact

83 CRI-26 58.33 66 87 41.67 70.33 22 9.65 3.1 2.89 2.83 erect D-green 0 well exserted Intermediate

88SEC 56.33 75 105 48.33 72 26 10.2 2.8 3.1 1.95 droopy D-green 0 well exserted Compact

3.25

90 CRI-33 61.67 83 105 43.33 95.67 42 11.6 2.6 2.34 droopy P-green 0 well exserted Compact

91 CRI-34 65.67 75 105 53 76.33 39 12.8 2.7 3.51 3.08 droopy P-green 0 well exserted Compact

3.63 3.64 droopy P-green 0 well exserted Compact

92 CRI-35 59 75 105 51 84.33 28 11.9 2.7

93 CRI-36 52.33 75 105 45 75.33 31 12.3 2.9 3.71 2.07 erect D-green 0 well exserted Compact 95 CRI-38 56.33 66 87 36.67 69.67 43 12.2 2.8 3.87 1.88 erect D-green 0 well exserted Compact

97 CRI-40 63 66 87 47 74 43 10.5 2.9 3.14 2.47 erect D-green 0 well exserted Compact

98 CRI-41 60.33 75 105 49 76.67 35 12.5 2.6 3.43 1.64 droopy P-green 0 well exserted Compact

99 CRI-42 61.33 66 87 40 75.33 39 12 2.8 3.65 1.61 droopy P-green 0 well exserted Compact

100 CRI-43 67.67 75 87 46.33 74.33 21 8.35 3 2.6 0.44 erect D-green 0 well exserted Compact 101 CRI-44 68.67 66 87 54 87 42 12.3 2.6 3.65 2.87 droopy P-green 0 well exserted Compact

101A 68.33 66 87 48.33 82.33 26 12.6 2.7 3.47 2.41 droopy P-green 0 well exserted Compact 102 CRI-45 66.67 75 105 59 78 26 11.2 3 4.35 2.46 droopy P-green 0 well exserted

Compact 103 CRI-46 66.67 66 87 50.33 66.67 25 12 2.5 3.34 1.6 erect D-green 0 well exserted Compact

104 CRI-47 60 83 105 45.67 83 46 11.6 2.7 3.78 1.89 droopy P-green 0 m-well exserted Compact 105

CRI-48 52.67 83 105 49 79.67 22 11 2.9 3.73 2.16 erect D-green 0 well exserted Compact

107 CRI-50 59 66 87 42 71.33 26 9.44 2.7 3.06 3.54 erect D-green 0 well exserted Intermediate 108 CRI-

51 54.33 66 87 50.33 72 24 10.9 2.8 3.57 2.39 erect D-green 0 well exserted Compact

110 CRI-53 54.67 75 105 53.33 63 34 9.71 2.8 2.85 1.61 erect D-green 0 well exserted Intermediate 111 CRI-54 57 66 87 43.67 77.33 29 10.1 2.6 2.36 2.23 droopy P-green 0 well exserted Compact

114 CRI-57 58 66 87 46.33 71 26 9.97 2.8 2.64 1.52 erect D-green 9 well exserted Intermediate

115 CRI-58 59 66 87 42.33 75.67 31 11.1 2.6 3.8 1.24 droopy P-green 0 well exserted Compact

119	CRI-62	54	66	87	37.67	65.33	38	11.9	2.7	3.63	2.5	erect	D-green	0	well exserted	Compact
120	CRI-63	59.33	66	87	48.67	80	27	11.9	2.8	3.61	2.08	erect	D-green	0	well exserted	Compact
122	CRI-65	63.33	75	105	55.67	76	33	12.4	2.6	3.81	1.77	droopy	P-green	0	well exserted	Compact
124	CRI-67	54.33	75	105	50.33	61.67	27	9.62	3	2.87	1.87	erect	P-green	0	m-well exserted	Intermediate
125	CRI-68	53.67	75	105	55	72	23	11.2	3.1	3.78	3.18	erect	D-green	0	well exserted	Intermediate
127	CRI-70	70.67	83	105	52.33	102.3	23	10.3	3.1	3.16	1.04	droopy	P-green	0	well exserted	Compact
128	CRI-71	56	75	87	44.33	70	22	10.3	2.8	3.82	2.24	erect	D-green	0	well exserted	Intermediate
131	CRI-74	77.67	75	105	54.67	84	24	11.4	3.3	4.37	2.13	droopy	P-green	0	well exserted	Compact
132	WAB450-5-1-BLI-DV6	69	75	87	63	93.33	21	10.4	2.8	2.86	3.88	erect	D-green	1	well exserted	Compact
133	IDSA 85	70.67	75	105	55.67	81.67	46	12.6	2.6	3.56	2.17	droopy	D-green	0	well exserted	Compact
134	TOX 3377	67.67	83	105	38	99	24	10.2	3	3.12	4.35	erect	P-green	0	Well exserted	Compact

Appendix 7. Binary data scored based on the morpho-agronomic characters

Accessions code/ Traits	L-Patterns		Basal-LS		Flag Leaf Angle			B-pubescence				Awning Characters					Li-Shape		Collar Color			B-Color		Auricle Color		P-exsertion		Panicle type			Days to heading	Grain maturity	Plant Height	Pro.Tiller	Grain yield	Grain Length	Grain Width	100-Grainw	Ligule Length	Culm length	Culm diameter	Leaf length	Leaf diameter
	Erect	Droopy	Green	Purple	Erect	Intermed	Horizontal	Des	Gla	Intermed	Pub	Absent	short & partly awned	short & fully awned	Long & partly awned	Long & fully awned	2-Cleft	Acute-Cuminate	Green	Pale green	Pale	Pale green	Dark green	Pale green	Whitish green	Well exserted	Moderately well exserted	Compact	Intermed	Open													
1	1	0	1	0	0	1	0	0	1	0	0	1	0	0	0	0	1	0	1	0	0	0	1	1	0	1	0	0	1	0	1	1	0	0	1	0	1	0	0	1	0	1	0
62	1	0	1	0	1	0	0	0	0	0	1	0	0	0	1	0	1	0	0	1	0	0	1	1	0	0	1	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1
93	1	0	1	0	0	1	0	0	1	0	0	0	0	1	0	0	1	0	1	0	0	0	1	1	0	1	0	1	0	0	1	0	0	1	1	0	1	0	1	1	0	1	0

104 0 1 1 0 0 1 0 0 0 1 0 1 0 0 0 1 0 0 1 0 1 0 1 0 0 1 0 0

1 1 1 0 0 1 0 0 1 1 1 1 1 0 11 0 1 1 0 0 1 0 0 1 0 0 0 1 0 0

0 1 0 0 1 0 1 0 1 0 1 0 1 0 0 1 1 0 1 1 0 0 0 1 1 1 0 0

12 1 0 1 0 0 1 0 0 1 0 0 0 0 1 0 0 1 0 0 0 1 0 1 0 1 1 0 0 1 0 1 0 0 0 0 0 1 0 1 0 1 0 0

17 1 0 1 0 1 0 0 0 1 0 0 1 0 0 0 0 1 0 0 1 0 0 1 1 0 1 0 0 0 1 1 0 0 0 1 0 1 0 0 0 0 0 0 18 1 0 1 0 0 1 0 0 1 0 0 1 0 0 0 0 0 1 1 0 0 0 1 1 0 1 0 1 0 0 0 0 0 1 0 0 1 0 0 0 0 0 0 19 1 0 1 0 0 1 0 0 1 0 0 1 0 0 0 0 1 0 0 0 1 0 1 0 1 1 1 0 1 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 20 0 1 1 0 1 0 0 0 0 1 0 0 0 0 1 0 1 0 1 0 0 1 0 1 0 0 1 1 0 0 0 0 0 0 0 0 0 1 1 0 1 0 0 0 22

1 0 1 0 0 0 1 0 0 1 0 1 0 0 0 0 1 0 0 1 0 0 1 0 0 1 1 0 1 0 1 0 0 1 0 1 1 0 0 1 1 0 1 0 0 0

23 1 0 1 0 1 0 0 0 1 0 0 1 0 0 0 0 1 0 0 1 0 0 1 1 0 1 0 0 1 0
1 0 1 0 1 0 1 0 0 1 1 0 0

24 1 0 1 0 1 0 0 0 1 0 0 1 0 0 0 0 1 0 1 0 0 0 1 1 0 0 1 0 0 1
1 0 0 0 1 0 0 0 0 1 1 1 0

25 0 1 1 0 1 0 0 0 1 0 0 0 1 0 0 0 1 0 0 1 0 1 0 1 0 0 1 1 0 0
1 0 1 0 1 0 1 0 1 1 1 1 1

26 1 0 1 0 1 0 0 0 1 0 0 0 0 0 1 0 1 0 0 0 1 0 1 1 0 1 0 0 1 0
0 0 1 0 0 0 1 1 1 1 1 0 1

27 1 0 1 0 1 0 0 0 0 1 0 1 0 0 0 0 0 1 0 1 0 0 1 1 0 1 0 0 1 0
0 0 1 1 0 0 1 1 0 1 1 0 1

28 1 0 1 0 0 1 0 0 0 1 0 1 0 0 0 0 1 0 1 0 0 0 1 1 0 1 0 1 0 0
1 0 1 0 1 0 1 0 1 1 1 0 0

29 1 0 1 0 0 1 0 0 0 0 1 1 0 0 0 0 1 0 0 1 0 0 1 1 0 1 0 0 1 0
0 0 0 1 0 1 0 0 0 1 0 1 1

34 1 0 1 0 1 0 0 0 1 0 0 1 0 0 0 0 1 0 0 1 0 0 1 1 0 1 0 1 0 0 0 0 1 1 0 0 0 0 1 1 1 1 0

36 1 0 1 0 0 1 0 0 0 0 1 0 0 1 0 0 1 0 1 0 0 0 1 1 0 1 0 1 0 0 1 1 1 0 1 0 1 0 0 1 0 0 0

38 0 1 1 0 0 1 0 0 0 1 0 0 0 0 0 1 1 0 0 1 0 1 0 1 0 1 0 1 0 0
1 0 1 0 1 0 1 1 1 1 0 1 0

39 1 0 1 0 1 0 0 0 1 0 0 1 0 0 0 0 1 0 0 1 0 0 1 1 0 1 0 1 0 0
1 0 0 1 1 0 1 0 0 1 0 0 0

41 1 0 1 0 1 0 0 0 0 1 0 1 0 0 0 0 1 0 0 0 1 0 1 1 0 1 0 1 0 0
0 0 1 1 1 0 1 1 0 1 1 0 0

42 0 1 1 0 1 0 0 0 0 1 0 0 0 1 0 0 1 0 0 1 0 1 0 1 0 1 0 0 1 0
1 1 1 1 1 0 1 1 0 1 1 1 1

44 0 1 1 0 0 1 0 0 1 0 0 0 0 0 0 1 0 1 0 0 0 1 0 1 0 1 0 1 0 0
1 0 0 1 1 0 1 0 0 1 1 0 0

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