POTENTIAL OF RICE (*Oryza spp.*) STRAW AS FODDER FOR WEST AFRICAN DWARF SHEEP

BY

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DEDICATION

This work is dedicated to:

My Lord and Saviour, Jesus Christ,

and to the memory of my mother, Janet Adeyoola Modupeola Odu.

CERTIFICATION

I certify that this work was carried out by Olatunbosun ODU in the Department of Animal Science, University of Ibadan, Ibadan.

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ABSTRACT

Conventional feedstuffs have not met the increasing demand of livestock industry. Rice plant, a food-feed cereal, can provide grains for humans and fodder for livestock. The potential of Rice Straw (RS) as fodder for sheep in Nigeria has not been adequately documented. Therefore, the potential of RS as fodder for West African Dwarf (WAD) sheep was investigated in this study.

Using Lattice design, 49 rice varieties of five cultivars: Interspecific Upland (IU), Interspecific Lowland (IL), *Oryza sativa* Upland (OsU), *Oryza sativa* Lowland (OsL) and *Oryza glaberrima* (Og) were assessed in hydromorphic ecology for Grain Yield (GY tonne/ha), Straw Yield (SY tonne/ha), Harvest Index (HI), Tillers Per Square Metre (TPSM) and Plant Height (PH). Straw samples were analysed for nitrogen, Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF), Metabolisable Energy (ME), *in-vitro* Organic Matter Digestibility (OMD), ash and silica contents using standard procedures. In a completely randomised design, 20 WAD rams were used to assess Voluntary Dry Matter Intake (VDMI) and Dry Matter Digestibility (DMD) of NERICA-14 (IU), NERICA-Lowland-20 (IL), ITA-321 (OsU), Cisadane (OsL) and CG14 (Og). Data were analysed using descriptive statistics and ANOVA at $\alpha_{0.05}$.

The GY of IL (3.6±1.0) and OsL (3.6±1.2) were higher than for IU (2.1±0.9), OsU (2.2±1.0) and Og (1.7±0.7). The SY of Og (5.0±2.6) was similar to 4.6±1.6 for OsL, but higher than 4.2±1.5, 2.7±1.0 and 3.0±1.2 for IL, IU and OsU, respectively. The HI of IL (0.46±0.07) was similar to 0.44±0.08 (OsL) but higher than 0.43±0.09 (IU), 0.42±0.09 (OsU), and 0.28±0.11 (Og). The TPSM of the cultivars ranged from 161.7 m^{-2} to 493.8 m^{-2}, with Og having the highest value of 493.8±207.4 m^{-2}. The PH of the cultivars ranged from 102.2 to 124.0 cm, with Og and OsU having higher values of 124.0±34.2 cm and 122.5±19.9 cm, respectively. Nitrogen of IL (0.91±0.28 %), IU (0.89±0.32 %) and OsU (0.87±0.32 %) were similar but higher than 0.82±0.31 % (OsL) and 0.83±0.24 % (Og). The NDF of OsL (67.1±2.5 %) was similar to Og (66.7±3.9 %), OsU (66.6±2.5 %) and IU (66.4±2.3 %); but higher than that of IL (65.9±2.5 %). The ADF and ME ranged from 48.7-51.5 % and 6.1-6.7 MJ/kg, respectively. The OMD of IU (46.1±5.3 %) and OsU (46.7±5.8 %) were significantly higher than values for OsL (44.6±6.1 %), IL (44.9±5.9 %) and Og (43.6±4.3 %). The ash content of IL (18.6±0.4 %), IU (18.8±0.3 %) and Og (19.4±0.7 %) were higher than 17.7±0.5 % and 17.6±0.5 % for OsU and OsL, respectively. The silica content of Og, 14.3±0.5 % was similar to 13.7±0.2 % for IU but higher than 13.4±0.3 %, 13.2±0.4 % and 12.9±0.3 % for IL, OsU and OsL, respectively. The VDMI (47.9-57.4 $gKg^{-1}BW^{0.75}day^{-1}$) and DMD (30.2-44.7 %) of WAD rams were similar among the varieties.

The grain and straw yields for the rice varieties were high. The voluntary dry matter intake and dry matter digestibility for sheep fed straws of the five representative rice varieties established the potential of rice straw as fodder for West African dwarf rams.

Keywords: West African dwarf rams, Food-feed cereal, Fodder crop, Voluntary dry matter intake, *Oryza spp*.

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CHAPTER ONE

1.0 INTRODUCTION

Tropical countries face a perennial problem of inadequate quality and quantity of ruminant feed, especially during the long dry season. The shortage of animal feed resources and increasing cost of traditional animal feeds have stimulated further emphasis on the utilization of agro-industrial by-products as feedstuffs for ruminant animals in most parts of the world. It is a normal practice in places like India, Vietnam and Bangladesh to harvest and store rice straw after harvesting the grain. Rice straw, a major by-product of rice cultivation is a feed resource in many rice-producing countries. It should therefore be getting considerable attention from governments, agencies and farmers' groups/associations who have been promoting increased rice production through increased cultivation. The attendant generation of straw from increased rice production could result in environmental problems if the straw produced is not harnessed for animal feeding. Use of rice straw as animal feed will not only help in mopping up the expected huge amount of straw to be generated as production increases but will also help in increasing livestock production, alleviate poverty and enhance the nutrition profile of sub Saharan Africans.

In South Asia and sub Saharan Africa crop wastes represent between 40 and 60% of all the feed for cattle, sheep, goat and other ruminant animals. Crop residues are important resources for farm animals. The demand to keep most of these resources for animal feeding stops many farmers from adopting conservation agriculture, which requires putting residues back into the soil. Animals consuming crop residues deposit their manure on the soil. Rice straw is a major crop residue. FAO (2014) projected the 2014 global yield of rice to be about 501.1 million tonnes. An earlier report by FAO (1983) indicated that only about 12% of the straw generated is fed to ruminants animals while most of the rest is burnt.

Rice straw availability will continue to increase as countries of West and Central Africa continue to sustain rice production even at the slow rate of 6% production rate per annum

(Africa Rice Centre, 2007). In the last twelve years, the Nigerian government has continually come up with policies to boost local rice production and discourage importation. This trend will likely be heightened with the recent global food challenge and with rice at the centre of world food discourse. As the need to cultivate more food crops for human use increases, availability of common property resources that serve as a source of grasses for livestock will continue to decline. Jodha (1992) stated that due to a decline in area under fallow, pasture and common lands, the availability of grasses has declined. Increasing population pressure on existing arable lands has led to encroachment of the land area under common property resource. The quantity and quality of grasses from the above sources also declined due to overgrazing, and lack of proper maintenance. Currently, rice straw like many other residues of cereals, legumes, vegetables and roots, is underutilized and often poorly managed in Nigeria and other countries of sub-Saharan Africa (SSA). As the arable land per inhabitant of sub-Saharan Africa is declining, there is no doubt that increased food and feed production will have to be met through increased productivity per unit area. Small-scale crop-livestock farmers who constitute the majority of farmers in SSA are finding it difficult to provide enough high quality forage for their animals. Native grasslands are often over-utilized and fallows are in the decline. Portions of land cultivated with improved perennial pasture species are hard to find in small scale farming systems. This scenario necessitates the imperativeness for more emphasis on, and the development of dual-purpose rice among other needs to meet the challenges of productivity per area and to meet the increasing meat and meat product requirement in sub-Saharan Africa.

Rice straw is unique relative to other cereal straws being low in lignin and high in silica. However, unlike other cereal straws the leaves are less digested than stems. Breeding efforts have been channelled towards developing short varieties. This development has reduced straw quantity but not the nutritive value (Van Soest, 2006). Identification and the development of rice varieties with good grains as food and sufficient, good quality fodder for animals will minimize the cost and losses incurred by herdsmen who have over time solved the problems of seasonal shortage of forage experienced in northern Nigeria by migrating to the southern region in search of pasture. Small scale, mixed crop-livestock farmers are the dominant farmers in Nigeria likewise in the entire sub-Saharan Africa. These categories of farmers depend largely on crop residues as source of roughages for ruminant livestock. Thornton *et al*. (2002) described this system as being more important than any other system in terms of their contribution to the total output of animal products in Sub Saharan Africa, involving more than 200 million poor people. Lenne and Thomas (2005) suggested the need for system-based approaches to more efficient and effective use of farm-produced fodder in African crop-livestock system, which should meet the increased demand for animal product and reduce poverty.

The most practicable option in developing countries is often for farmers to feed their crop residues to ruminant animals and then fertilize soils with the animals' manure. The farm animals provide poor farmers with many other essentials as well, including highly nourishing animal protein for the household, much needed year round cash, draught power, transport and other inputs for successful cropping. The utilisation of rice straw as fodder will also minimise the possible negative environmental impact of generation of straw from rice production in line with one of Millennium Development Goals to ensure environmental sustainability.

Doyle *et al*. (1986) reported the range of *in vitro* digestibility of rice straw as 30 – 55%. This wide range is a as result of variations in the contents of rice straw from different varieties. The cell wall constituents, measured as neutral detergent fibre (NDF) of some varieties may be as high as 86%, which implies that digestible cell content in such varieties are as low as 14%. The wide variation in crude protein content and some other constituents of rice straw also influence digestibility of such straws. Crude protein (nitrogen) levels of forages influence the extent of microbial degradation. Ibrahim *et al*. (1984) reported *in vitro* organic matter digestibility of 40% for straws of rice varieties in Sri Lanka, while Sannasgala *et al*. (1985) reported a range of 34 – 42% in three (3) Sri Lankan varieties. Roxas *et al*. (1984) reported a range of 30 – 46% in 15 varieties in the Philippines. Doyle *et al*. (1986) estimated a mean dry matter digestibility of rice straws of 43% by sheep from values obtained by various authors in Malaysia, Korea DPR, Australia and Thailand.

The two factors which limit rice straw digestion by ruminants are the low nitrogen content and the resistance posed by lignocellulosics. Various rice straw treatment approaches ranging from physical, chemical and biological methods are applied to boost straw utilization by ruminants in a bid to increase production of derivable products.

1.1 General objective

This study is aimed at documenting straw yields and fodder qualities (of the straws) of 49 rice varieties (which included 19 upland and 12 lowland inter-specific accessions, 6 upland and 8 lowland *Oryza sativa* and 4 *Oryza glaberrima* varieties) and their grain yields. It is also aimed at determining the voluntary intake and the digestibility of straws of rice varieties by WAD sheep.

1.2 Specific objectives

The study has as its specific objectives:

1. to compare grain and straw yield of some NERICA varieties, their parents and other commonly cultivated (released) varieties in Nigeria.

2. to determine the nutritional composition of the different varieties of straw using the Near Infra-red Reflectance Spectroscopy (NIRS).

3. to identify Nigerian rice farmers' considerations and attitude in choosing rice varieties for cultivation and the extent of current usage of rice straw for livestock feeding.

4. to investigate voluntary dry matter intake and digestibility of the straws of five (5) rice varieties by the West African dwarf ram.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The rice plant

The rice plant is an erect, semi-aquatic annual grass with an average height of 1.2 metre. The height of most varieties ranges from about 0.4 metre in dwarf varieties to 5 metre. Some floating varieties are also known to grow up to 7m tall. Rice can survive as a perennial plant, producing new tillers from nodes after harvesting; this phenomenon is known as ratooning. The plant has many variations with an average life span of 3 to 7 months depending on climate and variety. The rice plant has round and hollow stem, flat leaves, and panicles at the top of the plant. Rice grows well under both flooded and rain-fed conditions.

Cultivated rice, *Oryza sativa* L. ("Asian rice") and *O. glaberrima* ("African rice") are species from the genus Oryzeae which belongs to the Poaceae family. *O. sativa* is of Asian origin comprising of two types, the Indica and the Japonica. The Indica has long, wide to narrow, light green leaves and tillers very profusely. Its long and thin grains are borne on panicles that bear several small branches on the panicle which also bear grains. The Japonica type has light green leaves and tillers less vigorously compared to the Indica.

Oryza glaberrima originates from the inland delta of the river Niger. Its leaves are glabrous, while the glumes are smooth and hairless. *Oryza sativa* is cultivated more than the African species (*O. glaberrima*), mainly because of its higher yield potential (Wopereis *et al*., 2008).

2.2 The vegetative and the reproductive organs of the rice plant

2.2.1 The vegetative organs of the rice plant

The roots anchor the rice plant and are fibrous, having rootlets and root hairs. The secondary adventitious roots are produced from the underground nodes of the young culms. The rice root system is relatively shallow (Wopereis *et al*., 2008).

The stem is made up of a series of nodes and internodes. The internodes are hollow and smooth-surfaced. Each node has a leaf and a bud that can develop into a tiller. The lower internodes are shorter than the upper ones. The stem transports nutrients and takes air to the roots. The robustness and height of the stems are criteria affecting resistance to lodging. Other stems often originate from the nodes of the main stem. These are called secondary tillers. They also can grow and in turn produce tertiary tillers (Wopereis *et al*., 2008).

The leaves grow in alternate arrangement on the stem with only one leaf growing on each of the nodes. The last leaf (topmost), referred to as the flag leaf, wraps itself on the panicle while the sheath wraps the stem. The auricle and ligule are found at the junction between the leaf and the collar. The auricle is a 2-5mm crescent-shaped, hairy appendix. The ligule is a membrane whose length and shape varies with species and variety (Wopereis *et al*., 2008).

2.2.2 The reproductive organs of the rice plant

The terminal shoot of the rice plant is the inflorescence, the panicle. A spikelet is the unit of the inflorescence. The spikelet consists of the rachilla and the floret. The panicle is borne on the last internode. A single panicle can bear between 50 to 500 spikelets. The length and shape of the panicle varies in the different varieties. The rice plant is self-fertilizing (autogamous). The flower is made up of the male reproductive organs (pollen-bearing anthers) and the ovary (female organ). The rice grain is made up of glumes which are above the pedicels and link the spikelets to the secondary ramification with two husks called palea and lemma. The awns are prolonged portions of the ventral vein of the lower husk, which varies in length depending on variety and may be almost absent in some varieties. The husk wraps the rice grain. The endosperm feeds the embryo during germination (Wopereis *et al*., 2008).

2.3 Rice production in Nigeria

In Nigeria, over 2 million hectares of land is put to rice cultivation (FAOSTAT, 2000) with a yield of over 1.8 tons per hectare. Rice (*Oryza spp*.) is cultivated in virtually all the agro-ecological zones in Nigeria, but on a relatively small scale. Rice is an increasingly important crop in Nigeria. Its cultivation has become a tradition for some families and communities. Rice has become part of the everyday diet in many Nigerian homes (ODI, 2000).

As at 2000, 54 rice varieties have been released to serve the different ecologies and other specific needs in Nigeria (FAO, 2000). The Africa Rice Centre (ARC) developed a range of upland and lowland rice varieties for different ecologies known as NERICA (New Rice for Africa). NERICA varieties are products of crossings between African rice (*Oryza glaberrima* Steud) and Asian rice (*O. sativa* L.).

The highest hectarage under cultivation is in rain-fed lowland while the lowest is under mangrove swamp. On the basis of geographical zone, the central zone is the largest producer of rice in Nigeria; accounting for 44 per cent of the total rice output in 2000 followed by the Northwest with 29% and the Southwest with 4% (FAOSTAT, 2005). The main production season in the south is April-May, for planting and August-October for harvesting while it is June-July, for planting and November-December for harvesting in the north. Off-season production is from November-December for planting and March-April for harvesting in the south and January-February, for planting and May-June, for harvesting in the north (Maclean *et al*., 2002). The prevalent types of rice production systems in Nigeria include rain-fed upland, rain-fed lowland and irrigated lowland. Other less common rice production systems include deep water and mangrove rice (Singh *et al*., 1997)

Upland rice cultivation is an important rice production system in Nigeria and it accounts for 30% of the total area under rice. Rainfall is the only source of water generally limiting this system to areas with more than 1,300 mm of annual rainfall. Upland rice is typically intercropped with various other crops, including vegetables, maize, yam or cassava and it is predominant in the southern part of Nigeria but can also be found in the north. Rain-fed lowland rice is the most important system in Nigeria and accounts for approximately half of total rice area in Nigeria. This system is found mainly along the flooded river valleys such as the Niger basin, Kaduna basin and Benue basin of the northern states and in some eastern states as well. In most of these areas, the riverbanks or Fadamas are usually flooded during the rainy season, which lasts for 4-5 months. Only one crop is planted in a year, and there is no water control. Irrigated rice systems on the other hand became important during the late 1970s and 1980s with substantial government investment. They include lowlands with good water control, enabling two crops per year and have yields generally higher than in other systems. Deep water rice system can generally be defined as those where flooding achieves a depth of 60-100 cm, and floating rice system as those where flooding exceeds 100 cm (Akpokodje *et al*., 2001).

2.4 Utilization of rice straw in Nigeria

Rice straw is a major source of dry forage to the livestock of Nigerian pastoralists. Reports on the use of rice straw as fodder in Nigeria are limited**.** Rice straw yield from rice fields has records of large variation in yields from as low as 2.9 to 9.4 $tonha^{-1}$ (Summers *et al.*, 2001). Doyle *et al.* (1986) gave the total straw generated in Nigeria per annum in 1983 to be 1 million metric ton. Baba and Magaji (1998) in a survey on the use of crop residues by Fadama farmers and pastoralists in Sokoto and Zamfara States found that of the 54 Fadama farmers and 11 pastoralists, 39% of the Fadama farmers fed their cattle with rice straw, while all (100%) of the pastoralists used rice straw. These workers also reported that crop residues were sold in markets. Mention was made of cowpea, groundnut hay and sorghum straw but not rice straw in crop residues market transactions. Transport cost was also reported to be a major limitation in crop residue transaction due to bulky nature of crop residues.

2.5 General characteristics of rice straw

Rice straw contains about 80% of substances, which are potentially digestible and are therefore sources of energy. The digestibility of rice straw by ruminants is reported to be 45 to 50%. Also because of the slow rate at which it is fermented in the rumen, animals hardly consume up to 2% of their body weight. It therefore can only be used as a replacement for part of the forage ration and should not be used as a complete ration (Drake *et al*., 2002). Poorer animal performance usually occurred when rice straw was the only feed. Straws have at least slight pubescence (small hairs), which affects palatability. Good performance results have only been achieved by improved digestibility and intake by way of various chemical and physical treatments and nitrogen-source supplementation. Rice straw has low crude protein content whose digestibility is poor. It also has high silica content (8 to 15%), which is indigestible and also affects digestibility. Silica accounts for most of the ash content reported for straw, which can be as high as 17%. Rice straw is also high in oxalates, which decreases the absorption of calcium (Drakes *et al*., 2002).

Rice straw contains a relatively high proportion of leaves (60%), compared to other cereals' straws. Proportion of leaves in barley straw is 35%, oat straw has 43% while wheat has between 20-41% (Theander and Aman, 1984). Rice straw leaves contain less neutral detergent fibre than the stem and has more ash, which makes the leaves to have lower *in-vitro* dry matter digestibility (IVDMD) of 50% compared to 61% for the stems (Vadiveloo, 2000).

2.6 Nutritive quality of rice straw

The chemical composition of rice straw is influenced by varieties and growing seasons. Pronounced variability occurs in the contents of some components, but usually the cell wall constituents measured as neutral detergent fibre (NDF), are high (up to 86% of the dry matter). This indicates that the more readily digestible components of the cell contents are often only present in small amounts. Rice straw does not contain enough sugars, amino acids and minerals for efficient microbial growth (Doyle *et al*., 1986). Feeding ruminants with only rice straw, without any supplementation of the other required nutrient sources, will result in poor performance of the animals (Doyle *et al*., 1986).

The combination of low intake, low degradability, low nitrogen content and an unbalanced mineral composition means that rice straw alone may not even meet the animal's maintenance needs. Poor degradability is caused by a series of factors (Schiere and Ibrahim, 1989). The fibre is very difficult to degrade, which is partly an intrinsic characteristic of the straw fibre. Deng *et al*. (2007) reported 19 % lignin, 44 % cellulose, 20.1 % hemicelluloses and 9.8 % ash contents in varieties of rice in China (Table 1); while Jin and Chen (2006) reported values which varied widely from these in some other Chinese rice varieties (Table 1). The degradation of the straw fibre is also complicated by the poor functioning of the rumen due to the unbalanced availability of nutrients, the low protein content, lack of easily available energy and the low content of essential minerals such as P and S. Due to the low degradability and the poor rate of degradation, animals will tend to consume less. The mechanism regulating voluntary intake of low quality feeds, such as rice straw, is still not fully understood. The generally accepted theory of feed intake regulation for poor quality roughages is that the capacity of the rumen to process the feed is the major factor determining voluntary feed intake (Conrad, 1966; Baile and Forbes, 1974).

While the crude protein content is usually low (mean 4.1 %) there is a considerable range in the reported values (2.2 to 9.5 %). In rice straw collected from farms, that is, not including those from research stations, the crude protein content is below that required to maintain ruminants and it is taken for granted that nitrogen supplementation would be needed to ensure reasonable levels of intake and digestion. Hence, rice straw is looked on primarily as a source of energy yielding substrate (Doyle *et al*., 1986).

Shen *et al.* (1998) reported higher nitrogen and cellulose contents in rice grown during early seasons compared to late reasons rice. Rice straw consists predominantly of cell walls; and this is made up of cellulose and hemicellulose and lignin. Ruminants do not secrete the enzymes required to hydrolyse these components. The microbial population in the reticulorumen of ruminants produces cellulase and hemicellulases, while ligninase is not produced by these microbes. Lignin cannot be broken down in the rumen due to the inability of the reticulorumen, or the microbial population to produce ligninase.

Other factors that influence the nutritive quality of cereal straws and other crop residues, including rice straw are crop variety, tannin content, stage of harvest, length of storage, leaf to stem ratio, soil fertility and fertilizer application, as well as the effects of agronomic practices such as irrigation (Olaloku and Debre, 1991).

Table 1: Chemical composition of rice straw (%)

Country	Lignin	Cellulose	Hemicelluloses	Ash	References
China	19.0	44.0	20.1	9.8	Deng *et al*., (2007)
China	8.6	30.4	32.3	6.3	Jin and Chen, (2006)
Thailand	18.0	44.0	26.0	12.0	Sangnark and Noomhorm, (2004)

Source: Buranov and Mazza (2008).

2.7 Composition of rice straw ash

Ash content of rice straw, which makes it a low quality feedstock, can be as high as 17 %. The silica content of ash in rice straw can also be as high as 75-82 % of total ash. Baxter *et al*. (1996) reported rice straw ash as having an alkali (Na_20 and K_2O) content being less than 15 % of total ash. Mineral content of rice straw is imbalanced. The mineral composition of rice straw like other plants is largely dependent on the availability of minerals in the soil. Calcium and phosphorus contents of rice straw are usually below recommended levels. Crop residue based diets are most likely deficient in sodium, copper and phosphorus (Little, 1985). Most straws are deficient in the same three minerals in addition to sulphur, cobalt and calcium (Preston and Leng, 1986). The high concentrations of oxalates and silicates in some straws, such as rice straw, may further reduce the availability of calcium and magnesium, which are lost as silicates and oxalates in urine and faeces (Smith, 1987).

2.8 Silica in rice straw

Silica level in rice straw has been suggested to be highly dependent on soil type. The rice plant is among several silica accumulating plants. Silicon is the second most abundant element in the lithosphere (Ingri, 1978; Iler, 1978), its abundance made agronomists and nutritionists to overlook its possible metabolic role. It had always been regarded as a passive element. Epstein (1999) raised questions of its essentiality for higher plants. Mengel and Kirkby (2001) showed that there were large responses in rice yield and resistance to fungal diseases with adequate silicon nutrition.

Silica is a structural element in diatoms and a cell wall component in rice and many other grasses. It occurs in the vegetative tissues in lesser amounts (Van Soest, 2006). Electron microscopy scanning has shown that most of the silica deposit in rice straw is in the epidermal layer which is greater in the leaves than in the stems (Balasta *et al.*, 1989; Agbagla-Dohuani *et al.*, 2003; Ha *et al.*, 1994).

Silica is absorbed in the form of orthosilicic acid $Si(OH)_4$ (Ingri, 1978). Most of the silica in rice straw appears to be in the cell wall, but levels in the plant sap have been found to exceed that of the solution, indicating active transport. Jones and Handreck (1967) reported concentrations of between 400-800 ppm $Si0_2$ in xylem sap of rice. Silicic acid readily complexes with 1, 2 dihydradoxybenzenes, such as catechol, caffeic acid, tropolones and tannins to spontaneously form (at room temperature, without enzymes) 3 moles of diphenol per silicon atom (Weiss and Herzog, 1978). Mengel and Kirkby (2001) suggested the existence of such complexes in rice straw while Inanaga and Okasaka (1995) and Inanaga *et al*. (1995) suggests that silicon is bound in lignin-carbohydrate complexes.

2.9 Other uses of rice straw

When rice straw is burnt, the ash produced is described as highly pozzolanic and suitable for use in lime – pozzolana mixes and Portland cement replacement. It is a good partial substitute for cement. Rice straw generates about 15 % ash when burnt and 82 % of the ash is silica (El-Sayed and El-Samni, 2006). Particle board are produced from hammer – milled rice straw mixed with methylene diphenyl diisocyanate (MDI) resin to produce boards in a batch press. Rice straw is also described as being attractive as a potential renewable fuel (energy) source and carbon dioxide neutral (Atchisson, 1976; Jiang, 2007). Straw is inferior to coal (dominant solid fuel in electricity and heat generation). Straw has low energy density and heating value. It is also bulkier (more difficult in handling and transportation). The high alkali content of straw also results in slagging, fouling and grate sintering (Calvo *et al*., 2004; ECN, 2004). Commercial use of rice straw for energy is still not found in many rice producing countries because of the associated costs and lack of incentives or benefit for farmers to collect the straw.

Doyle *et al*. (1986) listed the following as other uses of rice straw:

i) burning
ii) fertilizer for paddy fields
iii) mulch for vegetable production

iv) substrate for mushroom growth

v) fibre subjected to acid hydrolysis and the resulting sugars used for single cell protein production

vi) beddings for livestock and poultry

vii) fibre for paper manufacture or use as construction materials and

viii) fuel to produce heat.

Burning of rice straw and stubble is known to be a common practice throughout Asia. The reasons for this practice includes; reduction of pest and diseases through soil sterilization, facilitation of soil preparation for a second rice crop or for off-season crops, and return of straw-trapped minerals to the soil. It is also practiced to solve the problems associated with the slow decomposition of straw.

Rice straw usage has been studied in Indonesia, Japan and Taiwan. The benefits of ploughed-in rice straw are not sufficiently marked to encourage its adoption by farmers (Lin, 1982). It was suggested to use rice straw first as animal feed and then use the resulting animal waste as fertilizer. Rice straw is used as mulch in vegetable gardens and yam planting operations. This practice keeps weeds suppressed. Rice straw is also used as sole substrate or mixed with other ingredients as growth medium for edible fungi. Fibrous crop residues such as rice straw are utilized for single cell protein production after their hydrolysis with acid (Doyle *et al*., 1986).

Doyle *et al*. (1986) reported that the use of rice straw as beddings for livestock and poultry is common in Asia, particularly when the animals are kept on a floor of earth or rammed clay. Rice straw is also used in the production of construction materials, such as boards and panels, and in paper making. Hilmersen *et al*. (1984) described situations where rice straw is harvested and used as fuel to produce heat in Bangladesh.

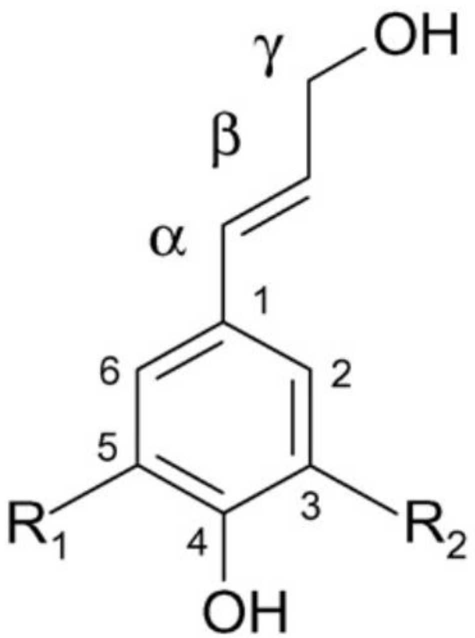
2.10 Oxalates in rice straw and their effects on ruminant nutrition

Tropical forages tend to contain more oxalates than species grown in the temperate, which suggests a relationship between temperature and oxalate accumulation in plants. Oxalic acid binds to calcium in the gut and reduces the absorption and the availability of calcium. Rice straw contains 1.0 - 2.5% oxalates (dry weight) (Libert and Franceshi, 1987). Rumen microbes have the ability to ferment oxalates (James and Butcher, 1972) and therefore may not present a problem for ruminants (Allison *et al*., 1981). Oxalate stones are known to have developed in other species other than ruminants exposed to oxalate – rich/laden diets. Siliceous calculi are often confused to be oxalate stones.

2.11 Lignin in rice straw

Lignin is the third most abundant natural polymer present in nature after cellulose and hemicelluloses. The estimated amount of lignin on earth is 300 billion metric tons with an annual biosynthetic production rate of 20 billion metric tons (Argyropoulos and Menachem, 1998). The chemical structure of wood lignins has been investigated extensively and several techniques have been developed for the characterization of wood lignins (Jung and Himmelsbach, 1989). Studies concerned with structure and properties of straw (grass) lignin are scarce. The structures of straw lignins are not yet well understood, nor are their precise interrelationships with other cell wall components (Scalbert *et al*., 1986; Wilkie, 1979). Since the early 1990s the interest in herbaceous crops and their lignin has increased dramatically due to the importance of bioethanol production from annually renewable biomass. Thus, herbaceous crops such as corn, wheat, rice and flax are receiving increased research attention.

As a major cell wall component, lignin provides rigidity, internal transport of water and nutrients and protection against attack by microorganisms. Lignin is an amorphous polymer consisting of phenylpropane units, and their precursors are three aromatic alcohols (monolignols) namely *p*-coumaryl, coniferyl and sinapyl alcohols (Figure 1). The respective aromatic constituents of these alcohols in the polymer are called *p*-



1. $R_1=R_2=H$
2. $R_1=OCH_3$; $R_2=H$
3. $R_1=R_2=OCH_3$

<u>Monolignols</u>
(1) *p*-coumaryl,
(2) coniferyl and
(3) sinapyl alcohols

Figure 1: Lignin monlignols

Source: Lewis and Yamamoto (1990)

hydroxyphenyl (H), guaiacyl (G) and syringyl (S) moieties (Lewis and Yamamoto, 1990).

Lignin does not exist in plant tissue as an independent polymer but it is bonded with other polymers, cellulose and hemicellulose forming complexes with them. Lignin is always associated with hemicelluloses, not only as physical admixtures, but through covalent bonds (Sarkanen and Ludwig, 1971). The lignin–carbohydrate complexes were first extracted with hot water (140 ◦C) from poplar wood by Traynard *et al*. (1953).

The lignin–carbohydrate complexes from herbaceous crops are structurally different from those in woods and contain ferulic bridges between lignin and carbohydrates (arabinoxylans) via ester-linked ferulic acids (Himmelsbach, 1993; Lapierre and Monties, 1989). Therefore, they are often referred to as "lignin/phenolics–carbohydrate" complexes (Figure 2). Ferulic acid is attached to lignin with ether bonds and to carbohydrates with ester bond. Ester linkages between *p*-coumaric and ferulic acids and lignin have been confirmed in milled wood lignin of grasses by analytical and spectrophotometric procedures (Higuchi *et al*., 1967).

Straw lignins contain up to 5% ferulic acid and a large proportion of the ferulic acid residues ester-linked to polysaccharides can also form an ether bond with phenylpropane units creating a bridge between wall polysaccharides and lignin, reducing the carbohydrate availability (Buranov and Mazza, 2008).

Lignin is always associated with carbohydrates (in particular with hemicelluloses) via covalent bonds at two sites: α-carbon and C-4 in the benzene ring, and this association is called lignin–carbohydrate complexes (LCC). In herbaceous plants, hydroxycynnamic acids (*p*-coumaric and ferulic acids) are attached to lignin and hemicelluloses via ester and ether bonds as bridges between them forming lignin/phenolics–carbohydrate complexes (Baucher *et al*., 1998; Sun *et al*., 2002). Because of this chemical nature of the lignin, it is practically impossible to extract lignins in pure form. Figure 2 shows lignin-carbohydrate complex found in wheat straw.

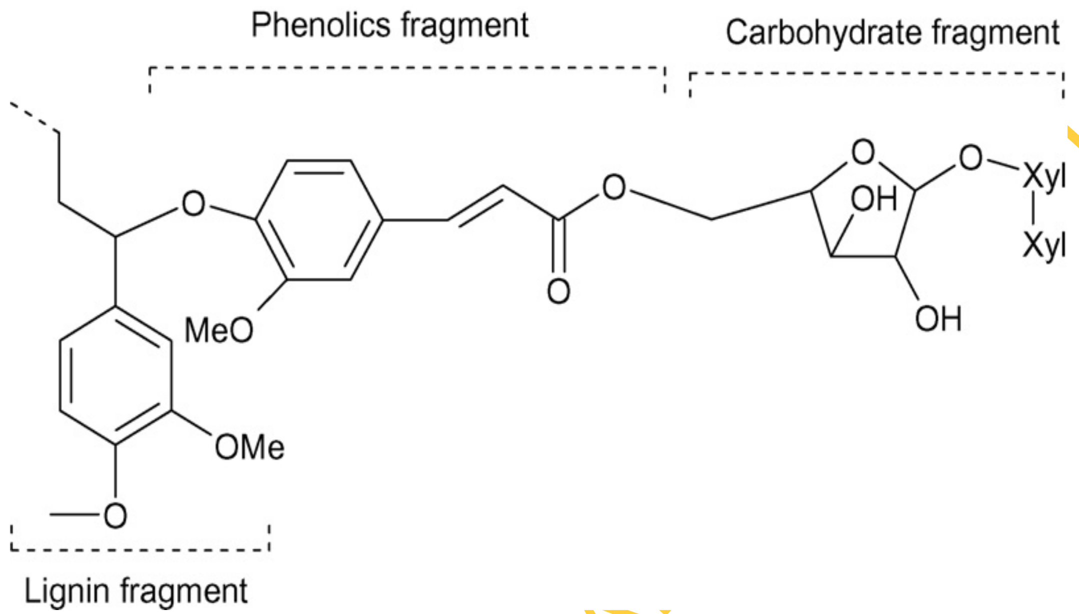


Figure 2: Lignin/phenolic-carbohydrate complex in wheat straw

Source: Sun *et al*.(1997)

The severally reported low dry matter digestibility of rice straw, attributable to high lignin and cellulose contents among others can be overcome to an extent by physical and or chemical modification. Grinding and chaffing rice straw improves its nutritive value. Grinding disrupts the encrusting materials (lignin) thus allowing microbes (in the rumen) direct access to the cellulose fibres.

European rice varieties' straws are reported to have a range of 80-100 g/kg lignin content (Agbagla-Dohnani *et al*., 2001). Lignin contents vary among the different section of the rice plant. The lowest lignin (6.4%) was found in the internode fraction while the highest content (19.4%) was found in the panicles (Jin and Chen, 2006). Rice straw lignin is called p-hydroxyphenyl - guaiacyl - syringyl (H-G-S) lignin as it contains all three monolignol units.

2.12 Other nutritional limitations of rice straw

Apart from the low digestibility and low nitrogen content of rice straw, the other limitations of rice straw as a good fodder include the slow rate of passage due to the rate straw particles are broken down to a size that can leave the rumen and the low level of fermentable N and low propionate fermentation pattern in the rumen.

2.13 Voluntary intake of forages by ruminants

Voluntary intake is the consumption of feed when there is no limitation on the amount of feed available. Debates on the determinants of intake regulation ruminants are inconclusive. Reid (1961) listed intake (amount) as the first limiting factor in forage-testing schemes. Animal performance is dependent on the intake of nutrients; however a question waiting to be answered is asked by Mertens (1994) "does intake determine animal performance (intake as an input) or does animal performance determine intake (intake as a response)?"

Voluntary intake is a function of both the intake potential of a feed material and the nutrient demand by the animal. Intake is the most important factor in determining quality of forage (Crampton 1957, Ventura *et al*. 1975), while Blaxter *et al.* (1961) and Minson *et al.*(1964) submitted that intake of a forage is more variable among animals fed alike than is digestibility. Waldo (1970) noted that complex interaction of feed, animal and the animal's environment cause great variation in the measurement of intake. Jarrige *et al.* (1986) described the fibre-bulk limitations imposed by forage. Intake of fibre may also be constrained due to resistance to removal of feed from the rumen, low palatability, nutrient imbalances and the environment (stress).The physical form of the forage may also contribute to the rate of degradation and removal of the material from the animal's gastrointestinal tract (G.I.T). Mertens (1994) reviewed several works and identified three (3) theories of intake regulation namely, physiological regulation, physical limitation and psychogenic modulation.

2.13.1 Physiological regulation

Intake potential of animals depends on species, sex, physiological state, size, body, shape and health (Ingvartsen *et al*., 1992). Environmental factors like ambient temperature and photoperiod can also affect and animals' intake potential and energy demand. Inclusion of hormone or growth promoters also influence intake. Long term intake regulation involves mechanism that control average daily intake over extended periods of time during which body weight equilibrium is attained and maintained. Intake would be controlled during homeostasis to maintain long term physiological equilibrium; such intakes would be coordinated with the control of metabolism to support changes in intake associated with physiological states, such as lactation and pregnancy (Bauman and Currie, 1980). Animals will reduce performance or lose weight to attain equilibrium between energy and output when consuming low quality diets (Mertens, 1994).

2.13.2 Physical limitation

Voluntary dry matter intake (VDMI) of low quality (digestibility) feeds is thought to be limited by the physical distension in the gastrointestinal tract. The theory that physical distension in the GIT limits VDMI is widely accepted (Campling, 1970; Grovum, 1987). When animals are fed diets that are palatable, yet high in bulk (fill) and low in available energy concentration, intake is limited by restriction of capacity in the GIT (Baile and Forbes, 1974). Campling and Balch (1961) demonstrated that the mass in the rumen affects intake by removing swallowed hay from the rumen, which increased the eating time of cows whereas added digesta to the rumen during a meal decreased intake. Van Soest (1965) observed that neutral detergent fibre content and dry matter (DM) digestibility explained the gut fill theory as VDMI of forages decreases with an increasingly negative slope as forage neutral detergent fibre content increases, such that the decrease is consistent with the theory that fibre mass in the GIT may inhibit VDMI.

2.13.3 Psychogenic modulation

Psychogenic regulation of food intake involves the animal's behavioural response to inhibitory or stimulatory factors in the feed or feeding environment that are not related to the feed's energy value or filling effect. Palatability has been identified as the feed characteristic that has the most impactful psychogenic modulation of feed intake. Baumont *et al.* (1989) observed that the duration and the rate of eating of forages were influenced by behaviour and palatability.

Mertens (1994) also detailed intake theories (models), which integrate the physiological, physical and psychogenic mechanisms. These are the static or steady state and the dynamic models.

2.14 Some other factors affecting voluntary intake

2.14.1 Rumen environment

Cellulolysis requires certain conditions such as adequacy of nitrogen (N), sulphur (S), minerals and optimal pH conditions to proceed at an optimal rate. Feed materials may also contain anti-nutritive factors which may not only inhibit degradation of feeds in which they are contained but also affect the degradation of accompanying feeds (Orskov, 1988). Soluble materials consisting largely of soluble carbohydrates and protein occupies little space in the rumen and it is largely fermented in the rumen. The soluble material contains bulk of the components such as N and S, which enhance microbial activities. The soluble content of forage hence plays a vital role in the process that ensures the degradation of the insoluble but potentially fermentable fraction of forage materials.

The rate at which large particles are reduced to small particles, which depends on chewing, rumination and microbial disintegration in the animal is a very important parameter in intake rate determination. If the rate at which large particles are reduced to particles small enough to enter the liquid phase and be exposed to outflow is greater than the rate at which small particles flow out then it will be no constraints to feed intake.

The rates at which small ground particles flow out of the rumen vary depending on forage type. Orskov (1988) showed that in circumstances in which the outflow of protein supplement was 0.06, the outflow of roughage was only 0.03. These differences reflect the length of time it takes for particles to traverse the solid mass of rumen contents and become suspended in the liquid phase from which outflow occurs.

The volume of the rumen determines how much fermenting materials can be accommodated at any one time. Unfortunately, rumen volume had been selected against in breeding programmes; carcass weight as a percentage of live-weight has always been considered advantageous. Cattle in Bangladesh have much higher gut content (33%) (Mould *et al*., 1982) than normally reported for Friesian cattle (Campling and Balch, 1961). Figure 3 shows the classification of the several factors that influence dry matter intake by ruminants as documented by Mertens (1994).

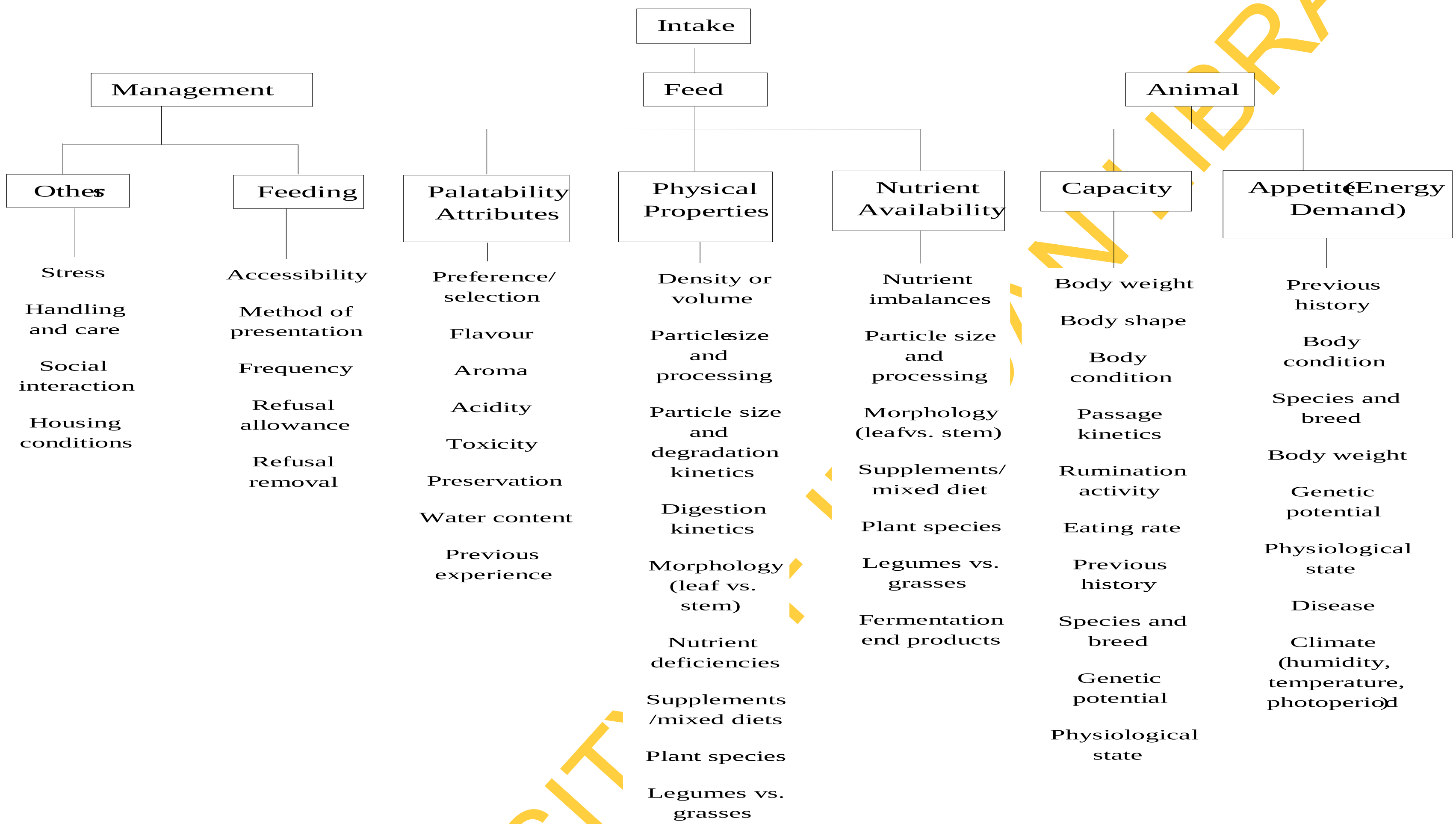


Figure 3: Classification of factors affecting the intake of feeds by ruminants

Source: Mertens 1994

2.15 Near infrared reflectance spectroscopy (NIRS) and forage quality analysis

Near infrared reflectance spectroscopy (NIRS) is a rapid and low-cost computerized method employed to analyse forage and grain crops for their nutritive value. It is technique that uses samples' near infra-red (NIR) absorbance characteristics to predict parameters of interest. Natural products absorb NIR radiation of specific regions or wavelengths. N-H, O-H and C-H bonds are strongly absorbed by NIR radiation. Reports of NIRS appeared for the first time in literatures in 1939. By 1983 NIRS instrument with sophisticated software for forage and feed analyses had been introduced to the American market.

Molecular absorptions in the NIR region are due to C-H, N-H or O-H bonds, which results from hydrogenic stretching, bending or deformation vibrations. Other important molecular absorption in the NIR region includes the carbonyl carbon to oxygen double bond stretching vibrations, carbon-to-carbon stretching vibrations, and metal halides (Mertens, 1994).

Near infrared region is a component of the infrared region just outside the visible region of the electromagnetic spectrum (EMS). Infrared (IR) light is emitted by the sun and absorbed by all biological compounds but not visible to the human eye. Chemical bonds in organic molecules vibrate, stretch and bend at frequencies similar to the vibrations of the EMS found in the IR region when struck by IR light. Wavelengths, which correspond to the frequency at which a particular bond is vibrating, are absorbed. Others are reflected. The NIR spectrometer projects a known quantity of NIR light onto a substance and then records the reflectance from the substance (Figure 4), storing the information in a computer (Stuth *et al.*, 2003).

Each major organic component of forages absorbs and reflects NIR light differently. The different reflectance characteristics are used to determine the quantity of the components in the material. This is possible because reflectance spectra from forage samples of established nutrients values would have been determined by wet chemistry are

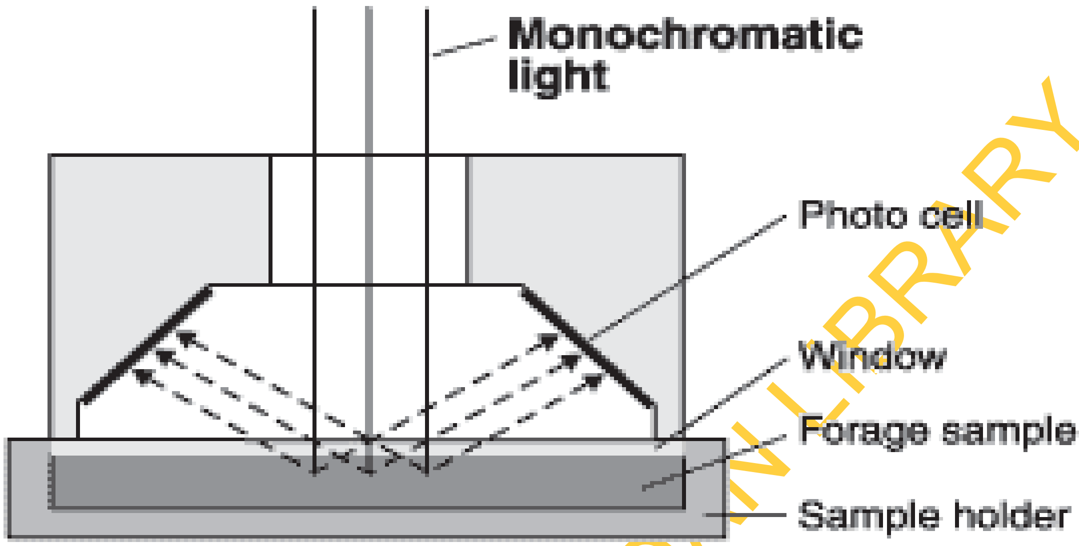


Figure 4: Diagram of how NIRS reads a prepared plant sample

Source: Schroeder (2004).

programmed into the computer. This procedure of developing a database, based on wet chemistry is known as chemometrics.

NIRS is used to quantify forage quality by direct determination of a constituent by obtaining both the near infrared (NIR) spectrum and the traditional chemical analysis on a number of individual samples, and then using this information to develop a predictive equation.

The near infrared (NIR) is immediately adjacent (800-2500nm, 104 to 4 x 1014 Hz) to the infrared region (red region in the visible light region). Infrared (IR) light is emitted by the sun and absorbed by all biological compounds but is not visible to the human eye. Chemical bonds in organic molecules vibrate, stretch, and bend at frequencies similar to the vibrations of the electromagnetic spectrum (EMS) found in the IR region when struck by IR light. The stretching and bending of primarily CH, NH, OH, CO and CC bonds as a result of the interaction between this radiation and biological material yields an abundance of chemical information about that material (Stuth *et al*., 2003).

Calibration is the process of creating a spectro-chemical production model (Shenk and Westerhaus, 1996). Chemometrics is the science of extracting information from chemical systems by data driven means. Traditional direct method of applying NIRS is to analyse a particular product with both NIRS and traditional wet chemistry and pair this information in the calibration set to calculate a predictive equation (Figure 5). We can then use only the NIRS and bypass the need for wet chemistry. NIRS is usually faster, less expensive, and is non-destructive (Stuth *et al*., 2003).

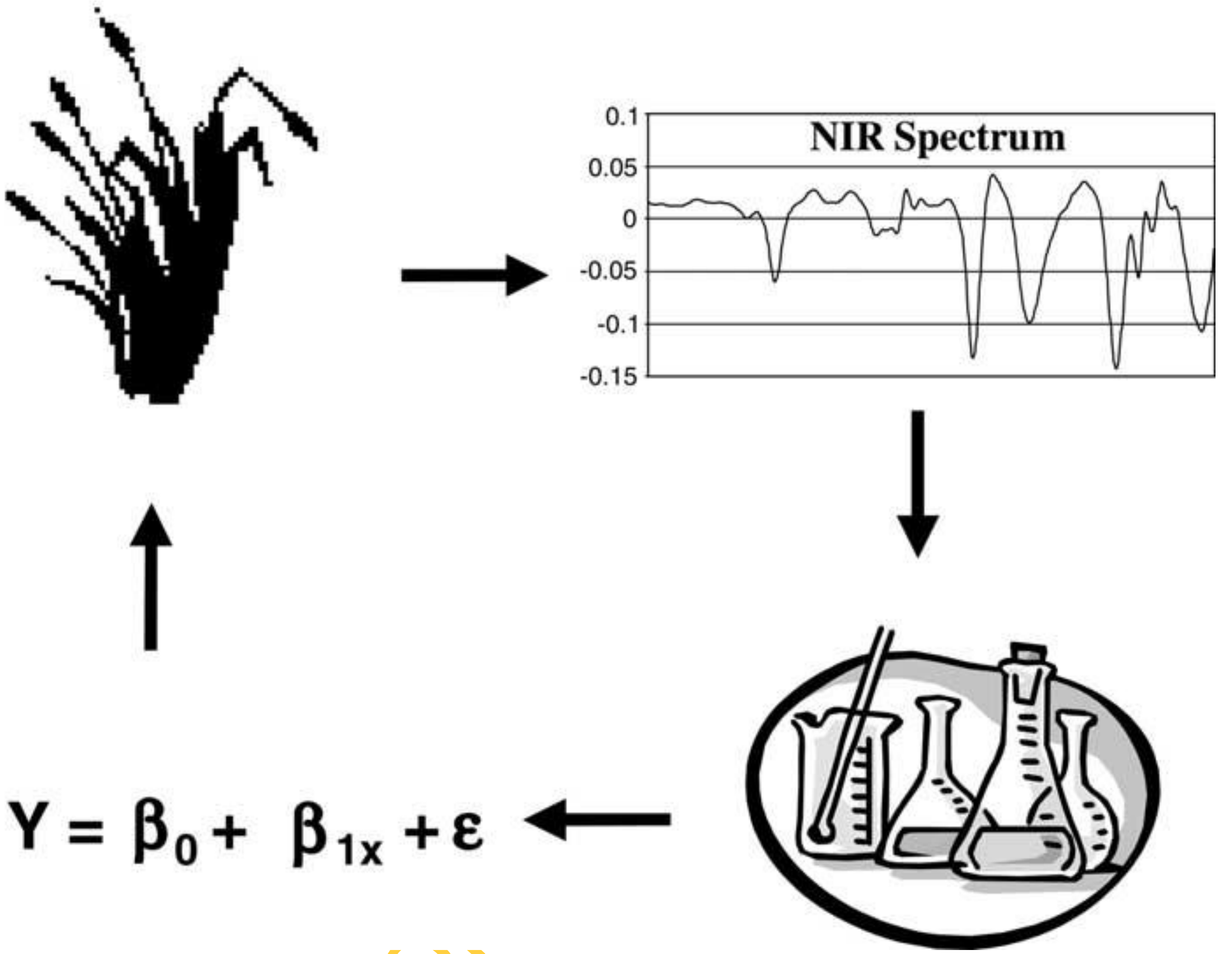


Figure 5: Calibration of NIRS equipment using traditional wet chemistry

Source: Stuth *et al*. (2003).

2.16 Advantages of NIRS over traditional wet chemistry procedures

The NIRS technique is rapid and less expensive than wet chemistry methods. The procedure does not require labour-intensive sample processing. It also accommodates large-scale sampling. It facilitates timely decision making on strategic nutritional adjustments in ration formulation to sustain production in farming enterprises. NIRS is also non-destructive, unlike traditional wet chemistry. The samples subjected to NIRS equipment are reusable. The technique is also environmentally friendly as no reagents are utilized. The technique allows for the determination of multiple values (factors) e.g. crude protein, digestible organic matter, acid detergent fibre and neutral detergent fibre in a single procedure.

However, processing of the calibration set for NIRS should be consistent with the methods to be used in routine analysis. Drying and grinding procedures are especially important due to the fact that water is a strong absorber of NIR light and particle size also affects the shape of the spectrum. The conditions under which samples are scanned should be as uniform as possible with respect to ambient temperature. As with particle size, temperature affects the shape of the spectra, shifting the expression of absorption peaks, possibly altering the interpretation of a spectrum (Stuth *et al*., 2003).

2.17 Importance of dual purpose or food-feed crops

Food-feed crops are the most important feed source for ruminants (Thomas, 2002). Small-scale, mixed crop-livestock systems are more important than any other livestock systems in their contributions to the total output of animal products, especially meat and milk (Sere and Steinfeld, 1996). In sub-Saharan Africa and India alone, estimated 140 and 370 million resource-poor livestock keepers respectively, could benefit from improved utilization of food-feed crops within these systems (Lenne *et al*., 2003).

Rice straw produced every year is plentiful and if well exploited, it could help overcome, to an extent, the shortage of feed to increase the number and performance of ruminants. Rice is one of the dominant foods consumed in Nigeria, and it has also attained prominence as the key food grain, which can be cropped up to 2-3 times per year, provided irrigation is available. Dual-purpose crops and particularly rice has the potential to fill in the gap for the shortage of fodder at some periods within the year. The most widespread technical constraint to increased ruminant production for farmers in the mixed crop-ruminant farming systems is their inability to feed animals adequately throughout the year. This is also true to seasonality in patterns of grass growth and forage supplies (Trach, 2003).

Numerous researchers have acknowledged the future and importance of agricultural by-products as feeds for livestock, particularly fibrous by-products, such as rice straw for ruminants. Sundstol and Owen (1984) emphasized the inevitability of straw being produced as a by-product of growing cereals for man. Over the next 25 years, rapid population growth, urbanization and improved incomes in developing countries will fuel further increases in demand for animal products. Farmers stand the chance of earning extra revenues from sales of such residues of dual-purpose-type crops.

2.18 Development of dual purpose crops in Africa

Mixed crop-livestock systems provide over 50% of world's meat and over 90% of its milk and are the most common form of livestock operations in developing countries (Von Kaufmann, 1999). Smith *et al*. (1997) had suggested that as mixed systems evolve in response to population growth and growing demand for livestock products there will evidently be increasing integration of crops and livestock over the next few decades. The role of dual-purpose or food-feed crops, has been, and continues to be an area of substantial interest. The idea of a crop from which farmers can harvest one product for human consumption and the residues of which they can feed to their livestock, is a highly appealing one (Thornton *et al*., 2003).

The aim of the rice breeding programs has been to increase grain yields and one of the consequences of this has been a shift towards a greater use of dwarf and medium types of rice. Whereas the growth duration of tall, traditional rice types is around 140 to 150 days, many of the newer varieties have a shorter growth duration, some as low as 90 to 100 days.

The changes in growth conditions, as well as in the genetic makeup of rice plants, have had important implications as regards grain quality. It is not known whether there have been significant alterations in straw quality, but it can be expected that the patterns of mobilization of nutrients from the vegetative parts of the plant to the grain would vary for these different rice varieties. Some farmers consider the straw from high yielding varieties to be less acceptable to animals (Hilmersen *et al*., 1984) although there is no clear experimental evidence for this.

In addition to the above factors, the variety of rice, the conditions of growth, and other factors, such as disease, may affect the characteristics of rice straw. They may be expressed in terms of variation in the proportions of different morphological components (leaf blades, leaf sheaths, stem internodes and nodes) that are present and in the physical and chemical characteristics of these components. These factors are important in determining the value of straw, whether it is used for feeding animals or for other purposes. Dr. M. S. Swaminathan, Director General, International Rice Research Institute (IRRI) in describing the new focus of the institute was quoted by Doyle *et al.* (1986) as saying that:

> *The past 25 years have seen marked increases in the quantity and quality of rice production. From our early work to develop high yielding modern varieties we have moved to develop varieties with genetic resistance to many insects and diseases that attack rice. While we first considered rice as a crop in isolation to achieve a breakthrough in raising the yield ceiling, we now emphasize rice as part of the whole farm system, and also the whole plant rather than just grain utilization, to increase farmers' income.*

Cowpea is a crop that has become established as a food-feed crop in Nigeria and most countries of sub-Saharan Africa. The haulm as a fodder material has commercial value in Nigeria and the entire West African sub-region. The mature pods are harvested and haulms are cut while still green and rolled into bundles containing leaves and vines. These bundles are stored on roof tops or on tree forks for use and for sale as 'harawa' (feed supplement) in the dry season; making cowpea haulms a key feed resource in crop-livestock systems (Singh and Tarawali, 1997). The International Institute of Tropical Agriculture (IITA) has global mandate for improving cowpea cultivars. IITA develops and distributes a range of improved breeding lines, combining multiple disease and insect resistances with early maturity and preferred seed types to over 65 countries. Between 1970 and 1988, cowpea research at the IITA concentrated primarily on developing and distributing grain-type cowpea cultivars (Singh *et al*., 1997). In 1989, IITA initiated a systematic breeding programme to develop dual-purpose cowpea varieties. Dual-purpose cowpea breeding programme was further enhanced with IITA's collaboration with International Livestock Research Institute (ILRI) (Tarawali *et al*., 1997).

Shirima (1994) found that maize contributes up to 39% of forage in Tanzania. Maize stover is recognized as an important forage for dry season feeding in East Africa. Maize contributes 1816.74 metric tons of fodder globally while the estimate for Africa is 340 MT. Both figures are the highest, globally and in Africa respectively. Maize is already managed by Kenyan highland dairy farmers as a food-feed crop (Romney *et al*., 2003) with its genetic potential as a stover being exploited. Sorghum residue is beginning to attain the status of a marketable commodity in India (Lenne and Thomas, 2005).

Global food needs will have to be met sustainably through increased productivity per unit area of land. Dual-purpose or food-feed crops will make this achievable while simultaneously utilizing farm "waste" "overload" that may result increasingly from the envisaged sustained continuous increased food production activities.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study one: Rice straw as fodder in Nigeria

3.1.1 Introduction

Most tropical areas of the world suffer seasonal dry periods in which pasture availability decreases. These countries face perennial problem of inadequate quality and quantity of ruminant feeds, especially during the long dry seasons. Consequently, alternative feed resources such as crop residues and agro-industrial by-products have become an increasingly way of feeding ruminants (Chenost and Kayouli, 1997). At such dry periods, livestock depend mainly on crop residues. Residues available to livestock in such areas are dependent on the prevalent crops cultivated in the areas. Pearl millet (*Pennisetum glaucum* (L.) R. Br.), sorghum (*Sorghum bicolor* (L.) Moench), and maize (*Zea mays* (L.)) are the principal cereals, fonio (*Digitaria exilis* (Kippist Stapf)) is important in some areas, and rice (*Oryza spp.*) is cultivated in delta areas (of West Africa) and along river and stream borders (Powell *et al.*, 2004). Crop residues are vital livestock feeds during six (6) to eight (8) months dry season in most sub-Saharan African countries. Nearly 70% of the crop residues are derived from cereals, with maize (*Zea mays*), sorghum (*Sorghum bicolor*) and pearl millet (*Pennisetum glaucum*) providing the largest portion in sub-Saharan Africa (Shumba, 1984).

Rice straw is a major source of dry forage to the livestock of Nigerian pastoralists. Baba and Magaji (1998) reported that 100% of pastoralists sampled, fed rice straw to their livestock. Rice straw has not attained the status of market commodity unlike residues of cowpea, groundnut and sorghum in Nigeria.

3.1.2 Objectives of study

The objectives of the study were to investigate if rice farmers:

i) have any considerations for straw quality and yield

ii) have been burning or storing straw for use as fodder

iii) own animals that could graze on the straw

3.1.3 Methodology

A structured questionnaire (Appendix i) was administered to rice farmers in three (3) local government areas in each of three (3) rice producing northern Nigerian states of Niger, Kaduna and Bauchi. Figure 6 shows the study area. Six (6) to eight (8) villages were visited in each of the local government areas (LGA) of Lavun, Gbako and Katcha in Niger state; Soba, Kajuru and Zangon Kataf in Kaduna state; and Bauchi, Warji and Dass in Bauchi state. Figure 6 shows map of study areas while Table 2 shows a description of the study areas.

The data were collected using one on one techniques in all the villages visited in all the LGAs of the three (3) states. The target persons were rice farmers irrespective of gender, religion or farm size. Twenty (20) respondents were interviewed in each of the three (3) LGAs of each of the three (3) states totalling 180 rice farmers. Data analysis was carried out using SPSS 16.

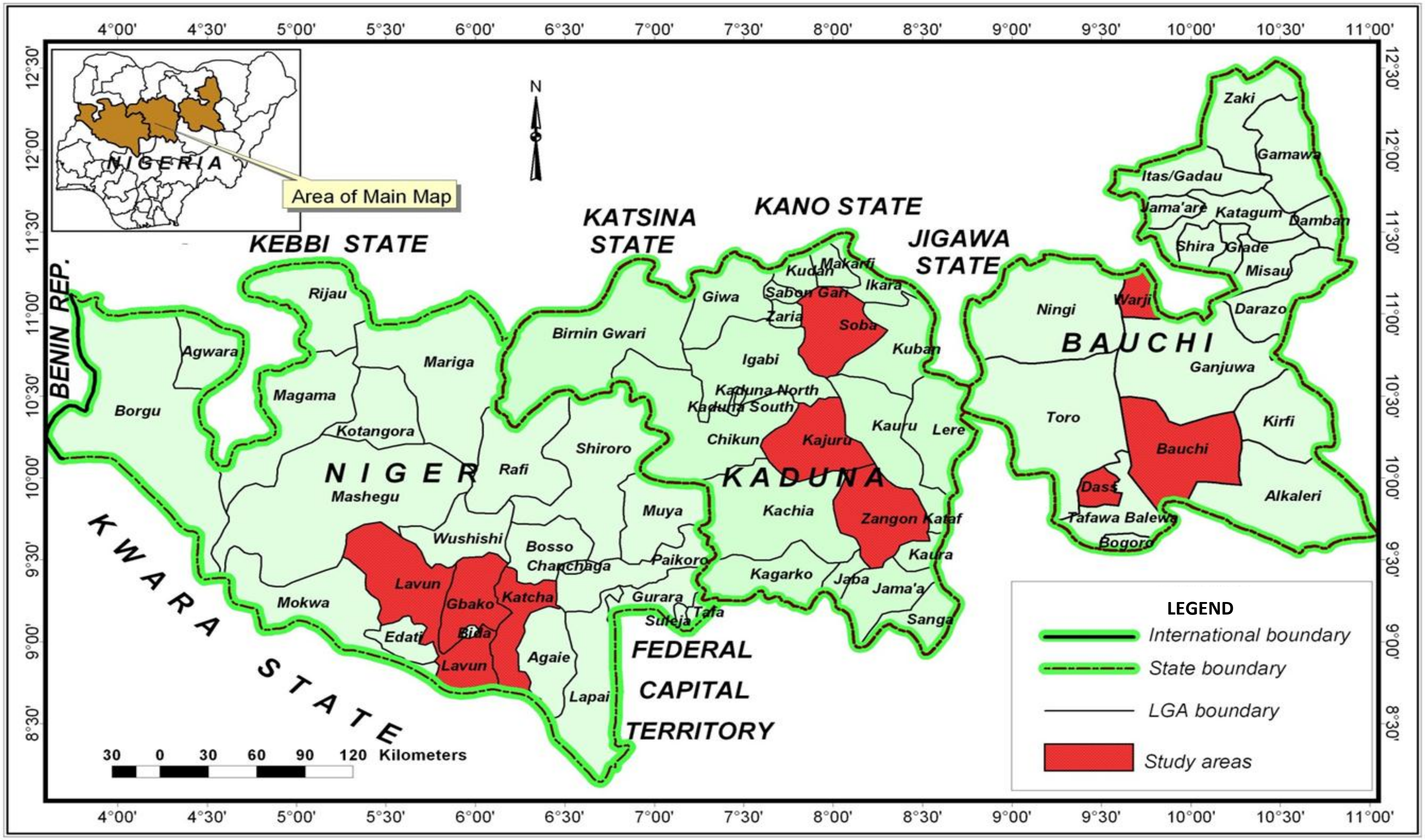


Figure 6: Map showing the study area

Table 2: Description of study areas

State	Description
Niger	The northern part of the Niger state falls within the West Sudanian Savanna and while the south falls within the Guinean Forest-Savanna Mosaic eco-regions. The local government areas (LGA) Lavun, Gbako and Katcha (Figure 6) are three (3) neighbouring LGAs in the core rice producing region of the state. Niger state is listed among the first five leading rice-producing states in Nigeria.
Kaduna	Kaduna state lies mainly within the West Sudanian Savanna eco-region. Kaduna state is also a leading rice-producing state in Nigeria. The LGAs surveyed are Kajuru (central Kaduna), Soba (northern Kaduna) and Zangon Kataf (southern Kaduna) (Figure 6).
Bauchi	Bauchi also lies within the West Sudanian Savanna eco-region. The three (3) LGAs surveyed are Bauchi (south), Warji (north west) and Dass (south) (Figure 6).

3.1.4 Demography

The name, name of village and local government area, sex, level of education, marital status and family size of respondents (rice farmers) were collected using the structured questionnaire (Appendix i).

3.1.5 Land use, rice farm size and type; and other crops cultivated

The survey also inquired on size of land committed to rice cultivation, other crops cultivated by respondents and the sizes of land committed to such crops. The distribution of rice production system (lowland or upland) was also documented.

3.1.6 Livestock ownership and feeding; source and type of feed resources

The survey also sought to investigate ruminant livestock ownership and how they are managed by rice farmers. The feed types that farmers have access to, or purchased and the crop residues used in feeding their animals were also documented.

3.1.7 Rice straw usage and disposal

The use and extent of rice straw usage in feeding ruminants was investigated. The survey also sought to know if rice farmers had previous financial transactions on rice straw. It was also investigated if respondents packed all, some or none of the rice straw generated in their rice cultivation activities. The survey inquired if respondents burned straw as part of land preparation activities, fertilization or as a means of getting rid of crop residues.

3.1.8 Expectations of rice farmers from new rice varieties

The expectation of rice farmers from rice breeding activities of relevant agencies was also investigated. The survey sought to know if fodder qualities of rice would influence respondents' choice of rice varieties.

3.2 Study two: Field evaluation of 49 rice accessions

3.2.1 Introduction

The yield and fodder quality of the residues of crops adopted by farmers as dual purpose crops play key roles in their consideration before adoption. Ceccareli (1993) and Kelley *et al*. (1996) reported that crop-livestock producers failed to adopt to large extent high grain-yielding varieties with less than desirable feed attributes. Yield attributes such as plant height, one thousand grain weight, tillers and panicles per metre square are indicators of both vegetative and grain yields. Harvest index, which is the weight of grain as a percentage of the total dry weight of the crop; is also a good criterion for assessing the yields of food and feed components of crops. Other parameters such as spikelet fertility, lodging and phenotypic acceptability are also evaluation parameters indicative of the success or otherwise of a crop.

3.2.2 Materials and methods

The study was carried out on the experimental field of the Africa Rice Centre located within the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. Ibadan (7º26´N; 3º54´E) represents the forest–savanna transition ecology with a bimodal rainfall pattern (1252.8 mm annual), an altitude of 210 m above sea level and ferric luvisols soil type with temperature ranges of 12–23ºC and 28–34ºC (minimum and maximum temperatures, respectively).

3.2.3 Description of the rice accessions

Forty nine (49) rice accessions were sourced from the Africa Rice Centre's Lowland and Upland Breeding Units representing five cultivar types namely (1) *Oryza glaberrima*, (2) *Oryza sativa* (lowland), (3) *Oryza sativa* (upland), (4) NERICA (lowland) and (5) NERICA (upland). Table 3 shows the list of the 49 accessions under their cultivar groups.

NERICA 1 to 18 are interspecifics of crossings between two *Oryza* species, *Oryza glaberrima* and *Oryza sativa*. NERICA 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and 11 are products of crossings between *O. sativa* – WAB 56-104 and *O. glaberrima*- CG 14. NERICA 12, 13, and 14 are interspecifics of crossings between *O. sativa* – WAB 56-50 and CG 14, while NERICA 15, 16, 17 and 18 are products of *O. sativa* WAB 181-18 and CG 14. They were all developed by the West African rice Development Association (WARDA) now Africa Rice Centre (ARC), Bouake in 1994. They are all adapted for upland ecology, with maturity periods ranging from 75 to 100 days (Africa Rice Centre (WARDA)/FAO/SAA, 2008).

NERICA lowland were selected for tolerance to rice mottle virus and African rice gall midge (Rodenburg *et al*., 2009). ART 10 is a work-in-progress line in the Upland Rice Breeding Programme of Africa Rice Centre, Ibadan.

NERICA lowland accessions are also interspecifics but adapted to lowland ecology. They are products of backcrossings. NERICA lowland 7, 8, 9, 14, 19, 20, 41, 42, 45, 49 and 60 are crossings between *O. sativa* – IR 64 and *O. glaberrima*- TOG 5681, while NERICA lowland 21 is a product of crossings betwween TOG 5681 and *O. sativa* -IR 1529-680-3-2 (Africa Rice Centre (WARDA)/FAO/SAA, 2008).

ITA 321 is a medium-maturing, high tillering, high yield potential variety adapted to hydromorphic and dry upland ecologies (Ukwungwu *et al*., 2007). It is also resistant to blast (Africa Rice Centre (WARDA), 2007). OS 6 originated from Zaire through pureline selection. Ofada is a generic name used to describe any kind of rice cultivated and processed in a group of communities in Ogun state and some rice producing clusters in South west Nigeria (NCRI/ARC. (2007)). WAB 189 (FARO 54) is a high-yielding, early maturing rainfed upland variety (Africa Rice Centre (WARDA), 2007), with big, bold grains (Ukwungwu *et al*., 2007).

WAB 56-104 is adapte for ecology a nd it was bred in Africa Rice Centre from a cross between IDSA 6 (from Ivory Coast) and IAC 164 (a Brazilian upland variety) (Africa Rice Centre (WARDA)/FAO/SAA, 2008). WAB 181-18 was also developed by WARDA. It is an improved *Oryza sativa* japonica-type (Africa Rice Centre (WARDA)/FAO/SAA, 2008).

WITA 4 (FARO 52) is a rainfed lowland variety, tolerant to iron toxicity and drought (Africa Rice Centre (WARDA), 2007). It is high yielding and was released in 2001 (Ukwungwu *et al*., 2007). Sipi (FARO 44) is also a high yielding lowland variety with long slender grains and high amylose content. It was introduced from Taiwan. It is short to semi-dwarf, early maturing and has moderate tolerance to drought (Ukwungwu *et al*., 2007). Cisadane was released as FARO 51, it is tolerant to African gall midge. It was released in 1993 (Ukwungwu *et al*., 2007). Suakoko 8 originated from Liberia. It is high yielding, tall lowland variety with relatively small grains. IR 64 and IR 72 originated from International Rice Research Institute. They are short, high yielding lowland variety (Chaudhary *et al*., 1998).

BW 348-1, which originated from Sri Lanka, is a lowland variety, tolerant to iron toxicity and drought stress (Chaudhary *et al*., 1998). TOX 4004 (FARO 57) is ahigh yielding rainfed lowland rice variety, tolerant to both drought and iron toxicity (Africa Rice Centre (WARDA), 2007).

Varieties CG 14, TOG 7442, TOG 7106 and TOG 7206 are *Oryza glaberrima* and are of African origin. They are naturally found in upland to deepwater ecology, with maturity periods varying from 3 to 6 months (Agnoun *et al*., 2012).

3.2.4 Establishment of rice accessions and plot layout

The land was disc-ploughed to facilitate levelling with a puddle rotavator. The forty-nine (49) accessions were seeded on wet bed nursery, and transplanted on their respective plots at the rate of 2 seedlings per hill, 21 days after seeding. The plots were on hydromorphic ecology. The experiments were laid out in Triple (7x7) Lattice Square Design (appendices ii and iii) The accessions were allocated randomly during both 2008 and 2009 field trials (appendices ii and iii). The test entries were planted on 147 plots (49 plots per replication). Each plot was

5x1m, consisting of 5 rows of 25 hills each. Hill spacing was 20x20cm. Total experimental land area of 771.4 m^2. Missing hills were re-transplanted 7 days after transplanting. The 2008 trial was established on August 18, 2008, while the 2009 trial was established in May 22, 2009. Plates 1 and 2 show the 49 rice accessions at thirty (30) and sixty (60) days, respectively, after transplanting.

3.2.5 Weeding and weed control

Pre-emergence herbicide was applied after transplanting, post-emergence herbicide at 21 days after transplanting and hand weeding at 42 days after seeding. Manual weeding was also carried out as at when necessary during the two year (2008 and 2009) trials.

3.2.6 Fertilizer application

After transplanting, 200 Kg/ha of NPK (15-15-15) was applied (basal). Urea (46% N) was applied at the rate of 50 kg/ha at 21 – 30 days after seeding (i.e. at tillering) and a second application of urea (46% N) was done at the same rate of 50 kg/ha at 42 – 50 days after seeding (i.e. at panicle initiation stage).

Table 3: List of 49 rice accessions and their cultivar groupings

Interspecific upland	Interspecific lowland	*Oryza sativa* upland	*Oryza sativa* Lowland	*Oryza glaberrima*
18 Upland NERICA accessions comprising: NERICA 1 to NERICA 18 and ART 10.	12 NERICA Lowland accessions comprising: NL 7, NL8, NL 9, NL 14, NL 19, NL 20, NL 21, NL 41, NL 42, NL 45, NL 49 NL 60.	WAB 56-104, WAB 181-18 WAB 189 (FARO 54), ITA 321 (FARO 53), Ofada OS 6	WITA 4 (FARO 52). Sipi (FARO 44). TOX 4004 (FARO 57). Cisadane (FARO 51). Suakoko 8 BW 348-1 IR 72 IR 64	TOG 7106 TOG 7206 TOG 7442 CG 14

NL denotes NERICA Lowland

ART 10 denotes ART 10-L-11-P1-1-1-B

Plate 1: 49 rice accessions with 3 replications 30 days after transplanting

Plate 2: 49 rice accessions with 3 replications 60 days after transplanting

3.2.7 Data collection

Data were collected using the procedures and ratings specified in the Standard Evaluation Systems for Rice (SES) (IRRI 2002). Data collected included date of seeding, seedling vigour at 30 days after sowing (DAS), tillers per square metre, panicles per square metre, plant height at maturity, lodging incidence, spikelet fertility (%), phenotypic acceptability score, threshability, 1000-grain weight (corrected to 14% moisture content (MC) basis), diameter of basal internode and grain yield (per hectare, on 14% MC basis). Table 4 shows the description of SES (IRRI, 2002) scoring for threshability, seedling vigour and phenotypic acceptability. Straw yield data was collected using the procedure of Osuji *et al*. (1993).

Statistical analysis was carried using general linear model (GLM) of analysis of variance (ANOVA), SAS (2009).

Table 4: Description of threshability, seedling vigour and phenotypic acceptability scoring

Scoring	1	3	5	7	9
Threshability (at maturity)	Difficult to thresh (less than 1%)	Moderately difficult (1-5%)	Intermediate (6-15%)	Loose (26-50%)	Easy (51-100%)
Seedling Vigour (at 30 DAS)	Extra vigorous (very fast growing; plants at 5-6 leaf stage have 2 or more tillers in majority of population)	Vigorous (fast growing; plants at 4-5 leaf stage have 1-2 tillers in majority of population)	Normal (plant at 4-leaf stage)	Weak (plants somewhat stunted; 3-4 leaves; thin population; no tiller formation	Very weak (stunted growth; yellowing of leaves
Phenotypic Acceptability Score(@ Maturity)	Excellent	Good	Fair	Poor	Unacceptable

Adapted from Standard Evaluation Systems for Rice (IRRI, 2002).

DAS: Days after sowing.

3.3 Study three: Near Infrared Spectroscopy (NIRS) analysis of straws of forty nine (49) rice accessions

3.3.1 Introduction

Near infrared reflectance spectroscopy (NIRS) is a very fast, precise, non-destructive technique for routine analysis of forages and other agricultural products. NIRS is a technique that utilizes a sample's near infrared (NIR) absorbance characteristics to predict parameters of interest. NIRS is currently the basis for quick, accurate, non-destructive and highly repeatable assays of many biological traits and compounds related with the organic (and also inorganic- ash content, silica content) composition of plant matter (Finney *et al.*, 1987; Shenk *et al.*, 1992). Osborne and Fearn (1986) explained that the ability of NIRS to determine these various compounds is due to the vibrational and rotational energies associated with H bond.

The different chemical bonds in products are responsible for the absorption of NIR radiation which varies from one bond-type to another. Samples high in moisture and or sugars will have higher absorptions in regions associated with hydroxyl (OH) bonds. With the thousands of different molecules in the average natural product, the information in the NIR spectra is very difficult to analyse and interpret. But with routine NIRS analysis, chemometrics have been developed over time. Spectra from NIRS instrumentation, chemometrics and reference values (from wet laboratory analysis procedures) are used to calibrate NIRS instruments.

The different organic components of forages (and grains) will absorb and reflect near-infrared light differently. Samples, which are representative of the samples to be analysed are chosen to create a calibration. These samples are analysed in the NIRS, and the spectra stored. Those samples are then sent to have the reference (wet laboratory) analysis performed on them. These are termed calibration samples.

The detection of specific nutrients is made possible because the reflectance spectra generated from the dried finely ground forage samples of established nutrient values (by conventional laboratory wet chemistry procedures) are programmed into computers installed with statistical models such as the full spectrum calibration methods, principal component regression (PCR), partial least squares regression (PLS), modified PLS (MPLS) and the neural networks (Shenk and Westerhaus, 1994).

3.3.2 Materials and methods

Straw samples were randomly taken from the three (3) replicates of the forty-nine (49) rice accessions from the field as at maturity for different accessions. The straw samples were cut 5 -10cm above soil surface (Tarawali *et al*., 1995). The whole plant materials (excluding panicles and roots) were chopped into small bits and dried in forced air oven at 65^{o}C till they attain approximately 950 g/kg dry matter (about 8 to 12 hours) (Shenk and Westerhaus, 1994).

3.3.3 Mixing and packing

The samples were ground through 1.00mm sieves and packed in labelled whirl park (Plate 3) for shipment to International Livestock Research Institute (ILRI) India for NIRS analysis. The ground samples were thoroughly mixed to minimize effects of repack error. Repack error is the differences between sample spectral measurements of several aliquots of a sample. Shenk *et al.* (1992) described repack error, averaging, compression and methods of minimizing these effects. The samples for the first year trial were shipped to ILRI, India in January 2009, while the second year trial samples were sent in December 2009.

Plate 3: Ground straw samples in labelled whirl packs

3.3.4 Data treatment, NIRS spectrum collection and reference data

The dried ground samples were analysed using FOSS NIR Systems 5000, WINISI Version 1.50 (Infrasoft International LLC). Fifty four (54) out of the one hundred and forty seven (147) samples were randomly selected and calibrated along with the existing global database with outliers excluded (Table 5). The same set of samples was also calibrated to generate a local data base for this project's batch of rice straw samples (Table 6).

Prediction equations were obtained using modified partial least squares (MPLS) and regression method. The residuals obtained after each factor is calculated are standardized (divided by the standard deviation of the residuals at a wavelength) to calculate the next factors. Shenk and Westerhaus 1995 reported that MPLS is often more accurate than the standard partial least squares (PLS) algorithm for agricultural applications. For cross-validation, the calibration set is portioned in groups; each group is then validated using a calibration developed on the other samples. The validation errors are combined in a standard error of cross-validation (Shenk and Westerhaus, 1995).

For this work, the spectral region was between 1100 and 2498 nm (at 2 nm intervals). Calibration equations for the rice straws are summarized on Tables 5 and 6. The Acid Detergent Fibre (ADF) had the most precise prediction with a determination coefficient of 0.99.

Table 5: Calibration of 54 out of 147 rice straw samples along with the global database at ILRI, India

Constituents	Number of samples (n)	Mean (%)	Standard deviation	Estimated minimum (%)	Estimated maximum (%)	SEC	RSQ	SECV	1-VR
Dry matter	466	93.9	1.5	89.4	98.4	0.37	0.94	0.43	0.92
Ash	468	19.5	3.5	9.0	30.0	0.57	0.97	0.65	0.97
Nitrogen	466	0.8	0.2	0.1	1.5	0.04	0.98	0.04	0.97
Neutral detergent fibre	150	64.5	2.8	56.0	73.0	0.78	0.92	1.19	0.82
Acid detergent fibre	151	51.1	5.9	33.5	68.8	0.64	0.99	0.88	0.98
Acid detergent lignin	148	3.7	0.7	1.6	5.8	0.26	0.86	0.36	0.73
OMD	475	45.3	4.7	31.3	59.3	1.11	0.94	1.28	0.92
Silica	101	16.2	2.2	9.6	72.7	0.59	0.93	0.82	0.86
Metabolizable energy (MJ/kg)	471	6.5	0.7	4.3	8.6	0.12	0.97	0.15	0.96

Note:

SEC: Standard error of calibration

SECV: Standard error of cross-validation

RSQ (R^2): Determination coefficient

OMD: *In vitro* organic matter digestibility

I-VR: Proportion of reference method variation explained by cross validation of predicted values.

.

Table 6: Local calibration of 54 out of 147 rice straw samples

Constituents	Number of samples (n)	Mean (%)	Standard deviation	Estimated minimum (%)	Estimated maximum (%)	SEC	RSQ	SECV	1-VR
Dry matter	51	92.5	1.3	88.7	96.2	0.2	0.98	0.27	0.95
Ash	49	15.5	3.6	4.7	26.2	0.5	0.98	0.87	0.94
Nitrogen	50	1.1	0.4	0.0	2.2	0.1	0.98	0.09	0.93
Neutral detergent fibre	52	65.5	3.1	56.3	74.6	1.2	0.84	1.85	0.63
Acid detergent fibre	50	44.9	4.8	30.5	59.2	0.4	0.99	0.97	0.96
Acid detergent lignin	48	4.3	0.6	2.4	6.1	0.2	0.85	0.42	0.52
OMD	52	47.7	2.9	39.0	56.4	0.6	0.95	0.76	0.93
Metabolizable energy (MJ/kg)	52	6.7	0.5	5.3	8.1	0.1	0.97	0.11	0.95

Note:
SEC: Standard error of calibration
SECV: Standard error of cross-validation
RSQ (R^2): Determination coefficient
OMD: *In-vitro* organic matter digestibility
I-VR: Proportion of reference method variation explained by cross validation of predicted values.

3.4 Study four: Voluntary intake and digestibility of straws of five rice varieties fed to rams

3.4.1 Introduction

Tropical countries face a perennial problem of inadequate quality and quantity of ruminant feeds. Thus alternative feed resources such as crop residues and agro-industrial by-products have been increasingly used. Rice straw is now increasingly being generated in most West African countries. Food-feed crops are the most important feed source for ruminants (Thomas, 2002). In SSA and India, 140 and 370 million resource-poor livestock keepers respectively, stand to benefit from food-feed crops within the prevalent small-scale, mixed crop-livestock systems (Lenne *et al.,* 2003). In Nigeria, to a large extent, straw is often left on the field to rot, to be grazed on by nomad's animals or even burnt. Rice straw once categorized as waste has become a major component of livestock feed in many rice producing economies. The rapid increase in its use has been due to several factors; such as increasing demand for food (meat and milk), greater pressure for agricultural land use, rising cost of better-quality feed and pollution problems resulting from waste disposal.

The realization of the wasting of enormous quantities of potential sources of energy/carbohydrates necessitates straw usage as fodder. With the increasing food demand and the rapidly expanding world population, ruminants in the future will have to depend more and more of these fibrous 'wastes', particularly straws. Idea of a crop from which farmers gets one product for human consumption and all the residues for his animal is highly appealing (Thornton *et al.*, 2003).

3.4.2 Materials and methods

3.4.2.1 Rice straw diets

Five rice varieties, CG14, NERICA 14, ITA 321, NERICA lowland 20 and Cisadane were planted in June 2010 on hydromorphic ecology at IITA (AH).The panicles and straws of the different varieties were harvested separately at maturity. Straws of the different varieties were sun-dried in a glass house (Plate 4). Straws were chaffed using a locally made chaffing machine (Plate 5), and stored in labelled bags (Plate 6).

3.4.2.2 Animals and their management

Twenty (20) West African dwarf rams aged between 12 to 18 months with mean body weight of 14.48kg were used for the experiment. The study was carried out at the Department of Animal Science, University of Ibadan. The animals were tagged and labelled, dewormed using Albendazole oral tablets and treated against ectoparasites with Ivomec© subcutaneously administered at the rate of 1 ml per 50 kg body weight.

Animals were confined in barns and group-fed their respective experimental diets. The experiment lasted for 21 days, including 14 days for adaptation (Osuji *et al.,* 1993).

On day 1 of the experiment, each animal was weighed and placed in individual metabolism cage (Plate 7) assigned in a completely randomized design with four replicates to the five sole rice straw diets (CG14, NERICA 14, ITA 321, NERICA L 20 and Cisadane). Feed was weighed and fed *ad libitum***,** and residue was weighed daily. Water was also provided *ad libitum*.

Plate 4: Rice straws being dried in glass house

Plate 5: Chaffing of dried rice straw in a locally made chaffing machine

Plate 6: Chaffed rice straw stored in labelled bags

Plate 7: Ram in metabolism crate

3.4.2.3 Sampling of feedstuff

Representative samples of feeds and leftovers were taken on a daily basis. Bulked samples of 7-day collection were oven dried at 65ºC to constant weight for 'as fed' dry matter (DM) determination. The bulked samples of the 7-day collection were mixed and ground through 2mm screen and stored in air-tight containers. The labelled samples were kept at room temperature until required for laboratory analysis.

3.4.2.4 Collection of faeces

From day 17 to 23 of the experiment, total faeces voided during the 24hr period were collected in the morning before feeding. The faeces were weighed daily and an aliquot for each animal was oven dried at 65ºC to a constant weight in forced-air oven and bulked. Dry matter was determined (AOAC, 1990). Samples were weighed and ground through 2mm screen.

3.4.2.5 Collection of urine

Total urine excreted by each ram was collected before feeding from day 17 to 23. Urine from each animal was trapped through a funnel into bottles placed under the cages into which drops of concentrated sulphuric acid was added daily to curtail volatilization of ammonia. An aliquot (10%) of total volume of daily urine excretion was collected, labelled and refrigerated till required for analysis.

3.4.2.6 Analytical Procedure

The feeds, faecal and urinary samples were analysed for nitrogen (N) (AOAC, 1990). Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined (Goering and Van Soest, 1970). Hemicellulose was calculated as the difference between neutral detergent fibre and acid detergent fibre.

3.4.2.7 Calculations

Voluntary Dry Matter Intake was calculated using the following formula;

Average daily dry matter intake = A – B

Apparent dry matter digestibility = [A - B – C/A – B] x 100

where:

A = average dry matter offered daily

B = average dry matter refused daily

C = average dry matter voided in faeces daily

Digestion coefficients for all the constituent nutrients of the diets were calculated using the dry matter values A, B, C and percentage nutrients in feed, refusal (orts) and faeces expressed on a dry matter basis. Percentage nitrogen in urinary samples and total volume excreted was used to determine quantity of nitrogen (in grammes) excreted daily to determine nitrogen balance for each animal.

3.4.2.8 Statistical analysis

Data were subjected to analysis of variance using (SAS, 2009) and means separated where variations were observed.

CHAPTER FOUR

4.0 RESULTS

4.1 Study one: Rice straw as fodder in Nigeria

4.1.2 Rice farmers' education, age, gender distribution and marital status

Statistical analysis showed that 25.0% of all respondent in the three (3) states had no education at all, while 17.8% indicated that they have primary school education. Those who had secondary education were also 17.8%. An aggregate of 16.1% of respondents also indicated that they had tertiary education, 21.7% had only Islamic education, while 1.7% had a combination of primary and Islamic education (Table 7).

The percentage of respondent who were married was 98.9%, while the unmarried rice farmers were 1.1% in all three (3) states (Table 7). The mean age of all respondents was 43.8±0.9 years (Table 7). The gender distribution showed that 95% of all respondents were males while 5% were females.

Table 7: Level of education (%), marital status (%), gender (%) and age distribution of rice farmers in Niger, Kaduna and Bauchi states

Level of Education	No Education (%)	Primary (%)	Secondary (%)	Tertiary (%)	Islamic (%)	Primary + Islamic (%)
	25.0	17.8	17.8	16.1	21.7	1.7
Gender		Male (%) 95.0		Female (%) 5.0		
Marital Status		Married (%) 98.9		Unmarried (%) 1.1		
Age Distribution Age (Years)		Niger 43.1±11.1	Kaduna 43.0±13.6	Bauchi 45.2±10.9	Aggregate 43.8±11.4	

4.1.3 Land use

The average area of land cultivated to rice by each farmer in the three states was 2.9 ha. Bauchi had the highest mean areas cultivated to rice per farmer (3.3 ha), while Niger and Kaduna had 2.4 ha and 2.9 ha respectively (Table 8). Many other crops were cultivated by farmers which varied from region to region. Maize, sorghum, millet, cowpea and groundnut were cultivated by most farmers and were common to all three states. They were cultivated by 96.7, 83.9, 55.0, 60.6 and 56.7% of rice farmers, respectively (Table 8). Also shown on Table 8 are the proportions of rice farmers cultivating other crops apart from rice, maize, sorghum, millet, cowpea and groundnut; while Table 9 shows rice farmers' management and usage approach and tendencies towards their rice fields.

4.1.4 Livestock production and ownership

The mean number of cattle, goats and sheep owned by rice farmers in Niger state was 2.6, 2.3 and 3.8, respectively; Kaduna 3.8, 6.0 and 2.4 and in Bauchi 2.2, 6.5 and 2.7, respectively. The mean number of cattle, goats and sheep owned by rice farmers in the three states were 2.9, 5.3 and 3.0, respectively (Table 10).

Figure 7 shows the distribution of the pattern or mix of the livestock owned by rice farmers. A total of 152 of the 180 sampled farmers owned ruminants, of the 152 farmers; 58 owned the three (3) species, while 28 owned only cattle and goats; 11 owned only cattle and sheep and 8 owned only goats and sheep.

Table 8: Mean area (ha) of land cultivated to rice and other major crops; and minor crops cultivated by rice farmers in Niger, Kaduna and Bauchi states of Nigeria

State	Niger	Kaduna	Bauchi	Aggregate
Major Crops				
Rice	2.4	2.9	3.3	2.9
Maize	0.4 (98.3)	2.7 (98.3)	2.8 (93.3)	2.0 (96.7)
Sorghum	0.7 (100.0)	1.1 (83.3)	1.8 (68.3)	1.2 (83.9)
Millet	0.4 (86.7)	0.3 (46.7)	0.3 (31.7)	0.3 (55.0)
Cowpea	0.3 (63.3)	0.7 (63.3)	0.7 (55.0)	0.6 (60.6)
Groundnut	0.2 (53.3)	0.6 (56.7)	1.0 (61.7)	0.6 (56.7)
Minor Crops	Farmers cultivating minor crops (%)			
Cassava	18.3			
Sugarcane	17.2			
Soyabean	27.8			
Tomato and pepper	18.3			
Yam	22.2			
Cocoyam	12.8			
Sweet Potatoes	11.1			

Note: Figures in parentheses are percentages (%) of rice farmers cultivating the different crops

Table 9: Other land use and rice cultivation issues

Other issues	%
Rice farmers who used same rice plots for over ten (10) seasons	95.6
Rice farmers who used same rice plots for between 5 and 10 seasons	4.4
Rice farmers who opened new fallows within last 3 seasons	8.3
Rice farmers who opened new fallows between the last 3-5 seasons	9.4
Rice farmers who used their rice plots for other crops	6.7
Rice farmers whose rice plots were strictly for rice	90.6
Rice farmers who rented out their rice plots	2.8
Rice farmers who did not plan to increase rice plot size	65.6
Rice farmers who cultivated rice on lowland ecology only	79.4
Rice farmers who cultivated rice on upland ecology only	12.8
Rice farmers who cultivated on both lowland and upland ecology	7.8

Table 10: Mean number of cattle, goats and sheep ownership in Niger, Kaduna and Bauchi states by rice farmers

Species	Niger	Kaduna	Bauchi	Mean
Cattle	2.6	3.8	2.2	2.9
Goat	2.3	6.0	6.5	5.3
Sheep	3.8	2.4	2.7	3.0

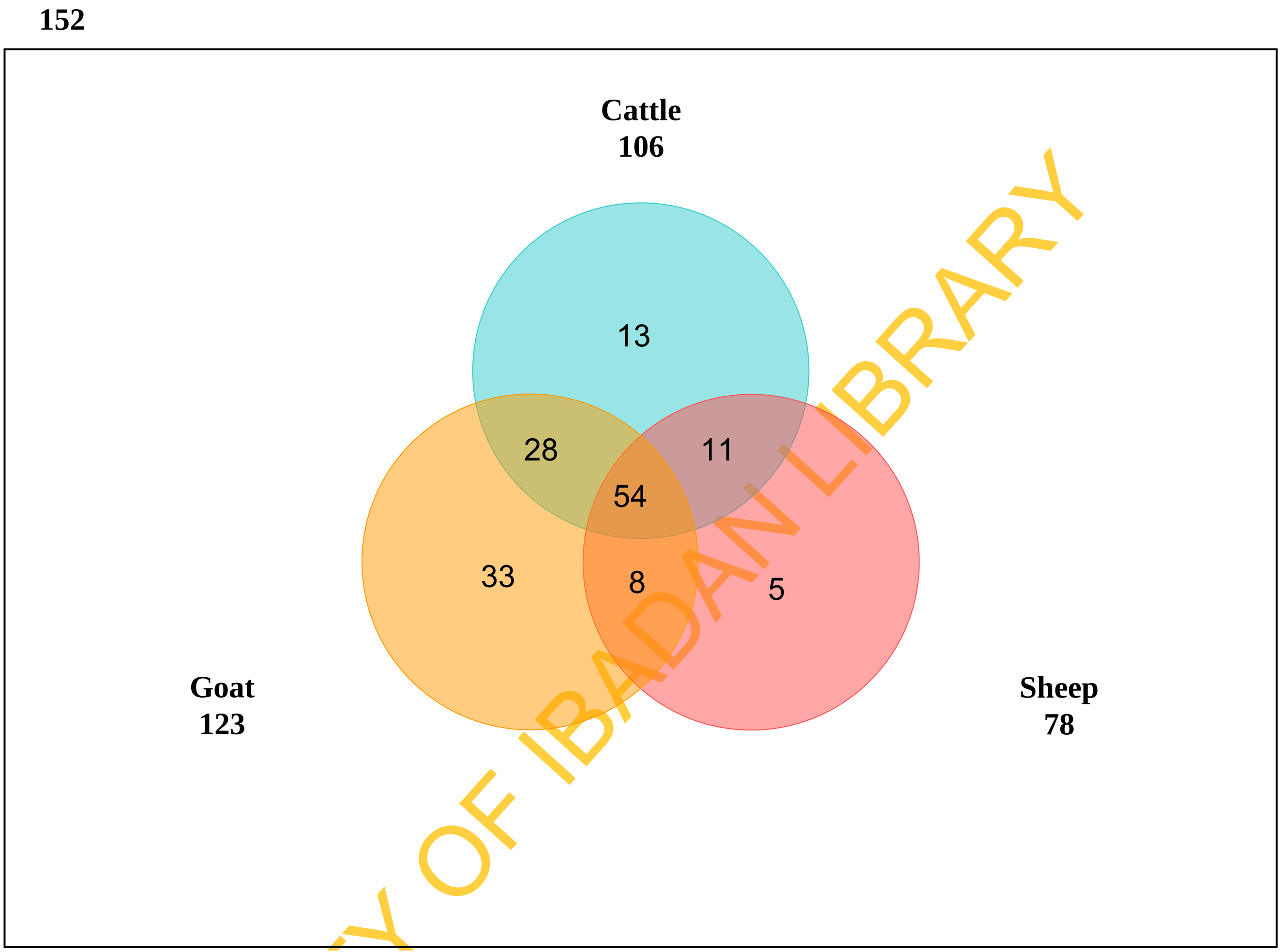


Figure 7: Distribution of ownership of cattle, sheep and goats by rice farmers in Niger, Kaduna and Bauchi states

4.1.5 Fodder materials used by rice farmers

Maize stover was used as fodder by 83.3% of rice farmers who owned livestock while 75% utilized sorghum stover and 77.2% used cowpea haulms. Rice straw was utilized by 67.2% of the livestock–keeping farmers. Groundnut haulms and ‘cut’ grass was used by 67.8 and 25.0% of the farmers, respectively (Table 11).

The farmers also sourced for fodder materials by harvesting them from their farms or have them packed from farms of family members and friends. Up to 68.9% of the farmers bought fodder materials, 47.2% allowed their animals to graze farms after harvesting of crops (Table 11).

4.1.6 Farmers’ access to communal grazing lands.

Rice farmers who claimed to keep livestock and who had access to grazing land or owned land designated as grazing lands were 8.9%. Also, 1.1% out of these had access to or owned grazing land with an estimated area that is above 2 hectare, while 1.7% indicated that the grazing land accessible or owned by them was greater than 1ha, 0.6% out of the 8.9% had access to or owned about 1 hectare of grazing land while 5.6% owned or had access to less than 1 hectare of grazing land (Table 12).

Table 11: Fodders/residues and sources of materials utilized by rice farmers to feed ruminants in Niger, Kaduna and Bauchi states

Fodder Type	Niger (%)	Kaduna (%)	Bauchi (%)	Mean (%)
Maize Stover	81.7	81.7	86.7	83.3
Sorghum Stover	81.7	66.7	76.7	75.0
Cowpea Haulms	70.0	78.3	83.3	77.2
Rice Straw	**76.7**	**70.0**	**55.0**	**67.2**
Groundnut Haulms	56.7	66.7	80.0	67.8
'Cut' Grass	20.0	33.3	21.7	25.0
Source of materials				
Cultivated	81.7	83.3	86.7	83.9
From other farmers (free)	13.3	3.3	1.7	6.1
Grazing	65.0	35.0	41.7	47.2
Bought	73.3	56.7	76.7	68.9
From relations (free)	15.0	3.3	1.7	6.7

Table 12: Distribution of hectarage of grazing land owned or accessible by rice farmers who owned ruminants in Niger, Kaduna and Bauchi states

	Niger (%)	Kaduna (%)	Bauchi (%)	Mean (%)
Range of grazing land owned or accessible to rice farmers:				
< 1 Hectare	3.3	11.7	1.7	5.6
About 1 Hectare	0	0	1.7	0.6
> 1 Hectare	5.0	0	0	1.7
About 2 Hectare	0	0	0	0
> 2 Hectare	3.3	0	0	1.1
Rice farmers with access/ownership of grazing land (%)	11.6	11.7	3.4	8.9

*Most grazing lands are common communal properties

4.1.7 Importance of rice straw to rice farmers

The proportion of rice farmers who considered rice straw as an important output of their rice plantings operation was 68.3% compared to 31.7% who considered straw unimportant. Also, only 15.6% of all 180 rice farmers interviewed reported that they packed all of the straw generated on their rice plots (Table 13). While 50.6% packed some of the rice straw, 32.6% did not pack any and 1.1% reported that their animals were made to graze straw on the fields.

Farmers who reported that they had never been approached by anyone to pack rice straw from their farms were 86.7%, while 12.8% indicated that they had been approached. Out of the 12.8% who were approached, 8.9% indicated that tokens were offered by the requesters. One farmer out of the 180 farmers interviewed reported that the requesters (straw-packing Fulani herdsmen) offered labour during planting season in exchange for the rice straw during and after harvest.

4.1.8 Other uses of rice straw by farmers.

Apart from its usage as fodder by majority of rice farmers, 2.2% of the farmers reported that they used rice straw in the construction of granaries and barns. Also 0.6% of rice farmers used rice straw in making door mats. Also, 1.1% of the farmers used rice straw as mean to control soil surface run-off, while 14.4% used rice straw as mulching materials in yam cultivation activities. A total of 6.1% also indicated that they had used rice straw at one time or the other in construction of walls and fences (Table 14).

4.1.9 Adoption of rice with improved straw fodder quality.

Rice farmers indicated that improvement of fodder quality was sufficient reason to adopt a new rice variety, 98.9% of the respondents indicated this. The same proportion (98.9%) also indicated that they would adopt a new variety of rice if the straw attracts additional income and also it a ready market for rice straw emerges (Table 14).

Table 13: Importance perception rating of rice straw, portions of rice straw gathered by farmers and report of request for rice straw from farmers in Niger, Kaduna and Bauchi states

	Niger (%)	Kaduna (%)	Bauchi (%)	Aggregate (%)
Portions of rice straw gathered by rice farmers:				
All	11.7	18.3	16.7	15.6
Some	65.0	51.7	35.0	50.6
None	23.4	30.0	45.0	32.8
None but grazed on by own animals	0.0	0.0	3.3	1.1
Importance of rice straw to rice farmers				
Important	75.0	73.3	56.7	68.3
Not important	25.0	26.7	43.3	31.7
Farmers approached for rice straw				
Approached	20.0	5.0	13.3	12.8*
Never Approached	80.0	95.0	86.7	86.7

*8.9% out of 12.8% reported that money (token) or labour** was offered in return for rice straw.

** One respondent reported that Fulani herdsmen assisted during rice planting season in exchange for the straw generated from the farm.

Table 14: Other uses and handling of rice straw; and reasons for adoption of rice varieties with improved straw quality by rice farmers in Niger, Kaduna and Bauchi states

Other uses/purposes	Rice farmers (%)
Construction of granaries/barns	2.2
Weaving of door mats	0.6
Erosion control	1.1
Mulching of crops (Yam)	14.4
Brick making/House Construction	6.1
Straw management	
Rice farmers who incur cost on labour to remove straws	30.6
Rice farmers who incur cost on straw transportation	5.6
Rice farmers who burn straw on their field as a means of improving soil fertility and or ridding their rice field of straw	8.9
Reasons for which new varieties may be adopted	Rice farmers (potential adopters) (%)
Improved straw quality, maintained grain quality	98.9
If straw attracts additional income	98.9
If a ready market for straw emerges	98.9
If livestock became very expensive, driving up straw demand	96.7
Improved straw fodder quality, with slightly less grain.	66.1

4.1.10 Straw handling by rice farmers

Farmers who reported that they incurred labour cost in riding their farms of rice straw were 30.6% of all respondents, while 5.6% incurred transportation cost in moving the straw to their storage facilities for use as fodder. The proportion of farmers who incinerated straw as a means of riding their fields of the materials and or as a mean improving soil quality was 8.9% (Table 14).

4.2 Study two: Field evaluation of 49 rice accessions

4.2.1 Seedling vigour

Seedling vigour rating was done at thirty days after sowing on a scale of 1 to 9 (Standard Evaluation Systems for Rice (SES), IRRI, 2002). The interspecific lowland group and *Oryza sativa* lowland had a more vigorous growth at 30 days after sowing with ratings of 2.3 and 3.2 (Tables 4 and 15). Most of the plants had 4 and 5 leaves per seedling with most of the stands having two tillers. The seedling vigour rating of *Oryza sativa* lowland group were statistically similar with rating of the *Oryza glaberrima* cultivar group, which had a rating of 3.7. The two upland cultivar groups (Interspecifics and Sativa) had the least vigour rating of 4.7 and 5.0, which are categorized as normal according to SES (IRRI, 2002).

NERICA 4 had the most vigorous seedlings with a rating of 2.3, while NERICA 16 had the worst rating of 7.0 within the interspecifics upland group. Accessions of this group had mean TDSV ratings ranging from 2.3 to 7.0 (Table 16). Within the interspecifics lowland group, NERICA-Lowland (NL) 45, 20 and 9 had TDSV rating of 1.0 while NL 14 had a mean rating of 1.7. NERICA-Lowland 41 had the poorest rating of 4.3 within this group (Table 17).

The *Oryza sativa* upland group had a mean rating that ranged from 3.0 to 6.3. Accession OS 6 had the best TDSV rating of 3.0 while WAB 181-18 and WAB 189 had mean ratings of 6.3 (Table 18). While the *Oryza sativa* lowland cultivar group had a mean TDSV rating ranging

Table 15: Means of some standard evaluation systems (SES) ratings of five rice cultivar groups

Cultivar Groups	Interspecific Upland	Interspecific Lowland	*Oryza sativa* Upland	*Oryza sativa* Lowland	*Oryza glaberrima*
Parameters					
Thirty-day seedling vigour[+]	$4.7^{a}±0.2$	$2.3^{c}±0.3$	$5.0^{a}±0.4$	$3.2^{bc}±0.3$	$3.7^{b}±0.5$
Maturity (days)	$117.3^{c}±0.7$	$130.5^{b}±0.6$	$119.4^{c}±1.2$	$135.3^{a}±1.2$	$130.9^{b}±4.2$
Spikelet fertility (%)	$84.8^{b}±0.92$	$85.2^{b}±1.2$	$84.7^{b}±1.8$	$87.0^{b}±1.9$	$92.0^{a}±0.9$
Lodging Incidence (%)	$3.3^{b}±1.2$	$0.0^{b}±0.0$	$2.4^{b}±2.2$	$5.2^{b}±1.9$	$61.3^{a}±2.7$
Phenotypic acceptability[+]	$5.3^{b}±0.1$	$3.9^{c}±0.2$	$5.3^{b}±0.2$	$4.0^{c}±0.2$	$7.3^{a}±0.3$
Threshability[+]	$6.9^{b}±0.1$	$8.5^{a}±0.2$	$7.1^{b}±0.3$	$8.4^{a}±0.2$	$6.4^{b}±0.3$
One thousand grain weight (g)	$31.5^{a}±0.4$	$28.8^{b}±0.5$	$31.4^{a}±0.6$	$26.3^{c}±0.6$	$28.0^{b}±0.8$

Test level: 0.05 [abc]Means with same superscripts on the same rows are not significantly different.

[+] : SES (Standard Evaluation Systems for Rice) rating.

Table 16: Means of some standard evaluation ratings of interspecifics upland (IU) rice

Accession	Thirty-day seedling vigour+	Maturity (days)	Spikelet fertility (%)	Lodging incidence (%)	Phenotypic acceptability+	Threshability+	One thousand grain weight (g)
NERICA 1	4.3[abcd]	120.5[cd]	89.3[ab]	0.0[b]	4.3[c]	5.7[cd]	30.6[defg]
NERICA 2	3.7[bcd]	116.7[cdef]	88.7[ab]	0.8[b]	5.0[bc]	7.0[abc]	30.7[defg]
NERICA 3	5.7[abc]	117.5[cdef]	84.1[abc]	0.0[b]	4.7[bc]	5.7[cd]	30.2[defg]
NERICA 4	2.3[d]	113.5[ef]	87.7[abc]	0.0[b]	5.3[bc]	7.0[abc]	29.5[efg]
NERICA 5	5.0[abcd]	117.5[cdef]	88.3[abc]	2.5[ab]	5.0[bc]	7.0[abc]	28.3[g]
NERICA 6	5.7[abc]	126.0[ab]	81.4[abc]	5.0[ab]	5.3[bc]	7.0[abc]	29.4[efg]
NERICA 7	4.3[abcd]	116.5[cdef]	79.9[abc]	3.3[ab]	5.3[bc]	7.0[abc]	33.6[bc]
NERICA 8	5.0[abcd]	119.2[cde]	80.5[abc]	0.0[b]	5.0[bc]	5.0[d]	30.5[defg]
NERICA 9	4.3[abcd]	112.3[f]	82.2[abc]	0.0[b]	5.3[bc]	6.3[bcd]	29.2[fg]
NERICA 10	3.7[bcd]	113.0[ef]	88.7[ab]	0.0[b]	4.3[bc]	7.0[abc]	29.1[fg]
NERICA 11	5.0[abcd]	117.2[cdef]	77.5[bc]	0.0[b]	5.0[bc]	6.3[bcd]	28.0[g]
NERICA 12	6.3[ab]	115.8[cdef]	79.8[abc]	6.7[ab]	6.0[ab]	7.0[abc]	38.8[a]
NERICA 13	5.0[abcd]	105.0[g]	75.5[c]	0.0[b]	5.0[bc]	7.0[abc]	34.9[b]
NERICA 14	3.0[cd]	115.0[def]	90.9[a]	0.8[b]	5.0[bc]	6.0[bcd]	31.2[cdef]
NERICA 15	5.0[abcd]	117.1[cdef]	90.2[ab]	0.8[b]	7.0[a]	7.7[ab]	32.1[cde]
NERICA 16	7.0[a]	118.8[cde]	83.9[abc]	3.3[ab]	6.0[ab]	7.3[abc]	32.6[bcd]
NERICA 17	3.0[cd]	113.8[ef]	83.9[abc]	10.0[a]	4.7[bc]	7.7[ab]	38.0[a]
NERICA 18	5.7[abc]	121.8[bc]	91.0[a]	5.0[ab]	5.7[abc]	8.3[a]	33.7[bc]
ART 10	6.3[ab]	129.7[a]	84.9[abc]	2.5[ab]	6.0[ab]	8.3[a]	28.7[fg]

Test level: 0.05 [abcdefg]Means with same superscripts on the same columns are not significantly different.

+: SES (Standard Evaluation Systems for Rice) ratings

Table 17: Means of some standard evaluation ratings of interspecifics lowland (IL) rice

Accessions	Thirty day seedling vigour[+]	Maturity (days)	Spikelet fertility (%)	Lodging incidence (%)	Phenotypic acceptability[+]	Threshability[+]	One thousand grain weight (g)
NERICA- L-7	2.3^{ab}	130.3^{abcd}	77.0	0.0	4.0	7.7^{b}	30.1^{a}
NERICA- L-8	2.3^{ab}	126.7^{d}	89.4	0.0	4.0	8.3^{ab}	28.4^{abc}
NERICA- L-9	1.0^{b}	127.7^{cd}	89.5	0.0	4.0	9.0^{a}	29.6^{a}
NERICA- L-14	1.7^{ab}	129.7^{bcd}	81.6	0.0	4.0	8.0^{ab}	28.9^{abc}
NERICA- L-19	3.0^{ab}	133.8^{ab}	88.0	0.0	3.3	7.7^{b}	28.4^{abc}
NERICA- L-20	1.0^{b}	131.7^{abcd}	84.4	0.0	3.0	9.0^{a}	29.2^{ab}
NERICA- L-21	3.7^{ab}	131.7^{abcd}	86.9	0.0	4.0	8.3^{ab}	27.2^{c}
NERICA- L-41	4.3^{a}	133.3^{abc}	84.8	0.0	4.3	9.0^{a}	27.3^{bc}
NERICA- L-42	2.3^{ab}	136.7^{a}	83.6	0.0	4.7	9.0^{a}	28.6^{abc}
NERICA- L-45	1.0^{b}	127.5^{cd}	88.6	0.0	4.0	9.0^{a}	30.0^{a}
NERICA- L-49	3.0^{ab}	128.7^{bcd}	81.3	0.0	4.0	8.7^{ab}	28.9^{abc}
NERICA- L-60	2.3^{ab}	129.8^{bcd}	87.8	0.0	3.0	8.0^{ab}	29.2^{ab}

Test level: 0.05 ^{abcd}Means with same superscripts on the same columns are not significantly different.

[+] : SES (Standard Evaluation Systems for Rice) rating

Table 18: Means of some standard evaluation ratings of *Oryza sativa* upland (OsU) rice

	Thirty day seedling vigour[+]	Maturity (days)	Spikelet fertility (%)	Lodging incidence (%)	Phenotypic acceptability[+]	Threshability[+]	One thousand grain weight (g)
WAB 56-104	3.7	118.7[c]	86.9[ab]	0.0	5.3	7.0[ab]	32.9[a]
WAB 181-18	6.3	118.7[c]	77.0[b]	0.0	4.3	6.3[ab]	29.8[b]
WAB 189	6.3	109.0[d]	92.5[a]	0.8	6.0	5.3[b]	33.0[a]
ITA 321	5.7	122.8[b]	77.1[b]	0.0	5.3	7.0[b]	32.69[a]
OS 6	3.0	123.5[ab]	83.4[ab]	4.2	5.0	8.3[a]	32.79[a]
Ofada	5.0	126.8[a]	91.3[a]	1.7	5.3	8.3[a]	27.21[c]

Test level: 0.05 [abc]Means with same superscripts on the same columns are not significantly different.

[+] : SES (Standard Evaluation Systems for Rice) rating.

from 1.7 to 4.3, WITA 4 had the best TDSV rating of 1.67, followed by IR 64 with a mean rating of 2.3. TOX 4004 had the poorest rating of 4.3 within this group (Table 19).

The *O. glaberrima* accessions had their mean TDSV rating ranging from 2.3 to 4.3, CG14 had a mean rating of 2.3, while TOG 7106 and TOG 7206 both had mean ratings of 4.3 (Table 20).

4.2.2 Maturity (days)

Oryza sativa lowland group had a significantly higher mean maturity period of 135.3 days. Interspecifics lowland and *Oryza glaberrima* groups had similar maturity periods of 130.5 and 130.9 days, while the upland cultivar groups, interspecifics upland and *Oryza sativa* upland also had similar maturity periods of 117.3 and 119.4 days. The periods recorded for the two upland cultivar types were significantly lower than the periods observed for both the interspecifics lowland and the *Oryza glaberrima* groups (Table 15).

Interspecifics upland accessions had average maturity periods that ranged from 105.0 to 129.7 days. ART 10 had the highest number of days to maturity (129.7 days), while NERICA 13 had the least number of days to maturity (105.0 days). Days-to-maturity of ART 10 was significantly higher than the mean days to maturity recorded for all the other accessions within this group except NERICA 6 which recorded 126.0 days (Table 16). The number of days observed for NERICA 13 was also significantly lower than days observed for all other accessions within the group.

NERICA lowland (NL) 8 had the least number of days-to-maturity (126.7 days) within the interspecifics lowland group, but this observed maturity period for NL 8 was only significantly lower than the days to maturity period observed for NL 41 (133.3 days), NL 19 (133.8 days) and NL 42 (136.2 days). NL 42 with mean days to maturity of 136.2 days was only significantly higher than the values recorded for 6 accessions within the group namely: NL 8, NL 9, NL14, NL 45, NL 49 and NL 60 (Table 17).

Table 19: Means of some standard evaluation ratings of *Oryza sativa* lowland rice

Accessions	Thirty day seedling vigour[+]	Maturity (days)	Spikelet fertility (%)	Lodging incidence (%)	Phenotypic acceptability[+]	Threshability[+]	One thousand grain weight (g)
IR 64	2.3[ab]	125.7[d]	90.7[ab]	0.0[b]	4.3[ab]	8.7[ab]	27.1[bc]
IR 72	3.0[ab]	126.3[d]	89.0[ab]	0.0[b]	5.3[a]	8.7[ab]	25.1[cd]
Suakoko 8	3.7[ab]	148.0[a]	96.6[a]	45.0[a]	3.0[c]	7.7[b]	22.1[e]
WITA 4	1.7[b]	138.8[b]	82.5[bc]	0.0[b]	3.0[c]	9.0[a]	26.7[bcd]
SIPI	3.7[ab]	127.5[d]	89.2[ab]	0.0[b]	5.0[a]	8.0[ab]	26.5[cd]
TOX 4004	4.3[a]	138.3[b]	71.2[c]	2.5[b]	4.3[ab]	7.7[b]	28.7[ab]
Cisadane	3.0[ab]	144.8[a]	89.6[ab]	0.0[b]	3.3[bc]	9.0[a]	29.5[a]
BW 348-1	3.7[ab]	132.7[c]	87.1[ab]	0.8[b]	3.3[bc]	8.7[ab]	24.6[d]

Test level: 0.05 [ab]Means with same superscripts on the same columns are not significantly different.

[+] : SES (Standard Evaluation Systems for Rice) rating.

Table 20: Means of some standard evaluation ratings of *Oryza glaberrima* rice

Accessions	Thirty day seedling vigour[+]	Maturity (days)	Spikelet fertility (%)	Lodging incidence (%)	Phenotypic acceptability[+]	Threshability[+]	One thousand grain weight (g)
CG 14	2.3	120.7[b]	93.1	72.5	7.67	6.3[a]	30.6[a]
TOG 7106	4.3	139.0[a]	92.4	90.8	7.67	8.0[a]	23.9[b]
TOG 7206	4.3	131.0[ab]	91.4	59.2	7.00	4.0[b]	25.6[b]
TOG 7442	3.7	133.0[ab]	91.0	55.8	7.00	7.3[a]	32.0[a]

Test level: 0.05 [ab]Means with same superscripts on the same columns are not significantly different.

[+] : SES (Standard Evaluation Systems for Rice) rating

Amongst the six accessions of the *Oryza sativa* upland group, Ofada had the longest maturity period of 123.8 days which was similar to 123.5 days recorded for OS 6. WAB 189 with mean days-to-maturity of 109.0 days had the least number of days-to-maturity. Accessions WAB 181-18 and WAB 56-104 had the same mean days to maturity of 118.7 days (Table 18).

Accessions IR 64, IR 72 and Sipi had significantly ($p<0.05$) lower mean number of days to maturity of 125.7, 126.3 and 127.5 days respectively within the *Oryza sativa* lowland group. Cisadane and Suakoko 8 had significantly longer days-to-maturity than the other accessions within the group; which were 144.8 and 148.0 days, respectively (Table 19).

Accession TOG 7106 had the longest number of days-to-maturity of 139.0 days which was not significantly different from 131.0 and 133.0 days recorded for TOG 7206 and TOG 7442 respectively within the *Oryza glaberrima* group. CG 14 had the least number of days to maturity (120.7 days) which was also similar to the number of days recorded for TOG 7206 and TOG 7442 (Table 20).

4.2.3 Spikelet fertility (%)

Oryza glaberrima cultivar group had a significantly higher spikelet fertility of 92.0% than all the other four (4) groups. Interspecifics upland, interspecifics lowland, *Oryza sativa* upland and *Oryza sativa* lowland had mean spikelet fertility of 84.8, 85.2, 84.7 and 87.0% respectively. The mean value recorded for these four groups were similar (Table 15).

NERICA 18 and NERICA 14 had the highest and similar spikelet fertility percentages of 91.0 and 90.9% respectively. However the figures recorded for the two were only significantly higher than the values recorded for NERICA 11 and NERICA 13, which were 77.5 and 75.5% respectively, but similar to values obtained for the fifteen (15) other accessions in the interspecifics upland group (Table 16).

The interspecifics lowland group had spikelet fertility that ranged from 77.0 to 89.5%. The values recorded by all members of this group were all similar (Table 17)

Within the *Oryza sativa* upland group, WAB 189 and Ofada had spikelet fertilities of 92.5% and 91.3% which were significantly higher than the percentages observed in WAB 181-18 and ITA 321 which were 77.0 and 77.1% respectively. Spikelet fertilities of 86.9% and 83.4% observed for WAB 56-104 and OS 6 respectively were similar to values obtained for WAB 189 and Ofada on one hand, and also similar to the values observed for WAB181-18 and ITA 321 on the other hand (Table 18).

The *Oryza sativa* lowland group had mean spikelet fertility that ranged from 71.2 to 96.6%. Suakoko 8 had a mean spikelet fertility of 96.6% which was significantly higher than the percentages observed for only WITA 4 and TOX 4004 which were 82.5% and 71.2% respectively (Table 19).

Oryza glaberrima accessions had similar spikelet fertility percentages. Accession CG 14 had 93.1% while TOG 7106, TOG 7206 and TOG 7442 had spikelet fertility percentages of 92.4, 91.4 and 91.0% respectively (Table 20).

4.2.4 Lodging incidence (%)

The incidence of lodging in the *Oryza glaberrima* group was significantly higher than observed in the other four cultivars. The accessions had 61.3% mean lodging incidence, while the interspecifics lowland had 0% lodging incidence. The 0% incidence observed in the interspecifics upland group was not significantly lower than 2.4, 3.3 and 5.2% observed in *Oryza sativa* upland, interspecifics upland and *Oryza sativa* lowland, respectively (Table 15).

Eleven (11) out of the nineteen (19) accessions in the interspecifics upland group recorded lodging. NERICA 17 recorded 10% incidence of lodging which was significantly higher than the observed level in eleven accessions (Table 16). Lodging incidence recorded for NERICA 17 was not significantly higher than the observed levels in NERICA 18 (5.0%), ART 10 (2.5%), NERICA 16 (3.3%), NERICA 12 (6.7%), NERICA 7 (3.3%), NERICA 6 (5.0%) and NERICA 5 (2.5%) (Table 16).

The interspecifics lowland accessions had no incident of lodging (i.e. they all recorded 0.0% lodging incidence) (Table 17), while only three (3) accessions of the *Oryza sativa* upland group, namely WAB 189, OS 6 and Ofada recorded 0.8, 4.2 and 1.7% mean lodging incidences respectively. These levels were not significantly different from the three (3) other members of the group which recorded 0.0% lodging incidence (Table 18).

Suakoko 8 had a mean lodging incidence of 45.0% which was significantly higher than recorded levels in TOX 4004 (2.5%), BW 348-1 (0.8%) and the three (3) other accessions within the *Oryza sativa* lowland group which recorded 0.0% lodging incidence (Table 19).

The *Oryza glaberrima* accessions all had high incidents of lodging. TOG 7106 had a lodging incident of 90.8% while CG 14, TOG 7206 and TOG 7442 had lodging incidences of 72.5%, 59.2 and 55.8% respectively which were not significantly different from one another (Table 20).

4.2.5 Phenotypic acceptability (PA)

The interspecifics lowland and *Oryza sativa* lowland accessions had phenotypic acceptability ratings of 3.9 and 4.0 respectively. The ratings of interspecifics upland and *Oryza sativa* upland were both 5.3 and 5.3, which was around rating 5 (fair) (Table 4). Accessions of the *Oryza glaberrima* group had the poorest mean rating of 7.3 (Table 15).

Accessions of the interspecifics upland group had mean ratings that ranged from 4.3 to 7.0 which hovered around ‘fair’ and ‘poor’ category (Table 16). The interspecifics lowland accessions had mean ratings that ranged from 3.0 to 4.7, with NL 60 and NL 20 with the best ratings of 3.0 (good) (Tables 4 and 17). *Oryza sativa* upland had mean ratings that ranged from 4.3 to 6.0, with WAB 181-18 having the best rating, ranging from 3.0 to 5.3 (Table 18). Suakoko 8 and WITA 4 had the best mean ratings of 3.0

among the *Oryza sativa* lowland group (Table 19). The *Oryza glaberrima* accessions had poor mean ratings. Accessions CG 14 and TOG 7106 both had a mean rating of 7.7 while both TOG 7206 and TOG 7442 had mean rating of 7.0 (Table 20).

4.2.6 Threshability

The five groups had their mean threshability rating ranging from 6.4 to 8.5. Interspecifics lowland had the best mean threshability rating of 8.5, closely followed by *Oryza sativa* lowland which had a rating of 8.4. Interspecifics upland and *Oryza sativa* upland also had mean ratings of 6.9 and 7.1. *Oryza glaberrima* had the least rating of 6.4 (Table 15).

Interspecifics upland accessions had a mean rating of 6.9. The mean ratings of the accessions of the group ranged from 5.0 to 8.3. NERICA 18 and ART 10 had mean ratings of 8.3 while NERICA 8 had the least rating of 5.0 (Table 16). Interspecifics lowland accessions had a mean rating of 8.5. NERICA lowland (NL) 9, 20, 41, 42 and 45 all had mean rating of 9.0 while NL 19 and 7 had the least rating of 7.7 within the group (Table 17).

The *Oryza sativa* upland accessions had mean ratings range of 5.3 to 8.3. Accessions OS 6 and Ofada had the highest rating of 8.3 within this group while WAB 181-18 had the least rating of 4.3 (Table 18). The mean threshability rating of *Oryza sativa* lowland accessions ranged from 7.7 to 9.0. Accessions WITA 4 and Cisadane had the highest rating of 9.0 while Suakoko 8 and TOX 4004 had the least ratings (Table 19).

Oryza glaberrima accessions' threshability ranged from 4.0 to 8.0. Accession TOG 7106 had the best rating within this group, while TOG 7206 had the least rating of 4.0. Accession CG 14 had a rating of 6.3 while TOG 7442 had 7.3 (Table 20).

4.2.7 One thousand grain weight (OTGW) (g)

The upland cultivar groups had higher one thousand grain weight of 31.5g and 31.4g for interspecifics upland and *Oryza sativa* upland, respectively. These weights were significantly higher than the values recorded for the other groups. Interspecifics lowland and *Oryza glaberrima* had similar mean one thousand grain weight of 28.8g and 28.0g respectively which were significantly higher than the mean weight of 26.3g recorded for *Oryza sativa* lowland (Table 15).

NERICA 13 and NERICA 17 with mean one thousand grain weight of 38.0g and 34.9g respectively were significantly heavier than all the other accessions of the interspecifics upland group. NERICA 11 had the least one thousand grain weight of 28.0g. The value was however similar to that of ten (10) other accessions within the group (Table 16).

The interspecifics lowland accessions had one thousand grain weight range of 27.2g to 30.1g. Accessions NL 7, 9 and 45 had mean one thousand grain weight of 30.1, 29.6 and 30.0g. These weight were similar to the weight obtained for the seven (7) other accessions namely NL 8, 14, 19, 20, 42, 49, and 60 but significantly greater than the one thousand grain weight of NL 41 (27.3g) and NL 21 (27.2g) (Table 17).

The *Oryza sativa* upland accessions had four (4) accessions with significantly higher one thousand grain weight; they are namely WAB 56-104, WAB 189, ITA 321 and OS 6. WAB 56-104, WAB 189, ITA 321 and OS 6 had mean one thousand grain weight of 32.9, 33.0, 32.7 and 32.8g respectively. WAB 181-18 had one thousand grain weight of 29.8g which was significantly heavier than 27.2g recorded for Ofada (Table 18).

Within the *Oryza sativa* lowland accessions, Cisadane had the significantly heaviest one thousand grain weight of 29.5g. Suakoko 8 had the least weight of 22.1g, which was significantly lower compared to the mean values obtained for all the other accessions (Table 17). Accessions CG 14 and TOG 7442 had one thousand grain weight of 30.6g and 32.0g, respectively, which were significantly heavier than 23.9g and 25.6g recorded for TOG 7106 and TOG 7206, respectively (Table 20).

4.2.8 Plant height (cm)

The *Oryza sativa* upland and *Oryza glaberrima* accessions had significantly higher ($p<0.05$) mean height than the three other groups. While *Oryza sativa* upland and *Oryza glaberrima* had mean plant heights of 122.5 cm, and 124.0 cm, respectively. The interspecifics lowland, *Oryza sativa* lowland and interspecifics upland groups had mean heights of 102.2 cm, 111.6 cm and 114.0 cm, respectively. The mean heights of both *Oryza sativa* lowland and interspecifics upland were significantly higher than the mean height recorded for interspecifics lowland (Table 21).

NERICA 6 and 7 with mean heights of 131.0 and 129.8 cm respectively had similar height with five (5) other accessions within the interspecifics upland cultivar group, while they had significantly higher mean heights that twelve (12) other accessions in the group. NERICA 8 had the shortest mean highest of 99.0 cm within the interspecifics upland group (Table 22).

Table 21: Straw and grain yields, plant height, diameter of basal nodes, harvest index, panicles and tillers per square metre of five rice cultivar groups.

Cultivars	Interspecific Upland (IU)	Interspecific Lowland (IL)	*Oryza sativa* Upland (OsU)	*Oryza sativa* Lowland (OsL)	*Oryza glaberrima* (Og)
Parameters					
Plant height (cm)	114.0^{b}±1.9	102.2^{c}±2.4	122.5^{a}±3.4	111.6^{b}±2.9	124.0^{a}±4.1
Diameter of basal node (mm)	6.2^{a}±0.1	6.1^{a}±0.2	6.4^{a}±0.2	6.0^{a}±0.2	4.9^{b}±0.3
Panicles/m^2	140.5^{c}±8.1	278.2^{b}±10.1	138.8^{c}±14.3	273.3^{b}±12.3	433.6^{a}±17.5
Tillers/m^2	163.4^{c}±10.0	301.4^{b}±12.5	161.7^{c}±17.7	301.2^{b}±15.3	493.8^{a}±21.7
Straw yield (tonne/ha)	2.7^{c}±0.1	4.2^{b}±0.2	3.0^{c}±0.2	4.6^{ab}±0.2	5.0^{a}±0.5
Grain yield (tonne/ha)	2.1^{b}±0.1	3.6^{a}±0.1	2.2^{b}±0.2	3.6^{a}±0.2	1.7^{b}± 0.2
Harvest index	0.42^{b}±0.09	0.46^{a}±0.07	0.42^{b}±0.09	0.44^{ab}±0.07	0.28^{c}±0.11

Test level: 0.05. ^{abc}Means with same superscripts along rows are not significantly different.

Table 22: Straw and grain yields, plant height, diameter of basal nodes, harvest index, panicles and tillers per square metre of nineteen (19) interspecific upland (IU) rice accessions at two seasons

Accessions	Plant height (cm)	Basal node diameter (mm)	Tillers/m^2	Panicles /m^2	Grain yield (tonne /ha)	Straw yield (tonne/ ha)	Harvest index
NERICA 1	100.4^{fg}	6.8^{ab}	133.8^{efgh}	113.2^{defg}	1.9	2.3^{b}	0.43^{abc}
NERICA 2	106.6^{fg}	5.6^{cd}	183.2^{abcde}	162.7^{abcd}	1.7	2.4^{b}	0.41^{abc}
NERICA 3	115.2^{bcdef}	6.3^{abcd}	168.5^{bcdef}	152.5^{abcde}	2.5	2.7^{ab}	0.48^{a}
NERICA 4	109.9^{defg}	5.9^{bcd}	177.3^{abcdef}	149.3^{abcdef}	1.4	2.4^{b}	0.38^{abc}
NERICA 5	104.8^{fg}	5.5^{cd}	165.3^{bcdefg}	145.2^{bcdef}	1.9	2.7^{ab}	0.41^{abc}
NERICA 6	131.0^{a}	6.8^{ab}	107.0^{gh}	98.2^{fg}	2.1	3.3^{ab}	0.36^{c}
NERICA 7	129.8^{a}	7.1^{a}	163.2^{bcdefg}	138.2^{bcdef}	2.2	3.0^{ab}	0.39^{abc}
NERICA 8	99.0^{g}	5.4^{d}	186.0^{abcde}	154.7^{abcde}	2.4	2.6^{ab}	0.48^{a}
NERICA 9	101.8^{fg}	5.6^{cd}	159.8^{bcdefg}	130.8^{bcdefg}	1.6	2.2^{b}	0.40^{abc}
NERICA 10	106.8^{fg}	6.2^{abcd}	212.7^{ab}	175.0^{ab}	1.9	3.0^{ab}	0.39^{abc}
NERICA 11	107.4^{fg}	5.3^{d}	178.7^{abcdef}	146.0^{abcdef}	1.7	2.2^{b}	0.44^{abc}
NERICA 12	108.4^{efg}	6.1^{abcd}	144.2^{cdefgh}	133.5^{bcdef}	1.9	2.3^{b}	0.45^{abc}
NERICA 13	124.0^{abcd}	6.5^{abc}	140.4^{defgh}	120.0^{cdefg}	2.0	2.2^{b}	0.47^{ab}
NERICA 14	114.4^{bcdef}	5.9^{bcd}	205.2^{abc}	169.2^{abc}	2.5	3.9^{a}	0.38^{abc}
NERICA 15	123.0^{abcd}	6.8^{ab}	95.3^{h}	79.8^{g}	2.1	3.6^{ab}	0.37^{bc}
NERICA 16	121.8^{abcde}	6.3^{abcd}	131.0^{efgh}	118.3^{cdefg}	2.3	2.5^{b}	0.45^{abc}
NERICA 17	111.4^{cdefg}	5.6^{cd}	198.5^{abcd}	180.2^{ab}	2.4	2.5^{b}	0.48^{a}
NERICA 18	124.8^{abc}	6.9^{ab}	117.2^{fgh}	103.0^{efg}	2.1	2.9^{ab}	0.42^{abc}
ART 10	128.2^{ab}	6.8^{ab}	236.7^{a}	199.0^{a}	2.5	2.8^{ab}	0.48^{a}

Test level: 0.05.

^{abcdefgh}Means with same superscripts along columns are not significantly different.

Accessions of the interspecifics lowland group had significant variation within the group. NERICA lowland (NL) 14 had the highest mean height of 112.2 cm but similar to the height recorded for NL 19, 20, 21, 41 and 49. NERICA lowland (NL) 14 was however significantly taller than NL 7, 8, 9, 42, 45 and 60 (Table 23). NERICA lowland 8 had the lowest mean height of 89.8 cm but similar to the height recorded for NL 9 (92.1 cm), NL 7 (96.3 cm) and NL 45 (91.9 cm) (Table 23).

Oryza sativa upland accessions also had significant ($p<0.05$) variation in their heights. OS 6 had the highest mean height of 143.7 cm, which was similar to 133.2 cm recorded for Ofada but significantly higher than values recorded for WAB 56-104 (124.0 cm), WAB 189 (117.7 cm) and ITA 321 (110.5 cm) and WAB 181-18 (105.9 cm) (Table 24).

Suakoko 8 had significantly ($p<0.05$) higher plant height than all the other members of the *Oryza sativa* lowland group with a mean height of 153.0 cm. Accessions WITA 4 and TOX 4004 which had mean heights of 123.1 cm and 126.2 cm, respectively, were significantly ($p<0.05$) taller than Cisadane (110.1 cm), Sipi (93.8 cm), IR 72 (78.9 cm), and IR 64 (89.8 cm); but similar to BW 348-1 which had a mean height of 117.9 cm (Table 25).

The *Oryza glaberrima* accessions had similar heights. Accession CG 14 had a mean height of 134.1 cm, while TOG 7206, TOG 7442 and TOG 7106 had mean plant heights of 122.7 cm, 120.1 cm and 119.2 cm, respectively (Table 26).

4.2.9 Diameter of basal node (mm)

Four cultivar groups, namely interspecifics upland, interspecifics lowland, *Oryza sativa* upland and *Oryza sativa* lowland had similar diameter of basal nodes, the values were 6.2 ± 0.1, 6.1 ± 0.2, 6.4 ± 0.2 and 6.0 ± 0.2 mm, respectively. The similar mean values were however significantly higher ($p < 0.05$) than 4.9 ± 0.3 mm observed for *Oryza glaberrima* (Table 21).

Table 23: Straw and grain yields, plant height, diameter of basal nodes, harvest index, panicles and tillers per square metre of twelve (12) interspecific lowland (IL) rice accessions at two seasons.

Accession	Plant height (cm)	Diameter of basal node (mm)	Tillers/m^2	Panicles/ m^2	Grain yield (tonne/ha)	Straw yield (tonne/ha)	Harvest index
NERICA- L 7	96.3^{def}	5.9^{bc}	255.8^{c}	238.7^{b}	3.8	4.3	0.47^{abc}
NERICA- L 8	89.8^{f}	5.8^{bc}	369.8^{ab}	351.7^{a}	3.4	3.6	0.49^{abc}
NERICA- L 9	92.1^{ef}	6.3^{abc}	349.5^{abc}	320.2^{ab}	3.7	4.1	0.48^{abc}
NERICA- L 14	112.2^{a}	6.7^{a}	241.2^{c}	219.8^{b}	3.4	5.2	0.41^{c}
NERICA- L 19	111.0^{ab}	6.3^{abc}	289.7^{bc}	271.0^{ab}	3.1	4.2	0.42^{c}
NERICA- L 20	111.1^{ab}	6.5^{ab}	294.5^{bc}	281.2^{ab}	3.6	4.8	0.45^{bc}
NERICA- L 21	109.9^{abc}	5.9^{bc}	272.7^{bc}	251.3^{ab}	3.2	4.1	0.43^{bc}
NERICA- L 41	106.5^{abcd}	6.0^{abc}	273.5^{bc}	249.7^{ab}	3.0	3.8	0.45^{bc}
NERICA- L 42	100.58^{bcde}	6.3^{abc}	243.3^{c}	240.3^{b}	3.5	4.4	0.45^{bc}
NERICA- L 45	91.9^{ef}	6.4^{ab}	334.8^{abc}	304.3^{ab}	4.1	4.2	0.50^{ab}
NERICA- L 49	104.4^{abcd}	5.6^{c}	287.2^{bc}	258.3^{ab}	4.0	3.6	0.53^{a}
NERICA- L 60	100.3^{cde}	6.2^{abc}	404.5^{a}	351.8^{a}	4.0	4.6	0.47^{abc}

Test level: 0.05.

^{abcdef}Means with same superscripts along columns are not significantly different.

Table 24: Straw and grain yields, plant height, diameter of basal nodes, harvest index, panicles and tillers per square metre of six (6) *Oryza sativa* upland rice accessions at two seasons

Accessions	Plant height (cm)	Diameter of basal node (mm)	Tillers/ m^2	Panicles/ m^2	Straw yield (tonne/ha)	Grain yield (tonne/ha)	Harvest index
WAB 56-104	124.0^{bc}	6.7	166.2^{ab}	127.7^{ab}	2.8	2.0	0.42^{ab}
WAB 181-18	105.9^{d}	6.4	178.3^{a}	137.2^{ab}	2.4	2.1	0.46^{a}
WAB 189	117.7^{cd}	5.8	113.0^{b}	95.3^{b}	2.8	2.0	0.41^{ab}
ITA 321	110.5^{cd}	6.0	171.8^{ab}	159.2^{a}	3.0	2.5	0.42^{ab}
OS 6	143.7^{a}	6.7	161.3^{ab}	147.2^{ab}	2.9	2.3	0.45^{ab}
Ofada	133.2^{ab}	6.5	179.5^{a}	166.0^{a}	3.8	2.2	0.35^{b}

Test level: 0.05.

[abc]Means with same superscripts along columns are not significantly different.

Table 25: Straw and grain yield, plant height, diameter of basal nodes, harvest index, panicles and tillers per square metre of eight (8) *Oryza sativa* lowland rice accessions at two seasons

Accessions	Plant height (cm)	Diameter of basal node (mm)	Tillers/m^2	Panicles/m^2	Grain yield (tonne/ha)	Straw yield (tonne/ha)	Harvest index
IR 64	89.8^{d}	5.8^{ab}	327.3^{ab}	294.2	3.5^{abc}	3.5^{cd}	0.50^{a}
IR 72	78.9^{e}	5.6^{b}	394.2^{a}	307.3	2.5^{c}	2.9^{d}	0.46^{ab}
Suakoko 8	153.0^{a}	6.5^{a}	275.0^{ab}	269.8	3.6^{abc}	6.9^{a}	0.34^{c}
WITA 4	123.1^{b}	6.0^{ab}	329.2^{ab}	305.2	4.0^{ab}	4.7^{bc}	0.46^{ab}
Sipi	93.8^{d}	5.5^{b}	297.8^{ab}	276.5	3.1^{bc}	3.5^{cd}	0.47^{ab}
TOX 4004	126.2^{b}	5.9^{ab}	234.2^{b}	221.8	3.6^{abc}	5.0^{b}	0.41^{bc}
Cisadane	110.1^{c}	5.8^{ab}	302.2^{ab}	275.8	4.0^{ab}	5.8^{ab}	0.40^{bc}
BW 348-1	117.9^{bc}	6.5^{a}	249.3^{ab}	235.3	4.6^{a}	4.6^{bc}	0.50^{a}

Test level: 0.05.

^{abc}Means with same superscripts along columns are not significantly different.

Table 26: Straw and grain yield, plant height, diameter of basal nodes, harvest index, panicles and tillers per square metre of four (4) *Oryza glaberrima* rice accessions at two seasons

Accessions	Plant height (cm)	Basal node diameter (mm)	Tillers/m^2	Panicles/m^2	Grain yield (tonne/ha)	Straw yield (tonne/ha)	Harvest index
CG 14	134.1	5.2^{a}	472.2	444.5	1.5^{ab}	4.3	0.27
TOG 7106	119.2	4.0^{b}	583.0	469.2	1.3^{b}	5.1	0.21
TOG 7206	122.7	5.7^{a}	396.8	356.5	2.2^{a}	5.3	0.32
TOG 7442	120.1	4.8^{ab}	523.3	464.3	2.0^{ab}	5.3	0.32

Test level: 0.05.

^{ab}Means with same superscripts along columns are not significantly different.

The interspecifics upland accessions had varied diameter of basal node values with NERICA 7 having the thickest mean diameter of 7.1 mm which was similar to the values obtained for ten (10) accessions within the group. The diameter of basal node of NERICA 7 was however significantly ($p < 0.05$) higher than the value recorded for NERICA 2 (5.6 mm), NERICA 4 (5.9 mm), NERICA 5 (5.5 mm), NERICA 8 (5.4 mm), NERICA 9 (5.6 mm), NERICA 11 (5.3 mm), NERICA 14 (5.9 mm) and NERICA 17 (5.6 mm) (Table 22).

The interspecifics lowland accessions also had significant variations in their diameter of basal nodes values. Accession NERICA lowland (NL) 14 had a mean diameter of basal node value of 6.7 mm which was significantly ($p < 0.05$) higher than the values obtained for only four (4) accessions in the group; namely NL 7 (5.9 mm), NL 8 (5.8 mm), NL 21 (5.9 mm) and NL 49 (5.6 mm).While its mean diameter was similar to the mean diameter of basal node of seven (7) other accessions (Table 23).

The *Oryza sativa* upland accessions had similar diameter of basal node values. Accession WAB 56-104 had the thickest diameter of basal node of 6.7 mm, while WAB 189 had the thinnest diameter of basal node of 5.8 mm within the *Oryza sativa* upland group (Table 24).

The *Oryza sativa* lowland group had variations in their diameter of basal node values. Suakoko 8 and BW 348-1 both had diameter of basal node value of 6.5, which was significantly thicker than 5.6 and 5.5 mm recorded for IR 72 and Sipi respectively. The diameter of basal node values recorded for the other four (4) members of this group did not differ significantly from both the higher figures recorded for the duo of Suakoko 8 and BW 348-1; and the lower figures recorded for IR 72 and Sipi (Table 25).

The diameter of basal node values of the *Oryza glaberrima* group had significant variations. Accessions CG 14 and TOG 7206 had mean DBN values of 5.2 and 5.7 mm which were significantly higher than the mean diameter of basal node value of 4.0 mm recorded for TOG 7106. TOG 7442 had mean diameter of basal node value of 4.8 mm that was similar to the diameter of basal node value recorded for CG 14 and TOG 7206 and that recorded for TOG 7106 (Table 26).

4.2.10 Panicles per square metre (m^{-2})

Oryza glaberrima accessions had significantly higher panicles per square metre of 433.6±17.5 m^{-2} than all the other the four groups. The lowland varieties had similar average values of 278.2±10.1 m^{-2} for the interspecifics lowland and 273.3±12.3 m^{-2} for the *Oryza sativa* lowland. The lowland accessions had significantly higher values than the upland groups which had values of 140.51±8.05 m^{-2} and 138.75±14.25 m^{-2} for interspecifics and *Oryza sativa* upland, respectively (Table 21).

The accessions of the interspecifics upland had mean panicles per square metre that ranged from 79.8 to 199.0 m^{-2}. ART 10 had mean panicles per square metre count of 199.0 m^{-2} which was similar to the figures obtained for seven (7) other accessions of the group, while it was significantly higher than the mean panicles per square metre of eleven (11) other members. NERICA 15 had the least count (Table 22).

NERICA lowland (NL) 8 and 60 had mean panicles per square metre of 351.7 and 351.8 m^{-2}, respectively. These figures were significantly higher than the count obtained for only three (3) other members of the interspecifics lowland group, namely NL 14 (219.8 m^{-2}), 42 (240.3 m^{-2}) and 7 (238.7 m^{-2}). The three (3) accessions also had similar mean panicle number with seven other members of the group namely NL 9, 19, 20, 21, 41, 45 and 49 (Table 23).

The *Oryza sativa* upland accessions had varied PPSM within the group. Ofada and ITA 321 had mean panicles per square metre values of 166.0 m^{-2} and 159.2 m^{-2} respectively, which were significantly higher than 95.3 m^{-2} recorded for WAB 189 but similar to 147.2, 137.2 and 127.7 m^{-2} recorded for OS 6, WAB 181-18 and WAB 56-104 respectively (Table 24).

The eight (8) accessions within the *Oryza sativa* lowland group had similar mean panicles per square metre values, with IR 72 recording the highest value of 307.3 m^{-2} (Table 25). The mean panicles per square metre for the group was 273.2±12.3 m^{-2} (Table 21), while TOX 4004 had the least PPSM of 221.8 m^{-2}. Accessions of the *Oryza glaberrima* group had similar mean panicles per square metre values. Accession TOG 7106 had the highest mean panicles per square metre of 469.2 while TOG 7206 had the least value of 356.5 m^{-2}. The two other accessions namely, CG 14 and TOG 7442 had mean panicles per square metre values of 444.5 and 464.3 m^{-2}, respectively (Table 26).

4.2.11 Tillers (m^{-2})

Oryza.glaberrima accessions had the highest mean number of tillers of 493.8 m^{-2}. The value was significantly highest in the group. The lowland cultivar groups, interspecifics lowland (301.4 m^{-2}) and *Oryza sativa* lowland (301.2 m^{-2}) also had significantly higher number of tillers than interspecifics upland and *Oryza sativa* upland (the two upland cultivar groups) which had 163.4 and 161.7 m^{-2}, respectively (Table 21).

Significant variation was recorded within the interspecifics upland group for number of tillers. Accession ART 10 had the highest tillers of 236.7 m^{-2}. This value was significantly higher than the value for eleven (11) other accessions but similar to the value recorded for seven (7) other accessions within the group. NERICA 15 had the least mean number of tillers (95.3 m^{-2})(Table 22).

The interspecifics lowland group accessions recorded significant variation in the number of tillers. While NERICA lowland 60 had the highest mean tiller number of 404.5 m^{-2}, which was significantly higher than observed mean values of eight (8) other interspecifics lowland accessions. NERICA lowland 14 had the least tiller number. The value recorded for NERICA lowland 14 (241.2 m^{-2}) was similar to the values recorded for 9 group members (Table 23).

Ofada had the highest mean tiller number of 179.5 m^{-2} which was significantly higher than 113.0 m^{-2} recorded for WAB 189 within the *Oryza sativa* upland group but similar to the value recorded for OS 6 (161.3 m^{-2}), ITA 321 (171.8 m^{-2}), WAB 181-18 (178.3 m^{-2}) and WAB 56-104 (166.2 m^{-2}) (Table 24).

Accession IR 72 had a mean tiller number of 394.2 m^{-2} which was similar to the mean value obtained for six (6) other accessions within the *Oryza sativa* lowland group, while TOX 4004 had the least value of 234.2 m^{-2} (Table 25).

The *Oryza glaberrima* accessions had similar tiller number, with TOG 7106 recording the highest value of 583.0 m^{-2} (Table 26).

4.2.12 Grain yield of the five cultivar groups

The lowland cultivar groups had significantly higher grain yields than all the three other groups. *Oryza sativa* lowland and interspecifics lowland had the highest mean grain yield of 3.6 ton/ha (Table 21). The *Oryza sativa* upland accessions had a grain yield value of 2.2 ton/ha, while interspecifics upland had a mean value of 2.1 ton/ha and *Oryza glaberrima* had a value of 1.7 ton/ha. The mean grain yield of *Oryza sativa* upland, interspecifics upland and *Oryza glaberrima* were however similar (Table 21).

Grain yields of the accessions of the interspecifics upland group were all similar. The mean grain yields of the accessions of this group ranged from 1.4 tonne/ha to 2.5 ton/ha. ART 10 had the highest mean grain yield of 2.5 tonne/ha while NERICA 4 had the least mean grain yield of 1.4 tonnes/ha (Table 22).

Accessions of interspecifics lowland group also had similar mean grain yields. NERICA lowland 45 had the highest mean yield of 4.1 tonne/ha, while NL 41 had the least mean grain yield of 3.0 tonne/ha within the group (Table 23). The accessions of the *Oryza sativa* upland group had mean grain yield ranging from 2.0 to 2.5 tonne/ha. The mean of the six (6) accessions did not vary significantly from one another (Table 24). Accession BW 348-1 had the highest mean grain yield of 4.6 tonne/ha within the *Oryza sativa* lowland group. This value only varied significantly from the mean values recorded for two (2) accessions, namely IR 72 and Sipi which had mean grain yields of 2.5 and 3.1 tonne/ha respectively (Table 25).

The mean grain yield of *Oryza glaberrima* accessions varied significantly within the group. Accession TOG 7206, with a mean grain yield of 2.2 tonne/ha was significantly higher than the yield of 1.3 tonne/ha observed for TOG 7106. The yield recorded for TOG 7206 did not however vary from 2.0 and 1.5 tonne/ha observed for TOG 7442 and CG 14 respectively. The yield of 1.3 tonne/ha recorded for TOG 7106 was also similar to the grain yield obtained for both TOG 7442 and CG 14 (Table 26).

4.2.13 Straw yields of the five cultivar groups

Oryza glaberrima and *Oryza sativa* lowland had a significantly higher straw yield of 5.0 tonne/ha and 4.6 tonne/ha. Straw yield of *Oryza sativa* lowland was however not significantly higher than interspecifics lowland group's mean value of 4.2 tonne/ha. The *Oryza sativa* upland and interspecifics upland had similar but significantly lower straw yield values (of 3.0 tonne/ha and 2.7 tonne/ha, respectively) compared to all other groups (Table 21).

The results in Table 22 show the performances of the nineteen (19) interspecific upland rice accessions. The mean straw yield of the group ranged from 2.2 tonne/ha to 3.9 tonne/ha, with a group mean of 2.7 tonne/ha. NERICA 14 had the highest mean straw yield of 3.9 ton/ha which was not significantly higher than ($p<0.05$) than recorded yield of nine (9) of the accessions of the group (Table 22). The mean straw yield of NERICA 14 was significantly greater than the value observed for NERICA 9, 13, 11, 12, 16, 17, 4, 2, and 1 (Table 22).

Interspecifics lowland accessions had mean straw yield ranged from 3.6 to 5.2 tonne/ha with a group mean straw yield of 4.2±0.2 tonne/ha. The mean straw yield of the twelve (12) accessions did not differ significantly ($p<0.05$) (Table 23).

The accessions of the *Oryza sativa* upland group also had similar means ranging from 2.4 to 3.8 tonne/ha, with Ofada having the highest mean straw yield of 3.8 tonne/ha (Table 24).

Suakoko 8 had the highest mean straw yield of 6.9 tonne/ha. This value did not differ significantly from the mean straw of 5.8 tonne/ha recorded for Cisadane, but was significantly higher than the mean straw yield of the six (6) other members of the *Oryza sativa* lowland group (Table 25). The mean straw yield of the group ranged from 2.9 to 6.9 tonne/ha with a group mean yield of 4.6 tonne/ha.

The mean straw yields of the accessions of the *Oryza glaberrima* did not differ significantly from one another. The mean straw yields of the group's accessions ranged from 4.3 tonne/ha to 5.3 tonne/ha with a group mean straw yield of 5.0 tonne/ha (Table 26). Figure 8 shows chart of the grain and straw yields of the five cultivar groups.

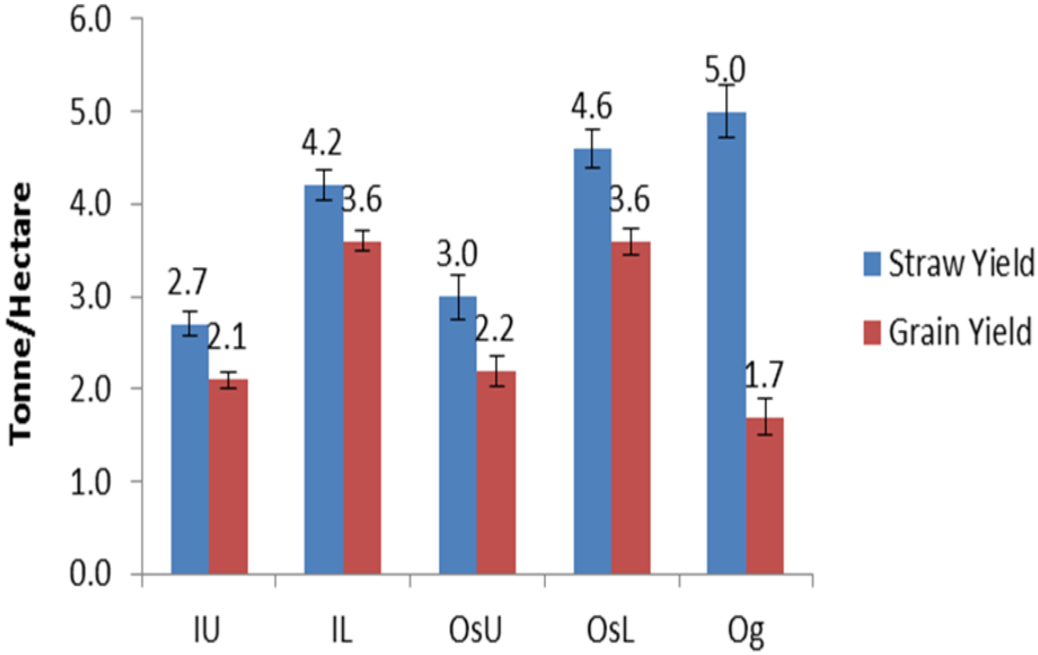


Figure 8: Straw and grain yields of five rice cultivars

IU: Interspecific Upland
IL: Interspecific Lowland
OsU: *Oryza sativa* Upland
OsL: *Oryza sativa* Lowland
Og: *Oryza glaberrima*

4.2.14 Harvest index

The interspecifics upland group had mean harvest index of 0.46 which was significantly ($p<0.05$) higher than the mean harvest indices recorded for interspecifics upland (0.42), *Oryza sativa* upland (0.42), and *Oryza glaberrima* (0.28), but similar to 0.44 recorded for *Oryza sativa* lowland (Table 21).

NERICA 3, 8, 17 and ART 10 recorded the same mean harvest index of 0.48 within the interspecifics upland cultivar group. This index was however only significantly higher than the index obtained for only NERICA 6 (0.36) and NERICA 15 (0.37) but similar to the various indices recorded for the thirteen (13) other members of this group (Table 22).

Interspecifics upland accessions also had varied harvest index ($p<0.05$). NERICA lowland (NL) 49 had harvest index of 0.53 which was similar to the harvest index recorded for five (5) other accessions within the group, namely NL 7, 8, 9, 45, and 60. While NL 14 and 19 had the lowest harvest indices of 0.41 and 0.42, respectively, and the indices were similar to the harvest indices recorded for eight (8) other accessions within the group (Table 23).

WAB 181-18 had the highest harvest index of 0.46 within the *Oryza sativa* upland group. The harvest index was however only significantly higher than the harvest index recorded for only Ofada (0.35) but similar to the harvest index of the other four (4) members of the group (Table 24).

The *Oryza sativa* lowland also had variations in the mean harvest index of the group's accessions. Accessions IR 64 and BW 348-1 had the highest harvest index of 0.50, but the index was similar to the indices recorded for IR 72 (0.46), WITA 4 (0.46) and Sipi (0.47). The indices recorded for both IR 64 and BW 348-8 were significantly higher than those obtained for TOX 4004 (0.41), Cisadane (0.40) and Suakoko 8 (0.34) (Table 25).

The *Oryza glaberrima* accessions had similar harvest indices. While TOG 7206 and TOG 7442 recorded mean harvest index of 0.32, CG 14 and TOG 7106 recorded 0.27 and 0.21 respectively (Table 26).

4.3 Study three: Near Infrared Spectroscopy (NIRS) analysis of straws of forty nine (49) rice accessions

There was a significant ($P < 0.05$) difference among the cultivars' mean straw nitrogen (N), metabolizable energy (ME), neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL), ash, silica contents and *in vitro* organic matter digestibility (OMD) as shown in Table 27.

4.3.1 Nitrogen content (%)

Interspecific lowland had a mean nitrogen (N) content of 0.91%, which was the same value obtained for interspecific upland and *Oryza sativa* upland. The mean value for Interspecific lowland was significantly ($P < 0.05$) higher than the values of 0.82% and 0.83% obtained for both *Oryza sativa* lowland and *Oryza glaberrima*, respectively (Table 27).

Within the interspecifics upland group, NERICA 11 and 14 both had higher N contents of 1.02% but this was not significantly higher than the N contents of the 13 other members of the group (Table 28a). Twelve members of the IL group had similar N contents, which ranged from 0.81 to 1.00% (Table 29a). The *Oryza sativa* upland cultivar group had significant ($P < 0.05$) differences in the N content of straws of the members of this group. Three accessions, namely, ITA 321, WAB 189 and WAB 181-18 had similar N contents of 0.98%, 0.89% and 0.88%, respectively. However, ITA 321 had a mean N content which was significantly ($P < 0.05$) higher than the values of 0.83%, 0.82% and 0.79% for WAB 56-104, Ofada and OS 6, respectively (Table 30).

Within the *Oryza sativa* lowland group, IR 64, IR 72 and Sipi had average straw N content of 1.05%, 1.01% and 0.97%, respectively which were significantly higher than ($P < 0.05$) N contents in the straws of TOX 4004, Cisadane, WITA 4, BW 348-1 and Suakoko 8 which had straw N contents of 0.75%, 0.73%, 0.73%, 0.70% and 0.62% respectively (Table 31).

Table 27: Mean of NIRS-analysed straw nutritive qualities, ash and silica content of five (5) rice cultivar groups

Cultivar Groups	Interspecific upland (19)	Interspecific lowland (12)	*Oryza sativa* (upland) (6)	*Oryza sativa* (lowland) (8)	*Oryza glaberrima* (4)
Dry matter (%)	94.0^{ab} ±0.1	94.0^{ab} ±0.2	93.7^{c}±0.3	93.8^{bc}±0.3	94.1^{a}±0.4
Nitrogen (%)	0.89^{ab}±0.03	0.91^{a}±0.03	0.87^{ab}±0.05	0.82^{b}±0.04	0.83^{b}±0.05
Neutral detergent fibre (%)	66.4^{ab}±0.2	65.9^{b}±0.3	66.6^{ab}±0.4	67.1^{a}±0.4	66.7^{ab}±0.7
Acid detergent fibre (%)	50.1^{b}±0.3	48.7^{c}±0.5	49.3^{bc}±0.7	49.0^{c}±0.6	51.5^{a}±0.6
Acid detergent lignin (%)	3.2^{b}±0.1	2.9^{d}±0.1	3.1^{bc}±0.1	3.0^{cd}±0.1	3.34^{a}±0.1
Metabolisable energy (MJ/kg)	6.5^{ab}±0.1	6.3^{b}±0.1	6.7^{a}±0.2	6.3^{b}±0.2	6.1^{c}±0.2
Ash (%)	18.8^{a}±0.3	18.6^{a}±0.4	17.7^{b}±0.5	17.6^{b}±0.5	19.4^{a}±0.7
Silica (%)	13.7^{ab}±0.2	13.4^{bc}±0.3	13.2^{bc}±0.4	12.9^{c}±0.3	14.3^{a}±0.5
OMD (%)	46.1^{a}±0.5	44.9^{b}±0.7	46.7^{a}±1.0	44.6^{b} ±0.9	43.6^{c}±0.9

Test level: 0.05 [abcd] Means with same superscripts along rows are not significantly different.

OMD: *In vitro* organic matter digestibility

Table 28a: Means of five (5) NIRS-analysed nutritive qualities of straws of nineteen (19) interspecific upland (IU) rice accessions

Accession	Dry matter (%)	Nitrogen (%)	Neutral detergent fibre (%)	Acid detergent fibre (%)	Acid detergent lignin (%)
NERICA 1	93.9^{abcde}	0.90^{abc}	65.9^{bcde}	49.7^{ab}	3.0^{abcd}
NERICA 2	94.0^{abcde}	0.87^{abc}	66.3^{bcde}	49.8^{ab}	3.2^{abcd}
NERICA 3	94.2^{abc}	0.87^{abc}	65.8^{cde}	52.0^{a}	3.4^{a}
NERICA 4	94.0^{abcd}	0.86^{abc}	66.0^{bcde}	50.6^{ab}	3.3^{abcd}
NERICA 5	94.3^{abc}	0.84^{abcd}	66.1^{bcde}	51.9^{a}	3.5^{a}
NERICA 6	93.2^{f}	0.77^{cd}	66.4^{abcde}	48.0^{b}	2.9^{d}
NERICA 7	93.8^{bcdef}	0.88^{abc}	65.4^{de}	48.0^{b}	2.9^{cd}
NERICA 8	94.0^{abcde}	0.94^{abc}	67.3^{abcd}	50.7^{ab}	2.9^{bcd}
NERICA 9	94.2^{abc}	0.93^{abc}	67.8^{abc}	50.3^{ab}	2.9^{cd}
NERICA 10	94.5^{ab}	0.95^{abc}	64.6^{e}	52.0^{a}	3.4^{ab}
NERICA 11	94.3^{ab}	1.02^{a}	66.4^{abcde}	51.7^{a}	3.1^{abcd}
NERICA 12	94.6^{a}	0.93^{abc}	65.7^{cde}	51.5^{a}	3.4^{a}
NERICA 13	94.4^{ab}	0.96^{abc}	66.8^{abcde}	49.5^{ab}	3.2^{abcd}
NERICA 14	94.4^{ab}	1.02^{a}	66.1^{bcde}	51.0^{ab}	3.2^{abcd}
NERICA 15	93.5^{def}	0.86^{abc}	68.1^{ab}	48.0^{b}	2.9^{d}
NERICA 16	93.3^{ef}	0.82^{bcd}	68.6^{a}	48.3^{b}	3.1^{abcd}
NERICA 17	94.5^{ab}	0.96^{ab}	65.3^{de}	50.2^{ab}	3.3^{abc}
NERICA 18	93.6^{cdef}	0.81^{bcd}	66.8^{abcde}	50.1^{ab}	3.3^{abcd}
ART 10	93.5^{def}	0.67^{d}	65.8^{bcde}	49.0^{ab}	2.9^{cd}
Mean	94.0	0.89	66.4	50.1	3.2
SEM	0.14	0.03	0.2	0.3	0.1

Test level: 0.05 ^{abcdef}Means with same superscripts along columns are not significantly different.

Table 28b: Means of four (4) NIRS-analysed nutritive qualities of straws of nineteen (19) interspecific upland (IU) rice accessions

Accession name	Metabolizable energy (MJ/kg)	*In vitro* organic matter digestibility (%)	Ash (%)	Silica (%)
NERICA 1	6.6^{abcd}	46.5^{abc}	18.9^{bcde}	13.7^{abcd}
NERICA 2	6.4^{bcd}	45.7^{bc}	18.9^{bcde}	13.8^{abcd}
NERICA 3	6.3^{cd}	45.1^{bc}	19.8^{abcde}	15.0^{ab}
NERICA 4	6.3^{bcd}	45.0^{bc}	19.0^{bcde}	14.3^{abc}
NERICA 5	6.1^{d}	44.0^{c}	19.5^{abcde}	14.7^{abc}
NERICA 6	7.0^{a}	47.8^{ab}	15.9^{h}	12.7^{cde}
NERICA 7	6.9^{a}	48.5^{a}	18.0^{defg}	13.0^{bcde}
NERICA 8	6.3^{cd}	45.2^{bc}	19.5^{abcde}	13.8^{abcd}
NERICA 9	6.4^{bcd}	45.9^{abc}	18.3^{cdef}	12.9^{bcde}
NERICA 10	6.3^{bcd}	45.6^{abc}	21.4^{a}	15.8^{a}
NERICA 11	6.2^{cd}	45.0^{bc}	20.3^{abc}	14.6^{abc}
NERICA 12	6.2^{cd}	44.0^{bc}	19.6^{abcde}	14.4^{abc}
NERICA 13	6.7^{abc}	47.5^{ab}	18.3^{cdef}	13.1^{bcde}
NERICA 14	6.4^{bcd}	45.6^{abc}	20.5^{ab}	14.5^{abc}
NERICA 15	6.9^{a}	48.4^{a}	16.4^{fgh}	11.7^{e}
NERICA 16	6.9^{ab}	47.0^{abc}	16.1^{fgh}	11.8^{de}
NERICA 17	6.4^{bcd}	45.7^{abc}	20.0^{abcd}	14.3^{abc}
NERICA 18	6.6^{abcd}	45.8^{abc}	17.8^{efgh}	13.2^{bcde}
ART 10	6.5^{abcd}	46.1^{abc}	17.9^{efg}	13.5^{bcde}
Mean	6.5	46.1	18.8	13.7
SEM	0.1	0.5	0.3	0.2

Test level: 0.05

^{abcdefgh}Means with same superscripts along columns are not significantly different

Table 29a: Means of five (5) NIRS-analysed nutritive qualities of straws of twelve (12) interspecific lowland (IL) rice accessions

Accession Name	Dry matter (%)	Nitrogen (%)	Neutral detergent fibre (%)	Acid detergent fibre (%)	Acid detergent lignin (%)
NERICA-L-7	93.9[bc]	0.81	64.5[b]	48.5[bcd]	2.8[c]
NERICA-L-8	93.8[bc]	0.96	66.6[ab]	48.6[bcd]	2.9[abc]
NERICA-L-9	93.8[bc]	0.93	66.0[ab]	48.2[cd]	2.8[cd]
NERICA-L-14	93.5[c]	0.97	65.4[ab]	47.6[d]	2.9[abc]
NERICA-L-19	93.6[bc]	1.00	65.0[ab]	46.6[d]	2.7[c]
NERICA-L-20	93.5[c]	0.88	64.7[ab]	47.1[d]	2.8[c]
NERICA-L-21	94.1[ab]	0.82	67.0[ab]	49.9[abc]	3.2[a]
NERICA-L-41	94.1[ab]	0.84	67.4[a]	49.9[abc]	3.0[abc]
NERICA-L-42	94.5[a]	0.87	66.2[ab]	50.1[abc]	3.0[abc]
NERICA-L-45	94.4[a]	0.97	65.5[ab]	50.3[ab]	3.2[ab]
NERICA-L-49	94.5[a]	0.86	67.3a	50.8[a]	3.0[abc]
NERICA-L-60	93.8[bc]	1.00	65.6[ab]	46.9[d]	2.9[abc]
Mean	94.0	0.91	65.9	48.7	2.9
SEM	0.2	0.03	0.23	0.5	0.1

Test level: 0.05 [abcd]Means with same superscripts along columns are not significantly different.

Table 29b: Means of four (4) NIRS-analysed nutritive qualities of straws of twelve (12) interspecific lowland (IL) rice accessions

Accession	Metabolizable energy (MJ/kg)	*In vitro* organic matter digestibility (%)	Ash (%)	Silica (%)
NERICA-L-7	6.3[bcde]	45.1[bcd]	18.9[ab]	13.9[ab]
NERICA-L-8	6.4[abcd]	44.9[bcd]	17.8[ab]	13.0[ab]
NERICA-L-9	6.4[abc]	45.7[abc]	18.2[ab]	13.2[ab]
NERICA-L-14	6.5[ab]	45.8[abc]	18.4[ab]	13.2[ab]
NERICA-L-19	6.7[a]	47.0[a]	18.1[ab]	12.7[ab]
NERICA-L-20	6.6[ab]	46.2[ab]	18.0[ab]	13.1[ab]
NERICA-L-21	6.0[e]	43.4[de]	18.6[ab]	13.5[ab]
NERICA-L-41	6.1[cde]	43.7[de]	18.4[ab]	13.5[ab]
NERICA-L-42	6.1[cde]	44.3[cde]	19.7[a]	14.2[ab]
NERICA-L-45	6.1[de]	43.8[de]	19.8[a]	14.6[a]
NERICA-L-49	5.9[e]	42.7[e]	19.2[ab]	13.8[ab]
NERICA-L-60	6.6[a]	46.6[ab]	17.6[b]	12.5[b]
Mean	6.3	44.9	18.6	13.4
SEM	0.2	0.7	0.4	0.3

Test level: 0.05 [abcde]Means with same superscripts along columns are not significantly different.

Table 30: Means of NIRS-analysed nutritive qualities of straws of six (6) *Oryza sativa* upland (OsU) rice accessions

Accessions	Dry matter (%)	Nitrogen (%)	Neutral detergent fibre (%)	Acid detergent fibre (%)	Acid detergent lignin (%)	Metabolizable energy (MJ/kg)	Organic matter digestibility (%)	Ash (%)	Silica (%)
WAB 56-104	93.9^{ab}	0.83^{b}	65.5	50.3^{ab}	3.2^{ab}	6.5^{ab}	46.5^{ab}	19.5^{a}	14.5^{a}
WAB 181-18	94.4^{a}	0.88^{ab}	66.7	51.6^{a}	3.3^{a}	6.2^{b}	44.7^{b}	19.2^{a}	14.3^{a}
WAB 189	93.6^{ab}	0.89^{ab}	66.5	49.3^{abc}	3.0^{ab}	6.8^{a}	47.6^{ab}	17.7^{ab}	13.3^{ab}
ITA 321	93.6^{ab}	0.98^{a}	65.5	47.0^{c}	2.8^{c}	6.9^{a}	48.8^{a}	17.2^{bc}	12.6^{ab}
OS 6	93.3^{b}	079^{b}	67.6	49.5^{abc}	3.3^{a}	6.6^{ab}	45.7^{b}	16.4^{bc}	12.8^{ab}
Ofada	93.2^{b}	0.82^{b}	67.7	47.9^{bc}	3.0^{ab}	6.8^{a}	47.0^{ab}	15.8^{c}	12.1^{b}
Mean	93.7	0.87	66.6	49.3	3.1	6.7	46.7	17.7	13.2
SEM	0.3	0.05	0.4	0.7	0.1	0.2	1.0	0.5	0.4

Test level: 0.05 [abc] Means with same superscripts along columns are not significantly different.

Table 31: Means of NIRS-analysed nutritive qualities of straws of eight (8) *Oryza sativa* lowland rice accessions

Accession	Dry matter	Nitrogen (%)	Neutral detergent fibre (%)	Acid detergent fibre (%)	Acid detergent lignin (%)	Metabolizable energy (MJ/kg)	OMD (%)	Ash (%)	Silica (%)
IR 64	94.2^{a}	1.05^{a}	64.6^{b}	48.9^{abc}	3.1^{ab}	6.2^{ab}	44.2^{ab}	19.6^{a}	14.6^{a}
IR 72	94.2^{a}	1.01^{a}	68.0^{a}	49.0^{abc}	3.0^{ab}	6.3^{ab}	45.1^{ab}	18.0^{ab}	12.4^{bcd}
Suakoko 8	93.0^{c}	0.62^{b}	67.7^{a}	45.5^{c}	2.9^{ab}	6.6^{a}	46.9^{a}	14.2^{c}	11.3^{d}
WITA 4	93.8^{ab}	0.73^{a}	67.0^{ab}	49.1^{abc}	2.9^{ab}	6.3^{ab}	44.1^{ab}	17.6^{b}	12.8^{abcd}
SIPI	93.9^{a}	0.97^{b}	64.8^{b}	48.6^{bc}	2.9^{b}	6.5^{ab}	46.1^{a}	19.4^{a}	13.8^{ab}
TOX 4004	94.0^{a}	0.75^{b}	67.9^{a}	50.0^{ab}	3.2^{ab}	6.0^{b}	42.6^{b}	17.9^{ab}	13.3^{abc}
Cisadane	93.3^{bc}	0.73^{b}	67.9^{a}	47.8^{bc}	3.0^{ab}	6.6^{a}	45.8^{a}	15.5^{c}	11.7^{cd}
BW 348 – 1	93.9^{a}	0.70^{b}	69.0^{a}	51.5^{a}	3.2^{a}	6.1^{ab}	43.5^{ab}	18.1^{ab}	13.5^{abc}
Mean	93.8	0.82	67.1	49.0	3.0	6.3	44.6	17.6	12.9
SEM	0.3	0.04	0.4	0.6	0.1	0.2	0.9	0.5	0.3

Test level: 0.05 ^{abcd} Means with same superscripts along columns are not significantly different.

OMD: *In vitro* organic matter digestibility

The straws of accessions in the *Oryza glaberrima* group had average nitrogen (N) values of 0.94%, 0.82%, 0.82% and 0.75% for CG 14, TOG 7106, TOG 7206 and TOG 7442, respectively. Nitrogen contents of the accessions within the *Oryza glaberrima* were not significantly different (Table 32).

4.3.2 Metabolizable energy (MJ/kg)

The metabolizable energy contents of *Oryza sativa* upland (6.7 MJ/kg) was significantly higher than the values obtained *Oryza sativa* lowland (6.3 MJ/kg), interspecifics lowland (6.3 MJ/kg) and *Oryza glaberrima* (6.1 MJ/kg); while interspecifics upland had similar value (6.5 MJ/kg) with *Oryza sativa* upland. The mean value obtained for interspecifics upland (6.5 MJ/kg) was similar to those of interspecifics lowland and *Oryza sativa* lowland. The *Oryza glaberrima* group had a metabolizable energy value which was lower compared to the mean value observed in all the other four groups (Table 27).

NERICA 6, 7, and 15 had the highest metabolizable energy values of 7.0, 6.9 and 6.9 MJ/kg respectively but not significantly higher than the metabolizable energy values observed for NERICA 16 (6.9 MJ/kg), NERICA 13 (6.7 MJ/kg), NERICA 1 (6.6 MJ/kg), NERICA 18 (6.6 MJ/kg), and ART 10 (ART 10-L-11 P1-1-1-B) (6.6 MJ/kg). NERICA 5 had the lowest metabolizable energy value of 6.1 MJ/kg out of the nineteen (19) members of the interspecifics upland group, but not significantly lower than figures observed for 13 group members (Table 28b).

NERICA lowland 19 and 60 had average metabolizable energy values of 6.7 MJ/Kg and 6.6 MJ/Kg respectively. These mean values of the two accessions were similar to the mean values obtained for NERICA lowland 8, 9, 14, and 20 which respectively had mean values of 6.4, 6.4, 6.5 and 6.6 MJ/Kg respectively. While the metabolizable energy values of the two accessions were both significantly higher than the values obtained for the NERICA lowland7, 21, 41, 42, 45 and 49 (Table 29b).

Table 32: Means of NIRS-analysed nutritive qualities of straws of 4 *Oryza glaberrima* rice accessions

Accession	Dry matter (%)	Nitrogen (%)	Neutral detergent fibre (%)	Acid detergent fibre (%)	Acid detergent lignin (%)	Metabolizable energy (MJ/kg)	OMD (%)	Ash (%)	Silica (%)
CG14	93.9[b]	0.94	67.0	51.8	3.4	6.2	44.1	19.5	14.5
TOG 7106	94.5[a]	0.82	66.2	52.3	3.4	5.9	42.6	19.9	15.0
TOG 7206	94.0[ab]	0.82	65.7	50.9	3.4	6.1	43.8	19.6	14.7
TOG 7442	94.0[ab]	0.75	67.9	51.0	3.2	6.2	43.8	18.5	13.0
Mean	94.1	0.83	66.7	51.5	3.3	6.1	43.6	19.4	14.3
SEM	0.4	0.05	0.7	0.6	0.1	0.2	0.9	0.7	0.5

Test level: 0.05 [ab] Means with same superscripts along columns are not significantly different.

OMD: *In vitro* organic matter digestibility

Within the *Oryza sativa* upland group, ITA 321, Ofada, and WAB 189, with mean metabolizable energy values of 6.9, 6.8 and 6.8 MJ/Kg respectively had significantly higher mean metabolizable energy values compared to WAB 181-18 which had a mean value of 6.2 MJ/Kg, but similar to the mean values obtained for WAB 56-104 and OS 6 which had mean metabolizable energy values of 6.5 and 6.6 MJ/Kg respectively (Table 30).

In the *Oryza sativa* lowland group, mean metabolizable energy values obtained for Suakoko 8 (6.6 MJ/Kg), Cisadane (6.6 MJ/Kg) were similar to values obtained for IR 64 (6.2 MJ/Kg), IR 72 (6.3 MJ/Kg), WITA 4 (6.3 MJ/Kg), Sipi (6.5 MJ/Kg) and BW 348-1 (6.1 MJ/Kg) but significantly higher than the mean value obtained for only TOX 4004 (6.0 MJ/Kg) (Table 31).

The *Oryza glaberrima* group members had similar mean metabolizable energy values which ranged from 5.9 MJ/Kg to 6.2 MJ/Kg (Table 32).

4.3.3 Neutral detergent fibre

Oryza sativa lowland had a mean neutral detergent fibre (NDF) content of 67.1% which did not differ significantly from values obtained for *Oryza glaberrima*, *Oryza sativa* upland and interspecifics upland which were 66.7% 66.6% and 66.4% respectively (Table 27). The mean neutral detergent fibre value for *Oryza sativa* lowland was significantly higher than the mean value obtained for interspecifics lowland (65.9%).

NERICA 16 had the highest neutral detergent fibre value of 68.6% which was not significantly higher than values obtained for NERICA 15, 9, 8, 13, 18, 11 and 6. NERICA 10 had the least neutral detergent fibre value of 64.6%, which did not vary significantly from values obtained for 14 other members of the interspecifics upland group (Table 28a).

The interspecific lowland accessions had mean neutral detergent fibre values that ranged from 64.5% to 67.4% (Table 29a). NL 41 had the highest neutral detergent fibre value of 67.4%, which was not significantly different from the values obtained for NL 49, 21, 8, 42, 9, 60, 45, 14, 19 and 20. NL 7 had the least mean neutral detergent fibre value of 64.5%, which was not significantly lower than the values of 67.0%, 66.6%, 66.2%, 66.0%, 65.6%, 65.5%, 65.4%, 65.0% and 64.7% obtained respectively for NL 21, 8, 42, 9, 60, 45, 14, 19 and 20. NL 41 and 49 with mean neutral detergent fibre values of 67.4% and 67.3% respectively varied significantly from value obtained for NL 7 (64.5%) (Table 29a).

Neutral detergent fibre values of all the six (6) accessions in the *Oryza sativa* upland group were similar. The mean values for Ofada, OS 6, WAB 181-18, WAB 189, ITA 321 and WAB 56–104 was 67.68%, 67.6%, 66.7%, 66.5%, 65.5% and 65.5% respectively (Table 30).

BW348-1, IR 72, TOX 4004, Cisadane, Suakoko 8 and WITA 4 had similar neutral detergent fibre values of 69.0%, 68.0%, 67.9%, 67.9%, 67.7% and 67.0% respectively. Sipi and IR 64 had significantly ($p<0.05$) lower neutral detergent fibre values of 64.8% and 64.6%, respectively. The values were however not significantly different from the value obtained for WITA 4 (67.0%) (Table 31).

The *Oryza glaberrima* accessions had similar neutral detergent fibre values of 67.9%, 67.0%, 66.2% and 65.7% for TOG 7442, CG14, TOG 7106 and TOG 7206 respectively (Table 32).

4.3.4 Acid detergent fibre (%)

The *Oryza glaberrima* group had a significantly higher acid detergent fibre content (51.5%) than all the other cultivar types. The interspecifics upland accessions had a mean acid detergent fibre value of 50.1% which was not significantly higher than the value observed for *Oryza sativa* upland (49.2%), which in turn had similar values with *Oryza sativa* lowland (49.0%) and interspecifics lowland (48.7%) (Table 27).

The interspecifics upland cultivar group had a mean acid detergent fibre value that ranged from 48.0 to 52.0%. NERICA 3 had the highest mean acid detergent fibre value of 52.0% which was not significantly higher than values obtained for NERICA 10, 5, 11, 12, 14, 8, 4, 9, 17, 18, 2, 1, 13 and ART 10. NERICA 6 had the least acid detergent fibre value of 48.0% within this group; which did not also vary significantly from the mean acid detergent fibre values obtained for NERICA 7, 15, 16, 13, 1, 2, 18, 17, 9, 4, 8, 14, and ART 10 (Table 28a).

The interspecifics lowland cultivar group had an acid detergent fibre range of 46.6 – 50.8%. NERICA lowland (NL) 49 had the highest mean acid detergent fibre value of 50.8%, which was not significantly different from values recorded for NL 45, 42, 41 and 21; the values were 50.3%, 50.1%, 49.9% and 49.9%, respectively. NL 19 had the least mean acid detergent fibre value of 46.6%, which also was similar to figures obtained for six (6) other accessions within the group, namely NL 60 (46.9%), 20 (47.1%), 14 (47.6%), 9 (48.2%), 7 (48.5%) and 8 (48.6%) (Table 29a).

Mean acid detergent fibre contents within the *Oryza sativa* upland cultivar group ranged from 47.0% to 51.6%. WAB 181-18 had the highest mean acid detergent fibre content of 51.6% which was significantly higher than values recorded for Ofada (47.9%) and ITA 321 (47.0%). Mean acid detergent fibre content in WAB 181-18 did not differ significantly from values obtained for WAB 56-104 (50.3%), OS 6 (49.5%) and WAB 189 (49.3%) (Table 30).

The *Oryza sativa* lowland cultivars had a mean acid detergent fibre content that ranged from 46.9% to 51.5%. BW 348-1 had the highest mean acid detergent fibre content of 51.5% which varied significantly from values obtained for Sipi (48.6%), Cisadane (47.8%) and Suakoko 8 (46.9%). The value obtained for BW 348-1 did not vary from the values obtained for TOX 4004 (50.0%), WITA 4 (49.1%), IR 72 (49.0%), and IR 64 (48.9%) (Table 31).

The *Oryza glaberrima* accessions had mean acid detergent fibre contents of 52.3%, 51.8%, 51.0% and 50.0% and 50.9% for TOG 7106, CG 14, TOG 7442 and TOG 7206 respectively. The acid detergent fibre contents of accessions within this group did not differ significantly (Table 32).

4.3.5 Acid detergent lignin

Mean acid detergent lignin (ADL) of the *Oryza glaberrima* accessions was significantly higher than the mean acid detergent lignin contents in all the other groups. *Oryza glaberrima* had a mean acid detergent lignin value of 3.3%, while interspecifics upland had an average acid detergent lignin value of 3.2% which was similar to the mean value of 3.1% recorded for *Oryza sativa* upland. The interspecifics lowland group had the least mean acid detergent lignin value of 2.9% which was not significantly lower than the value obtained for *Oryza sativa* lowland (3.0%) (Table 27).

NERICA 5, 3 and 12 had mean acid detergent lignin values of 3.4, 3.5 and 3.4% which were significantly higher than the value of 2.9% obtained for NERICA 6, 7, 8, 9, 15 and ART 10; but had similar values obtained for ten (10) other accessions within the group (Table 28a).

NERICA lowland (NL) 21 had the highest mean acid detergent lignin value of 3.17% within the interspecifics lowland group. This value was however only significantly higher than the mean acid detergent lignin values of NL 9, 20, 7, and 19 which had mean values of 2.8%, 2.8%, 2.8% and 2.7% respectively (Table 29a).

Two accessions, WAB 181-18 and OS 6 had similar mean acid detergent lignin value of 3.3% which was significantly higher than only the mean acid detergent lignin value of ITA 321 (2.8%) but similar to the mean values of the other three members of the *Oryza sativa* upland cultivar group (Table 30).

Acid detergent lignin (ADL) obtained for BW 348-1 was 3.2%, which was not significantly higher than values obtained for TOX 4004 (3.2%), IR 64 (3.1%), Cisadane (2.9%), IR 72 (3.0%), WITA 4 (2.9%) and Suakoko 8 (2.9%) (Table 31). The mean acid detergent lignin value obtained for BW 348-1 was higher than the mean value recorded for only Sipi (2.85%) within the *Oryza sativa* lowland group.

The mean ADL values for TOG 7206, TOG 7106, CG 14 and TOG 7442 were 3.4%, 3.4%, 3.4% and 3.2% respectively (Table 32). The values did not differ significantly.

4.3.6 *In vitro* organic matter digestibility (OMD)

The two upland cultivar groups had significantly higher mean i*n vitro* organic matter digestibility **(**OMD) values of 46.1% and 46.7% for interspecifics upland and *Oryza sativa* upland, respectively. While the lowland cultivar groups also had significantly higher i*n vitro* organic matter digestibility of 44.9% and 44.6% for interspecifics lowland and *Oryza sativa* respectively, than the *Oryza glaberrima* group which had a mean i*n vitro* organic matter digestibility value of 43.6% (Table 27).

Mean i*n vitro* organic matter digestibility values for accessions in the interspecifics upland group ranged from 44.0% to 48.5%. NERICA 7 and 15, with mean i*n vitro* organic matter digestibility values of 48.5% and 48.4% respectively differ significantly from NERICA 8, 3, 11, 4, 12, and 5 which had mean values of 45.2%, 45.1%, 45.0%, 45.0%, 45.0% and 44.0% respectively. The values for NERICA 7 and 15 did not differ from those obtained for NERICA 6, 13, 16, 1, 9, 18, 17, 2, 14, 10 and ART 10 (Table 28b).

NERICA lowland (NL) 19 had a significantly higher mean i*n vitro* organic matter digestibility of 47.03% than NL 7, 8, 42, 45, 41, 21 and 49 which had mean i*n vitro* organic matter digestibility values of 45.1%, 44.9%, 44.3%, 43.8%, 43.7%, 43.4% and 42.7% respectively. The range of mean i*n vitro* organic matter digestibility for the interspecifics lowland group was 42.7% to 47.0% (Table 29b).

The *Oryza sativa* upland group had a mean i*n vitro* organic matter digestibility range of 44.69% to 48.75%. ITA 321 had a significantly higher mean i*n vitro* organic matter digestibility than OS 6 (45.7%) and WAB 181-18 (44.7%) but did not differ significantly with the values obtained for WAB 189 (47.6%), Ofada (47.0%) and WAB 56-104 (46.5%) (Table 30).

Sipi, Cisadane, Suakoko 8, IR 72, IR 64, WITA 4 and BW 348-1 with mean i*n vitro* organic matter digestibility values of 46.1%, 45.8%, 45.5%, 45.1%, 44.2%, 44.1% and 43.5% respectively did not differ significantly from one another. Only TOX 4004 had a significantly lower mean i*n vitro* organic matter digestibility of 42.6% compared to Sipi, Cisadane and Suakoko 8 (Table 31).

The four (4) members of the *Oryza glaberrima* group namely; CG 14, TOG 7442, TOG 7206 and TOG 7106 had similar mean i*n vitro* organic matter digestibility values of 44.1%, 43.8%, 43.8% and 42.6%, respectively (Table 32).

4.3.7 Ash content

The *Oryza glaberrima* accessions, interspecific upland and lowland accessions with mean ash contents of 19.4%, 18.8% and 18.6% respectively had significantly higher ash contents than the two *Oryza sativa* groups. *Oryza sativa* lowland had a mean ash content of 17.6% while *Oryza sativa* upland had 17.7% (Table 27)

NERICA 10 had the highest ash content of 21.4% which did not differ with values obtained for seven (7) other members of the group namely; NERICA 14, 11, 17, 3, 12, 5 and 8 (Table 19b). The value obtained for NERICA 10 however varied significantly form values observed for NERICA 4 (19.0%), 2 (18.9%), 1 (18.9%), 9 (18.3%), 13 (18.3%), 7 (18.0%), ART 10 (17.9%), NERICA 18 (17.8%), 15 (16.4%), 16 (16.1%) and 6 (15.9%) (Table 28b).

Within the interspecifics lowland group, NL 45 and 42 had ash contents of 19.8% and 19.7% respectively which were similar to the values recorded for 9 other members of the group, but they both differed significantly from the value recorded for NL 60 (17.6%) (Table 29b).

Two of the *Oryza sativa* upland accessions, WAB 56-104 and WAB 181-18 had significantly higher ash contents of 19.5% and 19.2% respectively within the group. The values obtained for the two accessions did not however differ significantly from the mean ash content of WAB 189 (17.7%). Ofada had a mean ash content of 15.8% which was the least value within the group but not significantly lower than the values obtained for ITA 321 (17.2%) and OS 6 (16.4%) (Table 30).

Accessions IR 64 and Sipi had mean ash contents of 19.6% and 19.4% respectively. Their mean ash contents were not significantly differently from the mean ash contents of BW 348-1, IR 72, and TOX 4004, which had mean values of 18.1%, 18.0% and 17.9% respectively. The five accessions however had mean values that were significantly higher than the mean values for both Cisadane (15.5%) and Suakoko 8 (14.2%) (Table 31).

Oryza glaberrima accessions all had similar mean ash contents of 19.9%, 19.6%, 19.5% and 18.5% for TOG 7106, TOG 7206, CG 14 and TOG 7442, respectively (Table 32).

4.3.8 Silica

Oryza glaberrima accessions had a mean silica content of 14.3% which was significantly higher than mean values obtained for interspecifics lowland (13.4%), *Oryza sativa* upland (13.24%), and *Oryza sativa* lowland (12.9%) respectively; but not significantly different from 13.7% mean silica content recorded for interspecifics upland (Table 27).

Interspecific upland had a mean silica content range of 11.7% to 15.8%. NERICA 10 had a mean silica content of 15.8% which did not differ significantly from the mean values for ten (10) other members of the cultivar group (Table 28b). The value however differed significantly from the mean values obtained for the remaining eight (8) members of the group namely: ART 10 (13.5%), NERICA 18 (13.2%), 13 (13.1%), 7 (13.0%), 9 (12.9%), 6 (12.7%) 16 (11.8%) and 15 (11.7%) (Table 28b).

NERICA lowland (NL) 45 had a mean silica content of 14.6% which was similar to the values observed in ten (10) other members of the interspecifics lowland group (Table 29b). The mean silica content of NL 45 was only significantly higher than 12.5% obtained for NL 60.

Within the *Oryza sativa* upland group, WAB 56-104 and WAB 181-18 which had mean silica contents of 14.5% and 14.3% respectively were significantly different from Ofada (12.1%) but similar to the values obtained for WAB 189, OS 6 and ITA 321. The mean silica content values for these 3 accessions were 13.3%, 12.8% and 12.6%, respectively (Table 30).

Accession IR 64 with a mean silica content of 14.6% had a significantly higher Silica content than IR 72 (12.4%), Cisadane (11.7%) and Suakoko 8 (11.3%). Its mean silica content did not vary from the values obtained for Sipi, BW 348-1, TOX 4004 and WITA 4 which had mean values of 13.8%, 13.5%, 13.3% and 12.8%, respectively (Table 31).

The accessions TOG 7106, TOG 7206, CG 14 and TOG 7442 had similar mean values of 15.0%, 14.7%, 14.5% and 13.0%, respectively (Table 32).

4.3.9 Dry matter

Oryza glaberrima cultivars had a dry matter content of 94.1% which was significantly higher than dry matter contents of both *Oryza sativa* upland and *Oryza sativa* lowland groups which were 93.7% and 93.8%, respectively. The mean dry matter content of *Oryza glaberrima* did not however vary from the values recorded for interspecifics upland (94.0%) and interspecifics lowland (94.0%) (Table 27).

Interspecific upland had a mean dry matter content range of 93.2% to 94.6%. NERICA 12 had a dry matter content of 94.6% which was similar to dry matter contents of twelve (12) other accessions in the group (Table 19a). The value differed significantly from the values obtained for NERICA 7, 18, 15, 16, 6 and ART 10 (Table 28a)

NERICA lowland (NL) 42, 49 and 45 with mean dry matter contents of 94.5%, 94.5% and 94.4%, respectively, had significantly higher dry matter contents than NL 7, 8, 60, 9, 19, 14 and 20. But their mean dry matter contents were not significantly higher than the values obtained for NL 41 and NL 21 which were both 94.1% (Table 29a).

Accession WAB 181-18 which had mean dry matter content of 94.4% was similar to 93.9%, 93.6%, 93.6% obtained for WAB 56-104, ITA 321, and WAB 189 respectively. WAB 181-18 had significantly higher dry matter content more than both OS 6 and Ofada which had 93.3% and 93.2%, respectively (Table 30).

The accessions IR 64, IR 72, TOX 4004, Sipi and BW 348-1 had mean dry matter values of 94.2%, 94.2%, 94.0%, 93.9% and 93.8% respectively; which did not differ significantly, but all differed significantly from mean dry matter value recorded for Suakoko 8 (93.0%) (Table 31).

Accession TOG 7106 with a mean dry matter of 94.5% was similar to values obtained for TOG 7442 (94.0%) and TOG 7206 (94.0%) but differed significantly from the mean dry matter value obtained for CG 14 (93.9%) (Table 32).

4.4 Study four: Voluntary intake and digestibility of straws of five rice varieties fed to rams

4.4.1 Chemical composition of rice straw of five rice varieties

The chemical composition of five varieties of rice straws (CG 14, NERICA 14, ITA 321, NERICA lowland 20, and Cisadane) fed to West African dwarf (WAD) rams is shown in Table 33. The average dry matter content of the straws of the five varieties was 90.1%. CG 14 had a mean dry matter significantly higher dry matter content than the four (4) other varieties. NERICA 14 had significantly higher nitrogen (N) content than the four other varieties, which had similar N content (Table 33). NERICA 14 had a mean N content of 1.1% while CG 14, Cisadane, ITA 321 and NERICA lowland 20 had mean N contents of 0.8%.

Accessions ITA 321, CG 14 and Cisadane had similar neutral detergent fibre contents of 76.0, 75.0 and 72.0% respectively. NERICA lowland (NL 20) had the least neutral detergent fibre content of 65.0% which was similar to 69.0% recorded for NERICA 14. Variation was observed in the acid detergent lignin (ADL) contents recorded for the five varieties. Accession ITA 321 had a mean acid detergent lignin content of 13.0% which was significantly higher than the value recorded for all the other varieties. Accessions CG 14 and Cisadane had the least acid detergent lignin contents of 4.0%. The straws of the five varieties had similar mean ash contents, which ranged from 13.0 to 15.0 % (Table 33).

Table 33: Chemical composition of the straws of five rice varieties fed to rams

	Dry Matter (%)	Nitrogen (%)	Neutral detergent fibre (%)	Acid detergent fibre (%)	Acid detergent lignin (%)	Ash (%)
CG14	96.3[a]	0.8[b]	75.0[ab]	42.0	4.0[d]	14.0
NERICA 14	87.8[b]	1.1[a]	69.0[bc]	42.0	5.9[b]	15.0
ITA321	88.0[b]	0.8[b]	76.0[a]	41.0	13.0[a]	14.0
NERICA lowland 20	89.0[b]	0.8[b]	65.0[c]	36.0	5.0[c]	13.0
Cisadane	89.2[b]	0.8[b]	72.0[ab]	38.0	4.0[d]	14.0
Mean	90.1	0.9	71.4	39.8	6.4	14.0

Test level: 0.05 [abcd]Means on the same column with same superscripts are not significantly different.

4.4.2 Voluntary dry matter intake (VDMI) and apparent nutrient digestibility of straws of five varieties of rice fed to West African dwarf (WAD) rams

Mean dry matter intake per day and mean weight of each of the rams fed rice straw diets are shown on Table 34. Voluntary dry matter and nutrients intake (on metabolic weight basis) are shown on Table 35, while Table 36 shows relationship between voluntary dry matter intake (VDMI) and intake of neutral detergent fibre, acid detergent fibre, nitrogen, hemicellulose and nitrogen balance. Table 37 shows the apparent dry matter and nutrient digestibility of the straws of five varieties of rice fed to rams. While Table 38 shows the relationship between dry matter digestibility (DMD) and the digestibility of some components of straws of five rice varieties fed to rams.

The mean voluntary dry matter intake of the rams fed straws of the five rice varieties which ranged from 47.9 to 57.4 g/kg $BW^{0.75}d^{-1}$ did not vary significantly. Rams fed NERICA lowland 20 had the highest mean voluntary dry matter intake of 57.4 g/kg $BW^{0.75}d^{-1}$, while rams fed Cisadane recorded the least mean VDMI of 47.9 g/kg $BW^{0.75}d^{-1}$ (Table 35).

The neutral detergent fibre intake (NDFI) of the animals on the five treatments was similar. Rams fed NERICA lowland 20 had a mean NDFI of 37.7g/kg $BW^{0.75}d^{-1}$, while those on CG 14 recorded the least neutral detergent fibre intake of 31.7g/kg$BW^{0.75}d^{-1}$. The intake of acid detergent fibre by the rams on the five sole straw diets was also similar (Table 35). While the intake of nitrogen (N), hemicellulose and acid detergent lignin (ADL) varied among animals on the five treatments.

Table 36 shows the correlation coefficients and regression equation between voluntary dry matter intake (VDMI), neutral detergent fibre intake (NDFI), acid detergent fibre intake (ADFI), nitrogen intake (NI), Hemicellulose intake (HIn) and nitrogen balance (NB). Figure 9 shows the relationship between voluntary dry matter intake (VDMI) and both neutral detergent fibre and acid detergent fibre intake, while Figure 10 shows the relationship between VDMI and both hemicellulose and nitrogen intake of the animals on the five sole straw diets.

Table 34: Mean dry matter intake and mean weight of rams fed the sole straw diets

	Mean DM intake/day (g/day)	Mean weight (kg)	(Mean DM intake per day (g)/Body weight (g))X 100 (%)
CG14	353.8	14.1	2.5
NERICA 14	403.8	14.1	2.9
ITA321	378.4	14.1	2.7
NERICA lowland 20	428.1	14.7	2.9
CISADANE	383.7	15.3	2.5
Mean	389.6	14.5	2.7
SE	±20.4	±0.4	

Table 35: Voluntary dry matter and nutrients intake (g/kg BW$^{0.75}$ d^{-1}) and nitrogen balance of the straws of five varieties of rice fed to rams

	CG14	NERICA 14	ITA 321	NERICA Lowland 20	Cisadane	S.E
Nitrogen balance (g)	-1.2	0.4	-0.6	-0.7	0.1	±0.3
Voluntary dry matter intake*	48.1	55.4	51.6	57.4	47.9	±2.2
Neutral detergent fibre intake*	31.7	36.9	34.3	37.7	31.8	±1.4
acid detergent fibre intake*	20.4	23.2	21.1	20.5	17.9	±0.9
Nitrogen intake*	0.4^{b}	0.7^{a}	0.4^{b}	0.5^{b}	0.4^{b}	±0.0
hemicellulose intake*	11.4^{b}	13.7^{ab}	13.2^{ab}	17.2^{a}	13.9^{ab}	±0.7
Acid detergent lignin intake*	2.8^{d}	5.2^{bc}	13.2^{a}	5.6^{b}	3.4^{cd}	±0.9

Test level: 0.05 Means on the same row with same superscripts are not significantly different.

* gkg^{-1} BW$^{0.75}$ d^{-1}

Table 36: Relationship between VDMI and the intake of NDF, ADF, hemicellulose and nitrogen: and nitrogen balance of straws of five rice varieties fed to rams

	Regression equation	R^2	Correlation coefficient (r)
VDMI vs. NDFI	Y = 1.7456 + 0.6286X	0.9973	0.9986***
VDMI vs. ADFI	Y = 1.4007 + 0.3688X	0.8633	0.9292***
VDMI vs. NI	Y = 0.0302 + 0.0086X	0.4640	0.6812***
VDMI vs. HIn	Y = 0.3449 + 0.2598X	0.7649	0.8746***
VDMI vs. NB	Y = 58.706 + 1.099X	0.0152	0.1233 ^{ns}

*** Significant (P < 0.01), ns: Not Significant

VDMI: voluntary dry matter intake,
NDFI: neutral detergent fibre intake,
ADFI: acid detergent neutral fibre intake
NI: nitrogen intake,
HIn: hemicellulose Intake
NB: nitrogen balance

Table 37: Apparent dry matter and nutrient digestibility of the straws of five varieties of rice fed to rams

	CG14	NERICA 14	ITA 321	NERICA Lowland 20	Cisadane	S.E
Apparent dry matter digestibility (%)	44.7	44.2	30.2	39.2	38.9	±2.5
Neutral detergent fibre digestibility (%)	56.5	56.4	45.7	51.9	52.2	±1.9
Acid detergent fibre digestibility (%)	47.2	42.9	30.1	28.5	35.1	±3.1
Nitrogen digestibility (%)	34.8[ab]	50.8[a]	17..1[b]	17.3[b]	35.8[ab]	±4.1
Hemicellulose digestibility (%)	73.1	79.2	70.2	79.8	73.9	±1.4

Test level: 0.05 [ab]Means on the same rows with same superscripts are not significantly different

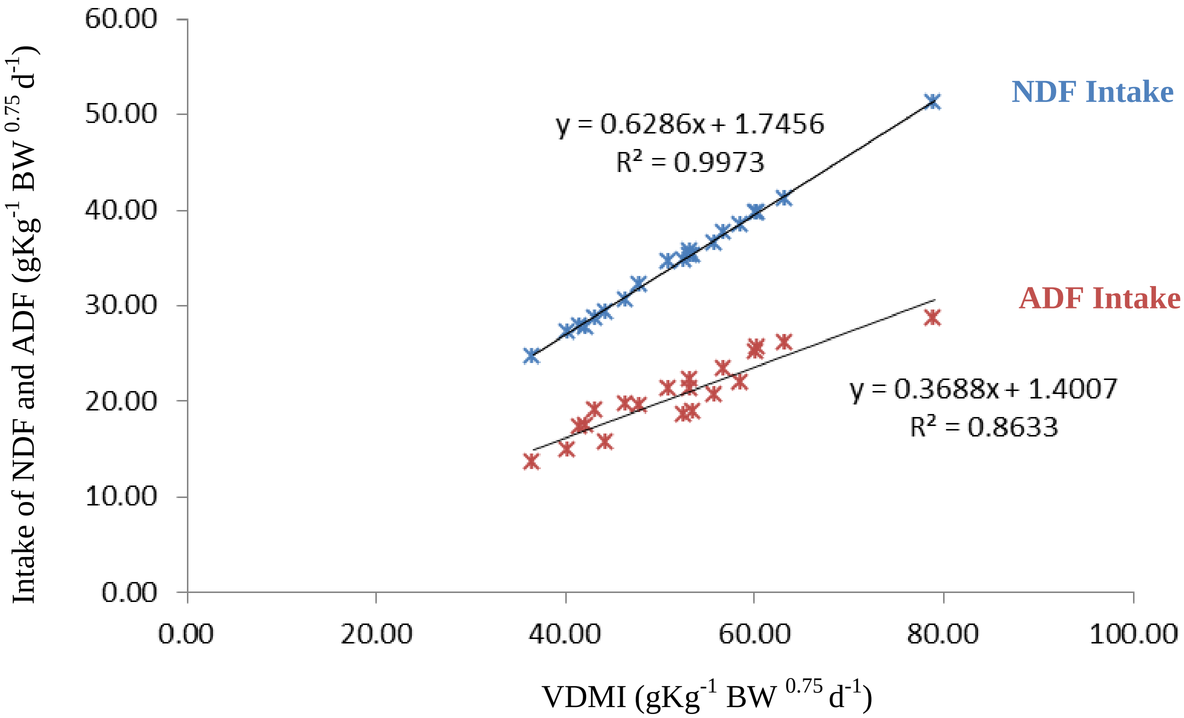


Figure 9: Relationship between VDMI and intakes of NDF and ADF of straws of five varieties of rice fed to WAD rams

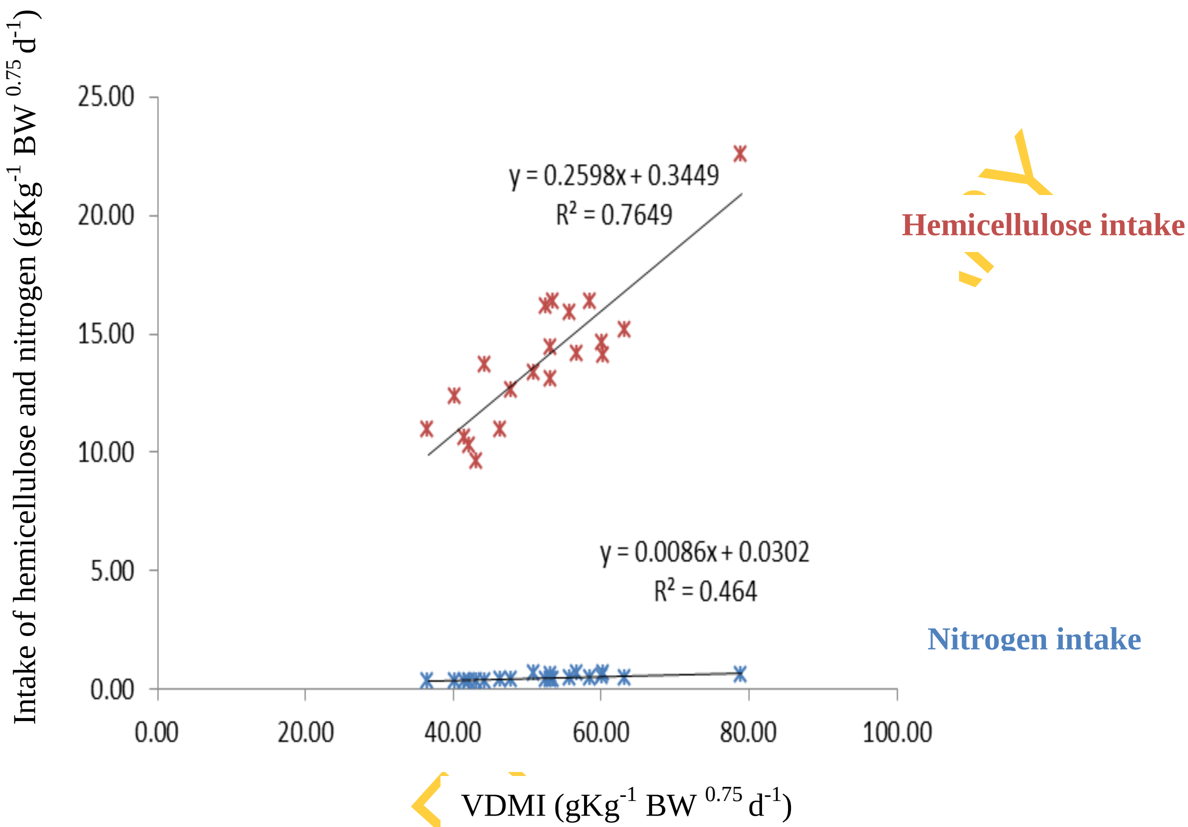


Figure 10: Relationship between VDMI and intake of nitrogen (N) and hemicellulose of straws of five varieties of rice fed to WAD rams

The rams on the five sole straw diets had similar apparent dry matter digestibility (ADMD). CG 14 had the highest digestibility of 44.7 %, which did not vary significantly from the figures obtained for the four other treatments. ITA 321 had the least digestibility of 30.2 % (Table 37). Digestibility of neutral detergent fibre of the five treatments was observed to be similar with CG 14 recording 56.5 % while ITA 321 had 45.7% neutral detergent fibre digestibility (Table 37). Acid detergent fibre digestibility did not vary significantly among the five treatments.

Nitrogen digestibility varied significantly among the five treatments. NERICA 14 had the highest N digestibility of 50.8% which was only significantly higher than the observed 17.1 % for ITA 321 and 17.3 % for NERICA lowland 20. CG 14 and Cisadane had N digestibility of 34.8 % and 35.8%, respectively (Table 37). Table 38 shows the relationship of apparent dry matter digestibility with digestibility of neutral detergent fibre, acid detergent fibre, N, hemicellulose and nitrogen balance (retention). Figures 11, 12 and 13 show the relationship of dry matter digestibility with the digestibility of neutral detergent fibre and acid detergent fibre; hemicellulose and nitrogen (N); and nitrogen balance, respectively.

Table 38: Relationship between dry matter digestibility (DMD) and the digestibility of some components of straws of five rice varieties fed to rams

	Regression equation	R^2	Correlation coefficient (r)
DMD vs. NDFD	Y = 22.12 + 0.7709X	0.9948	0.9974***
DMD vs. ADFD	Y = -6.9743 + 1.1089X	0.8101	0.9001***
DMD vs. ND	Y = -21.901 + 1.3457X	0.6667	0.8165***
DMD vs. HD	Y = 62.338 + 0.3272X	0.3156	0.5618***
DMD vs. NB	Y = -97.025 + 5.402X	0.4633	0.6807***

*** : significant ($p < 0.01$), ns: not significant

DMD: dry matter digestibility

NDFD: neutral detergent fibre digestibility

ADFD: acid detergent neutral fibre digestibility

ND: nitrogen digestibility

HD: hemicellulose digestibility

NB: nitrogen balance

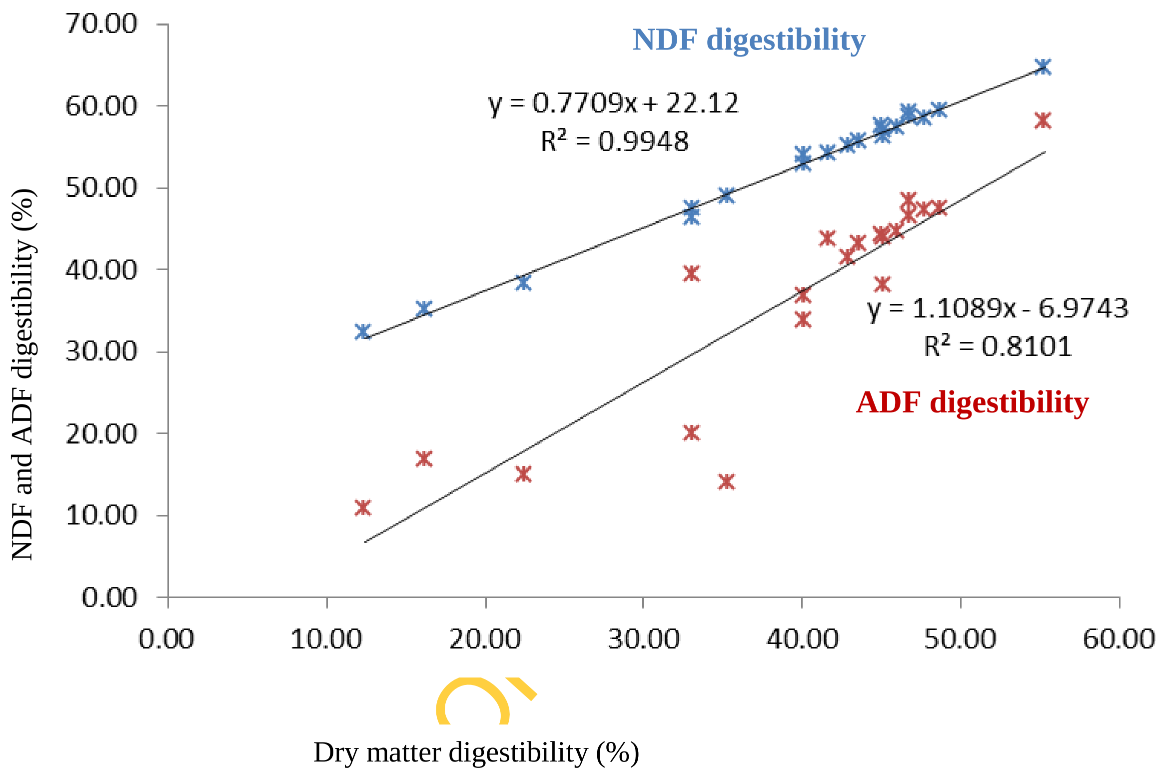


Figure 11: Relationship between dry matter digestibility (DMD) and digestibility of NDF and ADF of straws of five varieties of rice fed to WAD rams

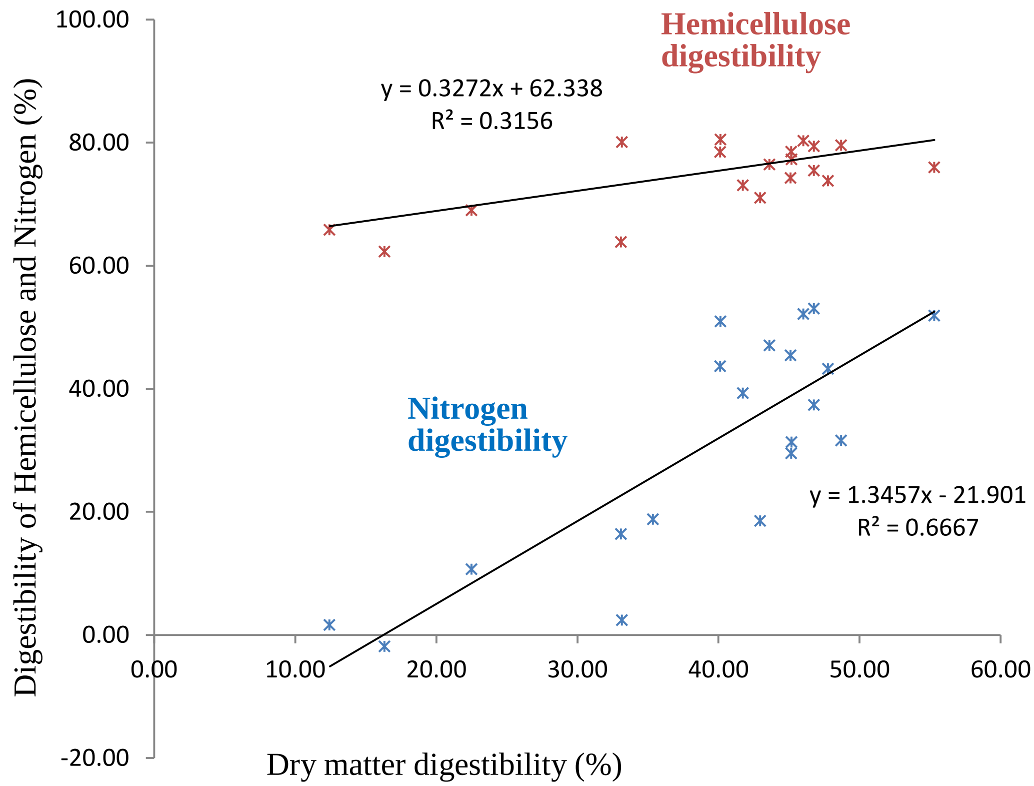


Figure 12: Relationship between dry matter digestibility (DMD) and digestibility of hemicellulose and nitrogen (N) of straws of five varieties of rice fed to WAD rams

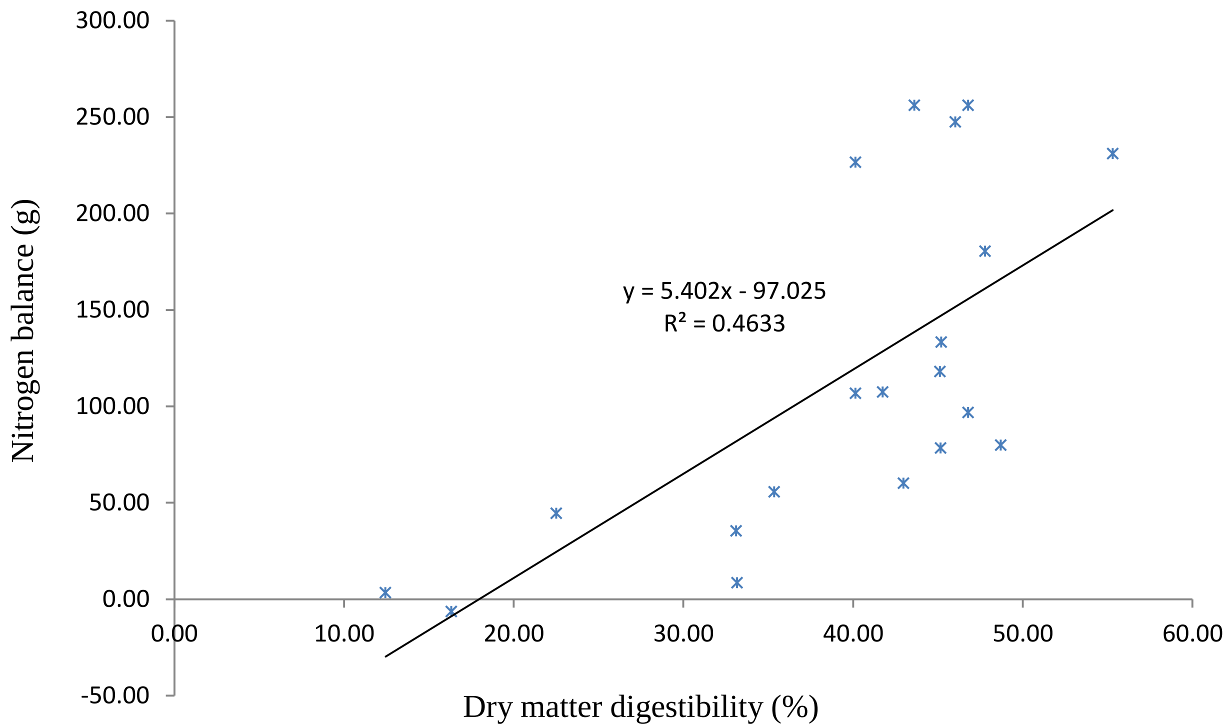


Figure 13: Relationship between dry matter digestibility (DMD) and nitrogen balance of straws of five varieties of rice fed to WAD rams

CHAPTER FIVE

5.0 DISCUSSION

5.1 Rice straw as fodder in Nigeria

Rice farmers cultivated at least 12 other crops which included maize, sorghum, millet, cowpea, groundnut, vegetables, cassava, sugarcane, soyabean, vegetables, yam, cocoyam and sweet potatoes. While only five of the crops namely maize, sorghum, millet, cowpea and groundnut are cultivated by more than 50% of rice farmers, the other seven crops are cultivated by between 10 to 28% of rice farmers while other crops not listed are cultivated by less than 10% of rice farmers. The area of land dedicated to rice by the farmers also exceeded that committed to maize cultivation which was a key crop cultivated by most farmers in the regions now considered as the key rice producing areas of Nigeria. While the mean land size committed to maize per farmer and the proportion of rice farmers cultivating maize were 2.0 ha and 96.7%, respectively; area of land committed to rice by the same farmers was 2.9 ha.

Rice farmers owned an average of 2.9 cattle per farmer, while goat and sheep ownership were 5.3 and 3.0 per farmer, respectively. A total of 152 rice farmers out of the 180 rice farmers owned at least one livestock. A total of 54 farmers owned combinations of cattle, sheep and goat. Baba and Magaji (1998) found that 93.0% of farmers in Sokoto and Zamfara owned livestock while 49.0% owned cattle.

Farmers depended more on five (5) crop residues as fodder source more than on ‘cut’ grass, suggesting that grass is scarce compared to the farm residues which are more accessible through cultivation (83.9%), purchase (68.9%), direct grazing (47.2%) and also, collected free from relations’ and friends’ farms (6.7% and 6.1%, respectively). Jodha (1992) suggested that availability of grasses had declined due to reduced lands on fallow and common land availability. Farmers therefore depended more or resources generated on their fields as source of fodder for their livestock. As much as 83.9% of rice farmers who owned animals depended on residues from their farms to feed livestock. This confirmed the description of most farmers in Nigeria like most other SSA farmers as suggested severally as mixed crop–livestock farmers (Lenne and Thomas, 2005; Thornton *et. al.*, 2002), with as much 67.2% of such farmers indicating rice straw as resource utilized in feeding their livestock. In Niger, Kaduna and Bauchi states, limited grazing resources are accessible by livestock owners with only 8.9% of such farmers/livestock owners having access to grazing (communal) land, and only 1.1% claiming to have access to such resources that are more than 2 hectares.

Dobermann and Fairhurst (2002) described straw as the only organic material available in significant quantities to most rice farmers. Rice straw's importance stems from the suggestion of Thorton *et al.* (2003), who described the idea of a crop from which farmers can harvest one product for human consumption and the residues with which they can feed to their livestock, as a highly appealing idea.

An aggregate of 68.3% of Nigerian rice farmers admitted rice straw as an important output of their rice-planting activities. This proportion is close to the proportion of rice farmers who packed and utilized (67.3%) rice straw in one way or the other (i.e. 15.6% of farmers who gathered all straw, 50.6% who gathered some and 1.1% whose animals grazed on-farm). Only 32.8% or rice farmers did not gather rice straw from their farm. Baba and Magaji (1998) reported that 39% of Fadama farmers fed rice straw to their cattle, while all pastoralists surveyed fed rice straw to animals in Sokoto and Zamfara states. Although, only 12.8% of rice farmers reported to have been ever approached to have rice straw packed form their rice fields, only 8.9% out of the 12.8% reported either barter or monetary transaction.

Some rice farmers indicated that they utilized rice straw for purposes other than as feed resource for their animals. A total of 2.2% of rice farmers indicated that they used rice straw in the construction of granaries and barns, 0.6% used straw in weaving mats. Mulching of crops, particularly yam appears to be the most important alternative use of rice straw as 14.4% of rice farmers reported its usage for this purpose. Erosion control and brick making were indicated by 1.1% and 6.1% respectively, of rice farmers as other usage of rice straw. Doyle *et al*. (1986) in a review listed burring, fertilizer for paddy fields, mulch for vegetable production, substrate for mushroom growth and bedding for poultry and livestock as means of utilizing rice straw. Other purposes listed in the review included usage as fibre for paper production and construction material, fuel and as source of fibre (sugar on hydrolysis) for single cell protein production.

A total of 98.9% of the farmers indicated their readiness to adopt rice varieties with improved fodder qualities; even if grain output remained unchanged, if it attracts additional income and if a ready market for straw emerged around their vicinities. Also, 96.7% of all rice farmers indicated that they would adopt rice with improved straw quality if the price of livestock shoots up driving demand for rice straw. While 66.1% of the farmers indicated that they would still adopt rice variety with improved straw quality even if grain yield slightly reduces.

A total of 5.6% of rice farmers claimed that they incur cost on transportation of rice straw to their storage facility/location, while 8.9% of all rice farmers indicated that they incinerated rice straw on their farms. Also, 30.6% of all respondents indicated that they incur cost on labour to remove straws from field in preparation for cultivation during the new planting season.

5.2 Field evaluation of 49 rice accessions

The five cultivar groups had varied seedling vigour ratings with the least vigorous accessions having normal rating (i.e. 5) by the Standard Evaluation Systems for Rice (SES) (IRRI 2002).

Seedling vigour varied within the cultivar groups. NERICA 3, 6, 12, 16, 18 and ART 10 had ratings above normal, while the 13 other members of the group had between rating 5 (normal) and 1 (extra vigorous) within the interspecifics upland group. All the accessions of the interspecifics lowland had seedling vigour ratings better than normal rating.

The *Oryza sativa* lowland group had longer maturity periods than interspecifics lowland, interspecifics upland, *Oryza sativa* upland and *Oryza glaberrima* accessions, while interspecifics upland had the shortest day-to-maturity. NERICA 13 had the shortest period, while IR 64, an *Oryza sativa* lowland accession, had the shortest day-to-maturity.

The *Oryza glaberrima* group had spikelet fertility of 92.0% than other groups. NERICA 18 and 14, interspecifics upland accessions had spikelet fertility values which were quite high and comparable to the mean value observed for *Oryza glaberrima*. McNeal (1960) observed that the number of kernels per plant in wheat had high association with yield in F2 and F3 generations. Rate of spikelet fertility is an important yield attribute in breeding considerations. *Oryza glaberrima* is a major genome contributor in the upland rice breeding activities in Africa, especially NERICA rice. Sroskopf and Reinbergs (1966) reported that SF accounted for 50.4% of variation observed in the yield of barley. Talwar (1976) reported grain per panicle as advantageous along with total tillers as selection index for grain yield in rice breeding.

Oryza glaberrima had 61.3% lodging incidence compared to the highest incidence of 5.2% observed among the other four cultivar groups. In a high yielding environment, lodging is the most important constraining factor on yield for most cereals including rice (Setter *et al*., 1997). Lodging in rice occurs as a result of strong winds, heavy rain, water management, plating density and excessive use of fertilizer (Min and Fei, 1984; Song *et al*., 1996). Plant height is also an important factor which affects lodging in rice. The *Oryza glaberrima* cultivars, which had the highest incidence of lodging, also had the highest average height, while the shortest cultivar group, interspecifics lowland, recorded 0% lodging. Ooawa *et al*. (1993) observed that differences in the degree of lodging and lodging index were largely dependent on the breaking strength of the basal internode. The *Oryza glaberrima* cultivars had the least basal internode diameter also had the highest lodging incidence.

Song *et al*. (2007) listed 1000 grain weight along with spikelet number per panicle as important components of grain yield. Katayama (1993) also suggested that 1000-grain weight was directly related to grain size and might be used to as bases for selection and classification. The upland cultivars, *Oryza sativa* upland and interspecifics upland, which were known to have wider grains were observed to have significantly higher 1000-grain weight of 31.4g and 31.5g respectively, while *Oryza sativa* lowland had the least 1000-grain weight of 26.3g. Yoshida (1983) also reported 1000-grain weight along with number of panicles per unit area, spikelet number per panicle, grain weight and spikelet fertility percentage as major yield components.

The grain yield of the two lowland cultivar groups: interspecifics lowland and *Oryza sativa* lowland were similar and highest. The observed high grain yield of the two groups also agreed with fact that that they had high tillers and panicles per square metre, which were only surpassed by *Oryza glaberrima*. Positive association of grain yield and panicles per metre square is widely reported. Mohamed *et al*. (2012) suggested the use of panicles per square metre and filled grains per panicle attributes of rice plant as selection criteria. Straw yield is also directly impacted by numbers of tillers per square metre. The *Oryza glaberrima* group which had the highest tillers per metre square, also had the highest straw yield.

5.3 Near Infrared Spectroscopy (NIRS) analysis of straws of forty nine (49) rice accessions

Low nitrogen (N) content of rice straw is widely reported as the first limiting factor of its use as fodder for ruminants. Rice straw is categorized as a poor quality forage. The range of nitrogen content observed in all the 49 rice straws fell within the widely reported N contents for other rice varieties' straw in other regions of the world.

Doyle *et al*. (1986) reported the crude protein content of rice straw to be between 2.2 to 9.5%, with mean value of 4.1%, while Abreu and Bruno-Soares (1998) reported similar mean crude protein (CP) value of 4.0 to 4.1% in three local rice varieties (namely : Koral, Ringo and Venaria). The mean N content of the straw of the five (5) cultivar groups ranged from 0.82 to 0.91%, which are equivalent to 5.1 to 5.7% crude protein (CP) contents (when multiplied by 6.25 conversion factor). The CP range of the groups falls within 2.2 to 9.5% CP range for various varieties reported by Doyle *et al*. (1986);

while Van Soest (1994) reported 0.35 to 1.20% N content range for various rice varieties' straw.

The accessions IR 64, NERICA 14 and NERICA 15 had the highest N contents of 1.05, 1.02 and 1.02%, respectively. These nitrogen contents are equivalent to 6.6, 6.4 and 6.4% CP, respectively. All the obtained nitrogen contents for all 49 varieties are within ranges obtained by various researchers.

The mean ME content of the five cultivar groups ranged from 6.1 MJ/kg (*Oryza glaberrima*) to 6.7 MJ/kg (*Oryza sativa* upland). NERICA 15 and 7 both had the highest ME of 6.94 MJ/kg among the 49 varieties. Al-Mamun *et al*. (2002) reported ME of 5.96 and 5.64 MJ/kg, respectively for improved and traditional rice varieties' straws. Abreu and Bruno-Soares (1998) reported 6.3 and 6.0 MJ/kg for two varieties, namely Koral and Ringo, respectively.

Neutral detergent fibre (NDF) values obtained for all five cultivar groups ranged from 65.9 (interspecifics lowland) to 66.7% (*Oryza glaberrima*). Rice straw is widely reported as having a very high ash content, which may be as high as 17%, of which silica accounts for 75 to 82%. Neutral detergent fibre (and acid detergent fibre) contents of rice straw are significantly affected by its high ash (and silica) contents. The high neutral detergent fibre content of rice straw implies that it contains low levels of soluble and easily digestible sugars and amino acids for efficient microbial growth and activity in the rumen when fed to ruminants without supplementation with other sources of these deficient nutrients. Doyle *et al*. (1986) concluded that animals fed sole rice straw diet performed poorly.

Acid detergent fibre constitutes about 50% of straws of all the 49 varieties analysed in this study. This high proportion of acid detergent fibre in the straws of the varieties indicated that their cellulose contents are high, which accounts for poor digestibility when rice straw is fed solely to ruminants.

Van Soest (2006) described rice straw as unique compared to other cereal straws as it contains low lignin and high silica content. Agbagla-Dohnani *et al*. (2001) reported some

European rice varieties' straws as having lignin content of 80-100 g/kg, while Deng *et al*. (2007) reported some Chinese varieties as having lignin contents that are as high as 19%. Jin and Chen (2006) however reported that some Chinese varieties' straws have lignin content as low as 8.6%. Sangnark and Noomhorm (2004) reported some Thai varieties' straw as having lignin contents of 18%. The highest acid detergent lignin content recorded amongst the 49 varieties' straw was NERICA 5 (3.5%). Van Soest (2006) reported rice straw lignin as 52 g/kg.

Ash content of the straws of the five cultivar groups were high, just as reported in most varieties from other regions of the world. The range varied from 17.6% to 19.4% in the five cultivar groups. The ash content of rice straw can be as high as 17%, while silica may account for as high as 75-82% of total ash. High ash content of rice straw is the major factor that qualifies it as a low quality feedstock. Sagnark and Noomhrom (2004) reported 12% ash content for straws of Thai rice varieties, while Deng *et al*. (2007) and, Jin and Chen (2006) reported 9.8% and 6.3%, respectively. Jenkins *et al*. (1998) reported 18.67%.

The silica content of the straws of the five cultivar groups ranged from 12.9% to 14.3%. The rice plant has been described to be among silica-cumulating plants. Van Soest (2006) reported the silica content of straws of some rice varieties to be 130 g/kg. Other silica-cumulating plants are *Equesetum* (horse tail), diatoms, sedges and cedars. NERICA 10 was observed to have had the highest silica content of 15.8% among the 49 rice varieties, while Suakoko 8 had the least silica content of 11.3%.

The *in vitro* organic matter digestibility (OMD) of the straws of rice varieties also varied among and within groups. Wang *et al*. (2006) observed 313g/kg *in vitro* organic matter digestibility in untreated rice straw, compared to a range of 368 to 513g/kg in rice straw treated with ammonia bicarbonate with levels ranging from 15 to 75g/kg. *Oryza sativa* upland cultivars had the highest *in vitro* organic matter digestibility of 46.7%, while *Oryza glaberrima* cultivars had the least value of 43.6%.

5.4 Voluntary intake and digestibility of straws of five rice varieties fed to rams

5.4.1. Chemical composition of the straws of the five varieties of rice

The nitrogen contents of straws from five varieties of rice fell within the documented low nitrogen content values for the straws of most rice varieties. Van Soest (1994) reported 0.35 to 1.20 %. The mean nitrogen content of the five varieties of rice was 0.9 %, while the N contents of the five varieties ranged from 0.8 to 1.1 %. The mean values obtained for all five treatments and the range of the means of the varieties were also similar to the range (0.8 to 0.9%) obtained in the NIRS analysis of straws of 49 rice varieties in this study.

The mean neutral detergent fibre value of 71.4 % observed for the five (5) varieties was also comparable to 69.3% reported on the Grain Repository of the CGIAR System-wide Livestock Programme (CGIAR-SLP). Doyle *et al*., (1986) reported that neutral detergent fibre of rice straw may be as high as 86.0%. The mean neutral detergent fibre range of the five varieties, namely, CG 14, NERICA 14, NERICA lowland 20, ITA 321 and Cisadane was 65.0 to 76.0 %.

The acid detergent fibre (ADF) of the five varieties had a mean value of 39.8 %; CGIAR-Systemwide Livestock Programme reported a mean of 44.3 % for rice straws sourced from different parts of the world. The acid detergent lignin (ADL) contents of the five varieties ranged from 4.0 to 13.0 %, and a mean of 6.4 %. Jin and Chen (2006) reported acid detergent lignin content of 8.6 % (China), Deng *et al.* (2007) 19.0% (China), while Sangnark and Noonhorm (2004) reported 18.0 % (Thailand).

The ash contents of the five varieties, which ranged from 13.0 to 15.0 % were similar. Baxter *et al.* (1996) reported rice straw as a low quality feed stock with ash content as high as 17.0 %. The ash contents of the five varieties were comparable to documented value of 17.0 % (Baxter *et al.,* 1996) and 12.3 % (Sangnark and Noomhorm, 2004). Other investigators observed and reported much lower values: 9.8 % (China) by Deng *et al*. (2007) and 6.3 %, Jin and Chen (2006).

5.4.2 Dry matter intake and apparent nutrient digestibility of straws of five rice varieties

The animals consumed less than 3% of their body weights for the five of their respective sole rice straw diets. While rams on NERICA 14 and NERICA lowland 20 both consumed 2.9 % rice straw compared to their body weights, rams on ITA 321 consumed 2.7 % while animals on both Cisadane and CG 14 consumed 2.5 %. The mean dry matter intake of the rams on CG 14 was 48.1 g/kg $BW^{0.75}d^{-1}$; NERICA 14, consumed 55.4; ITA 321, 51.6; NERICA lowland 20, 57.4 and Cisadane, 47.9 g/kg $BW^{0.75}d^{-1}$. Chowdhury and Huque (1997) reported voluntary dry matter intake of 76.0 and 55.0 g/kg $BW^{0.75}d^{-1}$ for cattle in two (2) separate trials with season accounting for the differences. Schiere *et al.* (1985) reported 79.2 g/kg$BW^{0.75}d^{-1}$ with urea treatment; 79.2 g/kg$BW^{0.75}d^{-1}$ was also reported with lick block supplementation and 75.1 g/kg $BW^{0.75}d^{-1}$ with rice bran supplementation in cattle.

While voluntary dry matter intake (VDMI), neutral detergent fibre intake (NDFI) and acid detergent fibre intake (ADFI) were all similar on the five treatments, nitrogen intake and hemicellulose intake varied significantly. Rams on NERICA 14 had significantly higher nitrogen (N) intake (0.67 g/kg$BW^{0.75}d^{-1}$) than all the other treatments. This may be due to the higher nitrogen content of NERICA 14 and higher intake (2.9%) of NERICA 14 (on per BW% basis) than Cisadane, CG 14 and ITA 321 treatments.

The digestibility of the dry matter (DM) contents of the five treatments did not also vary. Digestibility of the neutral detergent fibre, acid detergent fibre and hemicellulose (H) followed the same trend as the dry matter. Only nitrogen digestibility varied among the treatments. NERICA 14 also had a better nitrogen digestibility (50.8%) and a corresponding better nitrogen (N) retention of 0.36g compared to negative values of -1.22, -0.61, and -0.72 g recorded for CG14, ITA 321 and NL 20, respectively. Cisadane had slightly positive nitrogen retention of 0.08g.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Summary of findings

The usage of rice straw as fodder by 67.2% of ruminant animal-keeping rice farmers highlights its importance. The ownership of ruminant animals by 84.4% rice farmers complements this information. The appreciable straw yields of interspecifics upland, *Oryza sativa* upland and *Oryza glaberrima* varieties which gave lower grain yields could be described as compensatory attribute.

The fodder qualities of the straws were also comparable with documented qualities of straws of varieties in countries with thriving rice straw-dependent ruminant animals feeding programmes. West African dwarf rams consumed between 2.5 to 2.9% of their body weights of the straws of five varieties, with the voluntary dry matter intake ranging from 47.9 to 57.4 g/kgBW$^{0.75}$d$^{-1.}$

6.2 Conclusions

The grain and straw yields; and the fodder qualities of the 49 rice varieties indicated their potentials as sources of food for man and feed for his ruminant animals. The varieties' nitrogen contents are low just as the varieties in those other countries, but the roughages generated in the course of the production of rice have qualities that are comparable also to the depleting and scarce tropical grasses which originally solely nourished ruminants

The use of rice straw by most of the rice farmers indicated its importance as fodder for sheep. The voluntary dry matter intake and dry matter digestibility ranges obtained for sheep fed straws of five rice varieties suggested the potential of rice straw as fodder for West African Dwarf rams. Farmers stand the chance of earning extra revenues from sales of such residues of dual-purpose-type crops.

6.3 Recommendations

Rice straw usage as fodder should be encouraged to reduce air quality hazard, soil degradation and deterioration resulting from straw burning. Farmers should be encouraged to utilise as much as 70% of rice straw generated in their rice production in ruminant animal feeding. Stakeholders in agriculture which include policy makers, government at all levels, particularly states and the central government; rice-related research institutes in Nigeria should embark on projects, enlightenment and advocacy campaigns that will make our farmers convert rice straw which normally should be a nuisance to high quality human food.

Efforts of rice breeders should also be geared towards improving rice straw fodder qualities alongside quality and quantity of grain, which had always been the sole focus of their breeding and improvement activities. High straw yielding attribute of *Oryza glaberrima* varieties - parents of NERICA interspecifics, should be considered alongside high grain yielding attribute of *Oryza sativa* in future breeding efforts.

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Appendix i

International Livestock Research Institute

Rice Straw Usage in Nigeria

Village___________________ LGA______________________ State________________

Questionnaire Number_______________ Interviewer's Name___________________

Date of Interview and Time______________________________________

1. **Basic Socio-economic / Demographic Characteristics.**

a). Name of Respondent________________________________

b). Gender____________________ c). Age________________

d). Marital Status_____________

e). Education___________

1= No Education 2= Primary 3= Secondary 4= Secondary, 5= Islamic (Modrasat) 6= Others.

2. **Farm and Crop Management.**

1). How many plots of land did you own last cropping season?

(a). 1, (b). 2, (c). 3. (d). 4 (e). ≥5.

2). Out of these, how many plots did you commit to rice cultivation last cropping season.

(a). 1, (b). 2. (c). 3. (d). 4 (e). ≥5. (f) all my plots

3). What other crops did you plant last season?

		Land area covered
001	Sorghum	…………………ha
002	Maize	………………...ha
003	Millet	………………...ha

004	Cassava	………………...ha
005	Cowpea	………………...ha
006	Groundnut	………………...ha
007	Vegetables (leafy, pepper, onions)	………………...ha
008	Rice -------------	………………...ha
Others	------------	……………..…ha
	------------	………………...ha
	------------	…………………..ha

3. Rice

01 When was the most recent season that you planted rice?

(a.) 2007 (b.) 2008 (c.) 2009

02 For how long have you been using your plots to cultivate rice?

(a.) more than 10 seasons (b.) between 5 and 10 seasons(c.) less than 5 seasons.

03 When was the last time you opened a new fallow (virgin) for rice cultivation?

(a.) within the last 3 seasons (b.) between 3 & 5 seasons ago (c.) beyond 5 seasons.

04 Do you use the same plot more than one cropping season in a year?

(a) Yes (b) No (c). At times

05 Apart from rice, what else do you use your plots for?

(a.) Other crops (b.) grazing (c.) rental (d.) none

06 Do you hope to increase your rice field size during the next planting season?

(a). No (b).Yes, by less than 1 ha (c). Yes by 1 ha (d).Yes, more than 1 ha.

4. Rough Rice Output

01 What was the total production of paddy (grain) during the last cropping season?

----------------number of bags ----------------Kg

(Estimate local unit/bagging into Kg)

02 What was the total production of paddy (grain) during the cropping season before the last.

----------------number of bags ----------------Kg

(Estimate local unit/bagging into Kg)

03 What varieties of rice have you been cultivating?

Local varieties------------------------

Improved varieties------------------

----

04 What type of cultivation were you involved in during the last season?

Upland------------------%

Lowland----------------%

Irrigated----------------%

5. **Livestock and Feed Resources**

01 |Do you own and keep livestock?

(a) Yes (b) No

02 Which animals (ruminants) do you keep? (and how many of each?)

Cattle	Yes/No	How many?_______________
Goat	Yes/No	How many?______________
Sheep	Yes/No	How many?_______________
Donkey	Yes/No	How many?_______________

Camel	Yes/No	How many?_______________
Others /Specify_______	Yes/No	How many?_______________
____________	Yes/No	How many?_______________
___________	Yes/No	How many?_______________

03 How do you feed your animals during the wet and dry seasons?

	WET SEASON		DRY SEASON	
	Yes	No	Yes	No
1. Free range	( )	( )	( )	( )
2. Wet fodder	( )	( )	( )	( )
3. Dry fodder	( )	( )	( )	( )
4. Grains	( )	( )	( )	( )
5. Agro by product	( )	( )	( )	( )
6. Others_________	( )	( )	( )	( )

04 If fodder is used, which?

	Yes	No
1. Maize stover	( )	( )
2. Sorghum stover	( )	( )
3. Cowpea Haulm	( )	( )
4. Rice Straw	( )	( )
5. Groundnut Haulm	( )	( )
6. Cut Grass	( )	( )
7. Other cereal Straws	( )	( )
_________	( )	( )
_________	( )	( )
_________	( )	( )

05 How is your fodder material sourced?

Yes No

		Yes	No
1.	Cultivated by you	( )	( )
2.	Collected free from other farmers	( )	( )
3.	Grazing (within community)	( )	( )
4.	Bought	( )	( )
5.	Others (specify)	( )	( )

06 Are there periods during the year that getting fodder or other feed materials becomes very difficult?

(a.) Yes (b.) No

07 How long does such period last?

(a.) Less than 3 Months. (b.) Between 3 to 6 Months. (c.) More than 6 Months.

08 Do you have portion(s) of land designated as grazing land for your animals?

(a) Yes (b) No

09 If (08) above is "Yes", how many hectares?

(a). < 1ha, (b). 1 ha (c). > 1 ha (d). 2 ha (e). > 2ha

10 What fodder materials do you cultivate on such lands?

(a.) Ratoon of previous rice cropping operations

(b.) Grasses

(c.) Legumes

_________ others (Specify)

6 **<u>Rice Straw Management and Utilisation</u>**

1 How do you harvest your rice?

(a.) Panicle only.

(b.) Panicle and straw.

2 Do you place any importance on the straw generated in your rice-growing activities?

(a) Yes (b) No (c) Don't know

3 What portion of the rice straw generated on your rice field do you gather to be fed to your animals?

(a.) All. (b.) Some (c.) None.

4 Have you ever been approached by anyone requesting to park very large amount of straw generated on your farm?

(a) Yes (b) No

5. If 'YES' did the person state purpose for which straw will be utilized?

State purpose____

6. Were you offered any amount of money?

(a) Yes (b) No

7. If your straw is not gathered, then what is done to your straw after rice grain is separated from it?

(a.) burnt

(b.) sold

(c.) left to be parked away by anyone in need of it.

(d.) left to rot on the farm.

(e.) left to be grazed on by animals

8 If you do not feed rice straw to you livestock now, have you ever done so in the past?

(a) Yes (b) No

9. If you once fed your animals with rice straw, why do you not feed your animals with rice straw again?

Reasons…………………………………………………………….

……………………………………………...…………………

……………………………………….…..…………………

10. What other fodder materials do you use to feed your animals?

[ ] Straw of other cereals

[ ] Hay

Others (List) ____________________

____

____

11 Apart from feeding animals, what other things do you use rice straw for?

[ ]Roofing

[ ]Fencing

[ ]Construction of granaries/barns

[ ]Making beds

[ ]Making door mats

[ ]Erosion control

[ ]Mulching

[ ]Animal beddings

………………..

12 Do you incur any cost to get rid of rice straw from your farm?

(a) Yes (b) No

13 How is the cost incurred?

	Amount incurred
Labour	₦…………………
Transport	₦…………………
Fuel	₦…………………
Others ____________ (Specify)	₦…………………

14 Do you think burning of materials (like straw) on your farm has negative effects on the land?

(a) Yes (b) No (c) Don't know

15 What is the trend of the production output on the land where you have consistently burnt your straw?

a. Increasing

b. Decreasing

c. Unchanged.

d. Do not know

16 Would you adopt a rice variety (and use the straw for animal feed) if:

	Yes	No
Straw quality were improved and grain yield the same		
Straw quality improved and grain yield slightly less than current yield		
If rice straw attracts additional income		
A ready market for straw emerges around their area		
The price of other livestock feeds became more expensive		
They would ever consider a rice variety because of straw quality		

Appendix ii

2008 FIELD PLAN FOR LATTICE SQUARE DESIGN TREATMENT KEYS

TREATMENT	VARIETY	REPLICATION 1	REPLICATION 2	REPLICATION 3
1	NERICA 1	36	58	137
2	NERICA 2	46	69	143
3	NERICA 3	12	76	130
4	NERICA 4	21	92	120
5	NERICA 5	47	57	118
6	NERICA 6	40	70	106
7	NERICA 7	37	50	133
8	NERICA 8	15	77	145
9	NERICA 9	24	67	139
10	NERICA 10	26	54	103
11	NERICA 11	32	63	105
12	NERICA 12	42	88	101
13	NERICA 13	9	98	136
14	NERICA 14	14	51	146
15	NERICA 15	39	73	125
16	NERICA 16	44	86	110
17	NERICA 17	5	95	147
18	NERICA 18	2	68	123
19	CG14	34	55	134
20	WAB 56-104	8	64	100
21	WAB 181-18	16	83	104
22	WAB 189 (FARO 54)	19	87	135
23	ITA 321 (FARO 53)	41	82	142
24	OS 6	48	94	102
25	OFADA	49	75	140
26	IR64	13	60	124
27	IR72	38	97	117
28	SUAKOKO 8	33	79	122
29	TOG 7106	11	89	113
30	TOG 7206	18	53	109
31	TOG 7442	29	96	111
32	WITA 4 (FARO 52)	45	56	121
33	SIPI (FARO 44)	35	66	131
34	TOX 4004 (FARO 57)	22	90	126
35	CISADANE (FARO 51)	43	81	127
36	BW 348 – 1	17	61	129
37	NERICA-L-7	23	59	141
38	NERICA-L-8	4	78	138
39	NERICA-L-9	3	72	99
40	NERICA-L-14	1	52	115
41	NERICA-L-19	31	85	144
42	NERICA-L-20	27	71	108
43	NERICA-L-21	30	74	114
44	NERICA-L-41	10	80	112
45	NERICA-L-42	6	91	132
46	NERICA-L-45	7	62	107
47	NERICA-L-49	28	84	116
48	NERICA-L-60	25	93	128
49	ART 10	20	65	119

Replication 1

Column Row	1	2	3	4	5	6	7
Plot 1	**1** 40	**2** 18	**3** 39	**4** 38	**5** 17	**6** 45	**7** 46
Plot 2	**8** 20	**9** 13	**10** 44	**11** 29	**12** 3	**13** 26	**14** 14
Plot 3	**15** 8	**16** 21	**17** 36	**18** 30	**19** 22	**20** 49	**21** 4
Plot 4	**22** 34	**23** 37	**24** 9	**25** 48	**26** 10	**27** 42	**28** 47
Plot 5	**29** 31	**30** 43	**31** 41	**32** 11	**33** 28	**34** 19	**35** 33
Plot 6	**36** 1	**37** 7	**38** 27	**39** 15	**40** 6	**41** 23	**42** 12
Plot 7	**43** 35	**44** 16	**45** 32	**46** 2	**47** 5	**48** 24	**49** 25

Replication 2

Column Row	1	2	3	4	5	6	7
Plot 1	**50** 7	**51** 14	**52** 40	**53** 30	**54** 10	**55** 19	**56** 32
Plot 2	**57** 5	**58** 1	**59** 37	**60** 26	**61** 36	**62** 46	**63** 11
Plot 3	**64** 20	**65** 49	**66** 33	**67** 9	**68** 18	**69** 2	**70** 6
Plot 4	**71** 42	**72** 39	**73** 15	**74** 43	**75** 25	**76** 3	**77** 8
Plot 5	**78** 38	**79** 28	**80** 44	**81** 35	**82** 23	**83** 21	**84** 47
Plot 6	**85** 41	**86** 16	**87** 22	**88** 12	**89** 29	**90** 34	**91** 45
Plot 7	**92** 4	**93** 48	**94** 24	**95** 17	**96** 31	**97** 27	**98** 13

Replication 3

Column Row	1	2	3	4	5	6	7
Plot 1	**99** 39	**100** 20	**101** 12	**102** 24	**103** 10	**104** 21	**105** 11
Plot 2	**106** 6	**107** 46	**108** 42	**109** 30	**110** 16	**111** 31	**112** 44
Plot 3	**113** 29	**114** 43	**115** 40	**116** 47	**117** 27	**118** 5	**119** 49
Plot 4	**120** 4	**121** 32	**122** 28	**123** 18	**124** 26	**125** 15	**126** 34
Plot 5	**127** 35	**128** 48	**129** 36	**130** 3	**131** 33	**132** 45	**133** 7
Plot 6	**134** 19	**135** 22	**136** 13	**137** 1	**138** 38	**139** 9	**140** 25
Plot 7	**141** 37	**142** 23	**143** 2	**144** 41	**145** 8	**146** 14	**147** 17

Appendix iii

2009 FIELD PLAN FOR LATTICE SQUARE DESIGN TREATMENT KEYS

		Replication 1	Replication 2	Replication 3
TREATMENTS	VARIETY	PLOT	PLOT	PLOT
1	NERICA 1	38	93	108
2	NERICA 2	30	75	146
3	NERICA 3	21	63	123
4	NERICA 4	18	62	137
5	NERICA 5	46	64	113
6	NERICA 6	36	89	126
7	NERICA 7	19	76	104
8	NERICA 8	31	92	119
9	NERICA 9	17	68	135
10	NERICA 10	13	54	124
11	NERICA 11	5	65	144
12	NERICA 12	32	85	115
13	NERICA 13	10	51	116
14	NERICA 14	2	78	117
15	NERICA 15	25	58	139
16	NERICA 16	49	77	133
17	NERICA 17	28	86	99
18	NERICA 18	22	91	118
19	CG14	45	61	129
20	WAB 56-104	26	52	111
21	WAB 181-18	9	67	120
22	WAB 189 (FARO 54)	40	88	128
23	ITA 321 (FARO 53)	37	59	110
24	OS 6	48	80	130
25	OFADA	35	98	121
26	IR64	47	73	107
27	IR72	12	82	143
28	SUAKOKO 8	16	66	102
29	TOG 7106	6	81	101
30	TOG 7206	8	79	142
31	TOG 7442	33	50	109
32	WITA 4 (FARO 52)	29	72	136
33	SIPI (FARO 44)	24	60	138
34	TOX 4004 (FARO 57)	41	83	100
35	CISADANE (FARO 51)	3	55	105
36	BW 348 – 1	11	94	147
37	NERICA-L-7	39	71	127
38	NERICA-L-8	43	95	141
39	NERICA-L-9	1	96	145
40	NERICA-L-14	15	53	134
41	NERICA-L-19	23	56	103
42	NERICA-L-20	20	97	140
43	NERICA-L-21	34	70	125
44	NERICA-L-41	44	57	114
45	NERICA-L-42	7	87	122
46	NERICA-L-45	42	69	131
47	NERICA-L-49	4	74	106
48	NERICA-L-60	14	84	132
49	ART 10	27	90	112

Replication 1

Column Row	1	2	3	4	5	6	7
Plot	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	39	14	35	47	11	29	45
Plot	**8**	**9**	**10**	**11**	**12**	**13**	**14**
2	30	21	13	36	27	10	48
Plot	**15**	**16**	**17**	**18**	**19**	**20**	**21**
3	40	28	9	4	7	42	**3**
Plot	**22**	**23**	**24**	**25**	**26**	**27**	**28**
4	18	41	**33**	15	20	49	17
Plot	**29**	**30**	**31**	**32**	**33**	**34**	**35**
5	32	2	8	12	31	43	25
Plot	**36**	**37**	**38**	**39**	**40**	**41**	**42**
6	6	23	1	37	22	34	46
Plot	**43**	**44**	**45**	**46**	**47**	**48**	**49**
7	38	44	19	5	26	24	16

Replication 2

Column Row	1	2	3	4	5	6	7
Plot	**50**	**51**	**52**	**53**	**54**	**55**	**56**
1	31	13	20	40	10	35	41
Plot	**57**	**58**	**59**	**60**	**61**	**62**	**63**
2	44	15	23	33	19	4	3
Plot	**64**	**65**	**66**	**67**	**68**	**69**	**70**
3	5	11	28	21	9	46	43
Plot	**71**	**72**	**73**	**74**	**75**	**76**	**77**
4	37	32	26	47	2	7	16
Plot	**78**	**79**	**80**	**81**	**82**	**83**	**84**
5	14	30	24	29	27	34	48
Plot	**85**	**86**	**87**	**88**	**89**	**90**	**91**
6	12	17	45	22	6	49	18
Plot	**92**	**93**	**94**	**95**	**96**	**97**	**98**
7	8	1	36	38	39	42	25

Replication 3

Column Row	1	2	3	4	5	6	7
Plot 1	**99** 17	**100** 34	**101** 29	**102** 28	**103** 41	**104** 7	**105** 35
Plot 2	**106** 47	**107** 26	**108** 1	**109** 31	**110** 23	**111** 20	**112** 49
Plot 3	**113** 5	**114** 44	**115** 12	**116** 13	**117** 14	**118** 18	**119** 8
Plot 4	**120** 21	**121** 25	**122** 45	**123** 3	**124** 10	**125** 43	**126** 6
Plot 5	**127** 37	**128** 22	**129** 19	**130** 24	**131** 46	**132** 48	**133** 16
Plot 6	**134** 40	**135** 9	**136** 32	**137** 4	**138** 33	**139** 15	**140** 42
Plot 7	**141** 38	**142** 30	**143** 27	**144** 11	**145** 39	**146** 2	**147** 36