ASSESSMENT OF MORPHO-PHYSIOLOGICAL VARIATIONS IN TRADITIONAL AND IMPROVED CULTIVARS OF RICE (*Oriza sativa* L.)

BY

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ABSTRACT

A total of twenty two improved rice cultivars were collected from the National Cereals Research Institute (NCRI), Baddegi Rice Breeding unit and seventeen local cultivars collected from famers were examined for morhpo-physiological character variations, reaction to iron toxicity and African rice gall midge (AfRGM). The trials were conducted at National Cereal Research Institute (NCRI) Edozhigi substation for two years (2009 and 2010). Randomized complete block design (RCBD) was used in three replications. Eleven morpho-agronomic traits were used to characterize the experimental materials.

Data collected were subjected to analysis of variance (ANOVA) using Genstat 5 (2004), Principal Component Analysis (PCA), Correlation, Euclidean distance with complete linkage and Cluster analysis. The analysis of variance showed that plant height, leaf width, gall midge count at 62 days after transplanting (DAT), iron toxicity score at 20 DAT and total yield per plot were significant at 1% probability level while gall midge count at 42 DAT, iron toxicity score at 40 DAT and 60 DAT showed no significant difference. In the second year, leaf length, panicle length, iron toxicity score at 20 DAT, 40 DAT, days to 50% flowering, leaf width and total yield per plot were significant at 1% probability level. The cluster analysis of the morphological character of two years combined produced three groups (GP) based on similarities with respect to varietal type. Group one had four local and two improved varieties. Group two comprises of twenty six varieties out of which twelve were local and fourteen improved. Group three had five out of which two are local while three are improved. From the correlation analysis of morphological traits for two years combined, result showed that panicle length and weight of 1000 grain, gall midge count and weight of 1000 grain, gall midge count and days to 50% flowering, gall midge count and leaf width were positively correlated while iron score and plant height, were negatively correlated. The result of Principal Component Analysis (PCA) of two years combined revealed that the first five principal components accounted for 65.4% of the total variation with phenotypic acceptability, weight of 1000 grains and leaf length contributing more to the variation. The scatted diagram indicates variations among the variables. The result showed that no cultivar was immune to African Rice Gall Midge (AfRGM), although Ndawodzufugi and Babawagi (Local) varieties showed resistant reaction at 62 DAT in the first year. Most cultivars react at a range of moderately resistant to moderately susceptible (3 to 5). In the same vain 3 to 5 score is the response of these entries to Iron toxicity. NERICA L36 and Mass varieties showed high level of variation amongst other entries and therefore could be good parents for breeding. Also Ndawodzufugi and Babawagi varieties could be subjected to further screening to ascertain their actual level of tolerance. This study separated cultivar into meaningful agronomic groups from which selection of varieties with uniform morphological characters could be made as parents for further rice improvement programs.

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CHAPTER ONE

1.0 INTRODUCTION

Rice, *Oryza* species is a grass belonging to the Poaceae family. The plant is annual with the height of about 36cm – 150cm. The world's most consumed cereal after wheat (FAO 2004).

Most countries of the world cultivate varieties belonging to the *Oryza* type which has about twenty different species (Vaughan, 1989) but only two is of agricultural importance to humans. The two cultivated species include *Oryza sativa* and *Oryza glaberrima*. *Oryza sativa,* the common Asian rice found in most producing countries, originates in the East at the far foot of the Himalayas. Majority of the cultivated varieties belong to this species, which is characterized by its plasticity and taste qualities. The *Oryza glaberrima* species is an annual which originates in West Africa, covering a large region extending from the central Delta of the Niger River to Senegal.

Wide hybridization involving *O. sativa* and related wild species is adopted to broaden the gene pool of rice (Ng *et al*., 1991). The genus *Oryza* comprises species representing AA, BB, CC, BBCC, CCDD, EE, FF, GG, HHJJ and HHKK genomes. Of these species, *O. sativa* (2n=24 AA) is cultivated worldwide, whereas *O. glaberimma* (2n=24 AA) is limited to certain areas in West Africa (Ng *et al*., 1991). Wild species are important reservoir of useful genes for resistance to major diseases and pests, tolerance to biotic stresses and cytoplasic male sterility. However, several problems occur when transferring useful genes from wild species into cultivated rice (Brar *et al*., 1996). The barrier most commonly encountered is lack of crossability resulting from chromosomal and cytoplasmic differences. Biotechnology tools, such as embryo rescue and protoplast fusion, have been employed to overcome this difficulty, resulting in the production of several interspecific hybrids. More molecular techniques have been employed for monitoring of allian gene introgression. Evaluation of genetic diversity is a prerequisite for successful germplasim exploitation through breeding (Ng and Padulosi 1992).

The evaluation of morphological and agronomic characters and for the reaction to various stress conditions for diseases and pest resistance and for grain quality characters are of great importance (Sharma and Steel 1978). This variability should be exploited so as to develop new rice varieties with high stability to resist or tolerate adverse environments and biotic conditions. Awopetu and Gana, (1997) studied the genetic relationship of some rice varieties and concluded that origin; habitat and breeding background contribute to rice variability. International Rice Research Institute (IRRI) has also studied her collection for their morpho- agronomic characters with a view to determine the scope of their possible exploitation in breeding programs and concluded that the diversity of *O. glaberrima* is not as that of *O. sativa* (Chang, 2003). According to Ng and Padulosi (1992), continuous evaluation of germplasm should be done to broaden the genetic base of the species and identification of additional genes or alternative sources that control a particular trait for use in a crop improvement.

Phenotypic diversity of the cultivated rice exceeds that of the wild because of the ease with which man have used phenotypic characters as the criteria for selection making phenotypic diversity an important tool in varietal selection (Ng and Padulosi 1992).

The wide range of ecological conditions rice grows in West Africa is an evidence of the equally wide genetic variability found amongst cultivar of *O. sativa and O. glaberrima* (Rockwood 2001).

Despite the economic potentials of rice, its production is threatened by some biotic and abiotic stresses. Current estimates put global losses to pest at about 30% of potential world food, fibre and feed production (NRI, 1992). These constrains included mostly diseases and pest which contribute to the high yield loses in rice. Weed, stem borer, blast, brown spot, African rice gall midge, drought and iron

toxicity a nutritional disorder. Of all these, African rice gall midge and iron toxicity are becoming serious production constraints especially in the rain fed lowland, were 45% of rice production takes place (Singh *et al*., 1997).

1.1 Justification

Characterization and quantification of genetic diversity has long been a major goal in evolutionary biology. Information on the genetic diversity within and among closely related crop varieties is essential for a rational use of genetic resources (Second 1982). The analysis of genetic variation both within and among elite breeding materials is of fundamental interest to plant breeders. It contributes to monitoring germplasm and can also be used to predict potential genetic gains.

Diversity based on phonological and morphological characters usually varies with environments and evaluations of these traits require growing the plants to full maturity prior to identification. Protein or isozyme marker studies are also influenced by environment and reveal low polymorphism (Joshi *et al*., 2000). Now, the rapid development of biotechnology allows for easy analysis of a large number of loci distributed throughout the genome of plants.

1.2 Objectives of the study are as follows;

1. Determine the phenotypic variability that exists within these cultivars of rice.
2. Show the level of phenotypic association between local and improved cultivars of rice
3. Show the level of tolerance of traditional and improved cultivars of rice to AfRGM and iron toxicity.

CHAPTER TWO

2.0 LITERETURE REVIEW

2.1 Origin and distribution of rice

It is believed that rice cultivation began simultaneously in many countries over 6500 years ago. The first crop was observed in China (Hemu DU region) around 5000 B.C. as well as in Thialand around 4500 B.C. (Chang 2003). Some Japanese rice scientists postulated that rice might have originated from Southeast Asia including India, China, Thailand and Indonesia. They later appeared in Cambodia, Vietnam and Southern India. The species Japonica and Indica that extended to other Asian countries such as Korea, Japan, Myanmar, Pakistan, Sri Lanka, Philippines and Indonesia were from the early varieties identified. Japonica is an irrigated rice of temperate zone, with medium or short grains, also called round grain; it can be grown in a rain fed lowland rice of warm tropical zones. Indica is an irrigated rice of warm tropical zones, with long, thin and flat grains (WARDA, 1986). The Asian rice (*Oryza sativa*) was adapted to farming systems in the Middle East and Mediterranean Europe around 800 B.C. The Moros brought it to Spain when they conquered the country, near 700 A.D. After the middle of the 15th century, rice spread throughout Italy and then France, later propagating to all the continents during the great age of European exploration. It was believed that the early spread of rice was from Southeast Asia (IRRI, 1997).

About A.D. 1350, the historian, Ibn Batouta mentioned the existence of rice in Nigeria, which certainly was *O. glaberrima*. Between 1500 and 800 B.C., the African species (*O. glaberrima*) spread from its original center, the Delta of Niger River, by the indigenous inhabitant of the area. However, it never developed far from its origin. Its cultivation declined in favour of the Asian species (Ng *et al*., 1991). Lu and Chang (1980) argued that Asian rice entered into the Congo from Mozambique in the 19th century.

The earliest cultivation of *O. sativa* in Nigeria dated back to 1890 when upland varieties were introduced to the high forest zone in western Nigeria (Grist, 1986). The shallow swamp varieties from Guyana and Sri lanka gradually replaced the swamp varieties of *O. glaberrima* which is now confined to the far North of Nigeria and Sierra Leone. It is believed that *O. glaberrima* had replaced other cereal crops in part of West Africa in pre-colonial times before the introduction of Asian rice (Harris, 1976). The Asian, *O. sativa* was well established in many parts of Africa soon after it was introduced and had widely replaced the indigenous *O. glaberrima.*

The diversity of rice has gradually been reduced by selection of improved cultivars by farmers who may have abandoned the old traditional land races in favour of the improved germplasm (Ng *et al*., 1991).

2.2 Taxonomy of rice

The genus *Oryza* belongs to the tribe *Oryzaea* of the family poaceae. There are 12 general within the tribe (Vaughan, 1994). The genus *Oryza* contains approximately 22 species of which 20 are wild species and two *O. sativa* and *O. glaberrima* are cultivated (Vaughan, 1994). There is some confusion in the literature concerning the correct nomenclature of the species most closely related to *O. sativa* as they often lack clear distinguishing morphological characteristics (Vaughan and Morishima, 2003). At various times, more than 100 names have been proposed for the *Oryza* species including 19 for *O. sativa* alone (Oka 1988; Lu, 2004). Recently, Vaughan (2004) has proposed a new nomenclature for cultivated rice in Asia. *O. sativa* senus lacto subspecies, nivara (annual) and rufipogon (perennial), respectively. The species of *Oryza* indigenous to Africa are *O. bartti* (annual) and *O. longistaminatan* (perennial) which both have the same genome (AA) as those of the two cultivated species (Ng *et al.,* 1991).

2.3. Botany and reproductive biology of rice.

Rice is a typical grass, forming a fibrous root system bearing erect culms and developing long flat leaves. It has semi-aquatic lifestyle, requiring water particularly during reproductive growth phase. It produces multiple tillers consisting of a number of culms and leaves with/or without a panicle. The panicle emerges on the uppermost node of the culm from within a flag-leaf sheath and bears flower in spikelets (Grist, 1986).

2.3.1 The root of rice

Germinating seeds grows out roots (embryonic roots); these roots lived for only short time after which secondary adventitious roots grow from the underground nodes of the young culm. As the growth progresses, coarse adventitious roots develop in whorls from the node above the ground level. The root contain air-filled pore space through which oxygen diffuses, also the root is able to utilized respiratory mechanisms that uses limited amount of molecular oxygen. Seeds grown in the soil produce the protrude radicle first, but if the seed is submerged in water the coleoptiles emerges before the radical (Grist, 1986). The radicle develops from the base of the grain quickly followed by two additional roots, given rise to short lateral roots. The main rooting system however develops from the node of the stem below the ground. The rooting system is fibrous and develops horizontally rather than vertical. Swamp rice varieties develop more intensive root system under puddle soil condition than when grown under dry land condition whereas typical upland and wild rice varieties behave in the reverse way. The development of root is influenced by the soil texture, cultivation, water and air in the soil, amount of available nutrient and the transplanting system (Grist, 1986).

2.3.2 The culm

The culm consists of a number of nodes and hollow internodes that increase in length and decrease in diameter up the length of the culm. The node bears a leaf bud that may grow into a tiller. Primary tiller emerges from node near the base of the main culm in an alternating order and secondary and tertiary tillers emerge sequentially from these. Single leaf develops alternatively on the culm, consisting of a sheath, which encloses the culm and a flat blade. The leaf forms a collar or juncture between the sheath and blade and a liqule and two auricles develop on the inside of a juncture and base of the leaf blade respectively. Cultivars can vary widely in the length, width, colour and pubescence of the leaves (Grist, 1986).

2.3.3 The leaf

The node or nodal region of the culm bears a leaf. Leaves are borne alternately on the culm in opposite directions. One leaf is produced at each node. Varieties differ in the number of leaves produced (De Datta 1981). The topmost leaf below the panicle is the flag leaf. The flag leaf contributes largely to the filling of grains because it supplies photosynthetic products, mainly to the panicle. The leaf sheath and leaf blade are continues. A circular collar joins the leaf blade and the leaf sheath. The leaf sheath is wrapped around the culm above the node. The swelling at the base of the leaf sheet, just above the node, is the sheath pulvinus. It is sometimes incorrectly referred to as the node. Leaf blades are generally flat. Varieties differ in blade length, width, thickness, area, shape, color, angle and pubescence (Grist, 1986). With many parallel veins on the upper surface of the leaf, the underside of the leaf blade is smooth with a prominent ridge in the middle, the midrib. Most leaves possess small, paired ear-like appendages on either side of the base of the blade. These appendages are called auricles. Auricles may not be present on older leaves. Another leaf appendages is the ligule, a papery membrane at the inside juncture between the leaf sheath and the blade. It can have either a smooth or hair-like surface. The length, color and shape of the ligule differ according to variety (De Datta 1981). While rice

plant has auricles and ligules, common grassy weeds found in rice field normally do not have these features (De Datta 1981). These characteristics are often helpful in identifying weeds in rice fields when the plants are young (Grist 1986).

2.3.4 The inflorescence

The panicle emerges from the flag-leaf sheath and consists of a central rachis with up to four primary branches at each node. Primary and Secondary branches bear the flower spikelets. Each spikelets has a single floret and two glumes. It is enclosed by a rigid lemma, which is sometimes extended to form an awn, and partially enveloped the smaller palea. The floret contains six stamens and a single plumose ovary with two branches. At anthesis, two loule at the base of the floret swell and force the lammea and palea apart as the stamens emerges and elongate. The stigma is sometimes exposed as well. De Datta (1981) emphasized that the number of panicle varies between varieties and within the same variety grown under different conditions.

2.3.5 The rice grain

It is a single-seeded dry fruit with the pericap and seed coat fused. The rice hull includes the lemma and palea and their association structures- the lemmas, rachilla and awn.

The dehulled rice grain is called caryopsis, commonly referred to as brown rice because of the brownish pericap layer that enveloped it. Next to the pericap layers are the two-tegmen layer and the aleurone layers. The remaining part of the grain consists of the endosperm and the embryo. The endosperm provides nourishment to the germinating embryo. The embryo lies on the belly side of the grain and is enclosed by the lemma. It is the embryonic organ of the seed. Grain length varies with cultivars between 5 and 7mm, and grain can be round, bold or slender (Yoshida, 1988). The grain size or weight varies widely among rice cultivars. Grain weight is related to hull size, which is determined during

panicle development, however, environmental factors like temperature determines extent to which the grain is filled. Yoshida (1981) finds out that environmental stress such as drought, high and low temperature, salinity; low solar radiation increases the number of unfilled grain. Lodging increases number of unfilled grain especially if it occurs immediately before flowering (Yoshida, 1988).

2.4 Ecological requirements of rice

2.4.1 Effect of temperature on rice growth

The atmospheric temperature has considerable affect on growth and development of rice plant (Yoshida, 1988). Rice needs relatively high temperature for their optimum growth and development. Temperature requirement for rice is different for different growth stages. Rice crop can be grown successfully where average air temperature is 21^{o}C or more than 21^{o}C for up to 5 months (Yoshida 1988). The critical mean temperature for flowering and fertilization ranges from 16 to 20^{o}C. For vegetative growth a temperature range of 25 to 30^{o}C and for grain filling and ripening 20^{o}C to 25^{o}C was reported best. High temperature especially during night leads to loss of reserved food through greater respiration. For higher grain yield a day temperature of 25^{o}C to 32^{o}C and night temperature of 15^{o}C to 20^{o}C is preferable. Temperature beyond 35^{o}C affects not only pollen shedding but also grain filling (Yoshida, 1988). A higher mean temperature ranging between 25^{o}C to 32^{o}C per day would reduce the growth duration and accelerate flowering whereas a mean temperature of less than 15^{o}C would slow during vegetative growth and plants will fail to flowers. Grist, (1986) stated that, low temperature has been found to retard development of seedling and reduced tillering. Also plant height and number of leaves are affected causing delay in heading. He further finds out that low temperature after heading causes a decrease in the number of fertilized spikeletes. Therefore for vigorous vegetative growth moderately high temperature is required. It is well known that mild temperatures at night and clear sunny weather during

the day is better for high yield of rice, but temperatures less than 15ºC is not conducive for panicle initiation as well as for crop growth.

2.4.2 Effect of light on rice growth.

Clear sunny weather during ripening and moist-humid during vegetative phase is desirable for rice crop. Low solar radiation would hamper ripening of grains and would increase chaff production enormously. Rice crop prefers brighter and prolong sunshine for enhanced photosynthetic activity and higher yield. So, it should receive more than 300 sunshine hours during the last 45 days before harvest. Oka, (1988) stated that the minimum amount of solar radiation required for best yield in Japan have been estimated at 400 hours in the two months of the crop growth. Grist (1986) stated that light is not necessary a limiting factor to growth in the early stages of growth but becomes progressively more critical with age of the plant and particularly at panicle initiation. Oldeman and Frere (1982) showed that the number of tillers and ears increased with the intensity and quantity of light and that favorable yield response to high level of nitrogen occurs only when the crop receives high light level. Unlike the traditional varieties, modern rice varieties are insensitive to day length.

2.4.3 Effect of rainfall on rice growth.

Rice crop requires about 1400 to 1800mm of water. The high variability of tropical rains renders the success of rice cultivation uncertain in areas other than the great deltas and basins of large rivers. Varieties that mature between 100 to 150 days could be planted in areas with unimodal rainfall. In areas where the rainfall is bimodal early varieties if planted in April, might suffer from moisture stress at flowering time. The rainy season in West Africa may be continuous, or may be interrupted depending on the latitude. Moisture stress can damage or even kill plants in an area, which receives as much as 200mm/month rainfall in a day and then receives no rain for the next 20 days (IRRI, 1975).

2.4.4. Effect of latitude on rice growth.

Paddy rice thrives well over range of climatic conditions within latitude 45^{o}N and 40^{o}S (Grist, 1986). Areas like Africa, India, part of United Stated of America, China, Central America and Australia lies within latitude 45^{o}N and 40^{o}S are known for rice cultivation. It is also recorded that at latitude 30^{o}N and 40^{o}S high yield of rice could be obtained (Grist, 1986). Since high yield obtained under subtropical and warm-temperature climate could be attributed to the day length during the growing period, it is obvious that paddy plant will flourish well under different climatic conditions.

2.4.5. Effect of altitude on rice growth.

There is no conclusive evidence as to whether differences in altitude alone affect yield, but the nature of the plant is such that it is unlikely that altitude itself exercise great importance on yield, although lower night temperature may reduce respiration losses and so raise yield (Grist, 1986). According to Grist (1986), the altitude at which rice can be grown depends on latitude. It was recorded that rice is grown at 3000 meter altitude in the Himalayas, at 1800m altitude at the Philippines and over 1200 meter altitudes in South America (Grist, 1986).

2.4.6. Effect of edaphic factor on rice growth.

In West Africa, pattern of rainfall distribution and soil capacity to retain water helps to determine the success and failour of upland rice. Most upland soil of West Africa has low capacity to hold available water that is why even short dry spell duration significantly reduce grain yield (Moorman, 1973). He also found satisfactory correlation between yield levels and texture of soil in Northern Nigeria; coarse texture produced the lowest yields. A surface soil of medium texture can easily be worked because less

water is necessary for initial rice growth since water loss through the crakes is less compared to clay soils (IRRI, 1997).

The pH of paddy soils influence the availability and uptake of mineral elements by the plant (Grist, 1986). Most of the highly productive paddy soils of China are either slightly or strongly acidic, although rice can tolerate considerable extent variation in soil reactions. IRRI, (1992), stated that germinating rice seedling tolerant to acidic soil condition increase the pH of soil in the immediate vicinity of their roots. Despite the ability of the root system of paddy rice to change the pH of the soil around its root vicinity, rice field can also suffer from toxicity or deficiency of iron, zinc and phosphorous (IRRI, 1992). According to Mackill *et al.,* (1996), these problems are as a result of poor soil water management. The soil condition in which rice is grown is as broad as that of the climate. According to IRRI, (1997) soil texture varies from sand to clay; organic matter content varies form 1-50%, pH varies from 3-10, salt content from 0-1% and nutrient availability from acute to surplus.

2.5. Economic importance of rice.

Rice consumption in many homes in Nigeria has increase by 367 percent between 1970 and 1984. Also national production within this period was put at 12,000 metric tons (WARDA, 1986). WARDA, (1996) put rice per capital consumption at 21.2kg annually.

The increase in rice consumption in Nigeria led to the massive importation increase between 1970 from 2000 tones to 400,000 tones in 1980 (WARDA 1986). About 85% of the total rice production is for human consumption (WARDA 1986). Among cereals, rice and wheat share equal importance as leading food source for mankind worldwide (FAO 2004). Base on mean grain yield, rice crop produce more food energy and protein supply per hectare than wheat and maize. According to Lu and Chang, (1980)

rice can support people per unit of land than wheat and maize. Rice is a staple food for nearly one-half of the world population. It is a major source of calories to about 40 percent of the world (De Delta, 1981).

In industrial usage, rice is gaining importance in the making of infant food, snakes, breakfast cereals, fermented products and rice bran oil, rice wine which remains the major alcoholic beverage in East Africa. The coarse and silica-rich rice hull is finding new use in construction industry. Its low fiber content has led to an increase use of rice powder in polishing camera lenses and expensive jewelry. Rice straw is used as animal feed. However, rice straw which is used as stock feed in many parts of the world (Drake *et al*., 2002; FAO 2004), has the potentials to cause toxicity if fed in large quantities. This occurs through the high levels (1 to 2%) of oxalate present in the straw that can result in calcium deficiencies if supplement are not provided (FAO 2004).

Large volume of rice straw is used in the cultivation of paddy straw mushroom. It is also used in bags, mats making. In paper making industries rice straw is a raw material.

Rice starch can also serve as a substitute for glucose in oral dehydration solution for infant suffering from diarrhea. Rice is believed by some to have medicinal properties, although, this is not scientifically proven effective; it has been used in many countries for medicinal purpose.

Rice is a source of magnesium, thiamin, niacin, phosphorus, vitamin B6, zinc and copper. Some varieties have iron, potassium and folic acid. White rice is one of the poorest cereals in proteins; some improved varieties however may provide 14g of proteins per 100g. It ranks higher in available carbohydrates digestible energy and net protein utilization.

2.6.1 The African rice gall midge

Rice gall midge is one of most economic pest of rain fed and wetland rice in many Asian and African countries. The Asian rice gall midge is called *Orseablia oryzae* wood mason while the African species is called *Orseolia oryzivora* (Harris and Gagne, 1982). The midges belong to the family Diptera and cecidomylidia, the two are morphologically distinct. *Orsealia oryzivora* had been reported in Burkina faso, Cameroom, Coted'ivore, Guinea-Bissau, Senegal, Mali, Nigeria, Sudan, Zambia and Malawi (Grist 1986 and Alam *et al*., 1985). In Nigeria, the pest was first reported in Shandam, Plateau state and Badeggi in Niger State (Joshi and Ukwungwu, 1990). Then the insect was regarded as a minor rice pest. In 1988 total crop failure was experienced caused by AfRGM. The damage covered about 50,000 hectares of rice field in the Eastern state of which Abakaliki in Ebonyi state was worse hit. The yield losses were high as 80 percent (Ukwungwu and Joshi, 1992). AfRGM occur at the vegetative stage of rice crop because the larva cannot produce galls on tillers that have already formed a flower head. The pest does not kill the plant but infested tillers cannot produce grain (Williams *et al*., 2002, Gana *et al*., 2003). The level of infestation varies from one rice variety to another (Williams, 1996). Total crop failure may occur in fields with heavy infestation. Although rice varieties compensate for lost tiller by producing extra tillers (NCRI, 1998; Williams *et al*., 2002) but at times they are formed too late to contribute to grain yield.

2.6.2. Iron toxicity in rice

Bronzing is a nutritional disorder of the lowland rice associated with excess water-soluble iron. In this disorder, the leaves are first covered by tiny brown spots, which develop into a uniform brown colour. The initial soil iron content may be increased by iron coming from upland through interflow along the slop and may become very concentrated up to 300 – 500ppm at several iron toxic sites (Yoshida, 1981).

Iron toxicity in rice is associated with high ferrous iron concentration in the soil solution, poor water control, low PH and inadequate k^{+}.

The reductive conditions commonly found in clogged lowland soils are early signs of iron toxicity through the solubilization in soil solution of nearly all the iron content in its ferrous form (Fe^{2+}). This large amount of ferrous iron in solution causes disequilibrium in the mineral elements affecting growth of crops, especially rice. This ferrous iron (Fe^{2+}) is readily absorbed and concentrates in the leaves, causing discoloration of the lamina, reduction in tillering and significant yield losses.

The reduced soil condition that cause accumulation of soluble ferrous iron also lead to enhanced requirement for nutrient such as P & K needed to over come the stress (Sahrawat *et al*., 1996, Sahrawat, 1998).

The most cost efficient approach to improve rice production by reducing iron toxicity is the use of iron toxic tolerant rice cultivars (Abifarin, 1989). Under extreme iron toxicity a combination of tolerant rice cultivar and improved soil nutrient management may give the best result (Sahrawat *et al*., 1996).

2.7. Genetic variability studies in rice

The world's rice production has doubled during last 25 years, largely due to the use of improved technology such as high yielding varieties and better crop management practices (Byerlee, 1996). Further scope of crop improvement depends on the conserved use of genetic variability and diversity in plant breeding programmers and use of new biotechnological tools. There is wide genetic variability available in rice among and between wild relatives and varieties leaving a wide scope for future crop improvement. Moreover, rice is also an ideal model plant for the study of grass genetics and genome

organization due to its diploid nature, relatively small genome size 430 Mb (Kurata *et al*., 1994), significant level of genetic polymorphism (McCouch *et al*., 2001). Large amount of well conserved genetically diverse material (approximately 100,000 accessions of rice germplasm worldwide) and the availability of widely collected, compatible wild species.

Molecular markers have proven to be powerful tools in the assessment of genetic variation and in the elucidation of genetic relationships within and among species. Several molecular markers viz. RFLP (Becker *et al*., 1995), RAPD (Tingey and Deltufo, 1993), SSRs, ISSRs (Blair *et al*., 1999), AFLP (Zhu *et al*., 1998) and SNPs (Vieux,*et al*., 2002) are presently available to assess the variability and diversity at molecular level (Joshi *et al*., 2000). Information regarding genetic variability at molecular level could be used to help, identify and develop genetically unique germplasm that compliments existing cultivars.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Location

The experiment was carried out at Edozhigi, longitude 5^{o} 50^{l}E and latitude 9^{o} 05^{l}N one of the experimental fields of the National Cereal Research Institute Baddegi, to assess the morpho – physiological variation that exist amongst 17 traditional rice varieties (Local) and 22 improved rice varieties. The experiment was conducted during the 2009, 2010 cropping seasons.

3.2 Experimental activity

The activities carried out under this project include:

Collection of cultivars from farmer's field

Morphological Characterization

Characterization of local and improved rice cultivars for AfRGM resistance

Characterization of local and improved rice cultivars for iron toxicity tolerance

3.3 Collection of rice materials

The local rice varieties used for this experiment were collected from farmer's fields in Niger State rice growing villages and the improved varieties were collected from NCRI gene bank.

3.4 Experimental procedure and layout.

2009 seeding was done on 30/07/2009 on nursery bed measuring 25m X 1m covered lightly with soil to easy germination. The bed was kept weed free. Transplanting was done on 24/8/2009. The 2010 seeding was done on 27/7/2010 and transplanted on 17/8/2010. Three seedlings were transplanted per stand at 20cm X 20cm spacing. Randomized complete block design was used and the treatments were replicated three times on 5m X 1m plot size.

Table 3.1: List of varieties used for the experiment.

S/NO	NAME	TYPE	S/NO	NAME	TYPE
1.	FARO 19(1)	improved	2.	FARO 37(2)	improved
3.	FARO 30(3)	improved	4.	FARO 27(4)	improved
5.	FARO 44(5)	improved	6.	FARO 12(6)	improved
7.	FARO 15(7)	improved	8.	FARO 39(8)	improved
9.	FARO 48(9)	improved	10.	FARO 29(10)	improved
11.	FARO 51(11)	improved	12.	NCRO 49(12)	improved
13.	FARO 22(13)	improved	14.	NERICA L20(14)	improved
15.	ROK 5(15)	improved	16.	FARO 40(17)	improved
17.	FARO 52(18)	improved	18.	NERICA L36(19)	improved
19.	FARO 21(20)	improved	20.	CK 73(21)	improved
21.	WITA 8(22)	improved	22.	FARO 31(25)	improved
23	Manbechi(26)	local	24.	Ebagichi(27)	local
25.	Ndawozdufugi(29)	local	26.	Bokuchi(31)	local
27.	Dokochi(32)	local	28.	Tomawawagi(33)	local
29.	Babawagi(37)	local	30.	Mass(38)	local
31.	Shagari(40)	local	32.	Eyewawagi(41)	local
33.	Finiko(42)	local	34.	Damanle(43)	local
35.	Danboto(44)	local	36.	Ibrahim Tsadu(45)	local
37.	Ekach(47)	local	38.	Toma(48)	local
39.	Suakoko(49)	local			

The numbers in parenthesis are the numbers used to construct the dendogram and scattered diagram.

3.5 The following data were collected.

* Days to 50% flowering (DFF) – Recorded when half of the plants had flowered.

* Number of tillers (NOT) – Number of tillers on a hill was counted using 5 hills per entry per replication.

* Leaf length (LL) – Measured with a meter rule from the base to the tip of the leaf.

* Leaf width (LW) – measured from the middle of leaf using five sample (plant or leaves) per plot of each test entry.

* Plant height (PHT) – Taken from the base to the tip of the plant. Five representative samples were taken from each plot.

* Number of Panicle per meter square (PAM) – Were counted on five hills multiply by five given a total of 25 hills per plot.

* Phenotipic acceptability score (PA) – Over all judgment of the rice variety.

* Length of panicle (LP) – Taken from the base to the tip of last grain. A total of five panicles were measured for each entry.

* Number of grain per panicle (NGP) – Taken by counting the number of grains on five panicles for each entry.

* Hundred grains weight (HGW) – Taken by weighing hundred grains per replication for each test entry.

3.5.1 Data collected for AfRGM resistance.

The AfRGM infestation was scored at 42 and 62 days after transplanting (DAT) based on the standard evaluation system for rice (IRRI, 1996). Galls were counted on five hills of each plot. The percentage level of infestation was determined by finding the total numbers of galls per hill over the total number multiply by 100. The rating was as presented below:

Table 3.2: Scale used for scoring AfRGM

SES score	Rate	Percent tiller infestation
0	Highly resistant	0
1	Resistant	< 1
3	Moderately resistant	1 - 5
5	Moderately Susceptible	6 - 10
7	Susceptible	11- 25
9	Highly Susceptible	> 25

(SES) Standard Evaluation System for rice (IRRI, 1996).

3.5.2 Data collected for iron toxicity tolerance

Iron toxicity was scored by observing the bronzing effect on the leaves. This was done using the evaluation system for rice (IRRI, 1996). The score were taken at 40 and 60 days after transplanting. The rating is as presented below.

Table 3.3: Scale used for scoring iron toxicity

SES score	Rate
0	Highly resistant
1	Resistant
2	Moderately resistant
5	Moderately Susceptible
7	Susceptible
9	Highly susceptible

(SES) Standard Evaluation System for rice (IRRI, 1996).

3.6 Cultural practices in the experimental plot.

Weeding – This was done at 3 and 6 weeks after transplanting by hand pulling and hoeing.

Fertilizer application – Basal application of fertilizer was done a week after transplanting at the rate of 80: 40:40 kg of N_2, P_2O^5 and K_2O per hectare. At maximum tillering and panicle initiation stages, 40 kg of N_2 (urea) was applied as split application.

3.6.1 Harvesting and bagging – Grains were harvested at maturity by cutting with a sickle and bagged for further data collection.

3.7 Statistical analysis

Analysis of variance (ANOVA) was carried out using Genstat 5 (2004) version and Minitab 14.0 (2004) for correlation and principal component analysis. Scattered plots were produced based on the result of the first and second principal component analysis using Microsoft Excel windows. Cluster analysis that produced the dendogram was constructed using Minitab 14.0.

CHAPTER FOUR

4.0 RESULT AND DISCUSSION

4.1 RESULT

4.1.1 Variability amongst the morphological characters.

The result of analysis of the variance (ANOVA) for the quantitative characters for 2009 and 2010 trial is presented in the tables 4.1 and 4.2. There were highly significant differences amongst the entries in 2009. Plant height, leaf width, Gall count at 62 DAT, Iron toxicity score at 20 DAT and total grain yield per plot were significantly different at <1 percent level of probability. Panicle length, leaf length and 1000 grains weight were significantly different at <0.05 probability level. Iron score 60 DAT and phenotypic acceptability show no significant differences.

Result of 2010 revealed that leaf length, panicle length, iron toxicity score at 20 DAT, iron toxicityscore at 40 DAT, Days to 50 percent flowering, leaf width, 1000 grain weight, and total grain yield per plot were significant at <1 percent. Gall count at 62 DAT and NGP showed significant difference at <0.05 probability level. Gall count at 42 DAT, PAM, Iron toxicity score at 60 DAT and PA showed no significant differences at all (Table 4.2).

Table 4.1 Mean square analysis for the morphological characters 2009

	DF	PHT	LW	PL	GALL 42 DAT	GALL 62 DAT	PAM	NOT. 40 DAT	IRON 20 DAT	IRON 40 DAT	IRON 60 DA
BLOCK	2	378.691	6.319	74.722	303.715	78.220	33486.008	1401.366	2.472	4.935	0.423	0.00
0.618	0.075	36.984	6427.813	54.441								
TREATMENT	40	905.195**	3.975**	22.899*	48.213NS	48.165**	12013.242	507.451NS	2.265**	2.665NS	0.525NS	
175.463	2.171NS	0.047*	45.647*	162879.850**	589.341							
ERROR	80	135.795	0.572	9.117	26.857	14.145	7614.675	302.5833	0.338	2.602	2.548	
214.69	1.235	2.478	5.668	28.781	314.057							
G/MEAN	-	111.002	10.415	24.485	12.545	8.463	331.260	66.854	2.057	3.057	1.260	
77.366	5.569	0.989	32.984	641.862	154.990							
CV%	-	10.50	7.26	12.33	41.31	44.44	26.86	26.02	28.27	52.76	51.60	
0.00	19.27	13.31	20.84	18.17	22.87							

**Correlation is significant at 0.01 levels (2-tailed)

*Correlation is significant at 0.05 levels (2-tailed)

Table 4.2 Mean square analysis for the morphological character 2010

	DF	PHT	LW	PL	GALL 42DAT	GALL 62DAT	PAM	NOT. 40DAT	IRON 20DAT	IRON 40DAT	IRON 60DAT	DFF
BLOCK	2	102.813	2.724	70.682	0.756	8.854	1683.130	125.886	452.951	0.520	4.81	
1.130	0.008	0.911	0.135									
TREATMENT	40	495.170	3.633**	27.737**	0.591^{NS}	8.897	1571.504	70.457*	320.532*	1.519**		
5.293**	1.507^{NS}	178.998**	2.525^{NS}	0.035**								
ERROR	80	166.631	0.572	9.892	0.689	5.037	1096.047	41.928	193.951	0.387		

1.346	0.997	0.008	2.511	0.018							
G/MEAN	-	108.801	9.687	22.996	1.561	3.634	220.659	44.642	70.390	2.496	
4.382	2.309	77.886	5.260	0.999							
CV%	-	11.86	7.81	13.68	53.19	61.76	15.01	14.50	19.78	24.92	
26.48	43.24	0.12	30.12	13.25							

**Correlation is significant at 0.01 levels (2-tailed)

*Correlation is significant at 0.05 levels (2-tailed)

4.1.2 Custer analysis of morphological traits 2009

The cluster analysis using complete linkage method for the morphological traits in the 2009 trial showed two major cluster groups (fig 4.1). The first cluster includes 1, 7, 13, 43, 5, 12, 20, 33, 44, 15, 41, 40, 22, 38, 37 and 47. This group had mixture of both improved and local varieties (Table 4.3). The second cluster comprises of varieties 2, 17, 6, 48, 45, 49, 11, 31, 3, 18, 9, 25, 29, 8, 42, 4, 14, 10, 21, 27 and 19. This group is a mixture of local and improved varieties. These two major groups are linked together at 27% level of similarity. Varieties 20 and 33, 32 and 37, 4 and 14 showed a high level of similarity at 95%. Varieties with close similarities include 20 and 33, 32 and 37, 6 and 48, 11 and 31, 3 and 18, 8 and 42 (Fig 4.1). The first group had seventeen varieties out of which eight were improved and remaining seven are locals. The group is further grouped into sub groups indicating that these sub groups have more close genetic similarities.

The second group contains 22 varieties of which 14 are improved. The group also had sub groups indicating the close similarities existing amongst the varieties. In the second group, variety 19 stood alone indicating that it posses some characters that are far from the others although it was linked with the other groups at 7% similarity level (Fig 4.1).

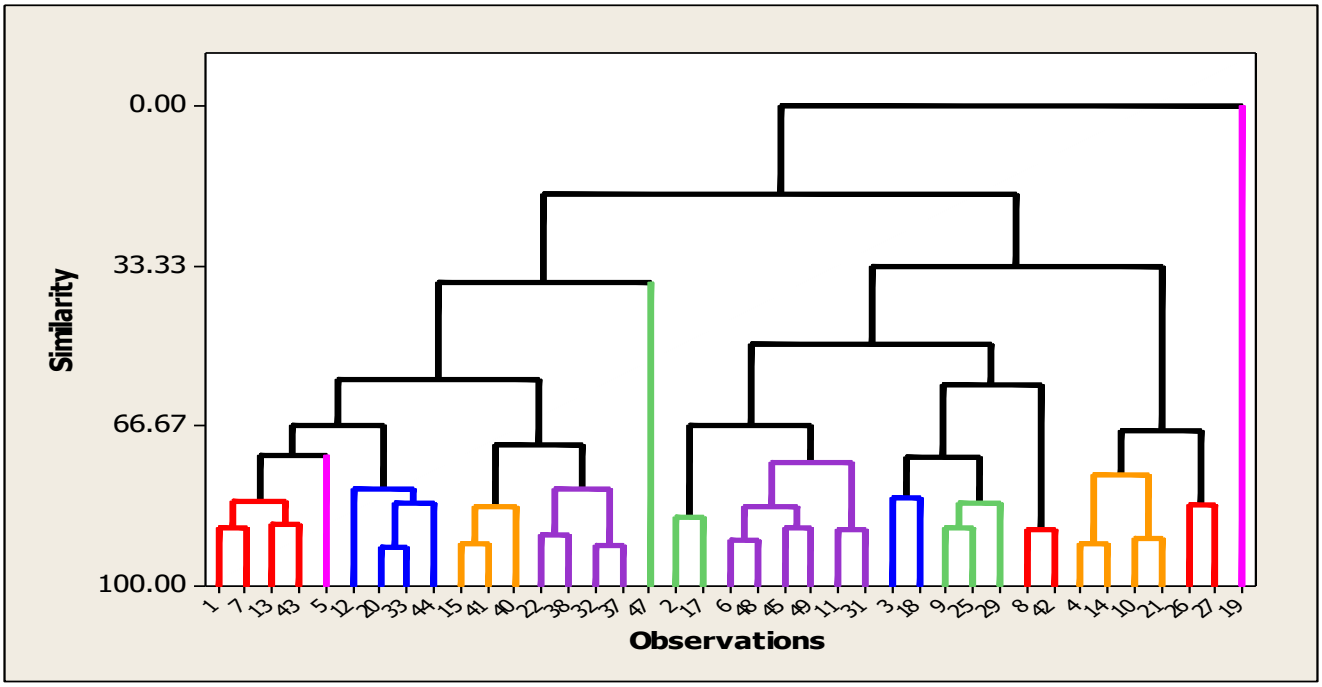

Fig. 4.1: Dendogram with complete linkage and squared Euclidean distance for 2009 trial

Table 4.3: Major groups from the Dendogram showing the arrangement of the varieties according to their relationship in 2009 trial

GP1		GP2	
Variety	Type	Variety	Type
FARO 19	improved	FARO 37	improved
FARO 15	improved	FARO 40	improved
FARO 52	improved	FARO12	improved
Danmale	local	Toma	local
FARO 44	improved	Ibrahim tsadu	local
NCRO 49	improved	Suakoko 8	local
FARO 21	improved	FARO 51	imprpved
Tomawawagi	local	Bokuchi	local
Danboto	local	FARO 30	improved
ROK 5	improved	FARO 22	improved
Eyewawagi	local	FARO 48	improved
ShagarI	local	FARO 31	improved
WITA 8	improved	Ndawodzufugi	local
Mass	local	FARO 39	improved
Babawagi	local	Finiko	local
Ekach	local	FARO 27	improved
Dokochi	local	NERICA L20	improved
		FARO 29	improved
		CK 75	improved
		Mambechi	local
		Ebagich	local
		NERICA L36	improved

4.1.3 Cluster Analysis of morphological traits for 2010 trial

Cluster Analysis with complete linkage method for the morphological traits of the varieties during the 2010 trial showed that there are two major cluster groups (Fig 4.2). The first group consists of 12 varieties which includes 1, 47, 3, 17, 18, 4, 25, 12, 15, 5, 9, 6, only variety number 47 is a local variety among these group (Table 4.4). The second cluster had 2, 31, 10, 11, 14, 22, 29, 7, 44, 45, 8, 42, 40, 41, 13, 33, 21, 20, 26, 27, 37, 32, 43, 49, 48, 19 and 38. This group had a large mixture between local and improved varieties (Table 4.4). Variety 27 and 37 showed high level of similarity at 97% (Fig 4.2). Also at high similarity levels are 44 and 45; 13 and 33; 8 and 42. The two clusters are joined to other cluster at 45% level. High level of genetic similarities exists amongst the two groups. This is exhibited by the smaller groups that exist within the groups (Fig 4.2).

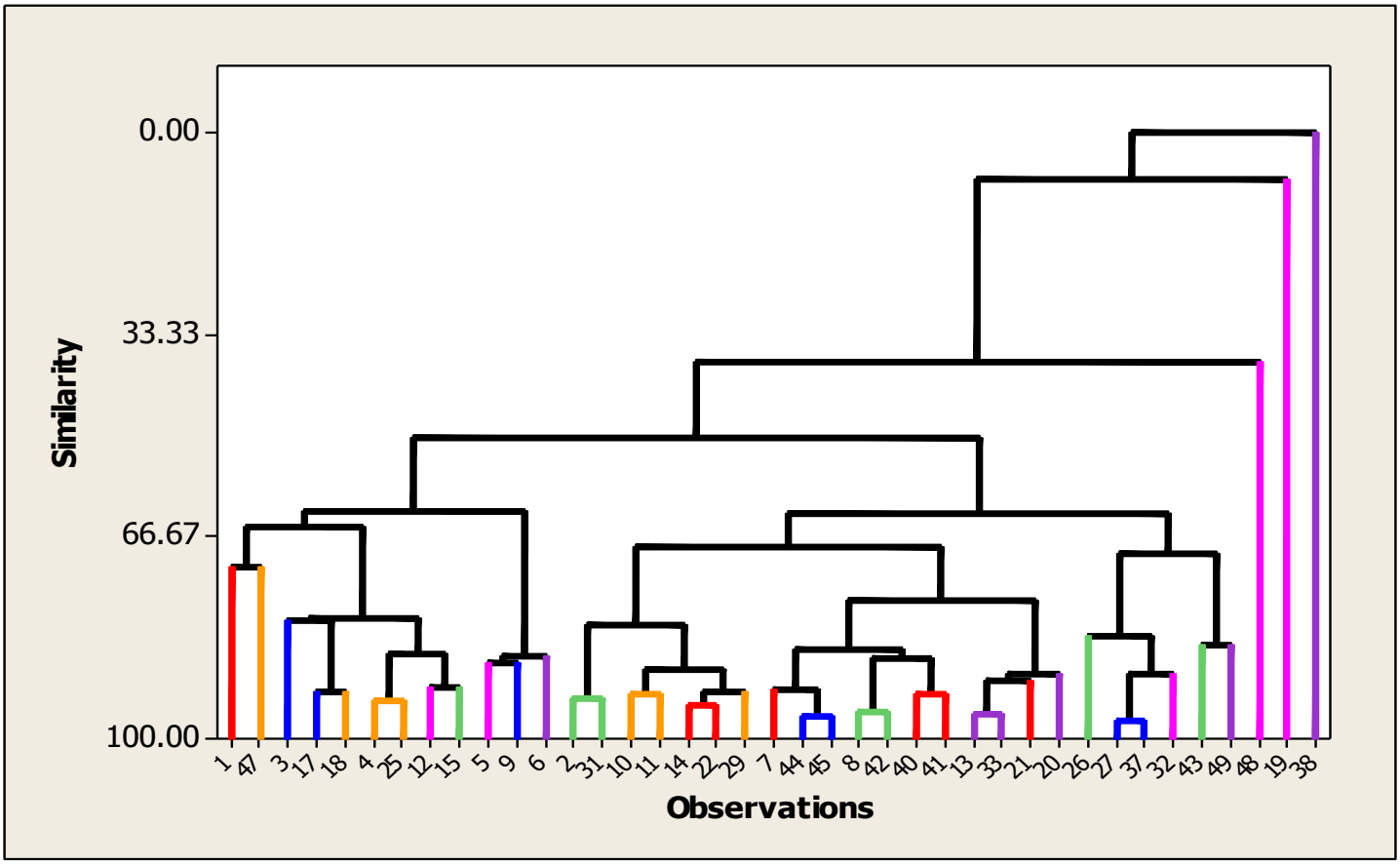

Fig. 4.2: Dendogram with complete linkage and squared Euclidean distance for 2010

Table 4.4: Major groups from the Dendogram showing the arrangement of varieties according to their relationship in 2010 trial

GP 1		GP 2	
VARIETY	TYPE	VARIETY	TYPE
FARO 19	improved	FARO 37	improved
Ekach	Local	Bokuchi	Local
FARO 30	Improved	FARO 29	Improved
FARO 40	Improved	FARO 51	Improved
FARO 22	Improved	NERICA L20	Improved
FARO 27	Improved	WITA 8	Improved
FARO 31	Improved	Ndawodzufugi	Local
NCRO 49	Improved	FARO 15	Improved
ROK 5	Improved	Danboto	Local
FARO 44	Improved	Ibrahim Tsadu	Local
FARO 48	Improved	FARO 39	Improved
FARO 12	Improved	Finiko	Local
		Shagari	Local
		Eyewawagi	Local
		FARO 52	improved
		Tomawawagi	local
		CK 73	Improved
		FARO 21	improved
		Mambechi	Local
		Ebagichi	Local
		Babawagi	Local
		Dokochi	Local
		Danmale	Local
		Suakoko 8	Local
		Toma	Local
		NERICA L36	Improved
		Mass	Local

4.1.4 Cluster analysis of morphological traits of two years combined.

The combined result of the two years had three major clusters (Fig 4.3). The first group had six varieties in which two are local varieties (Table 4.5). The second group had twenty six variety mixed in almost the same ratio. The third group had five variety also mixed. Varieties 14 and 22 had the highest similarity level at 96% (Fig 4.3). Varieties 13 and 33; 10 and 21; 4 and 25 have close level of similarity too. The three groups are linked at 37% level of similarity. Variety 38 and 19 stood alone and joined other groups at 28% level of similarity (Fig 4.3).

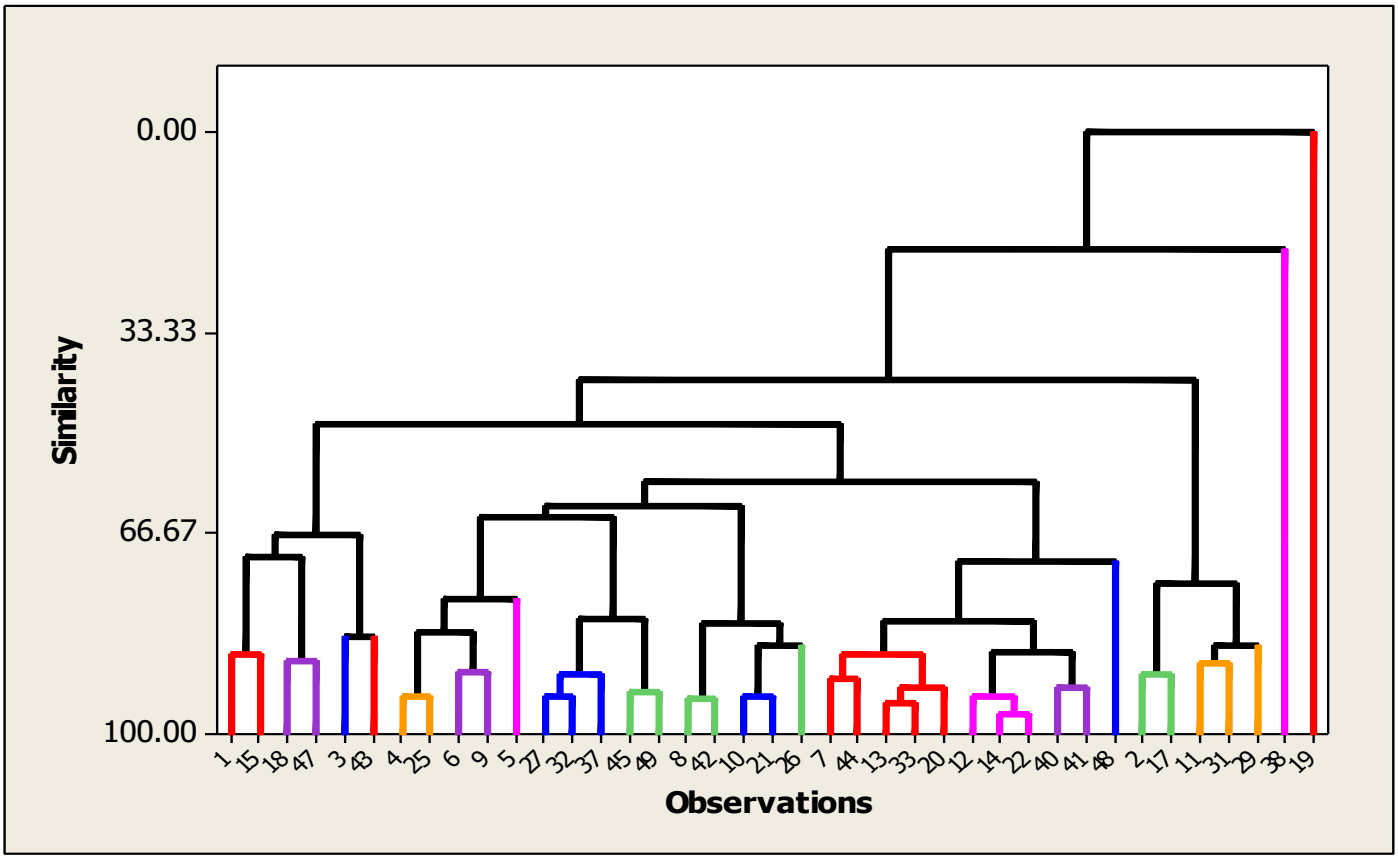

Fig. 4.3: Dendogram with complete linkage and squared Euclidean distance for two years combined

Table 4.5: Major groups from the Dendogram showing the arrangement of varieties according to their relationship for two years combined.

GP 1		GP 2		GP 3	
VARIETY	TYPE	VARIETY	TYPE	VARIETY	TYPE
FARO 19	Improved	FARO 27	Improved	FARO 37	Improved
ROK 5	Improved	FARO 31	Improved	FARO 40	Improved
FARO 22	Improved	FARO 12	Improved	FARO 51	Improved
Ekachi	Local	FARO 48	Improved	Bokuchi	Local
FARO 30	Improved	FARO44	Improved	Ndawodzufugi	Local
Danmale	Local	Ebagichi	Local		
		Dokochi	Local		
		Babawawagi	Local		
		Ibrahim Tsadu	Local		
		Saukoko	Local		
		FARO 39	Improved		
		Finiko	Local		
		FARO 29	Improved		
		CK73	Improved		
		Mambechi	Local		
		FARO 15	Impeoved		
		Danboto	Local		
		FARO 52	Impeoved		
		Tomawawagi	Local		
		FARO 21	Impeoved		
		NCRO 49	Local		
		NERCA L20	Improved		
		WITA 8	Local		
		Toma	Local		

4.1.5 **Correlation analysis of morphological traits for 2009 trial**

The result showed that 1000 GW and total yield per plot had positive significant relationship at $P<0.01$. Also is, total yield per plot and iron score (Table 4.6). Leaf width and panicle length, leaf width and gall count, Panicle per meter square and gall count, are moderately correlated at 0.05%. Phenotypic acceptability and panicle length and leaf length and gall count are negatively correlated at 0.05% level of relationship (Table 4.6).

Table 4.6: Correlation analysis of morphological traits, 2009.

	1000W	TYP	NGP	DFF	PA	LW	PAM	PHT	LL	PL	IRON	GALL
1000W	1	-0.411**	0.118	0.005	-0.26	0.263	-0.155	0.05	-0.23	0.103	0.178	0.075
TYP		1	0.028	-0.08	-0.109	0.16	0.074	0.219	-0.08	0.01	.450**	-0.049
NGP			1	-0.101	-0.073	0.009	0.072	-0.293	-0.145	-0.151	0.005	-0.049
DFF				1	0.15	0.201	0.124	0.212	0.083	-0.064	0.209	0.201
PA					1	-0.15	0.127	0.275	0.221	-321*	-0.093	-0.068
LW						1	0.132	0.073	-0.013	.325*	0.271	0.323*
PAM							1	-0.114	0.08	0.106	0.016	0.375*
PHT								1	0.128	0.092	0.171	-0.206
LL									1	-0.045	0.221	-0.366*
PL										1	-0.153	0.143
IRON											1	0.115
GALL												1

DFF Days to 50% flowering, **LL** Leaf length, **LW** Leaf width, **PHT** Plant height, **PAM** Panicle per meter square, **PA** Phenotypic acceptability, **PL** panicle length, **NGP** Number of grain per panicle, **1000GW** grain weight, **TYP** Total yield per plot..

**Correlation is significant at 0.01 levels (2-tailed)
*Correlation is significant at 0.05 levels (2-tailed)

4.1.6 Correlation Analysis of morphological traits for 2010 trial

Result of the correlation analysis of morphological traits in 2010 showed that the correlation between the weight of 1000 grain and total yield per plot had a moderate positive significant relationship at $P<0.01$ level. At $P<0.05$ significant level, panicle per meter square and leaf length, plant height and iron toxicity score had a moderate positive significant relationship (Table 4.7). The correlations between other parameters were either positive or negatively related with no significant differences.

Table 4.7: Correlation analysis of morphological traits, 2010.

	1000W	TYP	NGP	DFF	PA	LW	PAM	PHT	LL	PL	IRON	GALL
1000W	1	.476**	-0.063	-0.072	0.099	-0.273	0.18	0.093	-0.024	0.127	0.292	0.063
TYP		1	-0.07	-0.033	0.188	-0.063	0.212	0.219	0.012	0.176	0.336	0.009
NGP			1	-0.165	-0.178	-0.055	0.018	-0.267	-0.249	-0.234	-0.257	-0.079
DFF				1	0.158	0.036	0.063	0.183	0.045	0.065	0.124	-0.115
PA					1	0.307	0.076	0.302	0.261	-0.007	0.088	0.044
LW						1	-0.009	-0.052	-0.132	-0.056	-0.008	-0.05
PAM							1	-0.011	0.335*	0.132	0.131	0.004
PHT								1	0.178	0.099	0.324*	0.002
LL									1	0.024	0.139	-0.277
PL										1	0.064	-0.042
IRON											1	-0.176
GALL												1

DFF Days to 50% flowering, **LL** Leaf length, **LW** Leaf width, **PHT** Plant height, **PAM** Panicle per meter square, **PA** Phenotypic acceptability, **LP** Length of panicle, **NGP** Number of grain per panicle, **1000GW** grain weight ,**TYP** Total yield per plot..

**Correlation is significant at 0.01 levels (2-tailed)
*Correlation is significant at 0.05 levels (2-tailed)

4.1.7 Correlation analysis of morphological traits for two years combined.

Correlation analysis of combined result for two years (Table 4.8), showed that the correlation between weight of 1000 grain and panicle length, leaf width and gall count had moderate positive significant relationship at P<0.01 level. Days to 50% flowering and gall count, weight of 1000 grain and gall count had low positive significant relationship at P<0.05; while plant height and iron score showed a moderate negative significant relationship at P<0.01. Correlations between other parameters are either positive or negatively related with no significant differences (Table 4.8).

Table 4.8: Correlation analysis of morphological traits for two years combined.

	1000W	TYP	NGP	DFF	PA	LW	PAM	PHT	LL	PL	IRON	GALL
1000W	1	-0.014	-0.056	0.044	-0.059	0.208	0.215	-0.036	0.099	0.464**	-0.016	0.317*
TYP		1	-0.134	-0.105	-0.072	0.160	-0.290	-0.200	-0.197	-0.152	-0.018	0.094
NGP			1	0.151	0.037	0.153	0.213	0.066	0.002	0.209	0.123	0.176
DFF				1	0.314	0.061	0.315	0.241	-0.172	0.043	-0.029	0.355*
PA					1	-0.007	-0.029	-0.149	-0.123	-0.037	0.077	0.097
LW						1	-0.097	0.197	0.137	0.086	0.113	0.498**
PAM							1	0.146	0.106	0.312	-0.166	0.133
PHT								1	-0.025	0.009	-0.415**	0.176
LL									1	-0.078	0.114	-0.194
PL										1	0.031	0.098
IRON											1	0.158
GALL												1

DFF Days to 50% flowering, **LL** Leaf length, **LW** Leaf width, **PHT** Plant height, **PAM** Panicle per meter square, **PA** Phenotypic acceptability, **LP** Length of panicle, **NGP** Number of grain per panicle, **1000 GW** grain weight ,**TYP** Total yield per plot..

**Correlation is significant at 0.01 levels (2-tailed)
*Correlation is significant at 0.05 levels (2-tailed)
.

4.1.8 Principal component analysis of the morphological traits, 2009

Table 4.9 a and b presents the principal component and percentage contribution of each component to the total variation in the entire population. The first principal component accounted for 19.1% of the total variation in the population (Table 4.9a). Leaf length contributed more to the variation (0.106) (Table 4.9b), followed by phenotypic Acceptability (0.026). All other characters contributed negatively to the first component. Second principal component contributed 16.1% of the total variation. Characters that contributed to the component include PA (0.474), LL (0.384), NOT (0.360), PAM (0.351), TYP (0.217), DFF (0.174) and PHT (0.073). The following characters contributed negatively to the second principal component; 1000 GW, NGP, LW, PL, iron and gall midge score. The third principal component accounted

for 13.3% of the total variation in the population. Gall count contributed the highest (0.335) while number of tiller contributed less. Plant height (-0.601), total grain yield per plot (-0.335), iron score (-0.313), phenotypic acceptability (-0.208), days to 50% flowering (-0.200), leaf length (-0.201) and weight of 1000 grains (-0.151) contributed negatively to variation in the third principal component. Panicle length (0.607) contributed more to the variation in principal component four. Gall count (0.171) and panicle per meter square (0.007) contributed low to the variation. Number of grains per panicle (-0.471), Total yield per plot (-0.282), number of tillers (-0.144) and weight of 1000 grain weight contributed negatively. The fifth principal component accounted for 09.2% of the total variation with leaf length (0.458) given the highest contribution. Leaf width (0.042) and number of grain per panicle (0.107) contributed low. Days to 50% flowering (-0.490), gall count (-0.372), iron toxicity score (-0.225) and phenotypic acceptability (-0.171), contributed negatively to the fifth principal component. Cumulatively, these five principal components showed 68.9% of the total variation in the population.

Table 4.9a: Morphological traits and percentage of total variation of the principal component analysis 2009.

PRIN	EIGEN VALUE	PERCENTAGE	CUMMULATIVE
1	2.4890	19.1	19.1
2	2.0957	16.1	35.3
3	1.7272	13.3	48.6
4	1.4545	11.2	59.7
5	1.1922	09.2	68.9
6	0.9311	07.2	76.1
7	0.7728	05.9	82.0
8	0.6748	05.2	87.2
9	0.6076	04.7	91.9
10	0.3714	02.9	94.7
11	0.3372	02.6	97.3
12	0.2714	02.1	99.4
13	0.0749	00.6	100

Table 4.9b: Component (Eigen values), total variation accounting for 68.9% of variable combination to the first five principal components., 2009

Variables	PC1	PC2	PC3	PC4	PC5
Weight of 1000 grains	-0.199	-0.419	-0.151	-0.114	0.135
Total yield per plot	-0.302	0.217	-0.335	-0.282	0.328
Number of grain /panicle	-0.027	-0.101	0.278	-0.471	0.107
Days to 50% flowering	-0.216	0.174	-0.200	0.183	-0.490
Phenotypic Acceptability	0.026	0.474	-0.208	-0.122	-0.171
Leaf width	-0.376	-0.168	-0.047	0.305	0.042
Panicle per meter square	-0.411	0.351	0.275	0.007	0.223
Plant height	-0.036	0.073	-0.601	0.202	-0.012
Leaf length	0.106	0.384	-0.201	0.136	0.458
panicle length	-0.092	-0.222	0.103	0.607	0.311
Iron toxicity score	-0.330	-0.165	-0.313	-0.260	-0.225
Gall midge count	-0.386	-0.034	0.335	0.171	-0.372
Number of tillers.	-0.478	0.360	0.067	-0.144	0.217

4.1.9: Loading plot of first and second component using morphological traits of 2009 trial.

Loading plot of first and second component using morphological traits of 2009 trial revealed that weight of 1000 grain, phenotypic acceptability and panicle per meter square showed more degree of variation while leaf length and phenotypic acceptability, number of tillers and panicle per meter square are more similar (Fig 4.4).

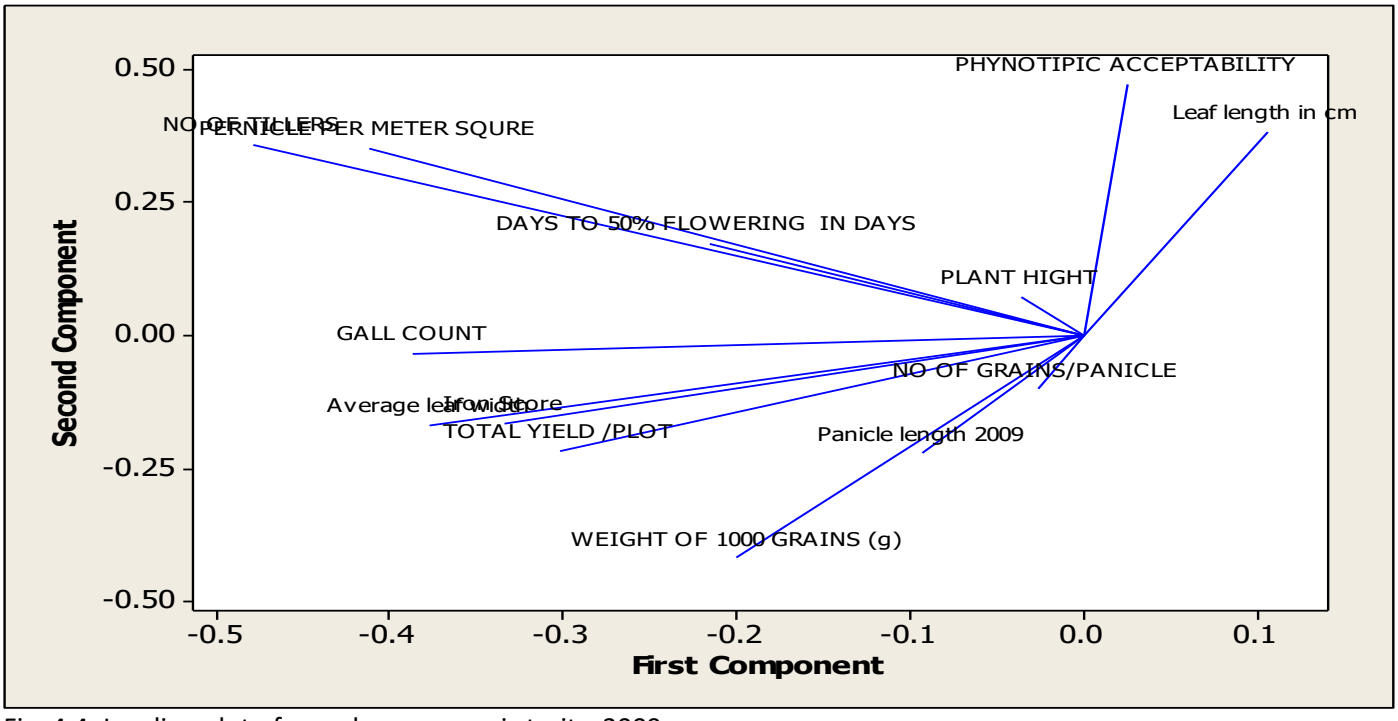

Fig. 4.4: Loading plot of morpho-agronomic traits, 2009

4.1.10: Scattered diagram of first and second component using morphological traits, from 2009 trial.

The scattered diagram of first component against the second component using morphological trait showed that the variables are at different level of variation and similarity among the quadrant. The grouping of varieties as denoted by their separation into quadrants showed the extent of relationship existing amongst the varieties (Fig 4.5). In the first quadrant are 40, 22, 4, 21, 10, 26, 38 and 14. The second quadrant had 13, 19, 32, 27, 37, 12, 33, 5, 20, 44 and 43. In the third quadrant are 3, 9, 41, 1, 7, 47 and 15. The fourth quadrant showed, 18, 48, 17, 2, 6, 11, 29, 49, 8, 25, 45 and 31. Some varieties like 43 and 44 and 45 and 31 are genetically related hence they are fused.

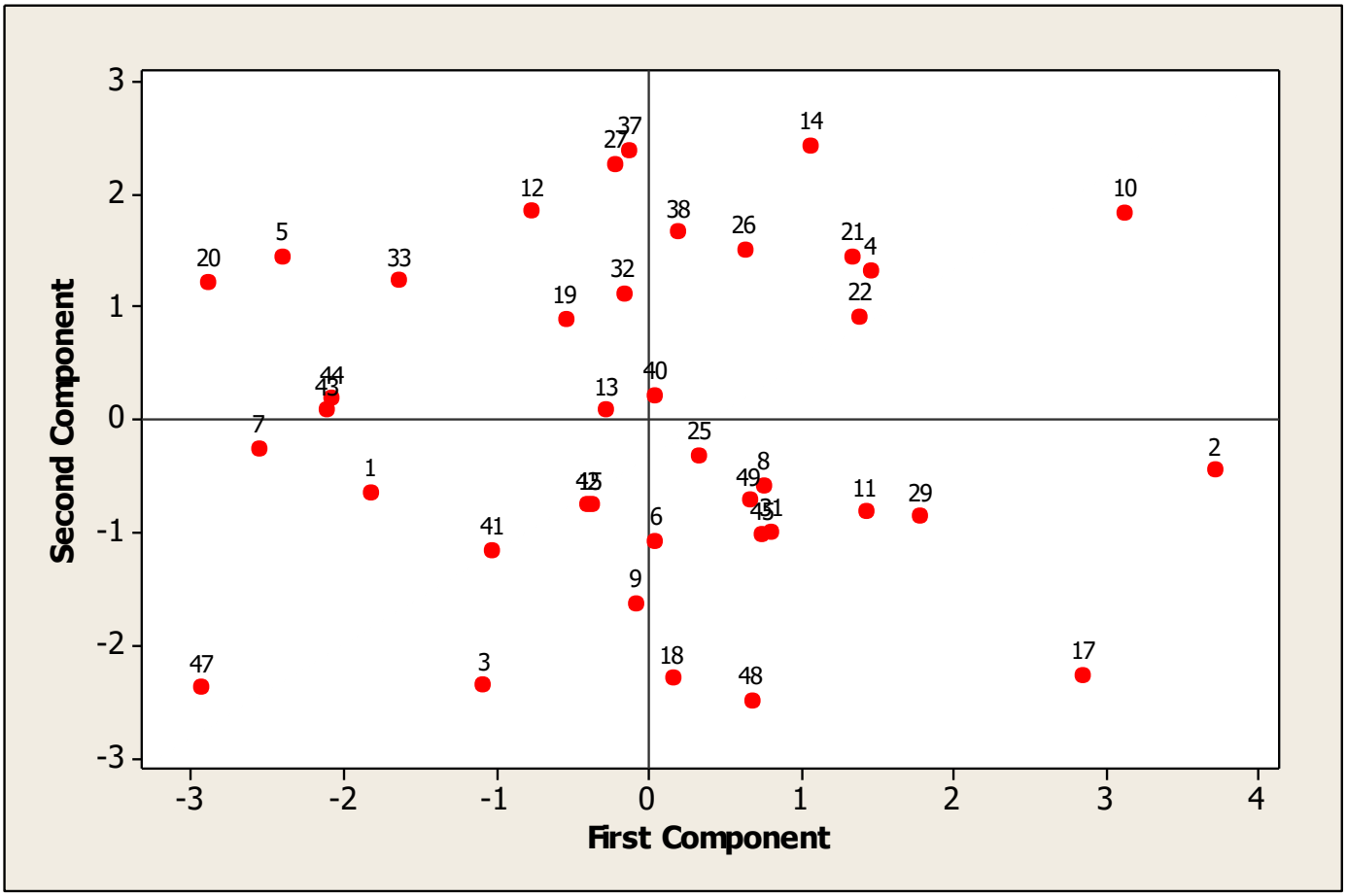

Fig. 4.5: Scatter diagram showing the position of individual varieties for 2009 trial.

4.1.11 Principal component analysis of the morphological traits, 2010

The first principal component accounted for 19.9% of the total variation observed (Table 4.10a). Number of grains per panicle (0.251) contributed more to the variation than others. Gall midge count (0.125) and leaf width (0.011) contributed least to the variation while total yield per plot (-0.391), iron score (-0.382), plant height (-0.370) number of tillers (-0.335), leaf length (-0.264), panicle per meter square (-0.239). Phenotypic acceptability (-0.304), days to 50% flowering (-0.153) and weight of 1000 grains (-0.330) contributed negatively to the first component (Table 4.10b). The second component contributed 12.4% of the total variation with the leaf width (0.427) contributing highest. Other major characters that contributed to the variation include, AP (0.333), DAF (0.330) and LL (0.257) while PH (0.162) contributing least to the variation. 1000 GW (-0.504), TYP (-0353), NGP (-0.244), PAM (-0.103), PL (-0.097), iron (-0.490), gall midge (-0.216) and NOT (-0.002) contributed negatively to the variation. The third principal component contributed 10.8% of the total variation in the entire population. NOT (0.531) contributed highest followed by NGP (0.459) and LW (0.357). PA (0.228), TYP (0.123) and 1000 GW (0.072) contributed least to the variation. DAF (-0.137), PAM (0.007), PH (-0.059), LL (-0.186), PL (0.484) iron score (-0.111) and gall midge (-0.067) contributed negatively to the third component. The fourth principal component contributed 10.0% to the total variation. The major characters that contributed highly to the variation include LL (0.516) and PAM (0.394) while NGP (0.236) and NOT (0.097) contributed least to the variation. 1000 GW (-0.68) TYP (-0.414), DAF (-0.050), PA (-0.243), LW (-0.254), PH (-0.246), PL (-0.097), iron toxicity score (-0.024) and gall midge (-0.540) contributed negatively to the variation. The fifth principal component accounted for 08.5% of the total variation. PAM (0.569), gall midge (0.438) PA (0.339) contributed highest in the variation while LW (0.324), LL (0.229), and TYP (0.055), contributed least. Those that contributed negatively to the variation include, 1000 GW (-0.010), NGP (-0.010), DAF (-0.205), PH (-0.240), iron toxicity score (-0.326) and NOT (-0.139). The five principal components showed 61.6% of the total variation in the population.

Table 4.10a Morphological traits and percentage of total variation of the principal component analysis.

2010

PRIN	EIGEN VALUE	PERCENTAGE	CUMMULATIVE
1	2.5822	19.9	19.9
2	1.6160	12.4	32.3
3	1.4084	10.8	43.1
4	1.2936	10.0	53.1
5	1.1072	08.5	61.6
6	0.9937	07.6	69.2
7	0.9007	06.9	76.2
8	0.7921	06.1	82.3
9	0.6711	05.2	87.4
10	0.5872	04.5	91.9
11	0.4785	03.7	95.6
12	0.3039	02.3	98.0
13	0.2652	02.0	100

Table 4.10b: Component (Eigen values), total variation accounting for 61.6% of variable combination to the first five principal components. 2010

Variables	PC1	PC2	PC3	PC4	PC5
Weight of 1000 grains	-0.330	-0.504	0.072	-0.068	-0.010
Total yield per plot	-0.391	-0.353	0.123	-0.414	0.055
Number of grain /panicle	0.251	-0.244	0.459	0.236	-0.010
Days to 50% flowering	-0.153	0.330	-0.137	-0.050	-0.205
Phenotypic Acceptability	-0.304	0.333	0.228	-0.243	0.339
Leaf width	0.011	0.427	0.357	-0.254	0.234
Panicle per meter square	-0.239	-0.103	-0.007	0.394	0.569
Plant height	-0.370	0.162	-0.059	-0.246	-0.240
Leaf length	-0.264	0.257	-0.186	0.516	0.229
panicle length	-0.148	-0.097	-0.484	-0.097	0.184
Iron toxicity score	-0.382	-0.049	-0.111	-0.024	-0.326
Gall midge count	0.125	-0.216	-0.067	-0.540	0.438
Number of tillers.	-0.335	-0.002	0.531	0.097	-0.139

4.1.12: Loading plot of first and second component using morphological traits of 2010 trial.

The loading plot of first and second component showed that weight of 1000 grain and leaf width showed more degree of variation compared to the other parameters. Leaf length and phenotypic acceptability, number of tillers and panicle per meter square showed more similarity (Fig 4.6)

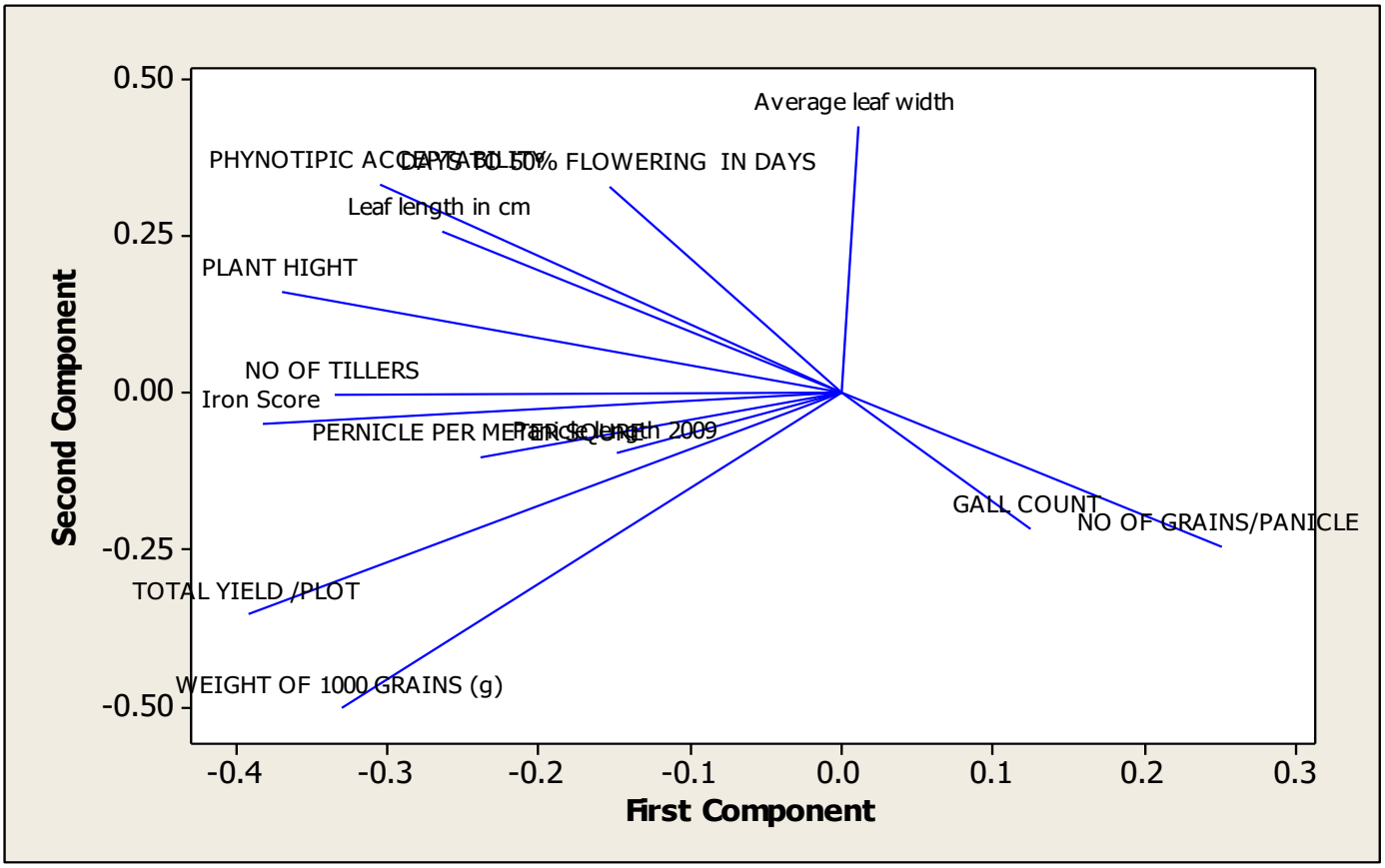

Fig 4.6: Loading plot of morpho-agronomic traits, 2010.

4.1.13: Scattered diagram of first and second component using morphological traits from 2010 trial.

The scatted diagram using the first and second principal component is as shown in fig 4.7. The fig shows variations among the entries. Varieties 29, 14, 12, 10, 31, 22, 21, 32, 38 are in the first quadrant; varieties 20, 26, 27, 37, and 19 are all in the second quadrant, while verities 13, 5, 41, 8, 7, 40, 44, 42, 43, 45, 47, 48, 49, 18 are found in the third quadrant and varieties 6, 33, 2, 4, 11, 15, 25, 3, 17, 9, are in the fourth quadrant (Fig 4.7). However, varieties in the same quadrant denote that they are more similar but varieties like 38, 37, 19, 18, and 47 irrespective of their quadrant have more degree of variation from the mid point meaning

that they defer more from other varieties. Also there are fusion of varieties such as 22 and 31; 43 and 45; 42 and 44 meaning that the fused varieties have very close genetic relationship amongst all the tested entries.

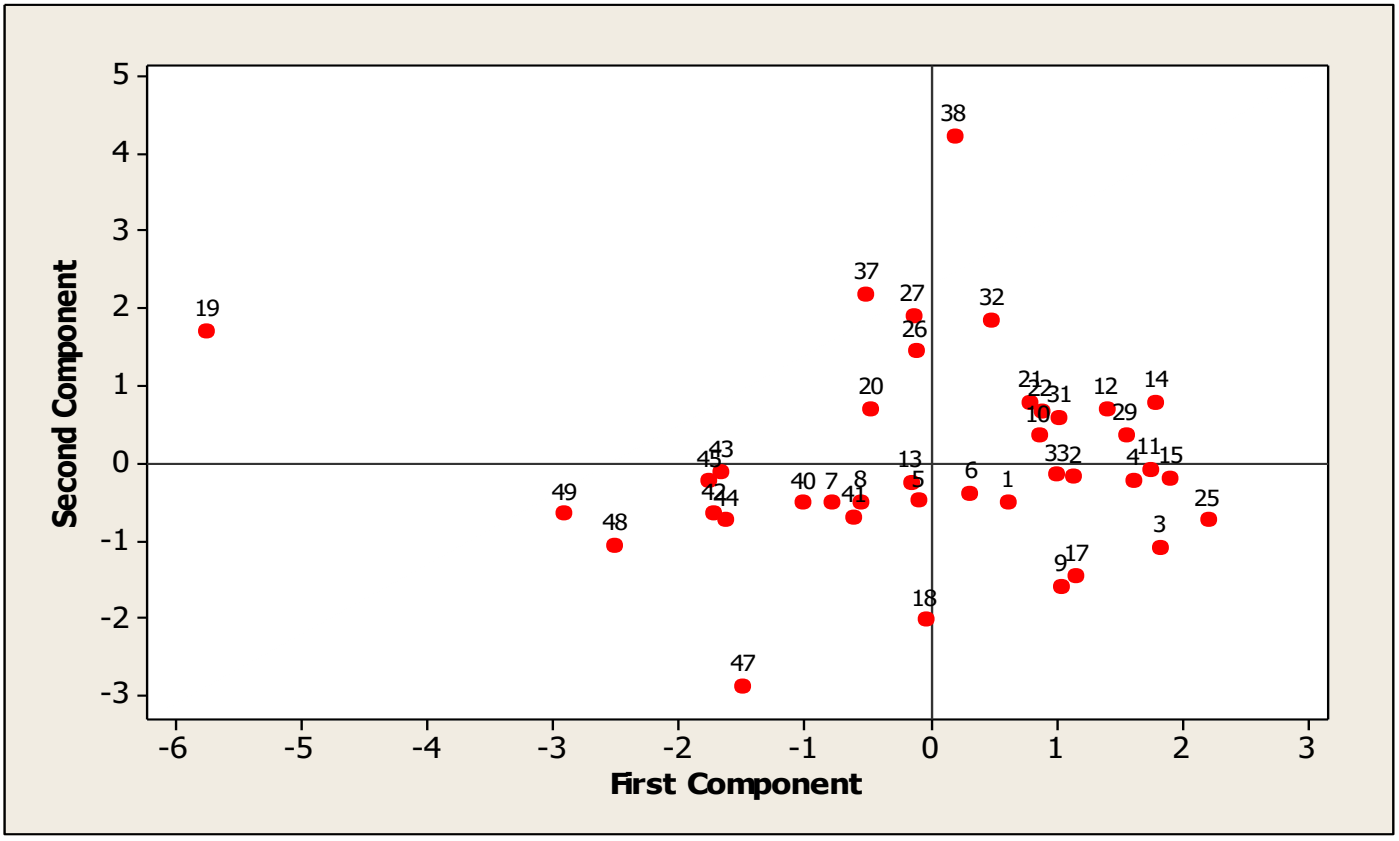

Fig.4.7: Scatter diagram showing the position of individual varieties 2010.

4.1.14: Principal components analysis for two years combined.

The principal component analysis and percentage contribution of each component to the total variation in the two years combined showed that the first principal component accounted for 17.8% of the total variation with only NGP (0.138) (Table 11 a and b), contributing positively to the variation. The remaining variables contributed negatively to the variation. The second principal component showed 14.20% of the total

variation. The major characters that contributed to the second component include LL (0.345%), PA (0.439)

and LW (0.344). NOT (0.116), PH (0.117) and DAF (0.157) contributed least. 1000 GW, TYP, NGP, PAM, PL, Iron and Gall contributed negatively. The third principal component accounted for 12.8% of the variation. PH 90.393), LL (0.226), PL (0.201) and iron toxicity score (0.153) are the major contributors to the variation. TYP, NGP, PA, DAF, LW, PAM, Gall midge and NOT contributed negatively to the variation. The fourth principal component showed 10.9% of the total variation in the population. 1000GW, TYP, NGP PAM, and NOT contributed positively to the variation. DAF, PA, LW, PH, PL, Iron toxicity score and Gall midge count contributed negatively to the variation. The fifth component contributed 9.6% of the total variation. Variables like DAF, PAM, LL, and PL Gall and NOT contributed positively to the variation. The entire five principal components accounted for 65.4% of the total variation observed.

Table 4.11a: Morphological traits and percentage of total variation of the principal component analysis. Two years combined

PRIN	EIGEN VALUE	PERCENTAGE	CUMMULATIVE
1	2.3203	17.8	17.8
2	1.8491	14.2	32.1
3	1.6699	12.8	44.9
4	1.4167	10.9	55.8
5	1.2462	09.6	65.4
6	0.9776	07.5	72.9
7	0.7919	06.1	79.0
8	0.7220	05.6	84.6
9	0.5855	04.5	89.1
10	0.4851	03.7	92.8
11	0.3760	02.9	95.7
12	0.2343	02.5	98.2
13	0.2354	01.8	100

Table 4.11b: Component (Eigen values), total variation accounting for 65.4% of variable combination to the first five principal components. Two years combine

Variables	PC1	PC2	PC3	PC4	PC5
Weight of 1000 grains	-0.240	-0.492	0.054	0.063	-0.160
Total yield per plot	-0.423	-0.347	-0.005	0.061	-0.197
Number of grain /panicle	0.138	-0.133	-0.440	0.313	-0.248
Days to 50% flowering	-0.246	0.157	-0.016	-0.272	0.294
Phenotypic Acceptability	-0.301	0.439	-0.060	-0.107	-0.168
Leaf width	-0.005	0.344	-0.215	-0.401	-0.204
Panicle per meter square	-0.284	-0.008	-0.414	0.257	0.427
Plant height	-0.362	0.117	0.393	-0.154	-0.055
Leaf length	-0.193	0.345	0.226	0.495	0.222
panicle length	-0.002	-0.246	0.201	-0.108	0.618
Iron toxicity score	-0.400	-0.205	0.153	-0.156	-0.218
Gall midge count	-0.001	-0.191	-0.373	-0.512	0.321
Number of tillers.	-0.429	0.116	-0.415	0.0126	0.018

4.1.15: Loading plot of first and second component using morphological trait for two years combined.

The loading plot of first and second component using morphological trait showed that leaf width, Number of grains per panicle, Gall count and weight of 1000 grain showed more degree of variation compared with the other parameters (Fig. 4.8)

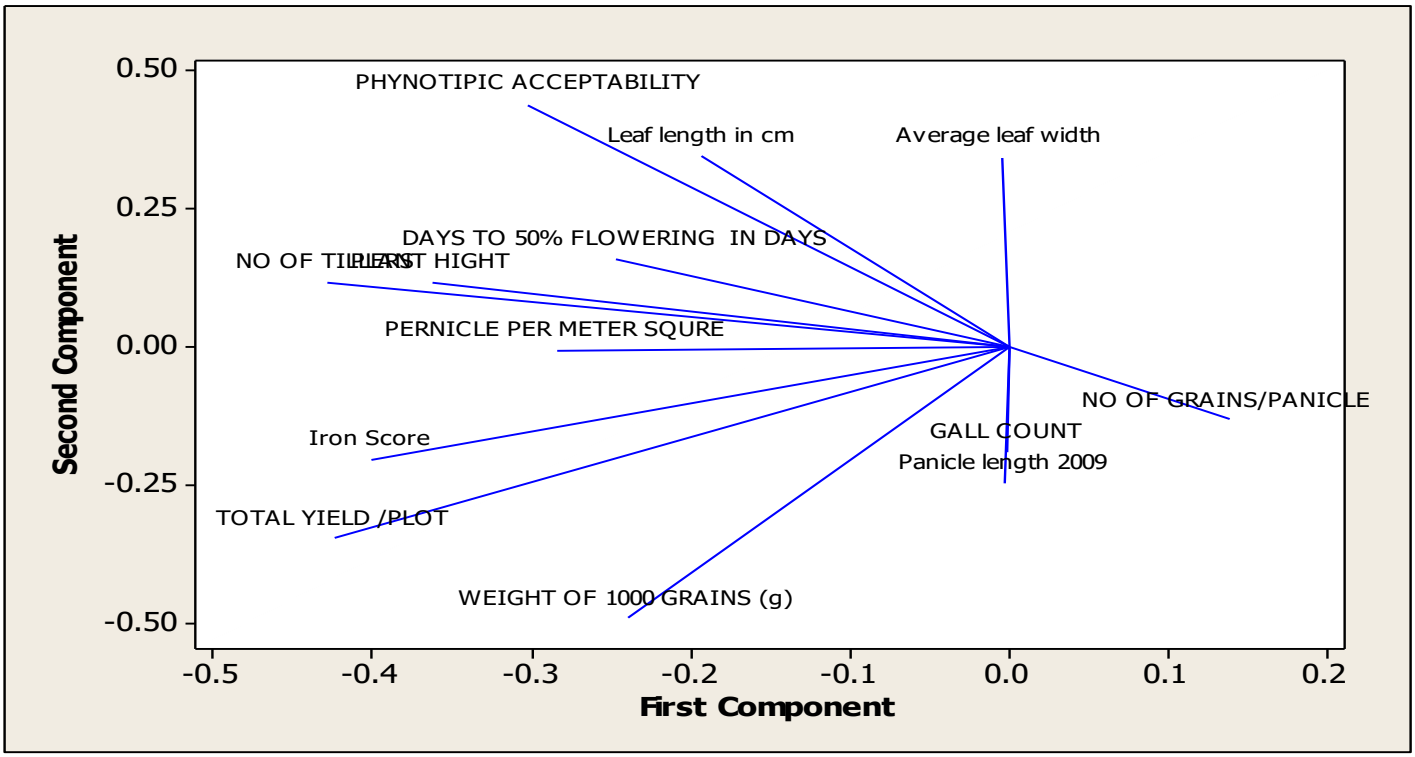

Fig. 4.8: Loading plot of morpho-agronomic traits, two years combined.

4.1.16: Scattered diagram of first and second component using morphological traits for two years

combined.

The scattered diagram of first component against the second component showed that the varieties are at different levels of variation and similarity. Varieties 14, 10, 4, 12, 22, 21, 32 and 38 are all in the first quadrant, while 20, 5, 26, 27, 37 and 19 are in the second quadrant. The third quadrant had varieties 47, 43, 44, 7, 49, 48, 42, 41, 1, 45, 13, 8, 40, 33 and 42 indicating the quadrant with high numbers of local variety (Fig 4.9). The fourth quadrant comprises of 6, 11, 25, 17, 18, 29, 12, 4, 9 and 3.

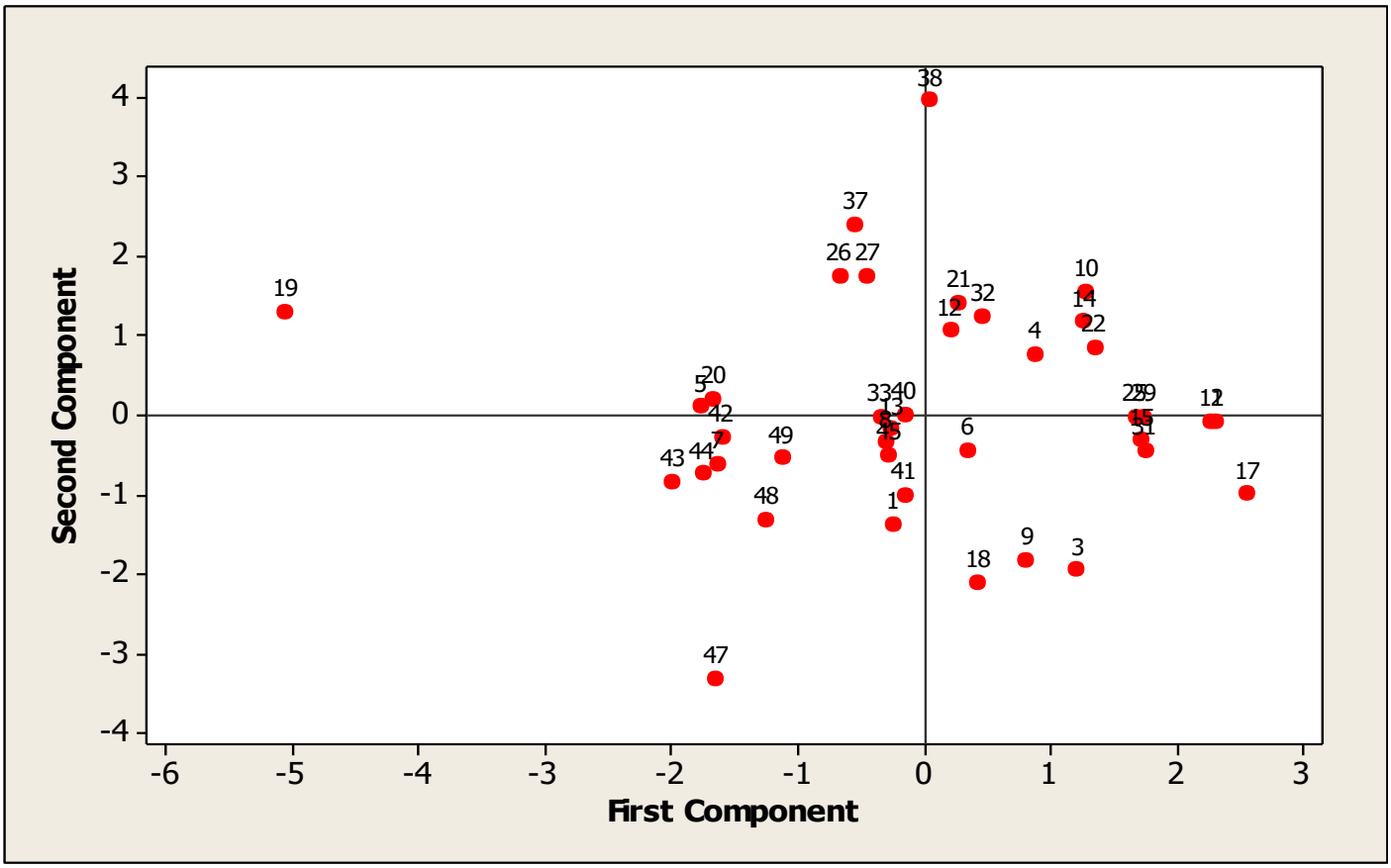

Fig.4.9: Scatter diagram showing the position of individual varieties in two years combined trial.

4.1.17: Reaction of varieties to iron toxicity

Table 4.12 and 4.13, Shows the reaction of the test entries to iron toxicity. Results showed that four improved and one local variety was resistant. At the score rate of 3 (moderately resistant) there is a mixture of improved and local varieties. At 60 DAT the result showed that majority of the entries had resistant reactions. In the 2010 result, only five local varieties were found to be in score 3 (moderately resistant) at 40 DAT. Most local entries were found to be moderately susceptible (score 5).

Table 4.12: Reaction of Varieties to Iron toxicity in 2009 trail

40 DAT Score	Name of Variety
0	NIL
1	FARO 37, FARO 12, NCRO 49, ROK 5, Mass (5)
3	FARO 19, FARO 30, FARO 27, FARO 44, FARO 15, FARO 39, FARO 48, FARO 29, FARO 22, FARO51, FARO 52, NERICA L20, FARO 40, NERICA L36, CK 73, WITA 8, FARO 31, Manbechi, Ndawozdufugi, Bokuchi, Dokochi, Tomawawagi, Babawagi, Shagari, Eyawawagi, Finiko Danboto, Ibrahim Tsadu, (28)
5	FARO 31, Ebagichi, Danmale, Ekachi, Toma, Suakoko. (6)
7	NIL
9	NIL
60 DAT	
0	NIL
1	FARO15, FARO 37, FARO 30, FARO 27, FARO 44, FARO 39, FARO 48, FARO 29, FARO 22, NCRO 49, NERICA L20, ROK 5, FARO 40, FARO 21, WITA 8, Ebabichi, Ndawodzufugi, Bokuchi, Dokochi, Tomawawagi, Babawagi, Mass, Shagari, Eyewawagi, Finiko, Ibrahin Tsadu Ekachi Toma Suakoko 8.(29)
3	FARO 19, FARO 12, FARO 51, FARO 52, NERICA L36, CK73, FARO 31, Manbechi, Danmale, Danboto, (10)
5	NIL
7	NIL
9	NIL

Table 4.13: Reaction of Varieties to Iron toxicity in 2010 trail

40 DAT Score	Name of Variety
0	NIL
1	NIL
3	FARO 37, FARO 27,FARO 44, FARO 12, FARO 15, FARO 39, FARO 48, FARO 29, FARO 51 NCRO 49 FARO 52, NERICA L20, ROK 5, FARO 40, FARO 21, CK 73, WITA 8, FARO 31 FARO 22, Ebagich, Ndawodufugi, Bokuchi, Dokochi, Danboto Damanle, Toma. (27)
5	FARO 19, FARO 30, Mambechi,Tomawawagi, Babawagi, Mass, Shagari, Finiko, Ibrahim Tsadu, Ekachi, Suakoko 8. (10).
7	NERICA L36, Eyewawagi (2).
9	NIL

60 DAT

0	NIL
1	FARO 30, FARO 27, FARO 44, FARO 12, FARO 15, FARO 39, FARO 48, FARO 29, FARO 22, FARO 51,NCRO 49, NERICA L20, ROK 5, FARO 40, FARO 21, WITA 8, FARO 31, Mambechi, Ebagichi, Ndawodzufugi, Bokuchi, Dokochi, Tomawawagi, Babawagi, Mass, Shagari, Eyewawagi, Danboto, Ibrahim Tsadu, Toma, Suakoko 8 (31).
3	FARO 19, FARO 37, FARO 52, NERICA L36, CK 73, Finiko, Danmale, (7)
5	NIL
7	NIL
9	NIL

4.1.18: **The reaction of varieties to AfRGM** in 2009 trial

At 42 DAT in 2009 most entries were susceptible; none of the entries had score of 0 or 1 that is none was resistant. Six entries had a score of 3. At 62 DAT two entries had a score of 1 (resistant reaction) they are Ndawozdufugi and Babawagi. (Table 4.14).

Table 4.14: Reaction of varieties to AfRGM in 2009 trial.

42 DAT Score	Name of variety
0	NONE
1	NONE
3	FARO 37, FARO 15, NERICA L36, Ndawozdufugi, Finiko, Suakoko 8(6)
5	FARO 27, FARO 39, FARO 29, FARO 40, CK 73, FARO 31, Manbechi, Toma(8)
7	FARO 19, FARO 30, FARO 44, FARO 12, FARO 48, FARO51, NCRO 49, NERICAL20, FARO52, FARO 21, WITA 8, FARO 22, Ebagichi, Bokuchi, Dokochi, Tomawawagi, Babawagi, Mass, Shagari, Eyewawagi, Danmale, Danboto, Ibrahim Tsadu, Ekach.(25)
9	
62 DAT	
0	NONE
1	Ndawozdufugi, Babawagi.(2)
3	FARO 27, FARO 48, NCRO 49, FARO 30, NERICA L36, FARO 21, CK 73, WITA 8, Manbechi, Ebagichi, Bokuchi, Dokochi, Shagari, Finiko, Danboto, Ibrahim Tsadu, Suakoko 8(17)
5	FARO 19, FARO 44, FARO 15, FARO 52, ROK 5, FARO 40, FARO 31, Mass, Eyewawagi, Toma FARO 37, FARO 39, FARO 51, FARO 22, NERICA L 20, Danmale.(16)
7	FARO 12, FARO 29, Tomawawagi, Ekach(4)
9	NONE

4.1.19: The reaction of varieties to AfRGM in 2010 trial

In the 2010 at 40 DAT no entry scores 0 or 1. Six entries, five local and one improved showed a moderately resistant reaction. Most entries are moderately susceptible. At 60 DAT only one entry showed a moderate resistance reaction. The remaining entries had the score range of 5 and 7.

Table 4.15: Reaction of varieties to AFRGM in 2010 trial.

42 DAT Score	Name of variety
0	
1	
3	WITA 8, Bokuchi, Babawagi, Danmale, Danboto, Ibrahim Tsadu.(6)
5	FARO 30, FARO 12, FARO 15, FARO 39, FARO 48, FARO 29, FARO 29, NCRO 49, FARO 52, NERICA L20, ROK 5, FARO 40, NERICA L36, FARO 21, CK 73, FARO 31, FARO22, Manbechi, Ebagichi, Ndawozdufugi, Dokochi, Tomawawagi, Mass, Shagari, Eyewawagi, Finiko, Ekach, Toma, Suakoko 8 (29)
7	FARO 27, FARO 19, FARO 37 FARO 44, (4)
9	
62 DAT	
0	NONE
1	NONE
3	FARO 37 (1)
5	FARO 19, FARO 44, FARO 39, FARO 29, NCRO 49, NERICA L20, FARO 21,FARO 22, FARO 48, CK 73, WITA 8, Ebagichi, Ndawozdufugi, Dokochi, Babawagi, Shagari, Bokuchi, Eyewawagi, Finiko, Danmale, Danboto, Ibrahim Tsadu, Toma, Suakoko 8 (24)
7	FARO 12, FARO 15, FARO51, FARO 52, ROK 5 , FARO 40, NERICA L36, FARO 31, Manbechi, Tomawawagi, Mass, Ekach, FARO 30, FARO 27 (14)
9	NONE

4.2 DISCUSSION

The result of the analysis of variance showed that leaf width, iron toxicity at 20 DAT and total yield per plot were significant in the two year trials. Gana (2006) in his work find out that iron toxicity is significant at 60 DAT.

The cluster analysis using complete linkage method of the morphological traits for two years combined showed the relationship that exists amongst the entries which produces three main clusters. This implies that the three main cluster groups have peculiar characteristics. However the subgroups from the main cluster showed that the entries might have evolved from the same ancestor. According to Awopetu and Gana (2006), rice within the same cluster evolved from the same ancestor. Varieties 3 and 43, 8 and 42, 7 and 44, 13 and 33, 11 and 31 and 18 and 47 are local and improved varieties joined at different level of similarities. Awopetu, (1982) pointed out that entries from the same location might have evolved similar growth forms, which after influenced the pattern of fusion. The grouping of these local and improved varieties may suggest that some local varieties are actually improved with different local names. However mechanical mixture and long term exchange of seeds from one farmer to the others may also be responsible for their characters positions.

The principal component analysis (PCA) of the two years combined reveals the total contribution of characters to the variation. The first five components accounted for 65.4% of the total variation. Characters with high variability are expected to provide high level of gene transfer during breeding programs (Gana 2006). This conforms to the findings of Aliyu *et al.,* (2000), that individual with genetic affinity will provide low gene transfer.

The scattered diagram derived from the PCA of two years combined showed variation amongst the entries. Entries 38, 19 and 47 irrespective of their quadrant showed distant relationship to the other entries. Also the

loading plots of the first and second component showed the degree of variation that exists within the components. Leaf width, Number of grains per panicle, Gall cunt and panicle length showed more variation.

Reaction of the entries to Iron toxicity showed that very few entries including a local variety showed resistant reaction. Most entries had score of 3 (moderately resistant). However the score in the population was between 1 and 5 which are mixture of improved and local varieties. According to WARDA (2001-2002) local varieties that are grown and selected by farmers for many years tends to have a measurable level of iron toxicity resistance. Iron tolerant cultivar absorbed less iron from the root to the leaves. Also, at any given concentration of iron in the leaves net photosynthesis rate were lower in iron-toxicity susceptible than in the iron-toxicity tolerant cultivar. (Audebert and Sahrawat 2000)

Response of the materials to AfRGM showed high level of infestation. During the first year trial, most entries had scores of 7 meaning that they were susceptible. No entry scored 0 or 1 and none was highly susceptible (9). Gana (2007), in his study find out that at 43 DAT AfRGM infestation score was between 7 and 9 (Susceptible and highly susceptible). At 62 DAT two local varieties (Ndawodufugi and Babawagi) had low tiller damage of less than one percent. It was observed that tiller damage at 62 DAT was lower than at 42 DAT. In the second year, the rate of reaction was scored between 3 and 7 at 42 DAT and 62 DAT (tiller damage above 11%), indicating that there was variation also in the second year. Percentage tiller infestation is commonly used to measure the level of infestation in rice crop (IRRI, 1996). Nwilene *et al*., (2002) finds out that the difficulty in identifying source material with stable resistance to AfRGM may be due to rice genotype differing in their reaction to genetically diverse pest population. Also Williams *et al*., (1999) concluded that AfRGM population at different locations has genetic differences that affect their ability to overcome host resistance. This result therefore indicates that the percentage level of midge infestation is high where this experiment was sited. Hence, Williams et al., (2002) stated that at infestation

levels from 0% to about 30%, increase percentage tiller damage by 1% could reduce yield to about 2 to 3%. This as well agrees with the findings of Singh *et al*., (1997) and NCRI, (2000) that this area is known to be AfRGM endemic area.

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

In most breeding programs, morphological traits are always indicators for breeding objectives.

However continuous evaluation should be done to broaden the genetic base of the species. The dendogram exposed the relationship that could be used as bases for parental selection during breeding program. The variation that exists within the population studied provides opportunity for improvement. Diversity pattern expressed by the scattered diagram and loading plot provide bases for selecting cultivars with diverse morphological variation. The grouping based on cluster analysis present cultivars in their smaller unit with specific character. This disallows using varieties with similar genetic background.

5.2 RECOMMENDATION

- NERICA L36 and Mass varieties showed low level of similarity amongst other entries they could therefore be used for breeding purposes.
- Ndawodzufugi and Babawagi varieties that showed resistant reaction could be subjected to further screening to ascertain their actual level of tolerance.

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