UNIVERSITY FOR DEVELOPMENT STUDIES

RICE (*Oryza* spp.) VARIETAL RESPONSE TO COMPOST AND TIMING OF NPK FERTILIZER APPLICATION IN THE GUINEA SAVANNA ZONE OF GHANA

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BY

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June, 2021

DECLARATION

I hereby declare that this thesis is the result of my own research and that no previous submission has been made in this University or elsewhere for a degree. The works of others which serve as source of information have been duly acknowledged in the references.

Eleazar Ofosu Krofa

(Student) …………………………….. ……………………………

Signature Date

I hereby declare that the preparation and presentation of the thesis was supervised in accordance with the guidelines on supervision of thesis laid down by the University for Development Studies.

Dr. Rufai Ahmed Mahama …………………………… ………………………..

(Principal Supervisor) Signature Date

Prof. Israel K. Dzomeku ….…………………….. ……..……………….

(Co-Supervisor) Signature Date

ABSTRACT

Soil fertility can be enhanced organically by compost and by chemical fertilizers such as N.P.K at recommended rate. In this study, a field experiment was conducted at the Savannah Agricultural Research Institute rice research field at Nyankpala in the Northern region of Ghana to determine the effect of compost and time of NPK fertilizer application on the growth and yield of NERICA rice varieties. The experiment was a 2 x 3 x 3 factorial treatment combination of rice variety, compost, and time of NPK fertilizer application laid out in a randomized complete block design with three replications. NERICA 4 and NERICA 14, upland rice varieties were combined with compost at 0, 1.5 and 3 t ha^{-1}, and NPK fertilizer application timing at 1 and 5 weeks after planting (WAP), 2 and 7 WAP and 3 and 6 WAP. Results revealed application of compost at 1.5 t ha^{-1} to NERICA 14 significantly ($P < 0.05$) enhanced crop chlorophyll content. Compost application at 1.5 t ha^{-1} was adequate to support gravimetric moisture content and maximum leaf area index (LAI). The results revealed that compost rate of 3.0 t/ha was needed to enhance phosphorus availability (27.84 mg kg^{-1}), panicle count (210), grain yield (1726 kg ha^{-1}), straw yield (4086 kg ha^{-1}) and dry matter accumulation (581.2 g m^{-2}). NPK fertilizer application timing at 1 and 5 weeks after planting (WAP) maximised chlorophyll content. NERICA 14 outperformed NERICA 4 in grain yield (1989 kg/ha and 1268 kg/ha respectively), tillering ability (237 tillers m^{-2}), earlier flowering (56 days), panicle count (217 panicles m^{-2}), straw yield (4020 kg ha^{-1}), dry matter accumulation (601 g m^{-2}) and higher 1000 grain weight (26.8 g). Compost at 3 t/ha is recommended for use in place of inorganic fertilizer. Nerica 14 is recommended as the best rice cultivar to select for optimum grain yield in upland rice farming, a combination of both Nerica 14 and compost at 3ton/ha is recommended.

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DEDICATION

To my wife Theresa Guanie, my children, Emmanuel, Debora, Faith-Becca, Favor and my late Mum and Dad.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Rice (*Oryza sativa* L.) is one of the utmost significant cereal crops in the world which is cultivated to nourish mankind (Chaturvedi, 2006). Rice is considered as a staple food for more than 50% of the world's population (Fageria, 2007) and consumed by hundreds of millions in Africa and Latin America and over two billion people in Asia (Muthayya *et al*., 2014). Rice occupies the first place in relation to area and total production. In 2008/2009, rice covered 59% of the total cultivated-cropped area of 1,555,940 ha, with an output of 4,523,693 metric tons and production of 2907 kg ha^{-1}. It is commonly cultivated in both tropical and subtropical regions (Singh *et al*., 2015).

It is one of the most important food protein and energy source and therefore the position of rice in accordance to food availability and socio-economic stability is obvious (FAO, 2003). Diaz-Ambrona and Maletta, (2014) predicted that by 2025 about 3 billion tons of cereals would be cultivating by the world's farmers to cater for an about 8 billion human population projected, which will necessitate a 25 % more rice to cater for the rising need of the globe.

Rice is becoming an essential food for consumers of urban and local (Nwanze *et al.*, 2006). But in Africa consuming rice domestically is significantly higher than producing domestically, necessitating rise importations that drain huge volumes of rare foreign exchange. Now, sub-Saharan Africa's (SSA) quest for rice which is doubled by the degree of the growth of population and consumption, is rising quicker than production (Seck *et al*., 2012). The degree of upsurge in demand has not been able to catch up by rural production across Africa.

In Ghana, the total rice consumption amounted to 500,000 tons in 2005 making it equal to 22 kg per capita consumption per annum (Tomlins *et al.*, 2005; JICA, 2007). Largely, Ghana hinges on imported rice to complement the shortfall in rice supply. Averagely, yearly rice importation is 400,000 tons (MoFA, 2009). In Ghana, the independency ratio of rice has deteriorated from 38 % to 24% in 1999 and 2006, respectively (Quaye, 2007). A basis of worry to the Ghana government is the bill for the importation of rice estimating at about US$ 500 million annually. Paramount to Ghana's agricultural development is increased domestically produced rice with higher keenness contrary to imported rice which will help elevate food security and foreign currency savings (JICA, 2007).

With the number of Africans in urban areas likely to rise from 38 % to 48 % by 2030, Africa's rice consumption is likely to grow in the future (Seck *et al.*, 2012).

There is the need therefore for the agricultural sector's stakeholders to ensure that the millennium goal of food security is achieved through improved and continued domestic production of good quality rice to replace importation and foreign exchange savings. These savings in foreign exchange can then be channelled to other vital sectors of Ghana's economy such as education and health.

1.2 Problem Statement and Justification

Upland rice remains one of the staple crops grown under rain fed conditions. The growth and development of rice crop is however constrained by depleted soils with low fertility status, low pH, drought, diseases, and pests incidence (Dzomeku *et al.*, 2007). According to Sanchez *et al.* (1997) declining soil fertility has militated against the growth of food cultivation in Sub Saharan Africa. Additionally, the degradation of soil has also led to the depletion of vital soil nutrient and diminishing levels of soil organic matter which is essential for crop growth (Woomer *et al.*, 1994). Mghase *et al.* (2010) reported that, rice average yields of one ton per hectare under upland ecology is of great concern to researchers and therefore the need to improve rice production in the country. According to Berkhout *et al*. (2015), rice farmers are cognisant of the role of fertilizer application through various on-farm trials and demonstrations. However, the availability of research and information related to the response of NERICA varieties to timing of inorganic fertilizer application is limited. This thus buttresses the fact that providing technology packages on soil fertility management with inorganic fertilizer application timing can boost rice production as it has been achieved in maize production.

Upland soils in Northern Ghana are usually low in organic matter due to yearly occurrences of bush fires and the continuous nutrient mining of the soil (Owusu-Bennoah *et al*., 1991). It is worth mentioning that farmers' management practices had one way or the other compounded the degradation of the upland soils leading to low soil fertility (Mghase *et al.*, 2010). Considering the erratic rainfall occurrences in Northern Region of Ghana, coupled with the early termination of the rains in October, compost application can boost rice production in the uplands by the retention of soil moisture during early termination of the rains (Stoop *et al*., 2002). Wopereis *et al*. (2009) opined that combined management of soil fertility can enhance the best and continual usage of soil nutrient reserves in combination with mineral fertilizers and organic alterations. This is crucial for maintaining or increasing of yield and income among many rice farmers in Sub-Saharan Africa.

Upland rice can be grown on any kind of soil but the best yields are usually obtained from those planted on deep, fertile and well drained loamy soils. This therefore buttresses the need to apply compost as organic amendment and timing of inorganic fertilizer application to increase the soil fertility; though the reaction to fertilizers by the upland varieties is already recognised in Ghana (Apaseku and Dogbe, 2013). The management practice of soil fertility and the knowledge for adoption to local environments can exploit inorganic fertilizer and organic amendment use efficiency and crop output (Pypers *et al*., 2011). These practices of compost application and timing of inorganic fertilizers if combined with the utilization of improved germplasm (NERICAs) can improve the management practices of soil fertility among rice farmers. This technology can increase the yields of upland rice, thereby solving the problem of food unavailability and poverty alleviation among the smallholder rice farmers. Assertion by Diagne (2006) indicates that farmers ought to know the quantity of compost to apply and the NERICA variety that respond better to different inorganic fertilizers prior to their application timing regimes.

1.3 Main Objective

To develop technology package of integrated soil fertility management using inorganic and organic fertilizers for upland rice varieties.

1.3.1 Specific Objectives

The specific objectives were to:

assess the effect of compost on the yield and yield components of rice.

determine the best timing of inorganic fertilizer for maximum performance of yield components and grain yield of two NERICA varieties.

ascertain if compost, timing of inorganic fertilizer application and rice cultivar selection has effects on yield components and grain yield of rice.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and Distribution of Rice

Rice has an extensive and diverse history in Africa. Like the Asian farmers, farmers of African possibly farm this grain about 3,000 years ago (Bellwood, 2007). Whereas Asian farmers developed the Oryza sativa, African farmers developed the species *Oryza glaberrima* (Loko *et al*., 2021) at about 500 years ago, *O. sativa* was grown in Africa and peasant farmers then have incorporated it into their schemes of rice production, many Asian species local varieties development and making Africa a central source of secondary variety (Carney, 1993).

According to research, the most antique domesticated traces of rice which is predicted to have happened between 9000- and 7000-years B.C. came from China. The subspecies, O*ryza sativa: indica* and *japonica* were known in China as Hsien and Keng, respectively (Oka, 1988). At about 3500 years ago, *Oryza glaberrima* was farmed in Africa (Carney, 2001; Heuer *et al*., 2003) in the West Africa's River Niger. *brailigulata* for *glaberrima* and *rufipogon* for *sativa* are known to being the wild parents for both species (Oka, 1988). From some differences noticed in many samples DNA, the dating grounded on the idea of Molecular (DNA) Clock and paleontological researches, supposed that the two produced species may have a shared ancestor possibly parted with the fragments of Gondwana (old supercontinent) more than 100 million years ago (Wendel and Cronn, 2003). Numerous reports stated that, more than four centuries ago, O*ryza sativa*, the species of Asia was carried into Africa, and is really the main one produced in Africa (http://www.warda.org). According to Oka (1988), *sativa* and *glaberrima* are grown in mixtures in many places in Africa, and the production area was predicted as a half of the entire field of rice in “the West African Inland. 2.2 The New Rice for Africa (NERICA)

O*ryza glaberrima* yield remains low owing to the fact that panicle can bear only insufficient grains and a record of cultivars are susceptible to lodging (Heuer *et al.*, 2003; Ishii, 2003) and shattering (http://www.warda.org). Some resistant characters have been developed by O*ryza glaberrima* to its predestined environment and presenting a number of valuable traits to overcome abiotic and biotic conditions for O*ryza glaberrima* survived in the environment of Africa with less human interference, (Heuer *et al.*, 2003). Otsuka and Kalirajan (2006) reported that the introduction of better-quality cultivars obtained from the Asian species with high possible yield under high conditions of input was not comparable to the projected outcomes. This could be drawn from the assertion that the natural environmental condition was less adapted most lines and others needed a number of inputs like water, pesticides and fertilizers and which are not usually accessible due to low income status of farmers in Africa. The target to put together the finest species of Africa (resistance to abiotic and biotic stresses) and species of Asia (potential of high yielding) made researchers of the West and Central African Rice Association (WARDA), to carry out a program of inter-specific hybridization in the mid 1990's and that begun the origin of NERICA (Balasubramanian, *et al*., 2007). NERICA have been widely used in Africa because of erratic rainfall, low soil fertility, resistance to tropical diseases and traits of high yielding (Kijima *et al.*, 2011).

Several efforts to cross O*ryza glaberrima* and O*ryza sativa* was not successful decades ago for the barriers of sterility in F1 progenies (Dingkuhn *et al.,* 1998). The progenies of F1 came from this crossing got nearly a hundred percent sterility (Heuer *et al.*, 2003). The tactic WARDA used to keep this issue of fertility was to backcross the F1 lines with the O*ryza sativa* parents at a minimum of two times (Somado *et al.,* 2008). Additionally, the population of BC2F1 was put to pedigree selection following the embryo rescue technique. The selection was made short using double haploid. This procedure was directed first to select seven upland lines named NERICA, followed by eleven additional upland cultivars (Somado *et al.*, 2008). In 2006, certified NERICA population was reported to have contained cultivars of about 88 and supposed to cover the chief Africa's rice ecologies. According to WARDA (2001), NERICA cultivars growing area may be up to 150,000 hectares. Working with researcher from Japan on the Inter-specific Hybridization Project (IHP), many other hybrids were developed by WARDA researchers (WARDA, 2001). With the adaptability to local conditions of their parent from Africa, these inter-specific hybrids were meant to syndicate the high yield of their parent from Asia (WARDA, 2001).

The researchers of NERICA first claimed NERICA was not intended to substitute local variety (WARDA, 2001). Indeed, the new seeds integration is not a new thing for the farmers of Africa. Habitually, new and old varieties are mixed and become part of the process of assortment contributing to the heritage of local genetic (Edwin, 2005). This peasant seed system could have been used by NERICA project researchers at the point of parting for their programme but, the team of the project feared that the recognised seed systems of the national research programmes would be too slow (Faso *et al.*, 2009). So, they elected to work with hybrids from their laboratories from the Consultative Group on International Agricultural Research (CGIAR) gene bank. The farmers view were only sought out by the researchers after developing the NERICA hybrids.

The NERICA varieties are better-off in protein than most rice varieties (Oikeh *et al.*, 2008b). When cooked, NERICA varieties have good taste with a very good aroma. Some countries are still testing the NERICA varieties. Other countries have however grasped the phase of multiplication of seed. Diverse NERICA varieties are already cultivated on a large scale elsewhere, especially varieties of the upland. This endorses rice consumption. From the farmers, traders normally buy the rice to trade on the markets in main urban centres. NERICA rice can be seen packaged beautifully in supermarkets in Togo (FAO, 2007).

2.2.1 NERICA 4 and 14 Varieties

The two NERICA varieties used in this study are NERICA 4 and NERICA 14. NERICA 4 had CG14 (*O. glaberrima*) and WAB 450 (*O. sativa*) as the parents whereas NERICA 14 had the *O. glaberrima* (CG 14) but two diverse sativa parentages (WAB 181-18 and WAB 56-50) (Somado *et al*., 2008). NERICA 4 and 14 have a potential yield of 5000 kg/ha but NERICA 4 recorded an average yield of 2856 kg/ha in Nyankpala and its environs (Somado *et al*., 2008). NERICA 4 variety matures between 95-100 days with an average height of 120 cm (Somado *et al*., 2008). Though it is unaffected by lodging and insects, it is moderately resistant to blast. It has a good tillering ability with basal leaf sheath colour of light green, a compact panicle with long grain sizes, white caryopsis, amylase content of 23 % and good cooking qualities. NERICA 14 has similar characteristics except that it matures earlier than NERICA 4 (between 75-85 days), has an average height of 110 cm, is moderately resistant to lodging and has a reddish caryopsis with medicinal properties (Sompong *et al*, 2011).

2.2.2 Rice Habitat and Growth

According to Defoer *et al.* (2004) five main rice ecologies are coexisting in Africa. These are:

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

The major rice ecologies in Africa

Upland rice (NERICA 14)

Rainfed lowland rice

Furrow Irrigated Rice

The cycle of rice differs from 90 days and 270 days in Sahel Zone and Forest Zone, respectively (Agnoun *et al*., 2012). The growing period of rice increases when exiting the zone of Sahel to the Forest Zone journeying the Sudan Savanna and the Guinea Savanna (Agnoun *et al*., 2012). The shortage of water and 1 - 3 months short rainy season elucidate the prevalence of 90 days eco phenotypes in the zone of Sahel (Agnoun *et al*., 2012). Rice benefits a longer rainy season when rolling into Savanna agro ecological zone. Therefore, the rising period of rice inclines to extend from 90 - 165 and from 165 - 210 days of the period of growth. Rainy season occupy a big part of the year's season justifying the long period of more than 210 days and reaching 270 days in the case of tropical forest (Agnoun *et al*., 2012). According to Whitmore *et al*. (1993), the quantity of sun radiation established in rainy tropical ecologies is low for the lastingly cloudy sky. This results in photosynthetic activity being decreased. Cloudy sky between yields is negatively correlated at irrigated lowland and the totality of rainfall is seen under rainy tropical ecology (Arraudeau, 1998).

2.3 Rice Culture

Meeting the growing demand of food for the swelling world population has been contributed greatly by the manipulation of genetic resources. By the use of short statured varieties high yielding with high sink capacity, green revolution enhanced yield of cereal crops including rice in the late 1960s (Foulkes *et al*., 2009). Owing to growing demands of food supplies, the effect of the green revolution is fading. Though people has become manifold, the area under rice cultivation has not changed. The choices accessible are to improve rice yield on the basis of per unit area (Cassman *et al.,* 2003) and develop cultivars of rice with high capability of yielding which can raise cultivation (Gibson and Fischer, 2004).

Using conventional and modern biotechnology for cultivating varieties having resistance against abiotic and biotic stress can upsurge yields of rice to meet the requirement of the world (Khush, 2005). The varieties have diverse physical and structural traits that can contribute to yield (Yang *et al.,* 2007; Yang and Hwa, 2008). Ashrafuzzaman *et al.* (2009) observed that, there is disparity in morphological and components of yield in dissimilar aromatic rice varieties. Irrigation management, fertilization, and good control of pest and disease enhance yield of rice (Tilman *et al*., 2002). The crop genotype has a pivotal role in the direction of the use of these resources and finally production of economic yield. Genetic and environmental factors are the factors of growth and yield features of genotypes hinged on. Alam *et al.* (2008) reported that, varietal assortment at any site has a vital role amid production factors. For maximum benefit from new genetic material, suitable management of crop, rest on various varietal growth characteristics.

Genotypes of rice have been improved by years breeding programme of researches from both international and local centres of research (Hazell, 2010; Peng *et al.*, 2010; Renkow and Byerlee, 2010; Ragasa *et al.,* 2013). Farmers can now access a number of these genotypes. Improved genotypes are used by a number of rice farmers in their cultivation in Ghana (Ragasa *et al.,* 2013) however, rice farmers in Ghana recorded average yields which linger to drop far beneath possible yields described by stations of research and experiment. In as much as these farmers endure to produce rice giving little care to the recommendations of integrated Rice Management (IRM) which among others underscores integrated soil fertility management (ISFM). Numerous interventions in the rice industry have also taken place in Ghana.

2.3.1 Upland Rice Production

Upland rice is cultivated on soils of free draining and as such the crop depends solely on rainfall (Dzomeku *et al.,* 2007)**.** Upland or rain fed rice under cultivation occupies an estimated area of 13 % of the total rice area of 143 million ha of the world under cultivation (Norman *et al*., 1995). It also dominates rice growing in West and Central Africa showing about 40 % of the total area under rice (WARDA, 2001). Upland rice can be best grown in areas with at least 200 mm of rainfall per month for a minimum of three months, though the length of time between raining days should not exceed 7 – 10 days. One original feature of rice is the ability to grow under different environmental conditions (Liu *et al*., 2019).

Each rice development stage: vegetative, reproductive and maturity, has its specific mineral needs and deviating from these needs may lead to substantial yield losses and vice versa (Wang *et al*., 2013). Rainfall regularity is therefore extremely important in successful production in tropical Africa. Onwueme and Sinha (1991) reported that a minimum of 750 mm of rain if evenly distributed is adequate for good yield, but lack of water during the reproductive phase may result in spikelet sterility and corresponding drop in yield. Sanjeewani and Ranamukhaarachchi (2009) also reported that good water management, variety and environment determine rice yield. Rice can be grown through two main methods, direct sowing and transplanting (Onwuene and Sinha, 1991).

Under upland conditions, high yields are likely. Yields of 7.0 and 7.2 t/ha were testified in the Philippines and Peru, respectively, under ideal conditions on experimental fields (Abifarin *et al.,* 1972). In Nigeria and Ethiopia, high yields of 5.4 t/ha and 6 t/ha were also described respectively (Ogunniyi, 2011).

There is high variability in P and N in soil of rice growing areas in Northern Ghana.
In lowland rice cultivation, the fertilizer effectiveness is a role of water supply and management (FAO/UNESCO, 1990). The enhanced upland rice varieties chiefly upland NERICA lines may call for different requirements of nutrient than the traditional upland varieties (*Oryza sativa* and *Oryza glaberima*) to improve rain fed cultivation (Okonji *et al*., 2012). With the present varied varieties of upland rice (*Oryza sativa* and *Oryza glaberima*), it may be essential to give endorsements for acceptable rates of fertilizer of P and N (Oikeh *et al.,* 2008a).
NERICA development could upsurge rice production in Ghana if farmers know the quantities of N and P fertilizers to apply and the varieties are able to improve with low rates of fertilizer input. Though there may be a few farmers who could pay for more chemical fertilizers, majority of farmers are in the bracket of inadequate input (Apaseku and Dowbe, 2013).
There are a lot of constraints associated with upland rice production of which drought or moisture stress is very crucial. Additionally, poor soil fertility, weed infestation, poor optimal plant stand, lack of soil and conservation of moisture as well as incidence of disease and pest such as leaf blast and stem borers could thwart efficient upland rice production. These can influence yield components of rice (Arraudeau, 1995).

2.4 Economic Importance of Rice

In Ghana, the most important staple food after maize is rice (*Oryza sativa* L.) and as a result of the growth of population, urbanization and changes in consumer eating habits,

its consumption keeps increasing (Wireko-Manu and Amamoo, 2017). The demand for rice as a staple food in Africa reflects a shift from traditional food (especially roots and tubers), to urbanization and socio-economic trends (Lopriore and Muehlhoff, 2003). Apart from utilizing the grain as food, rice and its by-products have other uses which cannot be overlooked. The dry matter of milled rice contains 88 % starch, basically; amylase and amylopectin, 6 to 8 % protein and 0.5 % sugars (Juliano, 1993). Due to its high digestibility and high nutritive value, white rice has become indispensable for use in baby and breakfast foods, and in diets for the sick (Young and Pellett, 1994). Rice is also used for production of starch, soft drinks alcoholic and beverages. Rice flour may be used as a blender in baking wheat bread. Rice bran and polish are fed to animals.

The hulls and polish are used in pharmaceutical industry for the production of phytin and vitamin B (Luh *et al.,* 1991). Straw of rice is also a valuable raw material for high-quality paper manufacturing. Other products made from straw include cardboards, ropes, packing materials, linoleum, handbags, hats and sandals, sacks and baskets, brooms and many other household articles (Purwandaru *et al*., 2018). Rice is the fifth most vital energy source in diet, making up 9 % of total caloric intake (Sharif *et al*., 2014).

In many poor food-insecure countries, the major source of income generation, employment and nutrition is rice production (Ericksen, 2008). The plentiful activities employ over millions of people who directly or indirectly work in rice cultivation or in related support services (Ericksen, 2008). Activities of the farm change to post-production processes, namely harvesting, threshing, drying, milling, trade and storage after harvesting rice. Norman and Kebe (2006) reported that, added employment chances for a large number of people are milled rice preparation for food, the conversion of milled rice to other products, and the use of broken rice, bran of rice, hulls of rice, husks of rice and straw of rice.

2.5 Agronomic Constraints of Rice Production

2.5.1 Soil Physico-chemical Requirements

The physical properties of the soil are considered important in the production of upland rice because of their ability to influence root growth, soil moisture preservation, and ease of cultivation after rainfall (Le and Roger, 2001). Linked physical properties are structure, texture, penetration resistance, and water-holding capacity.

Texture is how particle sizes are distribution in the soils. A soil can be classified as fine textured, medium or coarse. According to Sohi *et al.* (2010), the suitability of the soil is assessed by texture of the soil for the production of upland rice because it contains all inorganic particles which relate to plant growth. Soil texture has influence on water storage and transmission, aeration, and the soil's ability to supply nutrients that plants need. Soil texture is reliant on the nature of the development of soil and the total parent materials (Sumfleth and Duttmann, 2008). According to Dobermann and Fairhurst (2000), soil texture is reported to be the most essential soil property for rice cultivation with equal soil moisture regimes for similar mineral conformations. The status of soil moisture is affected by soil texture compared to any other soil property with the exception of topography (Sumfleth and Duttmann, 2008).

Buri *et al.* (2010) suggested that the plentiful, coarse-textured and sandy soils in upland rice cultivated areas in West Africa lower production due to low water retention capacity. According to Baligar *et al.* (2001), nutrients such as N applied to sandy soils quickly leached from of the root zone and results in soil infertility.

Higher amount of clay in Vertisols may bring about a number of disadvantages. However, with sufficient moisture in the soil can offer good yields, but land preparation normally necessitates a progressive level of mechanization (Buri *et al.*, 2010). Moisture deficit in smooth clay soil can cause yield reduction because of water conductivity which is restricted (Mosaddeghi *et al.*, 2009).

The amount of the soil' capacity to hold water is affected by soil physical features as well as its drive in the soil easily and the energy with which it is held. Energy and water-holding capacity are roles of pore size and soil texture (Sauer and Logsdon, 2002). Pores sizes that are larger can hold a lot of water with less energy, thus they drain faster. On the other hand, less water is held by smaller pores but hold it more tightly due to molecular forces between soil particles and water molecules (Sauer and Logsdon, 2002) and therefore, the flow of water is very slow in the smaller pores. Exchangeable ions of plant nutrients are held by these same kind of surface forces.

Water supply is one of the key constrains in upland rice cultivated areas such as lateritic soils of South Asia, cerrado soils in central Brazil and savanna soils in West Africa, (Lal, 2006). Humid areas may experience reduction in rice yields as a result of drought especially at reproductive stage (Lal, 2006). clay soils are reported to have high water holding capacity than that of sandy soils, placing sandy soils more prone to droughts excluding areas where rainfall pattern is well spread during the cropping season (Sauer and Logsdon, 2002). According to Mosaddeghi *et al.* (2009), the content of organic matter in the soil also impact the capacity of soil to hold water.

The most preferred soil for upland rice is fine-textured soil due to its capacity to hold water (Musa *et al.,* 2009). Holes and aggregates of the soil are stabilised by organic matter in the soil through the organic materials' bonding properties, such as organic gels, waste products of bacterial, worm emissions and casts and fungal hyphae (Bot and Benites, 2005).

Moreover, mineral soil materials mixed with organic matter influences an upsurge in moisture holding capacity of the soil. The topsoil, with high amount of organic matter has greater water storage (Bot and Benites, 2005). Baligar *et al.* (2001) also recommended planting of rainfed rice on fine-textured African soils due to hydromorphy.

A soil resistance to shear or compression forces is mostly forecast by the infiltration resistance (Lu *et al.*, 2010). Substantial energy is required for high penetration resistance to establish seedbeds and may obstruct root growth (Kirby and Bengough, 2002). Yield declines where nutrient and water uptake is impeded as a result of lack of root extension. Soil moisture content also influences penetration resistance (Asch *et al.*, 2005). Soil moisture suction is a force of compression that upsurges the abrasion of particles and overall resistance of soil at reduced moisture content (Lu and Likos, 2006). According to Zhang *et al.* (2009), there is a report on the consequence of the strength of soil on shoot and root of the growth of rice. A positive correlation was observed in a lateritic sandy clay loam between resistance of penetration and the length of root and shoot. They further stated that seedling emergence is reduced by higher resistance of penetration and is more noticeable on plumule than that of the growth of radicle (Zhang *et al.*, 2009). When resistance of penetration increases from 1.03 J cm^{-2} to 6.12 J cm^{-2} there is a corresponding decrease of extreme length of root from 10.8 cm to 1.7 cm.

Soils vary in their ability to store nutrients that are available to plants. Dark soils contain higher amount of organic matter content compared to red soils which are mostly found in the sub-Saharan Africa and are generally low in organic matter (Young, 1980). Upland soil nitrogen reserves are localized in the organic matter (Ballard, 2000). These reserves can be important but they are not easily available to the plant. N becomes available after mineralization of organic matter and fixed by aluminium and iron oxides thereby making it unavailable to plant in red sandy soils (Dobermann and Fairhurst, 2000). P reserves are mostly found in organic matter and fixed by iron oxides and aluminium thereby making it inaccessible to plants in red sandy soils (Kome *et al.*, 2019). The soils capacity to supply K especially in Northern Savanna is not a limiting factor (Apaseku and Dogbe, 2013).

2.5.2 Soil Fertility

Fertility of soil may be defined as the ability of the soil in the production of nutrient that enhances the growth of plant (Stockdale *et al*., 2002). Productivity encompasses the natural fertility of the soil with added nutrients such as organic residues, inorganic fertilizer, and other sources such as climate, soil biological and physical properties, management, and non-inherent factors that enhance crop production.

In Ghana, the cropping system that is carried out has an influence on the biomass dynamics of microorganisms and the soil fertility. Grant *et al*. (2002) reported that diversification and intensification of the system of cropping can impact the characteristics of the soil microbiologically, chemically and physically. The occurrence of varied soil microbial community is critical to ecosystem productivity. The diversity is prejudiced by soil management practices and the type of crop cultivated. Several studies have shown that exudates coming from plants have influence on soil microbes and the microbial community the soil around the roots (Ibekwe and Kennedy, 1999; Ohtonen *et al.*, 1999). Biomass produced by microbes exerts a control effect on organic matter dynamics of the soil and many available nutrients (Weil and Magdoff, 2004). Guerrero *et al.* (2005) observed that, microbial biomass is mostly used as an initial indicator of deviations in soil physical and chemical properties obtain from management of soil and stresses of the environment in ecosystems that are related to agriculture. Fertility of the soil provides a major role in cropping systems productivity and such its decline has been one of the biophysical limitations to West African sub-regions crop production including Ghana. Past achievements records revealed that, fertility of the soil and civilization is closely linked. The flourished civilization of the Babylonians, Asorians ad Mesopotamians, declined with a corresponding decrease in soil fertility (Tulu, 2002).

A major crop production constrain confronting Agriculture in Ghana is soil fertility. This is brought about by nutrient elimination and losses due to erosion of the soil. Most of our cultivated soils are deprived in the major nutrients of the plant needed for best growth of plant and this has resulted in low yield (Gruhn et al., 2000). The decline in nutrients of our soils has rendered most of our soils less productive. According to Rahman and Ranamukhaarachchi (2003), changes in fertility of soil normally occur in reply to management practices of land and the systems of land use. Saleque *et al.* (2004) observed that an upsurge in plant population enhances nutrient removal from the soil for the reason that, nutrients that are removed by crops from the soil exceed annual fertilizer replacement. Rigorous cropping enhances nutrient removal in a great quantity from the soil without contributing to the natural nutrient replacement (Narang *et al.*, 1990). According to Logah (2009), including legume crops in a rotation with non-legume crops helps the soil to become productive. However, agricultural systems through mechanization in our modern days have contributed much to the soil structure degradation and exhaustion of the fertility of the soil (Lal, 2002). Farmers in Ghana do not consider the type system of cropping that can maintain soil fertility status. Prices and market situation mostly dictate how crops are selected for cultivation. This situation may eventually affect the sustainability of agriculture production (Ranamukhaarachchi *et al.,* 2005). Currently, soils in many areas in Ghana hold little organic matter which is below 1.0 % (Gruhn, 2000) which is not adequate to support crop production. Above all, record soils are obtained from parent materials that are thoroughly weathered. They are ancient, and have leached for years (Benneh *et al.,* 1990) and also have low inbuilt fertility. Ghana soil fertility status will decline if necessary; actions are not taken to address this problem.

Nutrient dynamics in the Ghana should be studied to improve crop productivity to curtail economic problem in the country. Information on soil fertility for various systems of cropping is a robust basis for agricultural production which is sustainable (Ranamukhaarachchi *et al.,* 2005). Anderson *et al.* (1997) reported that systems of cropping govern the conditions of the soil and also have influence on soil properties. This is relatively due to how different crops response to nutrient uptake (Bassirirad, 2000). According to Grant *et al.* (2004), good management of nutrient is a vital part in the production of crop and does not only increase income, but also improves the quality of soil thereby reducing environmental damage. Howarth (2005) specified that nutrients management to enhance output and systems of cropping quality is a major contest that should be addressed through a blend of amendments of organic and soil organic matter management.

In Ghana, slash–and–burn farming which is a traditional process of maintaining soil fertility and as population increases and land gets scarce, bush fallow system is giving way to up-to-date technology of soil management (Danquah, 2020). Certain parts of southern and northern regions of the country have adequate lands that are still fallowing for farming purposes but the purpose of maintaining soil fertility may not be achieved due to rapid population increase that goes with human settlements (Livingston *et al*., 2011). Among the good methods of maintaining soil fertility in farming traditionally is the 'compound' system of farming practiced by crop farmers in the Guinea savanna and Sudan agro-ecological zones (Fosu and Tetteh, 2008). They grow crops in their surrounding areas intensively and maintained the soil fertility by applying residues of crops, animal manure and refuse from the household (Tittonell *et al*., 2005). The system has contributed in maintaining the soil fertility to the appreciable level which has enhanced continuous cropping and increase yields. Application of fertilizer and other soil improvements practices are carried out without considering the pattern of nutrient depletion by crops grown on the soil and impact of common farming system practiced on the fertility of the soil (Ajayi, 2007). This practice continuous to occur as an outcome of inadequate data regarding soil fertility in the area. The activity will bring about soil amendment being over application or under application and this would not meet the requirements of nutrient by crops (Maheshwari *et al.*, 2012). Chemical fertilizers are very costly and farmers will save money if the right application rate is used (Tulu, 2002). According to Arihara (2000), higher yields cannot be realized if the wrong application of fertilizer to crops is not curtail. It is very vital to learn how the soil fertility and microbial biomass differ with varying systems of cropping as this will assist planning of the practices of soil amendment. According to Grant *et al.* (2002) cropping system sustainability needs a complete balance between soil nutrients removal and nutrients replacement. This however, can only be realised when the trend of soil nutrient dynamics for various cropping systems is understood.

To achieve higher productivity of Ghana soils, adequate measures should be employed to maintain soil fertility. Priority should be given to maintaining fertility of soil in the systems of cropping of the tropics to promote yield (Arihara, 2000). According to Grant *et al.* (2004) a serious part of production of crop is effective nutrient management not only to recover financial gains but also to uphold the quality of soil and lessen the possibility of environmental damage. Howarth (2005) observed that a challenge that must be solved through a mixture of amendments of organic and management of soil organic matter (SOM) is nutrients management to keep output and excellence systems of cropping.

2.5.3 Soil Fertility Management and Its Effect on Rice Production

Tulu (2002) revealed that nutrients removal from the soil is reliant on the type of crop cultivated on the soil. In this respect, the practice of continuous cropping, crop rotation, mixed cropping among others, promotes depletion of the major nutrients in the soil in varying quantities as demanded by various crops. If the rate nutrient exhaustion is not well-adjusted by amendments of soil one has to aim at nutrient management and soil fertility maintenance (Bationo *et al.*, 1998).

Bationo *et al.* (1998) conveyed that, organic materials like the residue of crop, composts or manure for soil amendments are essential in sustaining cropping systems but they are not solution to mining of nutrient entirely. The adding of organic alterations matches in most circumstances, a process of reusing which cannot compensate for nutrient transferred through products of crop (Fagnano *et al.,* 2011). As a consequence, a vital requirement for the output of soil is the use of inputs such as inorganic plant nutrients from outside. In Michigan (on Typic Hapludafs), Logah (2009) likened plots under more varied system involving the rotation of wheat- soybean - corn with crops of clover cover and added manure from compost to plots under continuous corn monocropping fertilized with only NPK. Net mineralization in the system of rotation of soil could be 90 % higher than that soil in the monocropping after 70 days of development. Generally, through augmented biomass production, carbon inputs are boosted by inorganic fertilizers but soil N pools and active SOM such as microbial biomass is negatively affected by extreme application (McCarty and Meisinger, 1997). Soils with long term applications inorganic N is usually low in microbial biomass than soils that have received modifications organic (Collins *et al.,* 1992).

2.6 Effect of Fertilizer on Plant Growth

The use of chemical fertilizers has brought a major role in swelling production of crop globally (Manzar-ul-alam *et al*., 2005). In South Africa, nitrogen fertilizer is a key input for production of upland rice and its apt management is central to produce crops efficiently (Fageria, 2010). Increase in rice yield and quality is highly increased by judicious and proper use of fertilizers as earlier studies shown (Place *et al*., 1970). One of the most nutrients of yield limiting for yearly crops around the world is nitrogen and effective use of nitrogen is central for economic sustainability of systems of cropping

(Fageria, 2010). Due to sorption and precipitation reactions in soils crop use of applied fertilizer phosphorus is commonly low (Archana *et al*., 2016). Dose of fertilizer and time of fertilizer application determine the availability of P to rice grown on submerged soils. This is primarily because the applied P is habitually fixed very swiftly and is being reserved in the soil's top layers leading to slow and steady satiety of P-fixation sites on the soil (Archana *et al*., 2016). Along with other fertilizers zinc fertilizer is applied as basal. Zinc fertilizer may be mixed with other fertilizers for its requirement is very low *(*Naher *et al*., 2011).

Timing and rate of N fertilizer are crucial for best rice grain yield for nitrogen upsurges plant height, tiller number, leaf size (Doberman and Fairhurst, 2000). In Boro season, rice yield is increased to 6.04 t ha^{-1} from 3.33 t ha^{-1} owing to application of N fertilizer increased, but in T. Aman season, the effect was minimal (Naher *et al*., 2011). Crucial to increase the production of rice worldwide is efficient management of fertilizer under condition of environmentally friendly. Greenhouse gas emission is reduced by appropriate quantity of fertilizers applied onto soils (Naher *et al.*, 2011). Worldwide attention for efficient nutrient management is illustrated by yield plateau of rice and environmental adverse effects owing to disparity of use of chemical fertilizers (Naher *et al.*, 2011).

Release as well as applied N fertilizer losses reduction can be minimized by crop demand based fertilizer application (Naher *et al*., 2011). Phosphorus (P) uptake and soil inherent P supply ability determine P fertilizer requirements for a crop production (Naher *et al*., 2011). Cost of crop production may be upsurged by inefficient use of N. it is also a reason for environmental pollution. Use of acceptable rate of N with suitable time of application is a vital tactic in improving the efficient use of N (Fageria, 2010).

Producers can manage N efficiently for high output of rice while using diverse sources of N by understanding N fertilizer response in rice. Enhanced availability of right amount of nitrogen (120 kg N ha-1) increases the height of plant in response to N fertilizers application and assimilation, which improve the growth of plant (Chaturvedi, 2005). Nitrogen application significantly upsurges the height plants (Manirakiza and Şeker, 2020). N treatment the height of a plant can shows significant effect. Nie *et al.* (2009) informed that, urea at high N rate is less effective in improving plant growth of aerobic rice as compared to ammonium sulfate. In drought prone area, upsurge in yield of rain- fed rice is increased by the availability of phosphorus to the plant, and phosphorus fertilizer can also be used to reimburse for stem borer's injury in rice by increasing number of tillers (Gypmantasiri *et al*., 2003).

Two years' of studying, during the year 2002 and the year 2003 discovered that, with an application of nitrogen fertilizer- Super Net that contain Sulphur can upsurge all the features of growth, parameters of yield and grain nitrogen (N) significantly. Statistically, these results can be the same with treatment where ammonium sulphate nitrate is applied (Chaturvedi, 2005). It is required to identify each varietal best prescription and its effect on components of yield and other parameters of agronomy such as the cycle, lodging, the height of the plant and the amount of moisture of the grain, considering the importance of fertilization of nitrogen on grain yield of the rice plant, so to get proper understanding of said response of production (Chaturvedi, 2005). Fageria (2007) presented that the length of the maturation cycle correlates positively with the height of plant of the rice. Higher output was obtained with the applications of fertilizer at the rates of 90-60-90 kg/ha N - P_2O_5 – K_2O, respectively (Moro *et al*., 2008).

2.6.1 Effect of Fertilizer on Tillers per Plant

The quantity of panicles bearing tillers per area is a key function to the final yield making this an important yield component (Baloch, *et al*., 2006). Number of tillers is not significantly affected by split, application time and basal. Minimum tillers per plant however, are observed in the lower application rate but it responds more to 120 N kg/ha, in split or basal application. This designates that tiller numbers is increased by administering acceptable amount of N to rice (Said *et al*., 2014). Chaturvedi (2005) testified that owing to more accessibility of nitrogen in the soil, a greater number of tillers is recorded. Because P promotes tillering and root development in rice culture, it plays a central role in early vegetative growth stages (Haji, 2016).

2.6.2 Effect of Fertilizer on Panicles per Plant

During the vegetative phase nitrogen is needed by rice plants for tillering and growth promotion, which regulates the possible panicles number (Mae, 1997). In all urea sulfur-coated fertilizer, more panicles are found. In the production of rice, N application should be in adequate quantity to get higher number of larger panicles, (Said *et al.*, 2014). The length of panicle in all fertilizer treatments is significantly lowered by reducing N at 60 kg/ha (Said *et al*., 2014). The good source of higher number of panicles in rice crop may be fertilizers containing sulfur. Nesgea *et al*. (2012) also stated that at sowing, tillering and at the start of panicle, N taken up by rice safeguard an adequate length of panicle. Metwally *et al*. (2011) found that owing to the part nitrogen pay in the growth of crop, producing flowers and development of seed a significantly greater panicle length is recorded (Metwally, *et al*., 2011). It is essential to identify the best source and time of application of N given the importance of fertilization of N for panicles improvement.

2.6.3 Effect of Fertilizer on Grain Yield

Owing to unceasing and stable N supply into the soil by coated fertilizers to obtain the nutrients essential for physical processes, which in turn progresses yield of grain may be the conceivable motive for yield improvement. Significantly higher grain yields were recorded from fertilizers applied (Said *et al.*, 2014). Jadhav *et al.* (2004) a significant upsurge is also observed in yield of grain and straw of rice with nitrogen levels (Jadhav *et al*., 2004). Deep placement of urea and USG shows that field micro-plot experiment increases grain yield of rice which is related to the development in aboveground biomass, panicle, filling of grain and spikelet (Xiang *et al.*, 2013).

2.6.4 Effect of Compost on Rice Production

The decayed organic matter that in a course called compositing is compost. The various organic materials seen as waste products is recycled and produced a soil conditioner called compost. Compost has rich nutrients and is used as a fertilizer.

A sustainable method of management of waste is the conversion of waste of agricultural to the amendments of soil which is now gaining attention in the whole world and is accepted as a good management practice of soil for continuous production of crop (Adejumo *et al.,* 2016).

The general tactic for enhancing yield of crop per unit of capitals and maintaining them high must include a combined method to the soil nutrient management. A combined method identifies that soils are the reservoir of maximum nutrients crucial for the development and growth of plant, and that, nutrients managements have a key influence on the growth of plant, fertility of the soil and sustainability of agriculture. Increasing attention has concentrated on the use of organics as nutrients source for field crops in recent times (Palm *et al.,* 1997). The big test is to safeguard the effective nutrients use from the source of nutrients application. Harmonising release of nutrients from decaying organic materials which crops need, could lead to improved effectiveness in nutrient use (Mwale *et al.,* 2000) and this possibly will lessen the loss of nutrient (Myers *et al.,* 1994).

In rice farming, a good substitute to chemical fertilizers can be organic manures (Banik *et al.,* 2006). The standing of organic manure as humus source and nutrients for plant to enhance the fertility of the soil and the health of the soil of soils of the tropics has been recognized. The key attribute soil quality is soil organic matter (Friedel, 2000) and the health of the soil. Reddy *et al.* (2003) indicated that manure application infrequently physiologically impacts the growth of plant (Kawata and Soejima, 1976), offers substances that regulate growth and changes or improves soil biological, physical and chemical properties (Sudha and Chandini, 2003). In diverse types of soils, the significance organic component of the soil for exact properties of the soil or output of crop greatly varies (Delve *et al.*, 2000; Powlson and Olk, 2000).

Rate of decomposition and mineralization of different sources of nutrients is increased by the blend of inorganic fertilizers with organic sources (Mugendi *et al.*, 1999). To improve organic matter status, the usage of compost can be beneficial. The rich nutrients source with high amount of organic matter is compost. By using compost, soil physical properties and chemical properties can be improved, which may eventually increase yields of crop. A research done by Hussain *et al.* (2001) presented that, combining the amendments of chemicals with farm yard manure of 10 t ha^{-1}, significantly enhances porosity, void ratio, bulk density, hydraulic conductivity and the permeability of water, resulting in boosting yields of rice and wheat in soil with sodic in nature. These physical characteristics of soil of saline sodic can be improved by additional organic materials like chopped salt grass, straw of rice, straw of wheat and husk of rice. When compost is applied, it significantly upsurges the biomass, tillering, height of plant and yield of paddy (Hussain *et al.*, 1998).

The decay process changes possibly toxic or decayable organic material into a stabile product that is not toxic for development of soil and growth of plant. Fertilizer of compost has been used as mulch for the kept weed and improvement of fertility of the soil (Roe *et al.*, 1997).

Amendment of soil with compost look as if as it is made up of many round and irregular aggregates giving it an appearance of crumble in nature (Khan and Krishnakumar, 2018). The soil is helped by compost to recover from extreme conditions. Sandy soils drain quickly and it is reduced by adding more humus (Karlen and Stott, 1994). According to Khairi *et al.* (2015), the amount of chlorophyll in leaves is increased by compost, signifying an increase rate of photosynthesis and yield of rice.

A conclusion drawn by earlier studies indicates that throughout the season a standing depth of water is not required to increase yields of rice (Jahan *et al.*, 2004) and substitute irrigation does not have an opposing influence on rice development and growth (Li, 1999).

Deterioration in chemical, physical and biological properties of the soil is as a consequence of unceasing usage of inorganic fertilizers (Mahajan *et al*., 2008). Joined with rising prices, the adverse impacts of chemical fertilizers have resulted to increasing interests in the usage of organic fertilizers as nutrients source (Mahajan *et al*., 2008; Satyanarayana, 2002).

Through the alteration of soil chemical, physical and biological properties, compost helps in improving soil fertility (Haering and Evanylo, 2005). This in effect ensures high quality food crops production through better crop nutrient use effectiveness (Diels *et al.*, 2004). Quite a lot of research discoveries have publicized that improving nutrition of plant through organic modifications for continuous production of crop is an approach that is promising (Basha *et al.*, 2005). Arthanari *et al.* (2007) informed that reaction of rice to the supply of nutrient by fertilizer of organic and inorganic is widespread but differ with locations, soil and kinds of fertilizer. Likewise, crops respond otherwise to dissimilar composts under comparable condition of fertility of the soil. Also, Shu (2005) reported that compost obtained from hull of pea-rice and dung-tea of cattle varied in their composition of nitrogen and in their consequence on height of plant, tillers number, yield of dry matter and N, P, and K nutrient uptake of rice plants.

Application of compost enhances fertility of nutrient depleted soil (Chukwuka and Omotayo, 2008). Upland rice performance in response to application of compost hinge on constituents of nutrient of compost rather than compost types (Diacono and Montemurro, 2011). Cultivars of upland rice response to compost are also hinged on the readiness of nutrient (Doan *et al*., 2015). On highly nutrient depleted soil, onetime compost application will have many benefits to upland rice (Dada *et al.*, 2014).

Joined use of organic manures and fertilizers of inorganic has become very important for continuous cultivation and healthy soil maintenance. Organic manures do not only provide macro and micronutrients, but also improves soil chemical, biological and physical characteristics of reclaimed sodic soils (Mukesh *et al.*, 2012). Incorporation of organics such as farmyard manure, sulphitation press mud, green manuring and wheat remains in a mixture with fertilizers could uphold continuous rice yields as well as soil fertility in reclaimed sodic soils. Mukesh *et al.* (2012) showed that, green manure application, sulphitation press mud and green manuring increased the accessibility of the amount of Fe and Mn in the soil compared to the sole use of chemical fertilizers.

Source-separated organic domestic wastes compost and yard trimmings such as compost of bio waste is a valued organic fertilizer and soil conditioner which provides nutrients and humus (Vogtmann *et al.,* 1993). Landscaping and horticulture should not be the only used of compost, but also in farming in order to close nutrient cycles of nutrients. Management of compost of bio waste for beneficial use in farming must consider plans to meet nutrient requirements of crop and the environmental protection. On the average, bio waste compost comprises 11.5 g/kg total N (Vogtmann, *et al.*, 1993), yet the N exist mostly in the form of organic and therefore plants can not readily access it. This N can be mineralized, immobilized, denitrified and or leached.

Nitrogen mineralization of compost hinge on quite a lot of factors including the amount of compost N, compost C/N ratio, texture of soil and climate. In experiments carried out in the field, the factors nitrogen needs of crops and dynamics of absorption of nitrogen originate in addition.

The needs of potassium and phosphorus is chanced with a quantity of compost of about 20 t ha^{-1} farm manure. Since only part of the entire nitrogen contained in compost is mineralized in the first year, with long-term compost usage, the supply of N upsurges owing to the outstanding compost N, which in the following year, is mineralized separately. The rate and frequency of application of compost of bio waste should be selected such that it enhances yield of crop and lessen the leaching of NO_3–N but also, to avoid the compaction of soil through recurrent vehicle traffic for dispersal of compost. The reliable inorganic fertilizer uses with dearth skills of technical application among farmers who cultivate rice in less developed countries including Nigeria establishes disparity of nutrient of soil and pollution of the environment. To improve arable crop production, studies have concentrated on adding organic fertilizer as a substitute basis of outside input of fertility of soil (Liebman and Davis, 2000). The Use of animal and plant remains in the form of compost, as nutrients for plant and recycling of nutrient is a long-time agronomic practice. Activities as these improve continuous management of soil fertility for the teeming populace and lessening pollution of the environment. Varied researches across diverse ecosystems of agriculture have revealed importance sources of nutrient in the form of organic in improving yield of crop and soil quality improvement (Azza *et al.,* 2007; Fening *et al.,* 2011).

2.7 Optimizing Nutrient Use Efficiency

Particularly during the vegetative stage, nitrogen is highly needed by the crop (Qibtiyah *et al*., 2015). If the nitrogen is adequate for the crop, crop growth would proportionally upsurge. However, a smaller amount of nitrogen during the stage of growth may limit new cells formation and production, that will support the growth and affect crop development (Qibtiyah *et al*., 2015). In defining plant’s uptake of fertilizer and its delivery in the soil and plant, application time, Levels and nitrogen fertilizer sources play important role (Kichey *et al.,* 2007). For the production of submerged rice, nitrogen fertilizer applied is disposed to depletion in numerous ways, thus via volatilization soon after application of fertilizer. The end product of nitrification and denitrification process is nitrous oxide, the greenhouse gas (Naher *et al*., 2011).

2.8 Organic Materials

Biological, physical, and chemical characteristics of soils are broadly known to be improved by organic materials (Gregorich *et al.,* 2006). They include industrial and urban waste, crop remains, biomass of plant, compost, green manure, manure from farmyard, and waste of household and commercial products from animals or plant materials (Chan *et al.,* 2008).

In the early days of farming, adding substances to soil to enhance its capacity of nutrient was observed. Olden farmers distinguished that first yields from non-cultivated land were far improved than those of the following years (Altieri, 2000). For this, they move to virgin areas which once more presented similar pattern of yields reduction over time. In the end, it was revealed that spreading animal manure throughout the soil could improve plant growth on a plot of land (Altieri, 2000). Over time, fertilizer technology turns out to be far advanced. Novel substances that enhanced plant growth were exposed (Bloemberg and Lugtenberg, 2001). Ashes from burned weeds to soil were added by the Egyptians (Dowling, 2007).

Writings of ancient Greek and Roman designate that numerous excrements of animal were used, liable on the soil type or growth of plant (Hughes and Thirgood, 1982). It was also recognised that it was advantageous to plant leguminous crops on plots proceeding to wheat cultivation (Yanni *et al.,* 2001). Extra materials added comprise clay, waste of vegetable, sea-shells, waste from other assorted trash and from different manufacturing processes (Hughes and Thirgood, 1982). Prearranged investigation into technology of fertilizer commenced early of the seventeenth century. The first whole fertilizer of mineral which was a combination of saltpetre, potash, lime, nitrogen and phosphoric acid was developed by Glauber (Nene, 2012). The chemical requirements of plants were bare as days went by, consequential to better compositions of fertilizer. Sir John Lawes who drew a way for manufacturing a form of phosphate that was an active fertilizer, started the industry for producing chemical fertilizer (Dogor, 2013). After the First World War, the artificial fertilizer industry skilled momentous growth when facilities designed to produce explosives ammonia and synthetic nitrates were transformed to the manufacture of fertilizers of nitrogen-based (Johnson, 2016). The components of chemical that are absorbed by growing plants from the soil are substituted by Fertilizers. The soil growing potential were intended to improve and create an improved environment than the natural soil (Erisman *et al.*, 2008).

2.9 Climatic Factors

Upland rice is produced at the ecological bounds of the species and thus climate, predominantly rainfall, is a serious factor of its output (Li *et al.*, 2006). Upland rice is grownup in quite a lot of tropical zones. Rice is a water loving plant which typically needs yearly rainfall in surplus of 1500 mm. Maximum of the rice in the world is grownup under self-water supply and water is given as needed. The quantity may be in the area per hectare of 7 - 9 million litres (Tuong and Bouman, 2003).

The maximum variable and least foreseeable agro climatic element is rainfall (Tuong and Bouman, 2003). Its quantity and distribution regulate the cropping season of upland rice. Rice is very subtle to stress by water hence distribution of rainfall is more significant than periodic whole (Bouman *et al.*, 2007). Tuong and Bouman (2003) showed that even when more than 2000 mm annual rainfall was in the Philippines, water shortages reduced yields in experiments. The regimes of three rudimentary tropical rainfall disturb the culture of upland rice: even rainfall commonly throughout the year, a yearly peak of monomodal and bimodal (Wassmann *et al.*, 2009). Disparity of most seasonal and spatial rainfall is linked with inter tropical convergence zone (ITCZ) movement (Sachs *et al.*, 2009). The strength of the peaks of bimodal differs and the dry amount between the peaks controls the appropriateness of the pattern of cropping. To match the stages of critical growth to a pattern of bimodal, varieties of upland rice are frequently selected for period or sensitivity of photoperiod (Li *et al.*, 2006). Rainfall differences within the season of cropping is very significant to cultivation of upland rice and is key to genetic and agronomic technology develop for an area (Tuong and Bouman, 2003).

Cropping systems on upland rice, would have to be strategized around the sudden rainfall modification. Rainfall analysis probability is now used in upland rice investigate and planning in West Africa (Sakurai, 2006). Recent hard work to find favourable and adverse regions for the culture of upland rice are based on likelihood of periods of dry, which, concurring with the phase of reproduction is able to cause momentous losses of yield in Brazil (Heinemann *et al.*, 2008). According to Becker and Johnson (2001), drought is an unclear term commonly connecting to a time with lower normal rainfall in a certain location.

Daytime and seasonal disparities in temperature air are comparatively small in the belt of equatorial. The main temperature element is the elevation above sea level (Geerts, 2003). At higher latitudes, particularly when caused by changing regime of rainfall and radiation solar, variations of seasonal temperature are more different. Where elevation or latitude or both, cause temperatures of the night to fall below the limits, low temperature of air is very vital to upland rice (Sage, 2000). Low air temperature effects differ with the stage of growth of crop but a problem common in uplands is temperature as low as 14 - 18°C during start of panicle, development of pollen and meiosis. Cold tolerance development is a fundamental part of numerous breeding programs of upland rice in Asia (Wassmann *et al.,* 2009). Especially in combination with drought stress, upland rice also may suffer from high temperatures. According to a review by Prasad *et al*. (2008), effects of high temperature are specific for growth phase and the reproductive period is very sensitive before flowering. For both low and high temperature tolerance genotypic disparity occurs and may be imperative in breeding for conditions locally (Seck *et al.,* 2012).

A crop of tropical climate is rice. It is also however, successfully grown in humid to sub-humid areas under climate of subtropical and temperate. Almost all types of soils are used to produce rice with changing output (Timsina *et al.*, 2010). Rice is produced in any type of soil with high humidity with enough rainfall and irrigation facilities, under high temperature (Pantuwan *et al.,* 2002). Depending upon the climate and water readiness rice is grown in all seasons. Depending upon the variety, crop duration differs from 100 to 150 days.

2.10 Fertilizer Use in Rice Production

Kennedy *et al.* (2004) described fertilizers as substances added to soils to improve plant development and yield as well as improve soil fertility. They were further grouped into inorganic and organic but stated that organic fertilizers (manures) have comparatively low percentage of nutrients. The inorganic fertilizers nutrients are salts of inorganic gotten through chemical and physical processes of extraction (Sarkar *et al.,* 2005). Phosphorus, nitrogen and potassium are the three primary nutrients of plant (Kennedy *et al.,* 2004). Naturally, soils of Agriculture give very vital nutrients for the growth of plants. These nutrients however, might not be sufficient to kindle the growth plant and therefore, there is essential for added supply of nutrients for plant needs (Ibeawuchi *et al.*, 2007).

Fertilizers are to outfit the crop type that is cultivated and offers nutrients rapidly use by plants (Smil, 2000). They are easily accessible at most shops and quite suitable to use. Principally, constitutes of fertilizer potassium compounds, nitrogen and phosphorus but may also hold trace of elements that enhance plants growth (He *et al.,* 2005). Although throughout the world fertilizers of organic matter are still used currently chemical fertilizers are popularly known. Also, investigation is actualy led to decrease the damaging impacts on the environment of the use fertilizer and determining new, inexpensive fertilizers sources (Good *et al.,* 2004). Increase in output and levels of production per unit area are the primary result of fertilizer on cereal production is thereby reducing widespread farming/shifting cultivation (Smil, 2002). Mubiru *et al*. (2007, October) stated that, closely 8kg/ha increase in yield as an outcome of adding fertilizer of 1kg/ha. In consideration of this, farmers' economic earnings and the overall food accessibility is improved all over the world. Ghana and Africa at large are no longer seen at as places of land accessible where supply of crop for food could be increased by increase of the use of land owing to the rapid population growth (Duflo *et al.,* 2006). There is a necessity for technology adaptations such as the use of fertilizer and varieties of hybrid to make the most of the per unit area outputs of arable lands. However, the fertilizer use rate has been greater in Asia and Latin America than in Africa than (Ariga *et al.,* 2006). Size of farm, mechanization, accessibility of credit, coldness to extension service, potential of the ecology and presence of cash crops are the main issues that impact the adaptation of fertilizer in fields of maize (Mwabu *et al.,* 2006). Farmers would adopt the technology of the use of fertilizer based on learning of the farmer, profitability and detected changes among farms in vicinity of the farmers (Dogor, 2013).

2.10.1 Organic Fertilizers

A precise group of organic matters formed from decayed animal materials or plant, used as nutrients source for crops are organic fertilizers (Smil, 2000). Organic materials improve physical properties of the soil's leading to better aggregation, better structure, better drainage and water-holding capacity. These changes may however not do considerable to the soils of flooded rice in Asia where fields are typically flooded during land preparation by ploughing or rotovating and then tilling at soil saturation (puddling) which in the end terminates soil structure Koolen and Kuipers 2012). Specially formed Organic fertilizers are sold on the market in some countries. The rice soils physical properties in cases where soil is prepared without puddling as the direct dry seeding could possibly be improved by combined or surface-applied organic materials. The possible effects on physical properties of the soil will hinge on the practice of tillage and the decay the added rate of organic material (Yanni *et al.,* 2001).

The most likely advantage of organic constituents would be as important nutrients source on flooded soils (Eisenbies *et al.*, 2007). Improving the soil physical properties, slow-decomposing organic materials which have remained for a long time in the soil are more ideal. But those which have a higher amount of carbon-to-nitrogen or those with high components of recalcitrant like lignin' would be less desirable as sources of nutrient for crops (Eisenbies *et al.*, 2007). That which is most effective as source of nutrient for crops would have high vital nutrients concentrations and comparatively quick decay rates which can lead to an almost synchronized release of nutrients available for plant to concur with rice plants requirements (Eisenbies *et al.,* 2007).

In various phases of decay, organic matter of soil contains soil organisms, roots and plant residues. It has great effect on the soil fertility. Organic substance gives good structure of the soil, and allows the soil to take up water and to hold and aid in supply of nutrients. It also aids the existence of organisms in the soil. The organic matter of the soil holds some of the nutrients like N, P and S are held. Thus, the quantities of these nutrients will agree to the types of organic matter and quantities in soil. The soil colour and soil organisms' populations are affected by organic matter.

To preserve soil organic matter at good levels, organic inputs addition (animal manures and crop residues) is vital. Important nutrients source, which are mostly released at decomposition is organic inputs. Farmers ought to consider utilization of accessible organic resources before thinking of fertilizer application. It is also crucial to know the value of organic resources accessible as this has an influence on the nutrients existing for take up by the crop. Multiple nutrients are supplied by organic substances, and organic carbon that improve soil structure, soil pH, soil organic matter. Organic resources effects are exceedingly variable, as the wide varies of organic resources quality in the amount of nutrient and carbon. Smallholder farmers easily access organic resources in an inadequate quantity and are repeatedly not enough for the degree of crop production farmers required to crop enough food crops and excess for revenue. In addition to organic inputs, mineral fertilizers have to be applied. The importance of growing yields of crop and building soil fertility by merging the use of fertilizers with organic resources are highlighted by Integrated Soil Fertility Management (ISFM) highlights

2.10.2 Industrial Fertilizers

Material naturally or manufactured, that encompasses at least 5 percent of one or more of the three main nutrients (phosphorus, nitrogen and potassium), can be termed a fertilizer. Industrially man-made fertilizers are termed mineral fertilizers and have diverse colours and forms (granules or powder). Generally, Fertilizers are sold with a grade, or certain lowest amount of nutrient. The principal nutrients (N, P and K) are articulated as percent N-P_2O_5-K_2O (IFDC, 1980).

Fertilizers (organic and/or inorganic) are known to the rice farmers in providing dependable advantage from farming activity (Wijnhoud *et al.*, 2003). To ensure high grain yields, the readiness of nitrogen is vital in the production of rice. With the frequent escalation in the cost of chemical fertilizer and the introduction of high yielding rice varieties that need higher nitrogen levels, the resource poor farmers have struggle in accessing and utilizing the endorsed fertilizer application rate for production of rice.

Farming in a malls size entailing fertilizers sub-optimal use and other soil management practices leaves slight chance for farmers to pay for fertilizers to substitute nutrients detached from soils through reaped crops. Preceding to crop establishment, some mineral fertilizers and cow dung are frequently applied by Farmers. However, amounts applied are not up to nutrient requirements of upland rice in the area. Manyong *et al.* (2001) conveyed that in northern Nigeria, an average only 40 kg N/ha application is recorded. For production of upland rice, average nutrients applications are ranged 26.75–30.5 kg N, 1.64–3.28 kg P and 3.12–6.25 kg K/ha (Ezui *et al.*, 2008). Considering that 1 tonne of upland paddy rice production, these values are low. Koopmans (1990) also stated that rice desires to take up 15–40 kg N, 0.8–3.5 kg P and 14.3–40 kg K/ha which agree to the application of 51–133 kg N, 8–35 kg P and 48–133 kg K/ha for a recovery percentage of 30 % N, 10 % P and 30 % K applied. Regardless of soil type, these are also far under the widespread endorsement of 76 kg N, 13 kg P and 25 kg K/ha. Many explanations as well as, poor response under certain situations, the cost and accessibility of the fertilizers and farmers' absence of proper fertilizer-management skills may explain the lack of full-dose fertilization adoption (Olwande *et al.*, 2009). Paddy yields of low average of 0.7 t/ha on uplands are recorded (Ahmed *et al.*, 2009), equated to the national average of about 1.5 t/ha (Fashola *et al.*, 2006). There is a need to cultivate suitable fertilizer endorsements that are flexible to solve the farmers' varied situations.

2.11 Nutrients Requirement in Rice Production

Macro nutrients are nutrients wanted by plants in large quantities, usually more than 30 kg/ha. These are Sulphur (S), nitrogen (N), potassium (K), magnesium (Mg), phosphorus (P), calcium (Ca). Whether it is grown in a container or in the field, plants use inorganic minerals for nutrition. Inorganic minerals in soil are formed by multifaceted interactions involving breaking down of minerals of rock, decaying organic matter, microbes and animals. Roots take up mineral nutrients in an ion form in soil water. Several factors impact the absorption of nutrient by plants. Roots can access ions or the ions could be bonded to other elements or the soil (Jones and Jacobsen, 2003). A huge number of varied materials serve as bases of nutrients for plant. These are synthetic, recycled wastes, natural or a range of biological products counting microbial inoculums. Organic, mineral or biological nutrient the classes of nutrient sources (Roy *et al*., 2006).

Upland rice desires fertilization than lowland rice. West African soils are largely deficient in key nutrients in the order N > P > K (Wopereis *et al.*, 1999). Thus, fertilizing the rice crop is one of the fastest ways to upsurge productivity and cultivation in rice. Rice requires a heavy quantity of nutrient and it very sensitive to the volume and balance of nutrients in the soil. It is therefore essential to fertilize the crop using both organic and inorganic fertilizers (WARDA, 2002). However, sulphur (S), calcium (Ca) and magnesium (Mg) insufficiencies can also happen under circumstances of high break down of acid soil with low volume of organic matter (Smaling, *et al.*, 1997).

Whether it is grown in a container or in the field, plants need inorganic minerals for nutrition. Inorganic minerals in soil are formed by complex interactions involving the breakdown of minerals of rock, decaying organic matter, microbes and animals. Mineral nutrients are absorbed by roots in soil water as ions. The uptake of nutrient by plants is affected by numerous factors. Ions are either readily accessible by roots or could be bonded by other elements or soil (Jones and Jacobsen, 2001). Many materials can serve as sources of nutrients for the plant. These can be a range of biological products, natural, recycled wastes, and synthetic including microbial inoculums. “Nutrient sources are commonly classified as organic, mineral or biological (FAO, 2006). The most widespread limiting nutrients to production of food in Africa are phosphorous (P), nitrogen (N) and potassium (K) (Muthayya *et al.*, 2014) with nitrogen being the most central nutrient for rice production (Naher *et al.,* 2011). WARDA (1990) has already recognized P and N shortages as key limits to rice production in West African humid forest zone. However, magnesium (Mg) calcium (Ca) and sulphur (S) shortages can also happen under situations of high weathered acid soil with little volume of organic matter (Smaling, *et al*., 1997). Moreover, zinc (Zn) shortage and aluminum (Al) toxicity often related to manganese (Mn) toxicity are known in upland soils of West Africa (Mutsaer, *et al*., 1997).

Good nutrient content and balance in the soil is essential, especially for rice for appropriate crop production. Therefore, native soil fertility data particularly concerning N, P, K, Ca, Mg, S, Zn, Al and Mn soil renewal is vital for the production of rice in West Africa. Main soil mineral nutrient limitations need to be solved for sustainable upland rice production to be realized (Koné *et al*., 2009) as West African sub-region is noted to be little in inherent fertility and non-availability of some main nutrients (Buri and Wakatsuki, 1996). Big areas of numerous countries as well as Ghana, Togo, Benin and Nigeria are basically under a derived savannah and Guinea savannah (Windmeijer and Andriesse, 1993). The use of fertilizer may positively impact rice to cater for exhausted nutrients. For every tone of grain of harvested rice, it is valued that about 15–20 kg N, 2–3 kg P and 15–20 kg K is detached from the soil (Moro *et al.,* 2008). Owing to the high cost of rice import, these countries are developing strategies for local rice cultivation and required to be maintained with the needed skills and data (Koné *et al.*, 2009).

Fertilizers provide nutrients needed for growth, nutrition and health of the rice plant. Fertilizer scan be applied in organic or inorganic (mineral) states or both. Mineral fertilizers are manufactured. It is imperative that at the right time correct amount should be applied to get best yields and for environmental protection. Straight (single) fertilizers: These provide a single primary nutrient (e.g., N, P or K) to the crop. Compound fertilizers: These provide several nutrients (e.g., N, P and K) to the crop (Kumar *et al*., 2019).

In rain fed savanna uplands which are depleted, N is unquestionably the most vital nutrient for rice growth (Rashid-Noah, 1995). N is needed by the rice crop during its whole life cycle, especially, the starting of tillering and the starting of panicle stages (Olivier *et al.*, 2014). Dark green appearances are given by N to plant part as component of chlorophyll, fast growth promotion or upsurges height and tiller number, upsurges the number of spikelet (panicle) and influences filled spikelet percentage in panicle. Generally, N and P fertilizer application significantly influence rice grain yield.

It has also been established that P plays a central part in the physical growth of the plant though its effects are not seen as that of nitrogen (Oikeh and Horst 2001). Root development, tillering, pollination, period to maturity is stimulated by P and is also take part in the supply and energy transmission for all the processes of biochemicals in the rice plant. According to Holder (2011), preparation of land for planting frequently comprises some organic matter amalgamation, either from a preceding pasture of grass per legume, crop of green manure or from plants cut and transported to the field in paddy rice.

Habitually, K is a problem only in consecutive cropping seasons as revealed by some studies. It is thus likely that by giving yearly reduced quantity of K, the shortages of K in intensive lowland systems of production of rice can easily be overcome. A matter that merits more detailed investigation is the issue of fertilizer, which is not given adequate care (Sikuku *et al*., 2007).

Micro nutrients are plant nutrients that are required in small amounts usually 5 kg ha^{-1}. Special consideration and attention should be used because there is a thin boundary between too much or little in plants requirements, where too much will be damaging to the crop. Nickel (Ni), copper (Cu), manganese (Mn), Zinc (Zn), chlorine (Cl), iron (Fe), boron (B), and molybdenum (Mo) are the micro nutrients. It has been reported that occasional micro nutrient shortage is triggered sometimes by soil pH which is too high; therefore, a modification in soil pH may advance the readiness of micro nutrients. Moreover, the shortage of zinc (Zn) and the aluminium (Al) toxicity often related to the toxicity of manganese (Mn) are recognised in upland soils of West Africa (Mutsaer *et al*., 2017).

2.12 Types of Fertilizers Used in Rice Production

2.12.1 Straight fertilizers

Fertilizers which supply only single nutrient are straight fertilizers. Good instances are the urea and the ammonium nitrate that give only nitrogen. Only one primary nutrient like the N, P or K are supplied by straight or single nutrient fertilizers to the crop. Cost-effective for solving the shortage of a single macronutrient which is deemed as most non-available and can easily be mixed to meet the nutrient requirements of a specific field or crop is single fertilizers (Kumar *et al*., 2019).

2.12.2 Compound fertilizers

Compound fertilizers are blends of numerous nutrients in a single fertilizer. This method varies from a combination of a mixture of separate fertilizers to attain an average composition of nutrient. As it dissolves in the soil, each compound fertilizer particle brings nutrients mixture and evades the problem of any parting of particles during conveyance and application or handling. For farmers to choose the right source, certain nutrient proportions, that are generally accessible and endorsed for certain crops (Kumar *et al*., 2019).

2.13 Fertilizer Application Timing and Its Effects on Yield of Rice

Crop production and the maintenance of fertility of soil is increased by stable fertilizer application that is the primary prerequisite of sustainable agriculture. Environmental pollution is saved by an optimum dose of application of fertilizer and it safeguards farmer's returns. A resourced poor farmer is helped by practicing any fertilizer model with target yield. Minimum environmental pollution with higher crop productivity is guaranteed by efficient management of nutrient for bearable production of rice (Naher *et al*., 2011). Application of fertilizer should match with crop demand, with regards to growth stage, because of other agronomic practices that impact the fertilizer application efficiency, application time and method which are also crucially vital (Manzar-ul-alam *et al*., 2005). Nutrient loss from the system of soil-plant is reduced by right time of fertilizer application. Soil, climate, nutrient and rice variety is a determinant for time and methods of application of fertilizer (Naher *et al*., 2011). As fertilizer is expensive farm input and the efficiency of the use of fertilizer under soil of local area and climatic conditions are low, efficiency of maximum usage should be the mark for high economic earnings (Manzar-ul-alam *et al*., 2005).

An important management practice crop for improving efficient use of N for higher yield to be realized in crop production are application of optimal N rate and timing (Fageria and Baligar 2005). To add to that, improving the efficient use of N, can lessen production cost of crop together with pollution of the environment. Synchronization of the supply of nutrient with crop need is crucial in order to safeguard suitable quantity of absorption and use and best yield and quality and avoiding negative environmental impacts (Fageria, 2010).

Initiation of leaves and florets primordial is connected to adequate nitrogen supply to the crop plants throughout their early period of growth. At early growth stage, concentration of nitrogen in the leaf is associated with panicle per m2. At 1 to 4 weeks before heading, the spikelet number per panicle and the leaf blades' average nitrogen concentration is closely linked. Consequently, nitrogen application should not let the plant to suffer from its shortage at any phase of growth (Naher *et al*., 2011). Basal quantity may be prevented and ought to be applied after transplanting at 15-20 days if there is guarantee of water readiness for long duration variety (>150 days) (Naher *et al*., 2011). During the stage panicle initiation, nitrogen application need not integrate with soil for the reason that root mass at the aerobic zone of soil is adequate (Naher *et al*., 2011).

In environment of the Sahel, three splits apply nitrogen is endorsed for irrigated rice; thus 40% of the whole quantity two weeks after transplanting, 40% of the whole quantity at starting of panicle and the outstanding 20% at the phase of booting. Djaman *et al.* (2018) hypothesize that including hybrid rice, a fourth application of nitrogen at early flowering improve the filling of grain of cultivars of high yielding. Optimum application rate of nitrogen in diverse splits and timing significantly affects grain yield and components of yield (Djaman *et al*., 2018). Fageria (2010) stated that grain yield was significantly prejudiced by nitrogen treatments time. Over the world, scientists led many investigation on nitrogen fertilizer application time and found two choices: either application in three-splits or two-splits (Naher *et al*., 2011). One-third at the phase of final land preparation, mid-tillering phase and the rest at 5-7 days before panicle initiation (DBPI) is three-split nitrogen application includes (Dobermann and

Fairhaurst, 2000). Singh *et al.* (2002) showed that numerous recommendations of split of nitrogen fertilizer are conditions for varieties of high yielding, mostly application of nitrogen at the stage of flowering. However, according to many studies, P application at transplanting time is the practice that has been endorsed. Moreover, farmers do not pay much consideration on time of phosphorus fertilizers application causing low phosphorus use efficiency (Archana *et al*., 2016). With respect to time of application of P, application in split can also be successfully trailed in rice crop without any opposing effect on the rice grain yield that are grown in P accumulated soil (Archana *et al*., 2016).

Because P is a fixed nutrient in soil, its application should be at the final ploughing of the field. At tillering stage, P fertilizer application on rice field by top dressing may provide slight advantage in soils of high deficient (Naher *et al*., 2011). 50 percent of K should be basally applied and the rest at 5 – 7 days in light texture soils before the start of panicle along with second split of N application. At any stage up to panicle initiation, Sulfur may be top dressed (Naher *et al.*, 2011). In the morning, the application have a habit of having higher value than the late afternoon application (Qibtiyah *et al*., 2015). Fageria and Baligar (2005) reported that, in upland soils after irrigation, a substantial amount of N may be lost by denitrification and volatilization (Fageria and Baligar, 2005) Many results showed that, at diverse growth phases fertilizer treatment has a significant effect on plant development parameter. These parameter increased significantly with increased nitrogen fertilizer (Youseftabar *et al.,* 2012*).* Increase of yield of 6.13 and 5.39% is recorded owing to application of nitrogen in the dry and wet seasons, respectively. Principally at the application rate of nitrogen of 150 kg ha^{-1}, all varieties joint, increased of yield by 9.56% in the dry season and 7.63% in the wet season (Djaman *et al.,* 2018). In South America, Fageria (2010) applied a split N application with the total N applied being 300 mg kg^{-1}. Extreme dry weight of shoot of 13.91 g per plant was got in the treatment which had half N application at the start of tillering and at the start of panicle, and greater yield of grain of 12.65 g per plant was also gotten with the treatment of N timing of one third at sowing, active tillering and the initiation of panicle growth phase (Fageria, 2010). Half N applied at tillering initiation and outstanding at the starting of panicle growth phase was the second-best timing of N treatment in relation to yield of grain. Grain produced with this treatment was 12.32 g per plant. At sowing, the lowest treatment of grain yielding was the entire application of N. At this treatment, the yield of grain was 3.87 g per plant. At this treatment when the total N was applied at sowing, the least yield of grain may be related to losses of N owing to denitrification and volatilization. When application of N is applied in split fractions, the time for denitrification or volatilization losses is less. At the beginning of the growth of plant or seedling, the root system is not developed well and plants cannot take up the whole applied N at sowing and the dry weight of shoot also affect treatments time of N significantly (Chaturvedi, 2006).

Dry weight of shoot also significantly influenced by N timing treatments in Chaturvedi (2006) split N application. Maximum dry weight of shoot of 13.91 g per plant was gotten in the treatment which established half N at the start of tillering and the start of panicle. The second treatment which gave maximum dry weight of shoot of 12.71 g per plant was one third at sowing, active tillering and start of panicle growth phase. The minimum dry weight of shoot of 4.69 g per plant is given in the treatment which established entire N at sowing. Dry weight of shoot has a significant positive quadratic association with the yield of grain. Hence, about 92% inconsistency in grain yield was as a result of dry weight of shoot (Chaturvedi, 2006). Increase in the weight of shoot is vital for it is highly related with grain yield (Fageria, 2007). Fageria (2007) testified significant positive relation of dry weight of shoot with yield of rice grain.

2.13.1 Split application of fertilizers

The way of corresponding nitrogen supply for a pre-established yield target and a specified level of soil moisture, and then providing the rest of nitrogen as moisture environments is split application. Because nitrogen is very liable to being lost from soils, it needs careful management. By way of denitrification, leaching, surface volatilization and erosion, Nitrogen can be lost from the soil. Unlike the fine texture soils, it is readily leached in sandy soils. Nitrogen loss can be accounted for about 50 – 60 % of the applied quantity if not correctly applied. A large amount of the nitrogen may be lost before the crop absorbs it, if it is applied very early, and before the needs of the plant. Hence, there should be minimization of soil nitrogen at the time before the plant absorbs it. The way to realise that, is nitrogen application in a split form. The risk of loss of nitrogen and improvement of the effectiveness of the application can be reduced by splitting the nitrogen application (Alva *et al.*, 2006).

Although data on nitrogen needs of rain fed upland rice is present (Oikeh *et al.*, 2008a), its efficiency in the timing of application cannot be overemphasized. Fageria (2007) acknowledged that amid the necessary plant nutrients, among the utmost yields limiting nutrient for upland rice cultivation is nitrogen (N). Soil acidity, low amount of organic matter in rice growing soils, erosion of soil, use of low amount of N fertilizers by farmers owing to the fact that these fertilizers are expensive is associated with low level of N in upland rice. Low level of Nitrogen is connected to the fact that N use efficiency by the crop is low owing to losses through leaching, volatilization, erosion and denitrification (Fageria and Baligar, 2005). Hence, a vital complementary tactic in improving yield of rice and dropping cost of production is the use of N efficient genotypes blended with chemical fertilizers. N uptake and utilization efficiency of upland rice cultivars vary significantly (Fageria *et al.*, 1995; Fageria, 2007). Fageria (2009) also settled that, average yield of upland rice can considerably be improved by planting N efficient cultivars along with better crop management practices. One of the improved practices of crop management is to ensure timely application of the chemical fertilizer for its efficient use. It is a known fact in rice that, life cycle gets to an end after going through the following ten stages namely, seed germination, seedling, tillering, elongation of internode, initiation of panicle, panicle development, heading and flowering, milky stage, dough stage and maturity (Wopereis *et al.*, 2009). These ten stages are grouped into three stages, vegetative (germination to panicle initiation), reproductive (panicle initiation to flowering) and maturity (flowering to complete maturity).

Particularly in low-income countries where fertilizer is rather very expensive and increasing, increasing fertilizer use efficiency is very vital (Tsedalu *et al.*, 2015). Greatest care had better be considered in making choice of the type of fertilizer, time and mode of application. For various rice production systems, diverse nitrogen fertilizer application time recommendations are given. Use of the applied urea fertilizer by the crop at initial tillering phase is very low in North Western Amhara region (Tsedalu *et al.*, 2015). Therefore, it is required to apply fertilizers when the crop is vigorous to absorb the applied fertilizer to increase the crop yield and nitrogen use efficiency.

Two split applications, is splitting the fertilizers such as N into two portions and applying to crops twice. Three split applications is splitting fertilizers into three portions and applying three times to crops. When N application is split and a portion is put on later, nearly entire of the second application will be absorbed by the plant. Plants roots are well established by then, thereby well able to contact the N which by then, the plant nitrogen need is growing therefore absorption turns out to be much more effective.

2.13.2 Three Split Application of N

Maximum panicle can be produced by third treatment, thus 1/3 N applied each at sowing, at tillering, at the initiation of panicle growth stage, trailed by fourth treatment (half N applied each, at start of tillering, at the start of panicle growth stage). The second treatment (at sowing, the whole N is applied) yields lowest panicles number. Higher panicles number in the third treatment and forth treatments reflect in higher yield of grain in these two treatments. Significantly and linearly, grain yield is improved with panicle number (Fageria, 2010).

2.13.3 Four Split Application of N

Higher yield was also obtained from a four split (40, 30, 20, 10%) application of fertilizer thus after two weeks of transplanting, at the start of panicle, booting, and grain filling stages, respectively (about 10 days after flowering) as compared to the split of the Nitrogen fertilizer rate into three (40, 40, 20%) applications thus two weeks after transplanting, at the start of panicle and the booting stage, respectively, with a constant dosage of phosphorus and potassium applied at 26 and 50 kg ha^{-1} respectively (Djaman *et al*., 2018). According to Blumenthal *et al*. (2008), 6% upsurge in yield of rice and 25% upsurge in protein of grain was reported owing to dressing of nitrogen at the period of flowering (Blumenthal, *et al*., 2008). Wei *et al*. (2018) designated that at heading phase nitrogen application enhanced the filling rate of grain filling and time, number of filled grains as equated to application of nitrogen at tillering (Wei, *et al*., 2018). In respect to the components of yield, there are no significant variations in the split of 3 and 4 of nitrogen. However, the 4 splits can be slightly greater in values of N treatment (Djaman *et al.*, 2018). Also with regards to panicle weight, the filled of 4 split N treatment is higher and averaged 2.5 g contrary to the 3 and 4 splits N treatment which is 2.6 g (Djaman *et al.*, 2018). It is concluded that split application of N gives maximum yield of grain of upland rice based on the outcomes of this study (Fageria, 2010).

Yields of crops is a significantly affected by fertilizer application time. Reduction in nutrient losses, increased yields, upsurges nutrient use efficiency and preventions of environmental damage can be achieved by correct fertilizer application time (Tilman *et al*., 2002). Wrong time for applying fertilizers might cause damage to the crop, losses of nutrient, and fertilizer wastage.

Timing and regularity of the application of fertilizer is affected by soil type. Soil texture and Cation Exchange Capacity (CEC) are the two main soil properties which oversee the timing and frequency of application (Adamchuk *et al*., 2004). The manner of nutrient absorption of crops is based on optimum timing for fertilizer application. For the same, each nutrient has a distinct absorption pattern.

2.13.4 Basal Application of Fertilizers

Basal application is a process of applying fertilizers at planting or sowing. The main objective of basal application is to homogeneously dispense the fertilizer on the whole field and to blend it with the soil.

The general recommendation of fertilizer for rice is to apply 60–80 kg N, 30 kg P_2O_5/ha and 30 kg K_2O ha^{-1} (Moro *et al*., 2008). Efficiency in the management of nutrient translate to the supply of the recommended application rate of 30 kg P_2O_5 ha^{-1} and 30 kg K_2O ha^{-1} (basal) from NPK 15-15-15 fertilizer, which will also supply N equivalent of 30 kg ha^{-1} as basal N (Somado *et al.*, 2008). Hence, to achieve the endorsed rate of N of 60–80 kg ha^{-1}, a further 30–50 kg N ha^{-1} is required as a top dress by the end of the vegetative stage of the rice plant.

Applying more than 30–35kg N ha^{-1} (1½ bags of urea) in a sole dose (split) to lessen losses is not recommended. It is unsuitable to apply Sulphate of Ammonia in areas with high soil acidity especially areas where urea is unavailable (Oikeh *et al*., 2008a). According to Lynch *et al*. (2001), there is very minimal phosphorus movement in the soils. So, roots can take up phosphorus only from their very close environs. Phosphorus is in its soluble accessible form when first added to soil. But rapidly becomes inaccessible for plants in a term called “Fixation” (Weyens *et al.*, 2009). Key losses are through surface runoff and soil erosion since phosphorus applied remains at the topmost soil layer. Both yield and nutrient usage efficiency can be reduced by proper placement and time of fertilizer application, thereby growing net income for the farmer.

2.13.5 Basal and Split Application of Fertilizers

Okonje *et al*. (2012) obtained low yields of upland NERICA in soils of the moist Savanna of West Africa which were low in P and N. Though N fertilization is a key factor of yield, a basic P and potash dressing may be needed (Dobermann and Fairhurst, 2000). At transplanting half of nitrogen may be applied with the rest at the start of ear, and may be the application will be 150 – 250 kg N ha^{-1} (Ma *et al.*, 2007). WARDA (2001) recommended 60 – 60 – 30 N, P_2O_5, and K_2O for Ghana in two splits at 3 weeks after planting (WAP) and 6 WAP depending on the available soil nutrients, the rice variety and rainfall. The recommended fertilizer rates for northern Ghana rice is 60 – 60 – 30 kg N, P_2O_5, and K_2O (Dogbe *et al.*, 2013).

2.13.6 Top Dressing

Top dressing is fertilizers application principally nitrogenous fertilizers in closely sown crops like paddy and wheat, with the aim of providing nitrogen in a freely accessible form to growing plants or the spreading of fertilizers in standing crops without considering the crop row (Dhok, 2020). Crucial for enhancing both yield and quantity is timing fertilization with peak nutrient uptake demand. From early to middle of growing season, nutrient uptake rates are generally recorded highest, which is why it is generally very effective to practice fertilization near the time of seeding (Jones *et al.*, 2011). Near the soil surface, P would probably be bound and not migrate to the actively growing root system accounting for topdressing of P is not anticipated to affect crop yield (Jones and Jacobsen, 2003). Mid- and late- season application of N can affect yield of grain and quality for much of the plant N is transported to the grain for the synthesis of protein (Jones *et al*., 2011).

The chief practice of agronomy that affects rice crop yield and quality is nitrogen fertilizer application and correct time of its application, which needs at early and mid-tillering phases to make the greatest number of panicles and during reproductive phases to produce a greater number of spikelets per panicle and percentage filled spikelet (Lampayan *et al.*, 2010). Anil *et al.* (2014) found out that, interaction consequence of the levels of nitrogen and time of application on tiller number per m^2 and plant height of rice at various phases was statistically significant.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Site Description

3.1.1 Location

The study was conducted on the research field of the Savanna Agricultural Research Institute (SARI) at Nyankpala from June to December during the 2015 cropping season. Nyankpala, which is in the Tolon District is 16 km away from Tamale in the Northern Region of Ghana. It is also on altitude 183 m above sea level within latitude 09’ 25’N and longitude 0’ 58’W.

3.1.2 Climate

The experimental site experiences a unimodal rainfall pattern with a mean annual rainfall of 1100 mm, (SARI, 2012) that is consistently spread from June to October with the highest in August and September. The short rainy season is followed by long spell of dry season which is between October and April (Kugbe *et al.*, 2012). The climate is tropical, warm and semi-arid with the vegetation cover mainly grasses with few scattered trees.

3.2 Treatments and Experimental Design

In a randomized complete block design (RCBD) with three replications, a 2 x 3 x 3 factorial experiment was laid out. The experiment consisted of 18 treatments comprising of two rice varieties (NERICA 4 and NERICA 14), three fertilizer application timings (1WAP + 5WAP, 3WAP + 6WAP, 2WAP +7WAP) and three compost levels (0 t ha^{-1}, 1.5 t ha^{-1} and 3 t ha^{-1}). A block made up of a replicate and each had 18 plots. Individual plots were separated by 1 m alley and 1.5 m alley was used to separate blocks. A size of plot of 4 m x 5 m and experimental land area of 1530 m^2 (17 x 90 m) was used. Seeds of the two rice varieties were dibbled at 20 cm x 20 cm on 31st July 2015. A basal application of 30 kg K ha^{-1} and 60 kg P ha^{-1} in the form of K_2O and P_2O_5 respectively was used. Treatment application commenced for the various application dates as 7th, 14th and 21st August, 2015 (that is, at the tested application dates for the various treatments). Nitrogen was split-applied twice at 30 kg N ha^{-1}. Top dressing was done at 4th, 11th and 18th of September for the fertilizer application timing treatments.

3.3 Land Preparation

At a depth of 20 cm, the experimental field was ploughed and the harrowed done after two weeks. The experimental area was demarcated into experimental plots of 5 m × 4 m. The blocks were laid across the slope to check erosion and minimize variation due to fertility gradient that exists in the soil.

3.4 Planting

Germination test was done at the Rice Improvement Laboratory of the Savanna Agricultural Research Institute (SARI) to ascertain the viability of the NERICA seeds. A percentage of 85 viability was ascertained among NERICA seeds for planting. Planting was done on the 31st of July using a 20 cm graduated garden line with an inter row planting distance of 20 cm.

3.5 Fertilization

Urea (46 %), Triple Super Phosphate (46 %) and NPK (15-15-15) at a rate of 60-60-30 NPK kg ha^{-1} were the fertilizers used. All P_2O_5 and K_2O plus half of the N were applied as basal dressing and the rest of N top dressed at 1+5 WAP, 2+7 WAP and 3+6 WAP. The P was topped up by 30 kg ha^{-1} P_2O_5 using the TSP fertilizer.

3.6 Data Collection

3.6.1 Gravimetric Soil Moisture Content

Soils were sampled at the field of experiment at a depth of 0-15 cm by means of an auger. The fresh soils were weighed and oven dried at a temperature of 105 ^{o}C for 48 hours at 2 weeks intervals. Gravimetric soil moisture content was then calculated using;

$$\text{Gravimetric soil moisture \%} = \frac{\text{Wet weight} - \text{Dry weight}}{\text{Dry weight}} \times 100 \quad \text{....Equation 1}$$

3.6.2 Plant Stand

Plant stand per plot was taken at 3 WAP by counting only the emerged hills. The percentage plant stand is thus calculated as:

$$\text{\% Plant Stand} = \frac{\text{emerged hills counted}}{\text{supposed total hills}} \times 100 \quad \text{........Equation 2}$$

3.6.3 Tiller Number

At maximum tillering stage (50 DAP), tiller count was taken per m^2 with a quadrat. The quadrat was placed twice on each plot and at each throw; the tillers were counted and recorded. The mean tiller count was then calculated.

3.6.4 Chlorophyll Content

Ten randomly sampled mature leaves were tagged per plot. Five SPAD (Soil-Plant Analysis Development) measurements were taken per leave and the average recorded for each plot (Hiscox and Israelstam, 1979).

3.6.5 Leaf Area Index

Per each plot, five plants were used in determining the leaf area index (LAI). The first, middle and last leaf were measured to ascertain the average length and width (Watson 1952).

Calculation:

$$\text{LAI} = \frac{\text{LxWxNx0.72}}{\text{A}} \quad \text{.....................................Equation 3}$$

L = length of leaves, W = width of leaves, N = number of leaves per plant,

0.72 = constant for the determination of leave area index for rice

A = area covered per plant.

3.6.6 Days to 50 % Flowering

During the reproductive stage of the NERICA 4 and 14 varieties, the days to 50 % flowering of the treatment plots were taken by visually observing the emergence of the flowers of half of the plant population in the plot.

3.6.7 Days to Maturity

This was measured during grain ripening stage, where the days from seedling to the time where 85 % of the grains on the panicles of plant population were matured of the treatment plots for NERICA 4 and 14.

3.6.8 Panicle Count

Panicle count was taken with a 1 m^2 quadrant at maturity. Twice on each plot, the quadrant was placed and panicle number counted and recorded. The mean panicle was counted and calculated for each treatment.

3.6.9 Plant Height

Five plants in a plot were randomly selected and tagged and their heights measured at maturity, just before harvest. Plant height was taken by measuring the length from the ground level to the tip of the tallest panicle. The mean plant height was then calculated for each treatment.

3.6.10 Straw Weight

The straw of the harvested panicles in the net plot were weighed and recorded for each plot.

3.6.11 Grain Moisture Content

Grains sampled from the various plots were placed on an electronic moisture meter. Readings on the electronic moisture meter were taken and recorded.

3.6.12 Grain Weight

The net plot yield of the rice was weighed using an electronic scale. The weights in kg/plot were noted and adjusted to kg/ha at 14 % moisture content by using this formula:

Grain weight = $\frac{100-A}{86} \times W \times 744.05\ kg/ha$ ....Equation 4

A= % moisture content of grain at the time of weighing

W= weight of grain (kg/plot),

Net plot = 4.2 x 3.2 (13.44 m^2)

Net plot adjuster = 744.05

3.6.13 Thousand Grain Weight

Thousand grains of paddy rice were totalled from the grain yield of the net plot. This was then weighed with a small automatic electronic balance and the weight was noted.

3.7 Analysis of Soil and Compost Nutrient Composition

Before planting, samples of the soil and compost were picked for physical and chemical analysis in the laboratory by standard methods (Weil *et al.,* 2003). Randomly, samples of soil were taken from each of the plots within the depth of 0 – 20 cm. To remove plant root and other debris, the composite sample of soil was air dried and ground to pass through a 2 mm and 0.5 mm sieve. To determine the nutrient level prior to application of compost, a sample weight of 2 kg was weighed and taken to the laboratory for routine analysis. Illustrative samples were analysed for soil texture (% sand, silt and clay), pH, overall nitrogen, accessible phosphorus, organic matter content and exchangeable cations (potassium, calcium, sodium and magnesium).

3.7.1 Nitrogen

The soil sample was analysed for Nitrogen using the wet Kjeldahl method (Bremner and Mulvay, 1982). A sample weight of 2 g was put into digestion tubes and digested with Kjeldahl digestion mixture from dark brown colour till it changed to colourless solution at 360 ^{o}C. With distilled water, the sample was then topped up to 100 ml mark. Through the vapodest into a conical flask containing pink boric acid, an aliquot was distilled. The colour turned green as the boric acid received the nitrogen. From the green colour, it was then titrated with 0.1 M HCl to obtain a pinkish colour (Bremner and Mulvany, 1982). Total was calculated using this formula: Total N in the sample $=\frac{14(A-B)xNx100}{1000xW}$

……Equation 5

Where, A= volume of standard acid used in titration

B= volume of standard acid used in blank titration

N= normality of the standard acid

W= weight of soil samples used

3.7.2 Phosphorus

About 5 g of each of the samples was measured (weighed) into an extraction bottle and 50 ml of Bray 1 solution (0.03M NH_4F + 0.025M HCl) was included. The suspension was placed on a mechanical shaker at 180 strokes per minute for 5 minutes and then allowed to settle. Using N0. 42 Whatman filter paper, the supernatant was filtered into 100 ml volumetric flask and to make up to the volume, distilled water was added. Phosphorus in the filtrate was determined by Molybdate blue-ascorbic acid colour development method (Bray and Kutz, 1945).

Two reagents (A and B) were used to develop the colour. Dissolving 12 g of ammonium molybdate in 250 ml of distilled water, reagent A was prepared and 0.2908 g of antimony potassium tartrate was also dissolved in 100 ml of distilled water. The two dissolved solutions were added to 1000 mL of 2.5 M H_2SO_4 mixed thoroughly and made to the mark in a 2 L volumetric flask. By dissolving 1.056 g of ascorbic acid in 200 ml of reagent A and mixing thoroughly, reagent B was prepared. 5 ml aliquot of the filtrate was pipetted in duplicate into a 50 mL volumetric flask and the pH was attuned by adding few drops of P-nitrophenol indicator and few drops of ammonium hydroxide (4M NH_4OH) pending the colour of the solution turned to yellow. 8 mL of reagent B was added to the solution and then distilled water was used to make up to the mark. A blank was prepared using 8 ml of reagent B and 5 ml of distilled water. The spectrophotometer (Spectroquant ® Pharo 300 M) was calibrated using 5, 10, 15, 20, 25 and 30 mg/l standard P solutions. Phosphorus in the solution was known by reading the resultant colour intensity on the spectrophotometer, at a wavelength of 712 nm. The percentage of accessible concentrated phosphorus in the samples was determined using the formula below.

$$\text{P in sample (\%)} = \frac{(spectrophotometer\ reading\ (mg\ L{-}1)\ x\ volume\ of\ extract\ x\ 100)}{Weight\ of\ sample\ x\ volume\ of\ aliquot\ x106}$$

……….. Equation 6

3.7.3 Potassium

Air-dried soil samples were passed through 2 mm mesh. 10 g of the sample was measured (weighed) into 200 mL extraction bottles and at pH 7.0, 100 mL of 1N ammonium acetate (NH_4Oac) solution buffered was added. The bottles with the content were covered and on a mechanical shaker, shaken for one hour at 180 strokes per minutes. The suspension was allowed to settle after which it was decanted and sieved through No. 42 Whatman filter paper. 5 ml of filtrate was pipetted into 50 ml volumetric flask and deionized water was used to make up to volume. Potassium (K) concentration in the diluted extracts was determined by the flame photometer as described by Chapman (1983). To give a 100 full scale deflection at 10 mg/kg of potassium the flame photometer was standardized. The result was used to calculate the quantity of potassium contained in the samples as revealed in the formula below.

$$K\ (cmol_c kg^{-1}) = \frac{(R\ x\ Vol. of\ extract\ 103\ (g) x\ 102\ (cmol)\ x\ E)}{(Weight\ of\ soil\ x\ 106\ (\mu g)\ x\ 39.1)} \text{ .... Equation 7}$$

Where: R is the flame photometer reading (ppm), E = charge of K and 39.1 = atomic weight of K

3.7.4 Organic Carbon

Air-dried ground soil samples were sieved through 0.5 mm mesh. The quantity of organic carbon of the samples was calculated as described by Walkley and Black (1934). 1 g of each sample was measured using the weighing scale into 250 ml Erlenmeyer flask. 10 ml of 0.17 M potassium dichromate ($K_2Cr_2O_7$) solution and concentrated sulphuric acid (H_2SO_4) of 20 ml were included in the sample in the flask. The flask was then whirled to ensure the solution is in contact with all the sample particles and then allowed to stand on asbestos sheet for 30 minutes. Distilled water of 200 ml, 10 ml of orthophosphoric acid (H_3PO_4) and 2 ml of indicator of barium diphenylamine sulphonate were included in the solution in the flask. After the oxidation of the oxidizable organic material in the sample the unreduced $K_2Cr_2O_7$ residual in solution was titrated with 0.2 M ferrous ammonium sulphate solution till it changed to bright green colour end point. The percentage of organic carbon was calculated as:

$$\%\ OC\ in\ sample\ = \frac{[0.3\ x\ (10 - XN)] \times 1.33}{weight\ of\ sample} \text{ ....Equation 8}$$

Where: X is titre value of the ferrous ammonium Sulphate, molarity of the ferrous ammonium sulphate is N (0.2 M).

Calculation of the percentage of organic matter in the samples was done by multiplying the percentage of organic carbon value by a factor of 1.724.

3.7.6 Soil pH

Determination of soil sample was for pH was done in a 1:1 (soil: water suspension) before and after the experiment with Eijkelkamp 18.21 multi-parameter analyzer (Germany). 20 g of the samples were measured into a 50 ml beaker and a soil-liquid solution was formed by addition of 20 ml of distilled water. The suspension was stirred strongly with a glass rod for 30 minutes and the suspended soil particles allowed settling down for 30 minutes. Calibration of the pH meter was done and standard buffer solutions of pH 7 and pH 4. The electrode was placed into the supernatant of the soil solution and the corresponding pH value for the treatment recorded.

3.8 Data Analysis

Yield and other agronomic parameters were analysed by the use of analysis of variance (ANOVA) general treatment structure model using GenStat Release 12.1 (PC/Windows Vista) statistical package (12^{th} Edition) and treatment means compared using Fisher Least Significance Difference (LSD) at 5 % probability level.

CHAPTER FOUR

4.0 RESULTS

4.1 Gravimetric Moisture Content

The interaction effects of compost application by time of fertilizer application by variety; compost by variety and variety by fertilizer, significantly ($P > 0.05$) did not influence percentage moisture content of soil (Table 1). Additionally, the core consequences of time of application of fertilizer ($P = 0.878$) and variety ($P = 0.990$) did not significantly affect percentage gravimetric moisture content. However, there was a significant effect by the application of compost ($P = 0.027$) on gravimetric moisture content (Table 1).

The highest moisture content was recorded when 3 t ha^{-1} compost was applied which statistically was similar to 1.5 t ha^{-1} compost application. Equally, there was no statistical difference between application of 1.5t ha^{-1} gravimetric moisture content and the control (Table 1).

Table 1: Effect of compost, time of NPK fertilizer application and variety of rice on gravimetric soil moisture at planting (BEG), maximum tillering (MID) and harvest (HAV)

Treatment	BEG	MID	HAV
Compost (t ha^{-1})			
0	14.72	11.77	16.63
1.5	15.61	13.48	16.52
3	14.39	15.96	17.97
LSD (0.05)	2.308	3.015	3.079
Time of application (WAP)			
1 and 5	14.56	14.20	16.17
2 and 7	14.89	12.99	16.52
3 and 6	15.28	14.03	18.14
LSD (0.05)	2.308	3.015	3.079
Variety (V)			
NERICA 14	15.19	13.75	17.50
NERICA 4	14.63	13.73	16.38
LSD (0.05)	1.884	2.462	2.514

4.2 Soil pH

The interaction effects of compost application rate by time of NPK fertilizer application by variety, compost by variety, variety by fertilizer, compost by fertilizer, did not significantly ($P > 0.05$) influence soil pH. The main consequences of compost application rate ($P = 0.81$), fertilizer application ($P = 0.973$) and variety ($P = 0.848$) on soil pH after harvest were not significantly different. The pH ranged from 5.71 to 5.76 (Table 2).

4.3 Soil Organic Carbon

The interaction effects of compost application by time of fertilizer application by varieties was not significant (P=0.591), Also the interaction of variety by compost, variety by fertilizer, compost by fertilizer on soil organic carbon after harvest were not significant. The key consequence of compost application (P = 0.126), time of fertilizer application (P = 0.588) and variety (P = 0.157) did not also significantly influence soil organic carbon after harvest. Soil organic carbon ranged from 1.32 % to 1.44 % (Table 2).

Table 2: Effect of compost, time of NPK fertilizer application and variety of rice on soil pH and organic carbon

Treatment	Soil pH	% Soil organic carbon
Initial value	5.76	1.37
Compost (t ha^{-1})		
0	5.74	1.32
1.5	5.72	1.40
3	5.71	1.44
LSD (0.05)	0.12	0.13
Time of application (WAP)		
1 and 5	5.75	1.38
2 and 7	5.74	1.37
3 and 6	5.75	1.40
LSD (0.05)	0.12	0.14
Variety (V)		
NERICA 14	5.75	1.43
NERICA 4	5.74	1.36
LSD (0.05)	0.10	0.11

4.4 Total Nitrogen

Overall nitrogen concentration in the soil after harvest was not significantly ($P > 0.05$) affected by both the main and interaction effects of compost application, time of fertilizer application and varieties. Total N ranged from 0.085 to 0.088 (Table 3).

4.5 Available Phosphorus

The interactive effects of compost application by time of fertilizer application by variety; time of fertilizer application by variety and compost application by variety also had insignificant ($P > 0.05$) influence on available phosphorus. However compost application by time of fertilizer application significantly ($P < 0.05$) influenced available phosphorus. The core effects of time of fertilizer application and variety did not significantly ($P > 0.05$) influence soil available phosphorus after harvest, except compost application which significantly ($P < 0.001$) influenced available phosphorus (Appendix 6).

The application of 3 t ha^{-1}compost gave the highest phosphorus level (27.84) but there was no statistical difference between 1.5 t ha^{-1} compost applied (12.45) and the zero (12.04) Figure 2. The interaction effect of 3 t ha^{-1} compost application and 3+6WAP fertilizer application timing enhanced the highest level of available phosphorus (39.66) however 2+7WAP fertilizer timing produced a similar level of phosphorus (39.27) Figure 3.

4.6 Available Potassium

There were insignificant ($P > 0.05$) interaction effects of compost application by time of fertilizer application by variety, variety by compost, compost by fertilizer on available potassium after harvest. The core effects of compost application, time of fertilizer application, variety did not significantly ($P > 0.05$) influence available potassium after harvest (Appendix 5). Available K ranged from 57.16 to 58.01 (Table 3).

Table 3: Effect of compost, time of fertilizer application and variety of rice on total nitrogen (N) and available potassium (K)

Treatment	Total N	Available K
Initial value	0.086	57.16
Compost (t ha^{-1})		
0	0.085	57.20
1.5	0.086	57.60
3	0.088	58.01
LSD (0.05)	0.007	1.79
Time of application (T)		
1 and 5	0.085	57.22
2 and 7	0.086	57.31
3 and 6	0.085	57.28
LSD (0.05)	0.007	1.78
Variety (V)		
NERICA 14	0.085	57.17
NERICA 4	0.086	57.20
LSD (0.05)	0.006	1.45

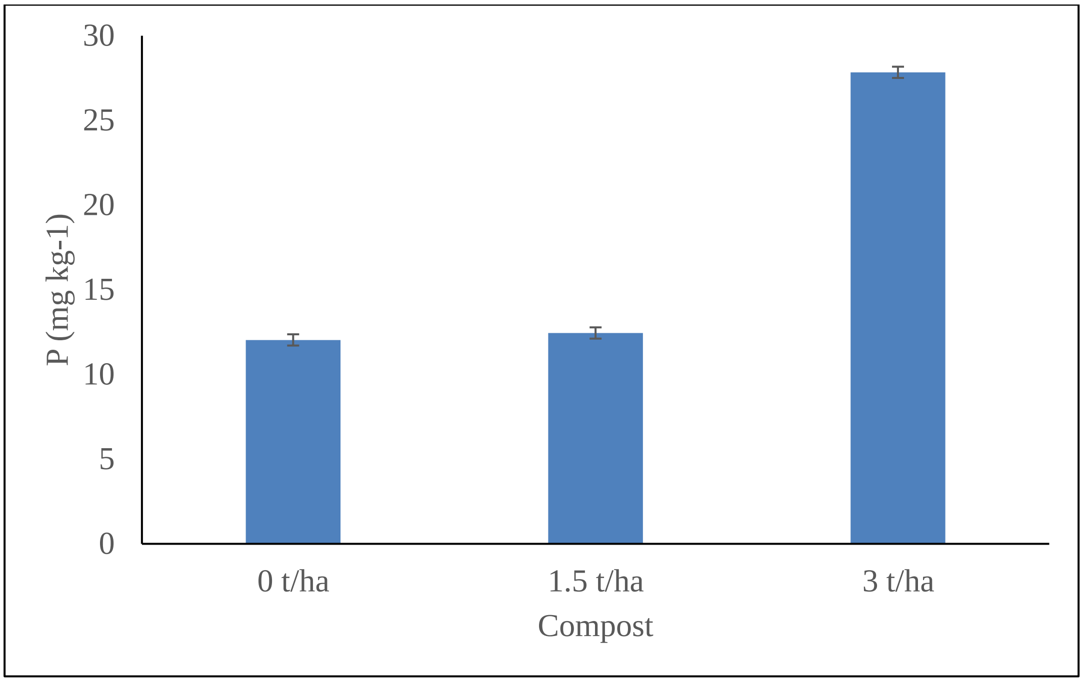

Figure 1: Effect of compost application on available phosphorus. Error bars represent SEM.

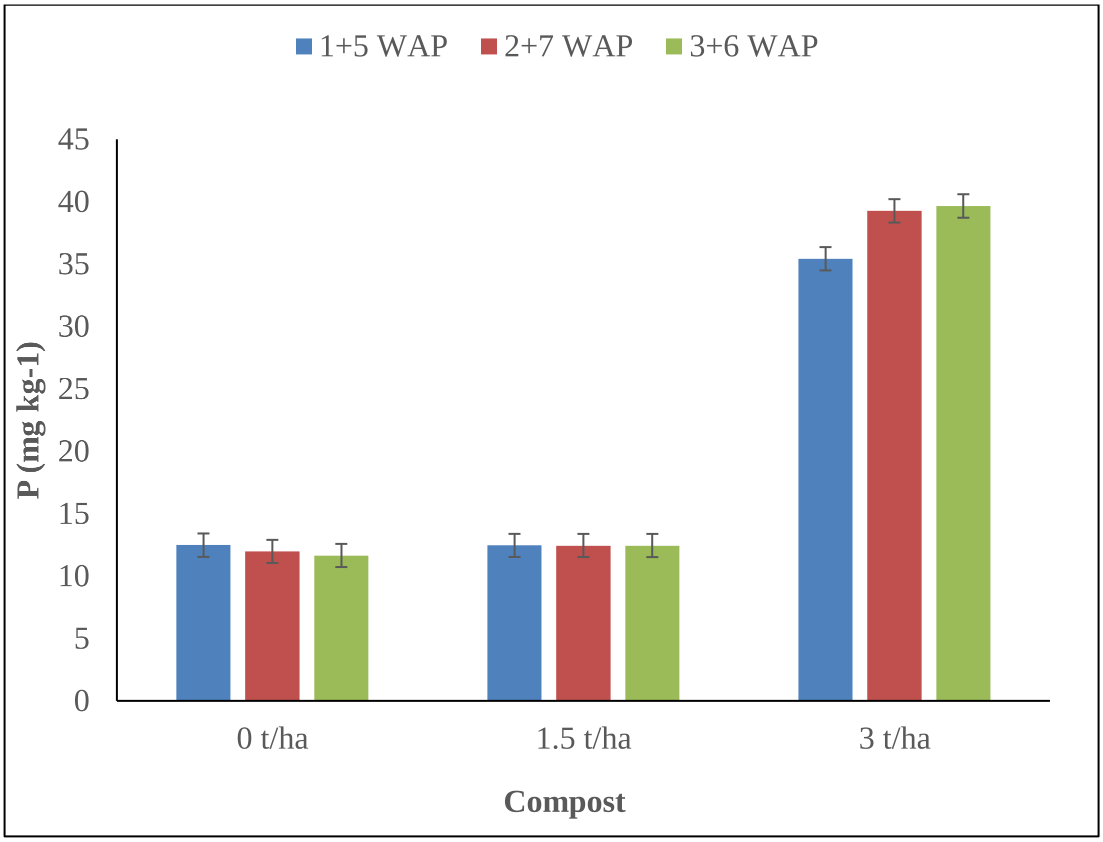

Figure 2: Interaction effect of compost application rate and time of fertilizer application on available phosphorus at harvest. Error bars represent SEM.

4.7 Tiller Count

The interaction effects of compost, variety and fertilizer application time did not significantly (P > 0.05) influence tiller count per m^2. Tiller count per m^2 was not significantly (P > 0.05) affected by time of fertilizer application. The main effect of compost application and fertilizer timing significantly (P > 0.05) did not influence tiller count per m^2. However, variety significantly (P < 0.01) had an effect on tiller count per m^2 (Figure 4).

NERICA 14 produced higher tiller count per m^2 than NERICA 4 (Figure 4).

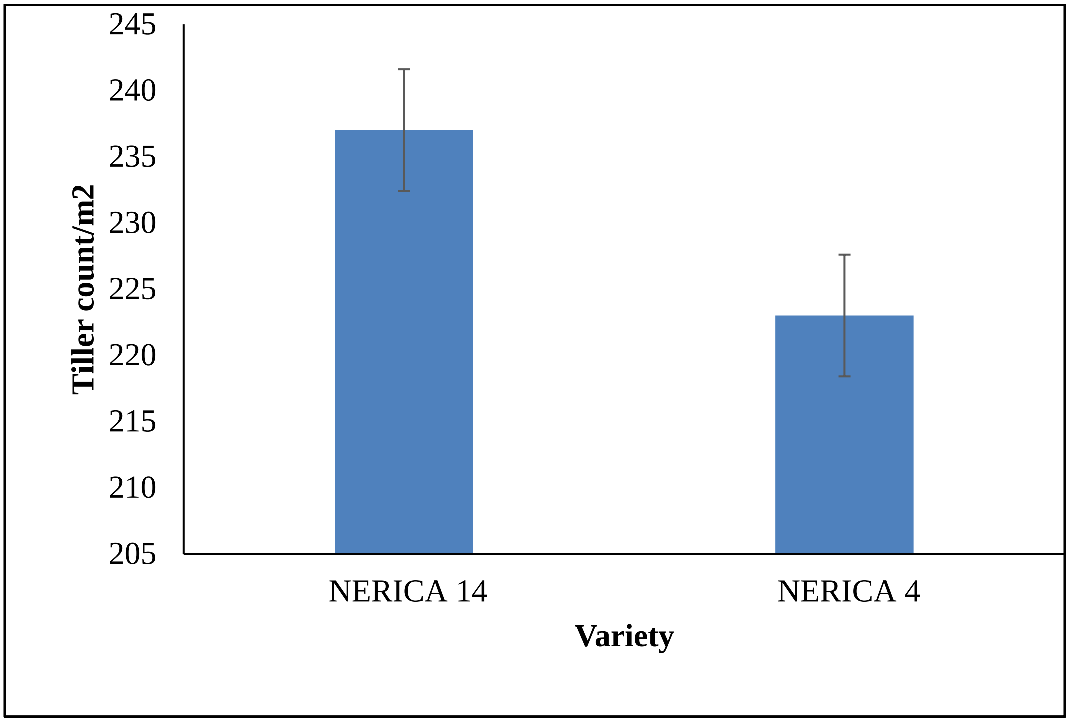

Figure 3: Effect of variety on tiller count. Error bars represent SEM.

4.8 Plant Height

The interaction effects of compost application rate by time of fertilizer application by variety, fertilizer timing by compost, fertilizer timing by variety and compost by variety did not affect plant height significantly (P > 0.05). Moreover, Compost rates did not significantly influence (P = 0.223) plant height at harvest. Height of plant was also not significantly affected by time of fertilizer application (P = 0.306). The variety did not significantly (P = 0.292) influence plant height. Plant height ranged from 108.9 to 112.6 (Table 4).

Table 4: Effect of compost, time of fertilizer application and variety of rice on germination percentage and plant height (cm).

Treatment	Plant height(cm)
Compost (C; t ha-^{1})	
0	108.9
1.5	109.8
3	112.6
LSD (0.05)	4.4
Time of application (T; WAP)	
1 and 5	109.3
2 and 7	112.3
3 and 6	109.6
LSD (0.05)	4.7
Variety (V)	
NERICA 14	109.4
NERICA 4	111.3
LSD (0.05)	3.6
LSD	
C x T	NS
C x V	NS
T x V	NS
C x T x V	NS

NS: not significant; LSD = least significance difference

4.9 Leaf Area Index

The interactions of compost by fertilizer by variety, compost by fertilizer, fertilizer by variety did not significantly ($P > 0.05$) affect leaf area index. The core effect of fertilizer application timing also had no significant effect ($P = 0.628$) on the leaf area index. However, the interaction of compost by variety significantly ($P = 0.036$) influenced leaf area index (Figure 5). The compost application significantly influenced ($P = 0.034$) LAI. The varietal difference in LAI was highly significant ($P < 0.001$).

The application of 3 t/ha compost gave the highest leaf area index in NERICA 14 (Figure 5). However, LAI produced by NERICA 14 with 1.5 t/ha compost was similar to the variety under 3t/ha compost. Similarly, application of 1.5 t/ha compost gave similar LAI in NERICA 14 to the control zero compost. Generally, NERICA 4 did not respond to compost application (Figure 5).

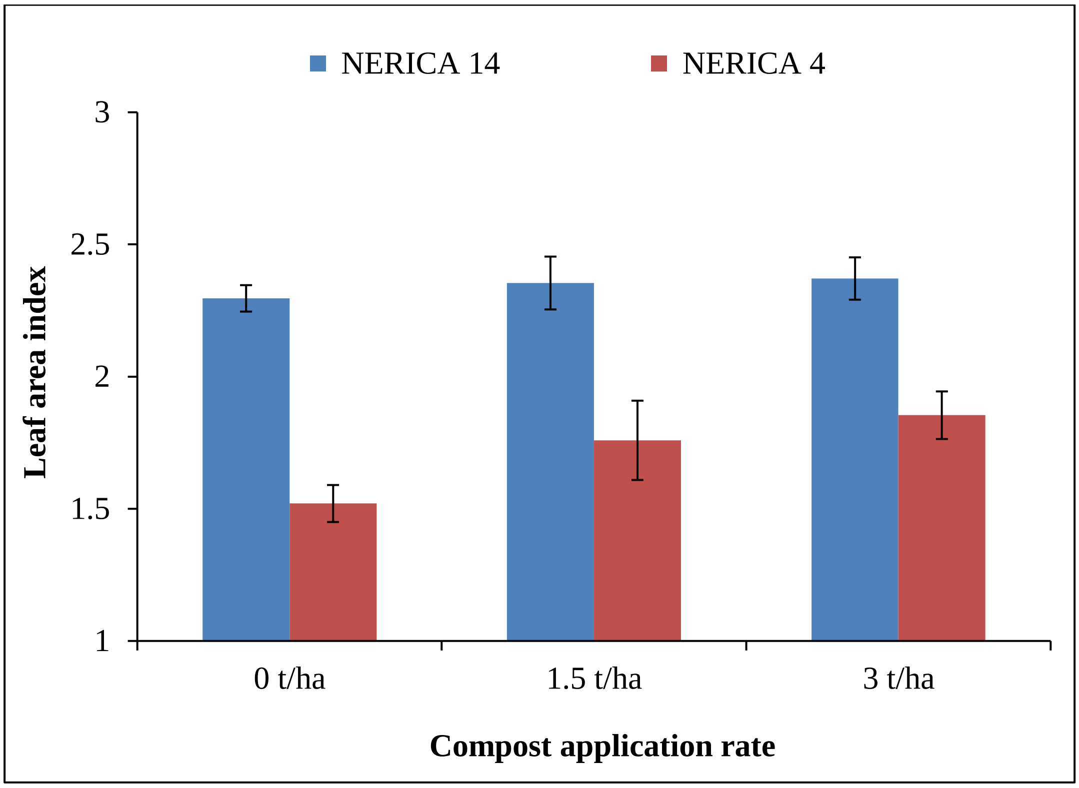

Figure 4: Interaction effect of compost application rate and variety on leaf area index. Error bars represent SEM.

4.10 Chlorophyll Content

The interaction effects of compost by time of fertilizer application by variety, compost by fertilizer, compost by variety and fertilizer by variety did not significantly ($P > 0.05$), affect the amount of chlorophyll. However, the chief impacts of variety ($P < 0.001$), compost ($P < 0.001$) and fertilizer timing ($P = 0.022$) influenced chlorophyll content significantly (Figure 6-8).

Compost application of 3 t ha^{-1} produced significantly the highest chlorophyll content while the control (0 t/ha) produced the lowest chlorophyll content (Figure 6). However, 1.5 t ha^{-1} of compost produced similar chlorophyll content as the control. NERICA 14 produced higher chlorophyll content than NERICA 4 (Figure 7). The timing of fertilizer application at 1&5 WAP also produced the highest chlorophyll content, followed by 2&7 WAP and 3& 6 WAP (Figure 8).

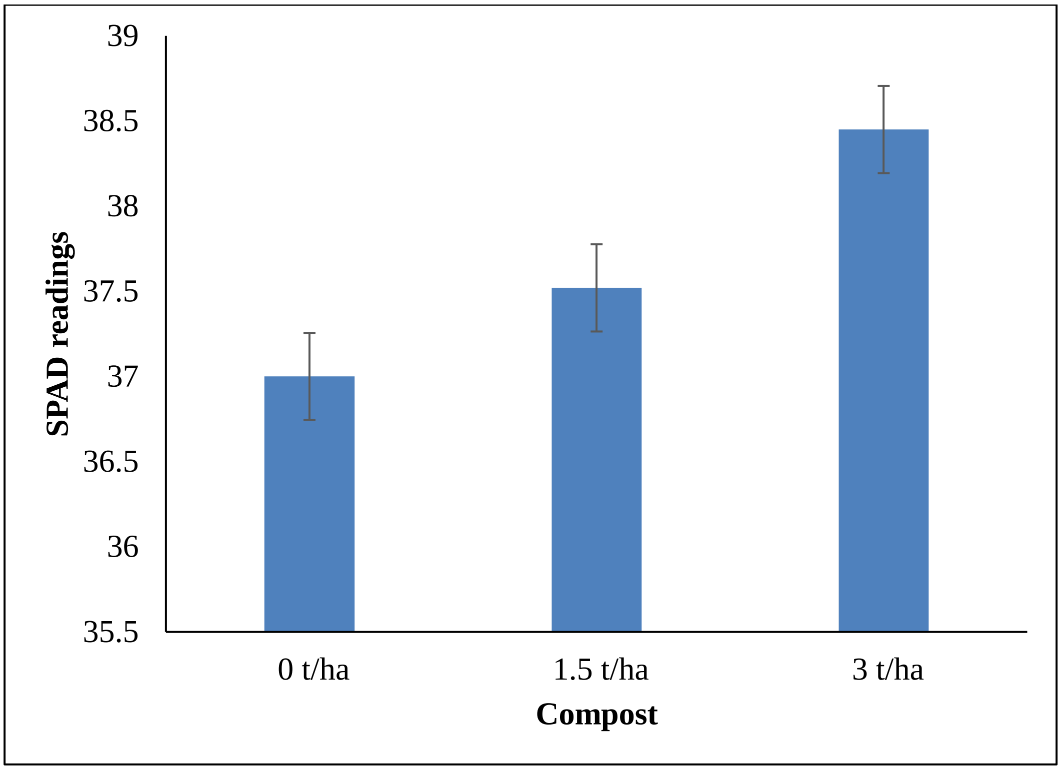

Figure 5: Effect of compost on chlorophyll content. Error bars represent SEM.

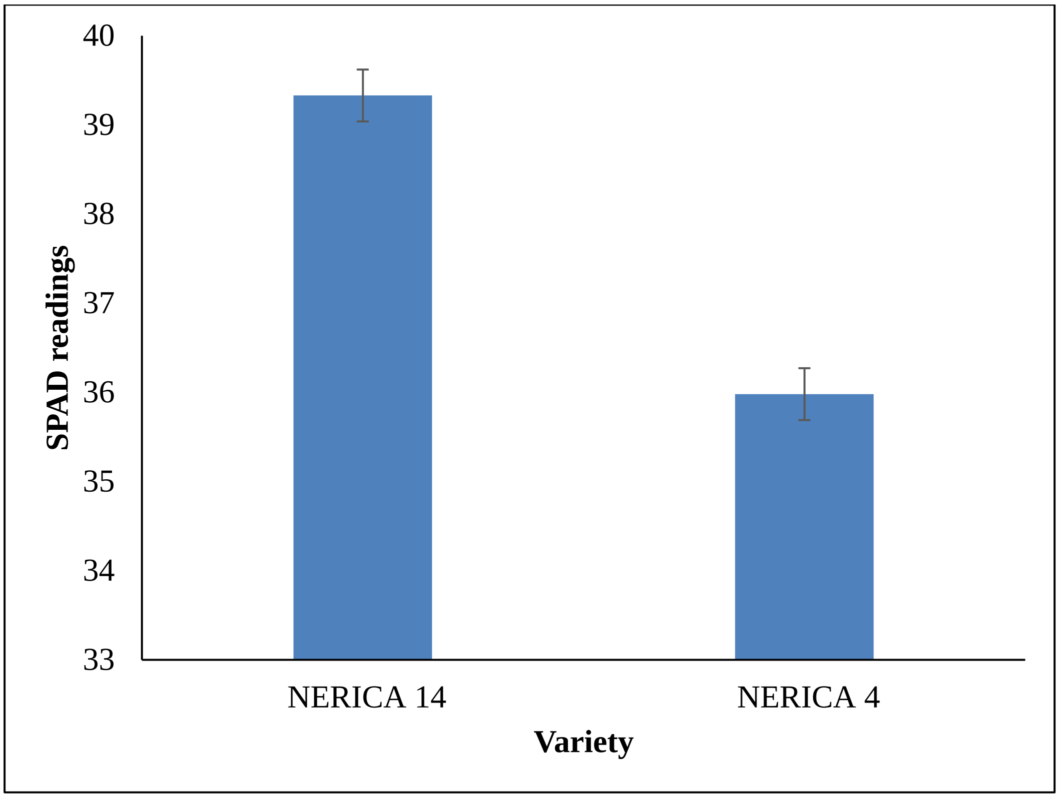

Figure 6: Effect of variety on chlorophyll content. Error bars represent SEM.

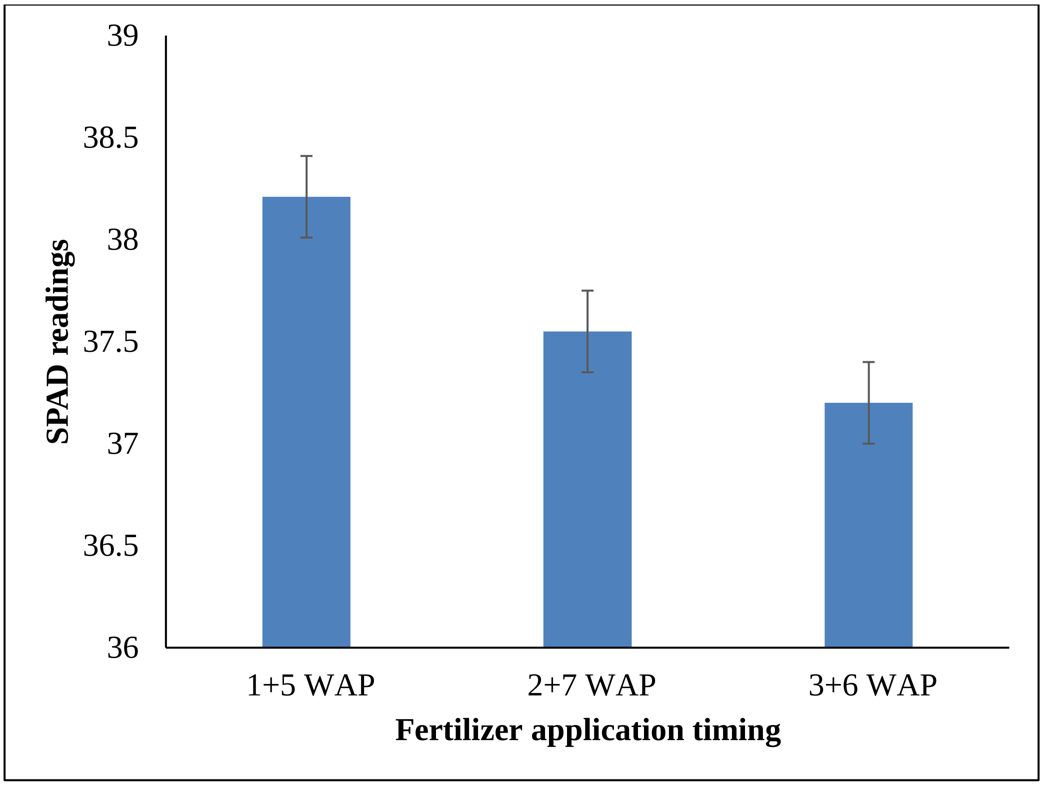

Figure 7: Effect of fertilizer application timing on chlorophyll content. Error bars represent SEM.

4.11 Days to 50% Flowering

The interaction effects of compost application rate, time of application of fertilizer and variety had no significant effect ($P > 0.05$), on days to 50 % flowering. Moreover, days to 50 % flowering was not prejudiced by time of fertilizer application ($P = 0.62$) and compost application rate ($P = 0.828$). However, the variety had significant ($P < 0.001$) impact on days to 50 % flowering. NERICA 4 variety took longer days for 50 % of the plants to flower than NERICA 14 variety (Figure 9).

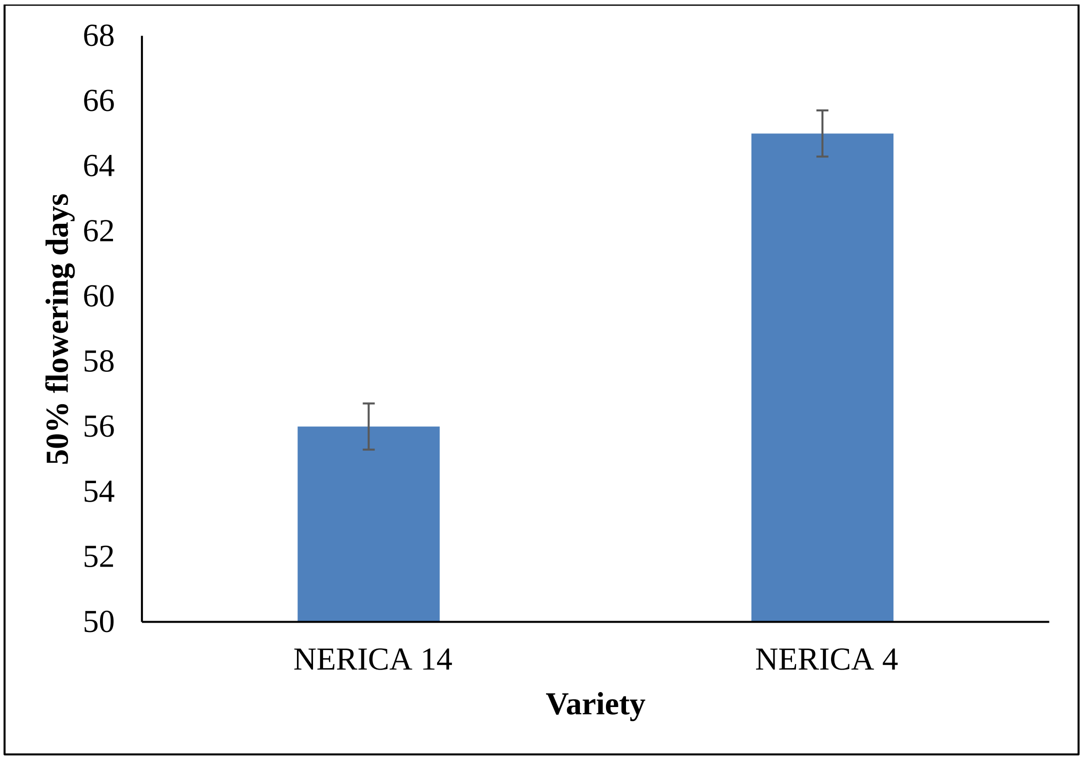

**Figure 8: Effect of variety on 50% flowering days.
Error bars represent SEM.**

4.12 Days to Maturity

The interaction between variety by time of fertilizer application gave a significant (P = 0.028) impact on days to maturity, though the interaction of compost by fertilizer by variety, compost by variety and compost by fertilizer did not affect days to maturity significantly ($P > 0.05$). The chief consequence of fertilizer application timing, rates of compost application significantly ($P > 0.05$) did not impact maturity days. However, days to maturity was affected significantly ($P < 0.001$) by the main effect of the varieties (Figure 10).

NERICA 4 and the application of fertilizer at 3&6 WAP treatment combination recorded the maximum days to maturity, followed by NERICA 4 at 2+7 WAP, and NERICA 4 at 1+5 WAP (Figure 10). However, NERICA 14 and the application of fertilizer at 1+5 WAP had significantly, the minimum days to maturity even though it had similar days to maturity as the treatment combinations of both NERICA 14 with 3+6 WAP, and NERICA 14 with 2+7 WAP (Figure 10).

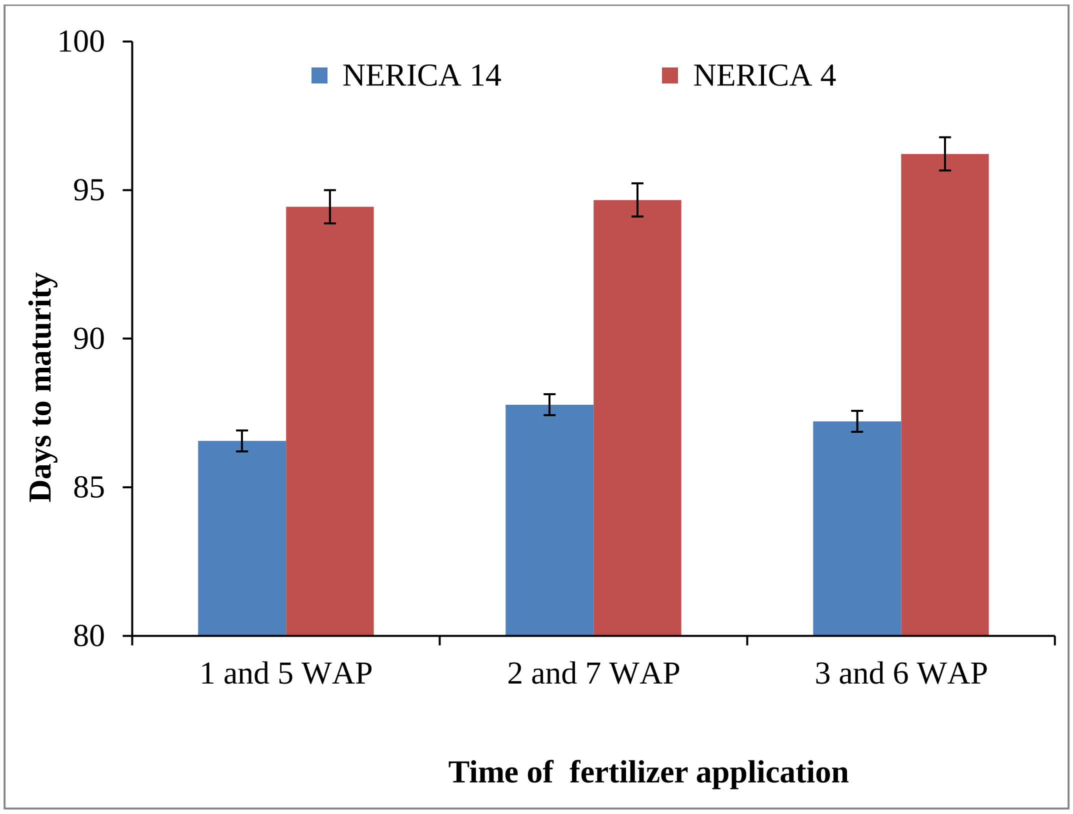

Figure 9: Interaction effect between variety and time of fertilizer application on days to maturity. Error bars represent SEM.

4.13 Panicle Count

The interaction effects among compost application rate by time of fertilizer application and variety, compost and variety, compost and fertilizer, variety and fertilizer significantly ($P > 0.05$) did not have any significant impact on panicles per m^2. Time of fertilizer application did not significantly influence ($P = 0.118$) panicle per m^2. Variety significantly affected panicles per m^2 significantly ($P < 0.001$), also the rate of compost application significantly ($P = 0.26$) affected panicle per m^2 (Figure 11).

Compost application of 3 t/ha produced the highest number of panicles per m^2, but 1.5 t/ha compost gave similar value as the control (Figure 11). NERICA 14 produced a higher number of panicles per m^2 than NERICA 4 (Figure 12).

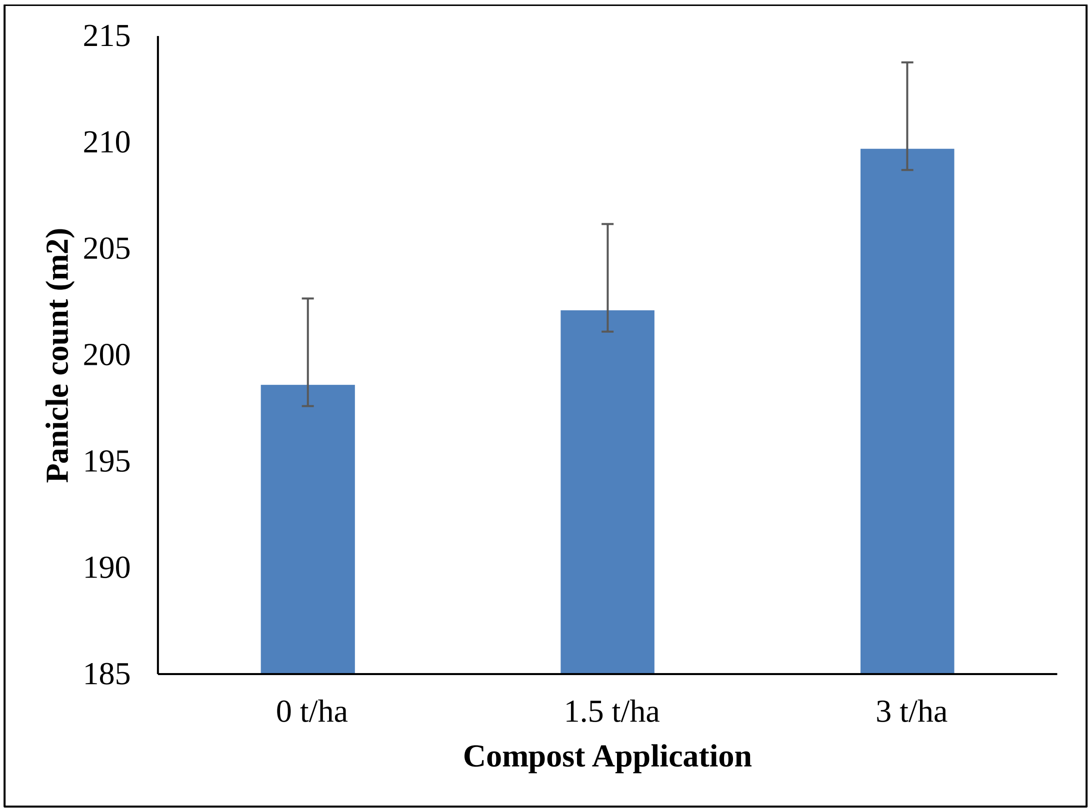

Figure 10: Effect of compost application rate on panicle count. Error bars represent SEM.

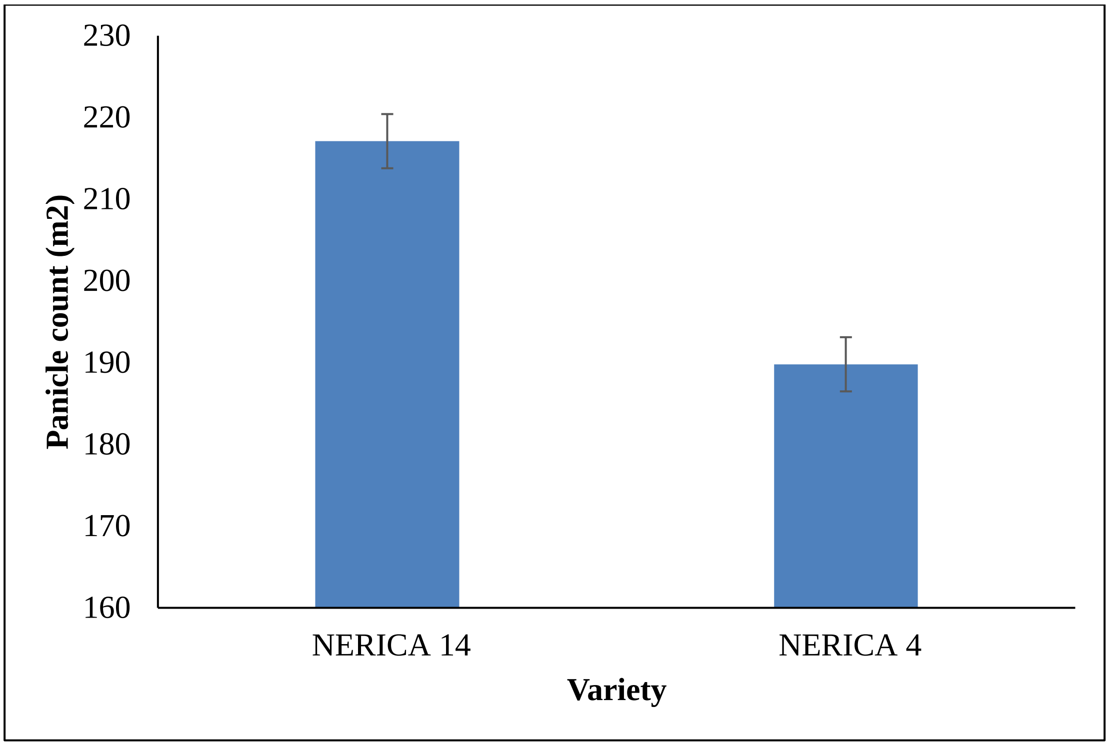

Figure 11: Effect of variety on panicle count. Error bars represent SEM.

4.14 Grain Yield

The effects of interaction of the rate of the application of compost by time of application by variety, variety by fertilizer, variety by compost, compost by fertilizer significantly did not influence ($P > 0.05$) grain yield. The main outcome of variety ($P < 0.001$) and rate of compost application ($P = 0.032$) affected grain yield significantly but time of fertilizer application did not significantly ($P > 0.058$) influence grain yield.

The compost application of 3 t ha^{-1} gave significantly the highest grain yield, trailed by 1.5 t ha^{-1} of compost application and the control (Figure 13). However, there was no statistical difference between the control and the application of 1.5 t ha^{-1} of compost in terms of grain yield. NERICA 14 produced higher yield of grain than NERICA 4 (Figure 14).

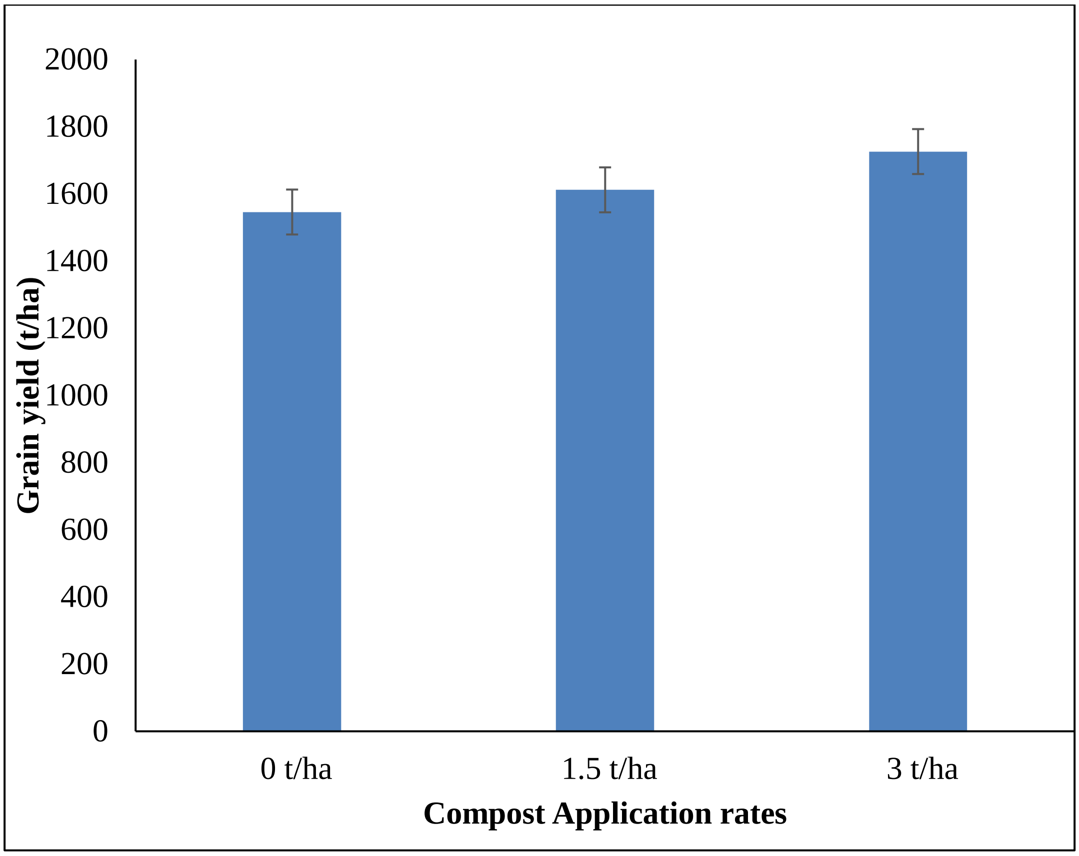

Figure 12: Effect of compost application rates on grain yield.
Error bars represent SEM.

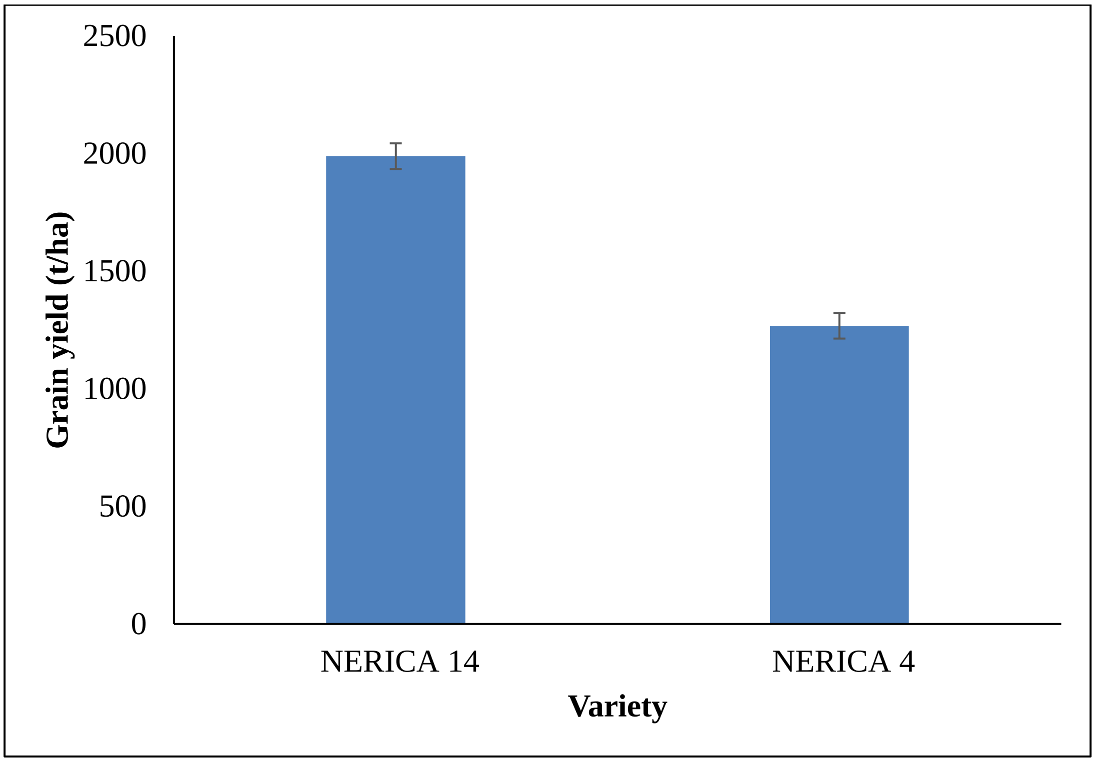

Figure 13: Effect of variety on grain yield.
Error bars represent SED.

4.15 Straw Yield

The interaction effects of compost application rate by time of fertilizer application by variety, compost by variety, compost by fertilizer, fertilizer by variety significantly ($P > 0.05$) did not influence straw yield. Straw yield was not significantly ($P = 0.123$) impacted by the time of fertilizer application. However, variety and compost application rate affected straw yield significantly ($P < 0.001$)

Compost application of 3 t ha^{-1} gave significantly the highest yield of straw, followed by 1.5 t ha^{-1} of compost and the control (Figure 15). There was no statistical variation between 1.5 t ha^{-1} of compost application and the control treatment. NERICA 14 produced higher straw yield than NERICA 4 (Figure 16).

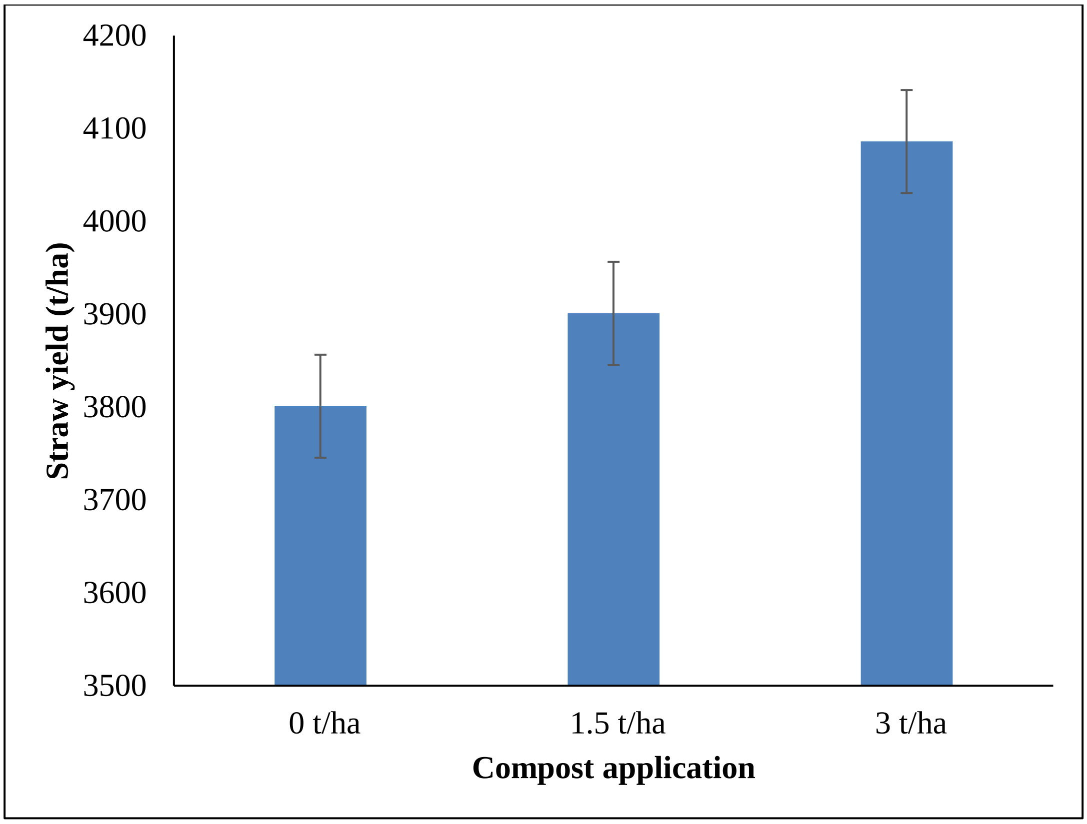

Figure 14: Effect of compost application rate on straw yield. Error bars represent SEM.

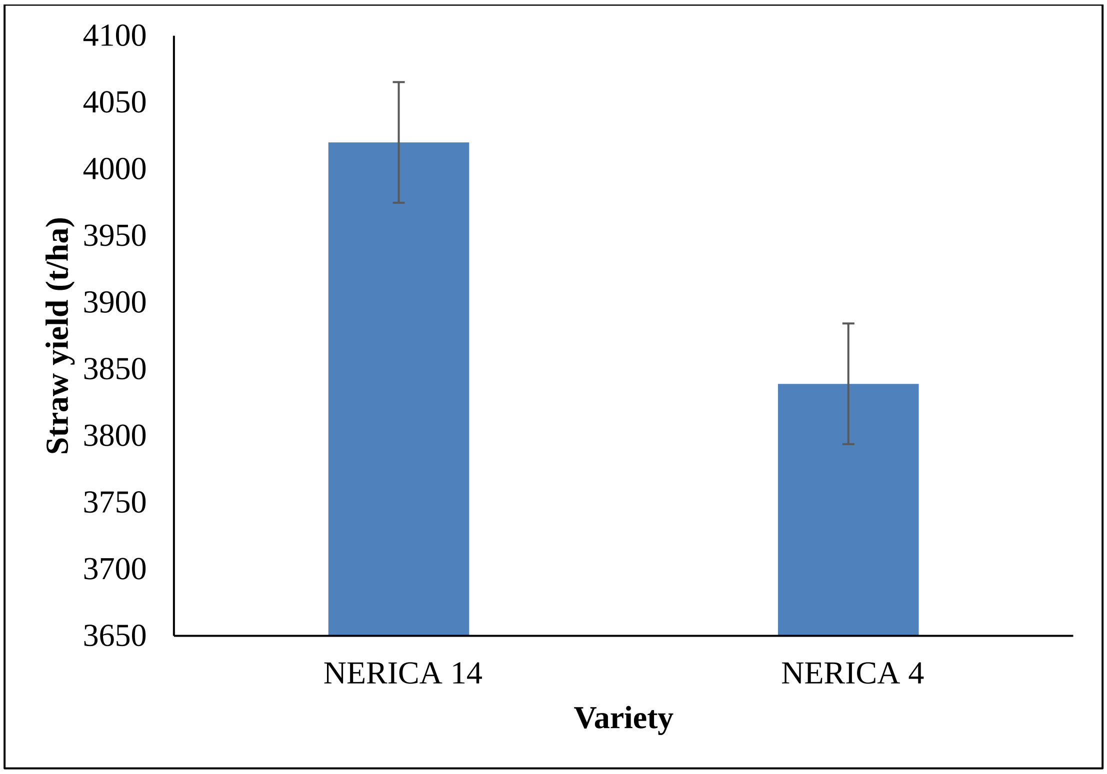

Figure 15: Effect of variety on straw yield. Error bars represent SEM.

4. 16 Dry Matter Accumulation

The interaction effects of compost application rate by time of fertilizer application by variety, compost by fertilizer, compost by variety, fertilizer by variety did not significantly affect (P > 0.05) dry matter accumulation. Fertilizer application time did not have significant effect (P = 0.823) on dry matter build-up. However, the compost application rate significantly (P < 0.001) affected dry matter accumulation. Additionally, there was significant varietal effect (P < 0.001) on d dry matter accumulation (Figure 18).

Dry matter accumulation increased with increasing compost rate (Figure 17). NERICA 14 produced significantly higher dry matter accumulation than NERICA 4 (Figure 18).

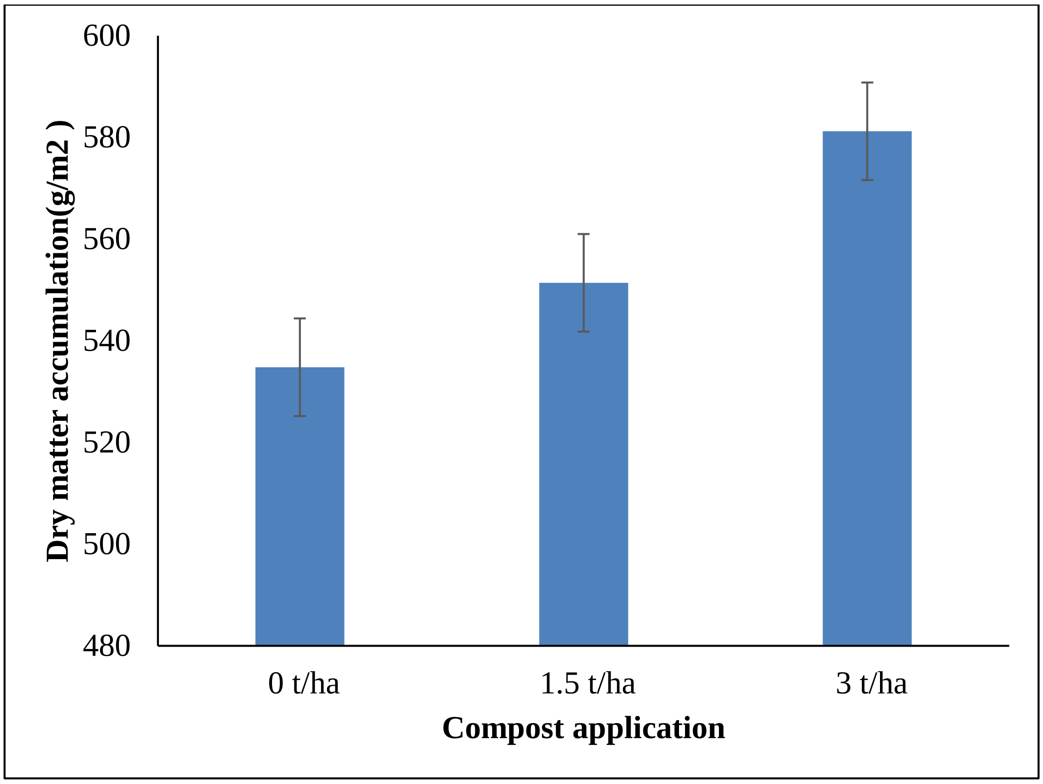

Figure 16: Effect of compost application rate on dry matter accumulation. Error bars represent SEM.

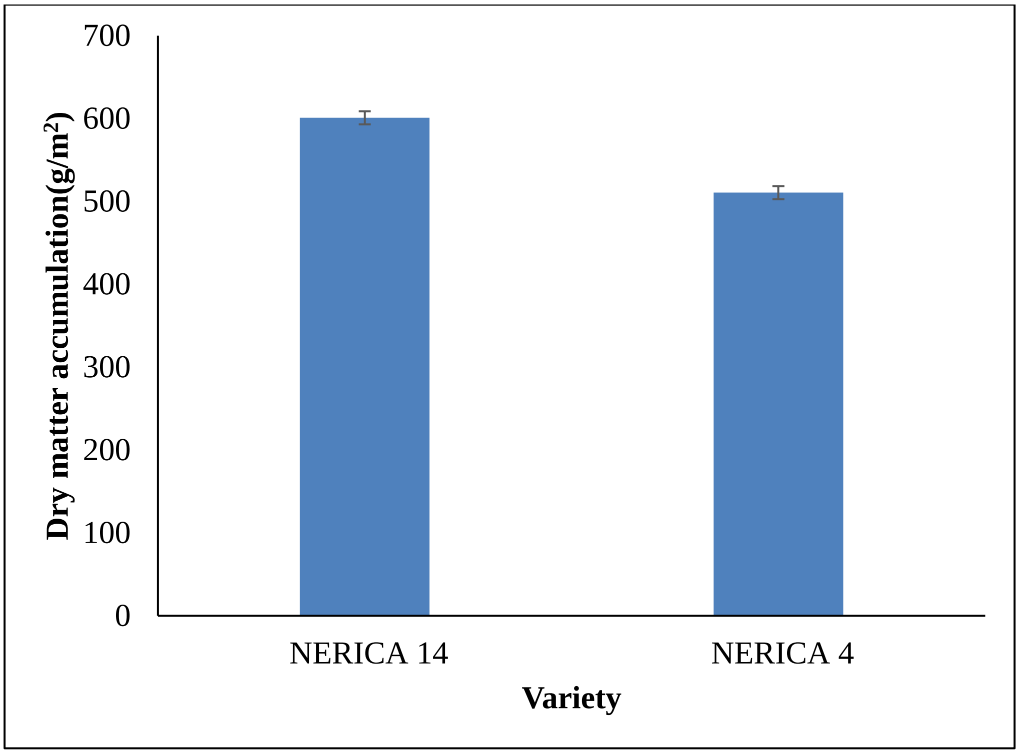

Figure 17: Effect of variety on dry matter accumulation. Error bars represent SEM.

4.17 Thousand Grain Weight

The interaction effects of compost application rate by time of fertilizer application by variety, variety by fertilizer, variety by compost, compost by fertilizer did not significantly ($P > 0.05$) affect thousand grain weight. The effect of fertilizer application timing ($P = 0.158$), compost application ($P = 0.277$) rate did not affect thousand grains weight significantly. However, variety significantly ($P = 0.03$) had effect on thousand grains weight.

NERICA 14 produced higher thousand grains mass) than NERICA 4 (Figure 19).

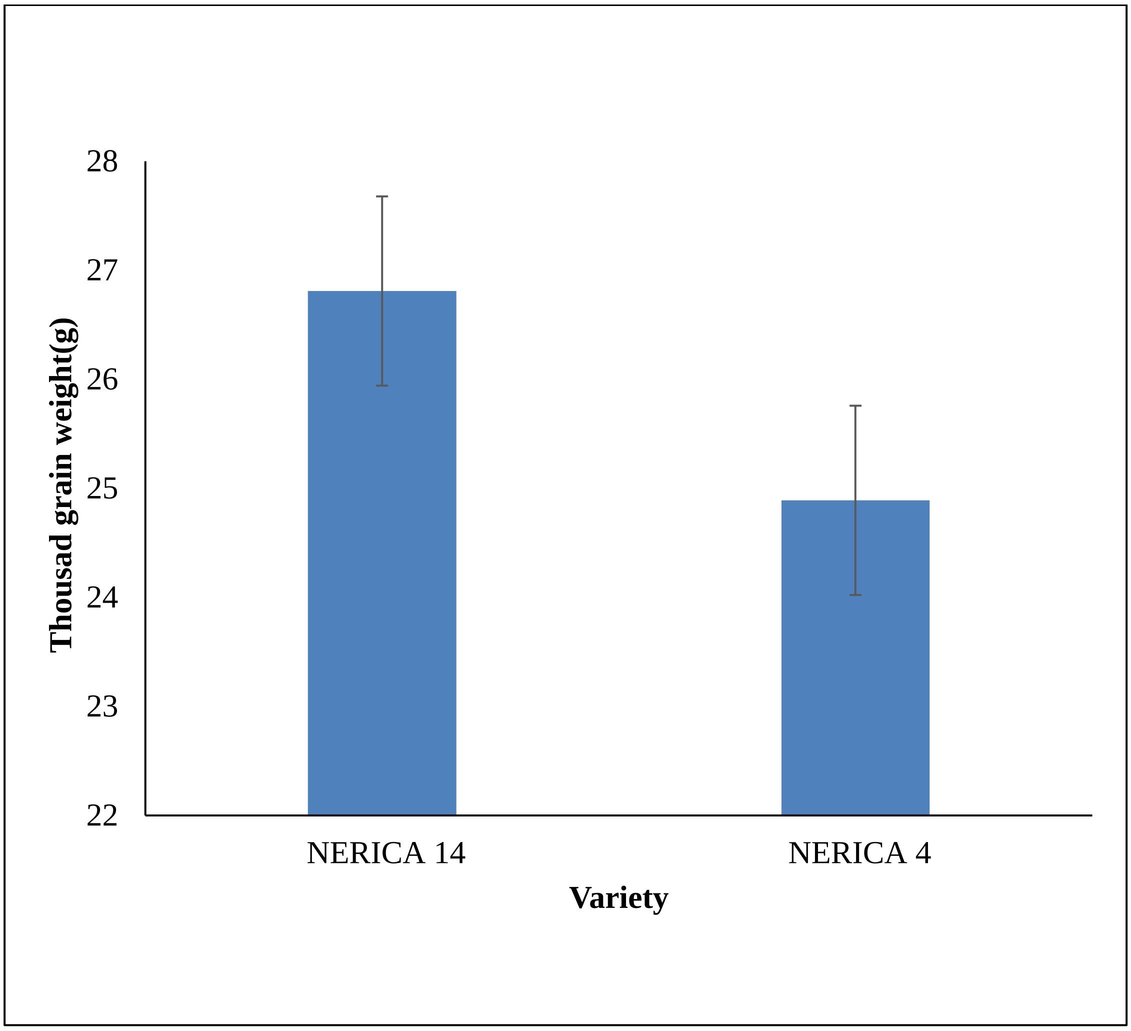

**Figure 18: Effect of variety on thousand grain weight.
Error bars represent SEM.**

4.18 Phenotypic Correlation

The correlation coefficients of the parameters were significant ($P < 0.05$); except for grain output and tiller count per m^2 (r=0.228), which was not significant though positively correlated. Correlation between grain yield and leaf area index (r=0.774), grain yield and panicle number per m^2 (r=0.693), grain output and 1000 grains weight (r=0.271) were all positively correlated (Table 10).

Table 5: Effect of compost, time of fertilizer application and variety of rice on pairwise correlations among yield and yield components

Variables	Panicle	Tiller	LAI	1000 grain	Grain yield
Panicle	1.000				
Tiller	0.306*	1.000			
LAI	0.642*	0.447*	1.000		
1000 grain	0.304*	0.329*	0.312*	1.000	
Grain yield	0.693*	0.228	0.774*	0.271*	1.000

* Significant at P< 0.05 level

CHAPTER FIVE

5.0 DISCUSSION

5.1 Effect of Compost Application, Time of Fertilizer Application and Variety on Percentage Gravimetric Moisture Content.

Application of compost increased percentage gravimetric content. The outcome is in agreement with the investigation by Bot and Benites (2005) who observed that compost application increased the gravimetric moisture content. Mosaddeghi *et al*. (2009) also inferred that organic matter content which includes compost had positive impact on water holding capacity of the soil. This indicates that generally soil moisture content responded to the application of compost at higher level like 3 t ha^{-1} in this study.

5.2 Effect of Compost Application, Time of Fertilizer Application and Variety on Some Soil Chemical Properties

Soil pH was measured to evaluate the possible nutrient shortages, crop continuity, pH adjustment requirements, and to know proper testing approaches for other soil nutrients, such as phosphorus. In the present study, soil carbon-based substance, soil pH, total nitrogen, potassium and existing phosphorus were not impacted by the treatments. The absence of the interaction outcome of the nutrients applied on the two NERICA varieties might be due to the heritable potential of the varieties. This implies, the two varieties might be efficient in utilizing the available nutrients in the soil with the same potential.

5.3 Effect of Compost Application, Time of Fertilizer Application and Variety on Tillers in rice production

NERICA 14 variety produced better rice growth than NERICA 4 variety as a result of its higher tiller count per m^2. This difference in tillering ability could be credited to the genetic variability of the varieties. In a similar nutrient environment. Khan *et al.* (2007) conveyed that, the height of a plant hinge largely on genes of a plant and the conditions of the environment. This discovery settles with (Roy *et al*., 2014; Sultana, 2008) who reported that, tillering was influenced by rice varieties due to their genetic makeup. However, the finding disagrees with Getachew and Birhan (2015) who stated that tiller number was not significantly influenced by rice variety. The differences in these findings might be due to the type of varieties used.

5.4 Effect of Compost Application, Time of Fertilizer Application and Variety on Leaf Area Index

The interaction of NERICA 14 and 3 t ha^{-1} of compost application produced significantly the higher leaf area index than the other treatment combinations and it could be due to added nutrients and other benefits derived from the compost to the soil (Elfeel and Abohassan, 2016; Tadesse *et al*., 2013) and the genetic potential of NERICA 14 variety (Hussain *et al*., 2014)

The application of compost increased leaf area index more than the control and it might be attributed to the additional nutrients that were added from the compost to the soil (Elfeel and Abohassan, 2016; Tadesse *et al*., 2013). This discovery is in conformity with past studies (Sarwar *et al*., 2007; Bejbaruha *et al*., 2009; Lah *et al*., 2011; Agegnehu *et al*., 2016) that the application of compost increases rice growth. Among the compost application rate, 3 t ha^{-1} produced better rice growth than 1.5 t ha^{-1}, due to its higher leaf area index. This could be due to more nutrients readiness at the higher rate of compost application that provided more nutrition to the plants and consequently enhancing better rice growth establishment. This discovery is in support of Anil *et al*. (2014) who asserted that, the greater the rate of fertilizer (nitrogen), the greater the nutrition of the plant and therefore the better the growth of the plant.

NERICA 14 variety produced better rice growth than NERICA 4 variety as a result of its higher leaf area index. This could be ascribed to the heritable variability of the variety. Hussain *et al.* (2014) stated that leaf area index was significantly influenced by rice varieties.

5.5 Effect of Compost Application, Time of Fertilizer Application and Variety on Chlorophyll Content

The use of compost enhanced the chlorophyll content than the control and this could be attributed probably to the extra N that was added from the compost to the soil (Elfeel and Abohassan, 2016; Tadesse *et al*., 2013). This is in conformity with past studies (Sarwar *et al*., 2007; Bejbaruha *et al*., 2009; Lah *et al*., 2011; Agegnehu *et al*., 2016) that the application of compost increases rice growth as a reason of increased chlorophyll content. The use of compost 3 t/ha produced better rice growth than 1.5 t/ha probably as a result of its higher chlorophyll content. This could be owing to nutrients readiness at the greater rate of compost providing more nourishment to the plants and consequently enhancing better rice growth. This supports Anil *et al*. (2014) who asserted that, the higher the rate of fertilizer N, the higher the nutrition of plants and consequently the better the growth of plants.

Plants that received fertilizer application at 3 and 6 WAP produced the highest chlorophyll content than the other treatments and it could be due to the time the parameter was measured. Chlorophyll content was measured three days after the sixth week fertilizer application; thus, the plants were able to take up more nutrients which in turn led to its higher chlorophyll content. This outcome marched with Bekere *et al.* (2014) who detailed that, chlorophyll content increased after fertilizer application. The authors likewise conveyed that; time of fertilizer application had significant consequence on chlorophyll content of rice.

NERICA 14 variety produced better rice growth than NERICA 4 variety as a result of its higher chlorophyll content. This could be ascribed to the genetic variability of the varieties. Khan *et al.* (2007) informed that, the height of a plant rests on the genes of the plant and the conditions of the environment. This finding agrees with Roy *et al*. (2014) and Sultana (2008) who reported that plants height, dry matter accumulation and tiller count per m^2 were influenced by rice varieties probably as results of their genetic makeup. Moreover, Hussain *et al.* (2014) stated that chlorophyll content were significantly influenced by rice varieties.

5.6 Effect of Compost Application Rate, Time of Fertilizer Application and Variety on Days to 50% Flowering and Days to Maturity

NERICA 14 variety produced inflorescence earlier than NERICA 4 variety as a result of its genetic variability. This confirms one of the many advantages of the NERICA varieties which are early maturing thereby earliness in flowering (Somado *et al.,* 2008). Earliness in maturity followed the same trend as days to 50% flowering.

The interaction between NERICA 14 and timing of fertilizer application produced significantly the earliest maturing variety than the other treatment combinations and it could be owing to the genetic makeup of the NERICA 14 variety (Hussain *et al*., 2014)

5.8 Effect of Compost Application Rate, Time of Fertilizer Application and Variety on Panicles number per m^2

The results revealed that NERICA 14 produced higher number of panicles per m^2 than NERICA 4. This might be attributed to the superior genetic ability of the variety to utilise nitrogen more efficiently (Somado *et al*, 2008).

5.9 Effect of Compost Application, Time of Fertilizer Application and Variety on Grain Yield

The use of compost improved grain yield as compared to the control and it might be attributed to the additional nutrients that were added from the compost to the soil (Elfeel and Abohassan, 2016; Tadesse *et al*., 2013). This finding conforms with preceding studies (Sarwar *et al*., 2007; Bejbaruha *et al*., 2009; Lah *et al*., 2011; Agegnehu *et al*., 2016) that the application of compost increases rice growth. Among the compost application rate, 3 t ha^{-1} produced better rice growth than 1.5 t ha^{-1} as a result of its higher grain yield. This could be due to more nutrients readiness at the higher rate of compost application that provided more nutrition to the plants and consequently enhancing better rice growth. This finding supports Anil *et al*. (2014) who asserted that, higher rate of fertilizer (nitrogen) result in higher nutrition of plant. Therefore, the better the growth of plants.

NERICA 14 variety produced higher grain yield than NERICA 4 variety as a result of its better growth This could be credited to the genetic variability of the varieties.

5.10 Effect of Compost Application Rate, Time of Fertilizer Application and Variety on Thousand Grain Weight

NERICA 14 variety produced higher thousand grain weight than NERICA 4 variety and could be due to its exceptional growth indicators. It might also be attributed to the higher yielding ability of the NERICA 14 variety as a result of its ability to produce more photosynthetic matter for the production of grains than the other variety during flowering and grain filling stages. This outcome is line with Sultana (2008) and Getachew and Birhan (2015) who stated that yields of grains and components are significantly prejudiced by rice variety. However, Lampayan *et al*., (2010) asserted that timing of fertilizer properly enhanced panicle numbers and greater amount of filled spikelets thus increasing thousand grain weight.

5.11 Effect of Compost Application Rate, Time of Fertilizer Application and Variety on Dry Matter Accumulation

The application of compost increased dry matter build-up than the control and it might be attributed to the additional nutrients that were added from the compost to the soil (Elfeel and Abohassan, 2016; Tadesse *et al*., 2013). This finding is in conformity with earlier studies (Sarwar *et al*., 2007; Bejbaruha *et al*., 2009; Lah *et al*., 2011; Agegnehu *et al*., 2016) that the administration of compost increases rice growth.

NERICA 14 variety produced better rice growth than NERICA 4 variety as a consequence of its higher dry matter accretion.

5.12 Effect of Compost Application Rate, Time of Fertilizer Application and Variety on Straw Yield

The application of compost increased straw yield than the control and it might be attributed to the additional nutrients that were added from the compost to the soil (Elfeel and Abohassan, 2016; Tadesse *et al*., 2013). This finding conforms with earlier studies (Sarwar *et al*., 2007; Bejbaruha *et al*., 2009; Lah *et al*., 2011; Agegnehu *et al*., 2016) that the administration of compost increases rice growth. Among the compost application rate, 3 t ha^{-1} produced better rice growth than 1.5 t/ha resulting in higher straw yield. This could be due to more nutrients accessibility and improvement of soil structure at the higher rate of compost application that provided more nutrition to the plants and consequently enhancing better rice growth.

5.13 Effect of Compost Application Rate, Time of Fertilizer Application and Variety on Yield Components of Rice

Plants that received compost application produced higher grain yield than plants without compost application and it might be due to their high panicles per m^2. Patel *et al*. (2010) asserted that the number of panicles is the greatest significant issue that led to disparity in grain yield of rice. The finding is the same as the one by Bekere *et al*. (2014) reported that, the higher the panicles per m^2, the higher the grain yield of rice. The control (no compost application) produced significantly the low grain and straw yields and it could be accredited to the absence of additional plant nutrients from the compost to the soil (Elfeel and Abohassan, 2016; Tadesse *et al*., 2013). Among the compost application rate, 3 t ha^{-1} produced higher straw and grain yield than 1.5 t ha^{-1} and it might be due to former higher nutrient concentrations as a result of it higher rate than the latter. Anil *et al.* (2014) stated that higher rate of a fertilizer influences higher availability of its nutrient concentrations.

5.13.1 Effect of Fertilizer Application Timing

Significantly, time of fertilizer application did not affect grain and straw yield as well as yield components. This might be ascribed to the fertilizer rate which was applied to the treatments. All the treatments received the same rate of the fertilizer and therefore have the same nutrient concentrations. Moreover, Getachew and Birhan (2015) reported similar grain yield and yield components among different time of fertilizer application with the exception of 1000 grains weight. However, the result disagrees with Jemberu *et al*. (2015) who described that fertilizer application timing had a significant consequence on rice harvest and components under controlled greenhouse condition.

5.13.2 Implication for NERICA Rice Varieties

NERICA 14 variety produced significantly higher thousand (1000) grains weight than NERICA 4 and this might be due to the genetic variations in the varieties. It is in conformity with earlier research (Sultana, 2008; Bekere *et al*., 2014; Getachew and Birhan, 2015) that thousand grain weightn is affected by the genetic variability of the variety. Nevertheless, the finding disagrees with Hussain *et al.* (2014) who reported similar thousand grains weight among four different varieties of rice and they attributed it to the genetic nature of the varieties.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Grounded on the objectives of the research, it was determined that;

- the research revealed that, the application of compost increased rice growth and yield. Compost application at 3 t/ha gave the highest yield which is 1726 kg/ha. Also, number of panicles per m^2 was also highest in 3 t/ha treated plots as well as
- Time of fertilizer application significantly influenced chlorophyll content of rice.
- The type of variety used for cultivation is very important since the varieties used in the study significantly influenced rice growth and grain yield. Nerica 14 recorded the highest yield (1989 t/ha), higher tiller count ($251/m^2$) and thousand grain weight (26.7 g). The application of 3 t ha^{-1} of compost fertilizer marginally improved or maintained the chemical properties of the soil after harvest.

6.2 Recommendations

- NPK fertilizer application timing at three and six weeks after planting, combined with 3 t ha^{-1} of compost with NERICA 14 could be recommended to farmers since this package increased rice growth and yield.
- Compost at 3 t/ha can be used as a substitute for inorganic fertilizer by farmer to achieve higher yield in upland rice cultivation.
- Compost application rate of 3 t/ha can be used in Nerica 14 farms for optimum yield.
- The study should be repeated with different rates of NPK fertilizer application to assess their consequence on the growth and produce of upland rice.

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APPENDICES

Appendix 1: Effect of compost application, time of fertilizer application and variety on gravimetric soil moisture at maximum tillering.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	3.82	1.91	0.10	
Variety	1	0.00	0.00	0.00	0.990
Compost	2	159.62	79.81	4.03	0.027
Fertilizer timing	2	15.55	7.77	0.39	0.678
Variety × Compost	2	15.48	7.74	0.39	0.679
Variety × Fertilizer timing	2	107.46	53.73	2.71	0.081
Compost × Fertilizer	4	77.52	19.38	0.98	0.432
Variety × Compost × Fertilizer timing	4	42.55	10.64	0.54	0.709
Residual	34	673.40	19.81		
Total	53	1095.40			

Appendix 2: Effect of compost application rate, time of fertilizer application and variety on soil pH

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	0.50708	0.25354	7.57	
Variety	1	0.00125	0.00125	0.04	0.848
Compost	2	0.01424	0.00712	0.21	0.81
Fertilizer	2	0.00185	0.00092	0.03	0.973
Variety × Compost	2	0.00481	0.00241	0.07	0.931
Variety × Fertilizer	2	0.0006	0.0003	0.01	0.991
Compost × Fertilizer	4	0.00901	0.00225	0.07	0.991
Variety × Compost × Fertilizer	4	0.00316	0.00079	0.02	0.999
Residual	34	1.13825	0.03348		
Total	53	1.68026			

Appendix 3: Effect of compost application rate, time of fertilizer application and variety on soil organic carbon

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	0.13757	0.06878	1.99	
Variety	1	0.07259	0.07259	2.1	0.157
Compost	2	0.15252	0.07626	2.2	0.126
Fertilizer	2	0.03731	0.01865	0.54	0.588
Variety × Compost	2	0.1488	0.0744	2.15	0.132
Variety × Fertilizer	2	0.03799	0.01899	0.55	0.583
Compost × Fertilizer	4	0.07437	0.01859	0.54	0.709
Variety × Compost × Fertilizer	4	0.07373	0.01843	0.53	0.712
Residual	34	1.17618	0.03459		
Total	53	1.91106			

Appendix 4: Effect of compost application rate, time of fertilizer application and variety on total nitrogen

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	0.0002641	0.0001321	1.27	
Variety	1	0.0000311	0.0000311	0.3	0.587
Compost	2	0.0001348	0.0000674	0.65	0.528
Fertilizer	2	0.0000201	0.0000101	0.1	0.908
Variety × Compost	2	0.0000049	0.0000025	0.02	0.977
Variety × Fertilizer	2	0.0000189	0.0000095	0.09	0.913
Compost × Fertilizer	4	0.0000178	0.0000044	0.04	0.996
Variety × Compost × Fertilizer	4	0.0000199	0.000005	0.05	0.995
Residual	34	0.0035232	0.0001036		
Total	53	0.0040348			

Appendix 5: Effect of compost application rate, time of fertilizer application and variety on available potassium

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	42.111	21.056	3.07	
Variety	1	0.463	0.463	0.07	0.797
Compost	2	31.444	15.722	2.29	0.116
Fertilizer	2	0.111	0.056	0.01	0.992
Variety × Compost	2	1.815	0.907	0.13	0.877
Variety × Fertilizer	2	10.037	5.019	0.73	0.489
Compost × Fertilizer	4	0.444	0.111	0.02	0.999
Variety × Compost × Fertilizer	4	5.185	1.296	0.19	0.943
Residual	34	233.222	6.859		
Total	53	324.833			

Appendix 6: Effect of compost application rate, time of fertilizer application and variety on available phosphorus

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	9.589	4.795	1.21	
Compost	2	2920.862	1460.431	369.69	0.001
Fertilizer	2	12.144	6.072	1.54	0.230
Variety	1	0.071	0.071	0.02	0.894
Compost × Fertilizer	4	42.768	10.692	2.71	0.046
Compost × Variety	2	0.493	0.246	0.06	0.940
Fertilizer × Variety	2	0.264	0.132	0.03	0.967
Fertilizer × Variety × Variety	4	0.195	0.049	0.01	1.000
Residual	34	134.316	3.950		
Total	53	3120.702			

Appendix 7: Effect of compost application rate, time of fertilizer application and variety on germination percentage

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	20.593	10.296	3.89	
Compost	2	4.593	2.296	0.87	0.429
Fertilizer	2	2.259	1.13	0.43	0.656
Variety	1	73.5	73.5	27.74	<.001
Compost × Fertilizer	4	4.519	1.13	0.43	0.788
Compost × Variety	2	3.111	1.556	0.59	0.561
Fertilizer × Variety	2	3.444	1.722	0.65	0.528
Compost × Fertilizer × Variety	4	2.444	0.611	0.23	0.919
Residual	34	90.074	2.649		
Total	53	204.537			

Appendix 8: Effect of compost application rate, time of fertilizer application and variety on tiller count per m^2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	313.9	157	0.57	
Compost	2	244.5	122.3	0.44	0.646
Fertilizer	2	1255.8	627.9	2.27	0.119
Variety	1	2871.1	2871.1	10.39	0.003
Compost × Fertilizer	4	20.3	5.1	0.02	0.999
Compost × Variety	2	91.1	45.6	0.16	0.849
Fertilizer × Variety	2	121.5	60.8	0.22	0.804
Compost × Fertilizer × Variety	4	8.7	2.2	0.01	1.00
Residual	34	9399.6	276.5		
Total	53	14326.5			

Appendix 9: Effect of compost application rate, time of fertilizer application and variety on leaf area index

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	0.16414	0.08207	2.22	
Compost	2	0.27718	0.13859	3.74	0.034
Fertilizer	2	0.03489	0.01745	0.47	0.628
Variety	1	5.45942	5.45942	147.42	<.001
Compost × Fertilizer	4	0.0693	0.01732	0.47	0.759
Compost × Variety	2	0.2724	0.1362	3.68	0.036
Fertilizer × Variety	2	0.04509	0.02255	0.61	0.55
Compost × Fertilizer × Variety	4	0.0989	0.02472	0.67	0.619
Residual	34	1.25913	0.03703		
Total	53	7.68045			

Appendix 10: Effect of compost application rate, time of fertilizer application and variety on chlorophyll content

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	3.048	1.524	1.38	
Compost	2	19.581	9.791	8.84	<.001
Fertilizer	2	9.443	4.722	4.26	0.022
Variety	1	151.671	151.671	136.9	<.001
Compost × Fertilizer	4	0.162	0.041	0.04	0.997
Compost × Variety	2	0.548	0.274	0.25	0.782
Fertilizer × Variety	2	3.089	1.544	1.39	0.262
Compost × Fertilizer × Variety	4	0.55	0.138	0.12	0.973
Residual	34	37.668	1.108		
Total	53	225.762			

Appendix 11: Effect of compost application rate, time of fertilizer application and variety on days to 50 % to flowering

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	4.704	2.352	0.36	
Compost	2	2.481	1.241	0.19	0.829
Fertilizer	2	6.37	3.185	0.48	0.62
Variety	1	988.167	988.167	150.46	<.001
Compost × Fertilizer	4	0.296	0.074	0.01	1.00
Compost × Variety	2	0.111	0.056	0.01	0.992
Fertilizer × Variety	2	25.333	12.667	1.93	0.161
Compost × Fertilizer × Variety	4	3.556	0.889	0.14	0.968
Residual	34	223.296	6.568		
Total	53	1254.315			

Appendix 12: Effect of compost application rate, time of fertilizer application and variety on days to maturity

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	157.37	78.685	15.15	
Compost	2	11.593	5.796	1.12	0.339
Fertilizer	2	4.926	2.463	0.47	0.626
Variety	1	996.741	996.741	191.87	<.001
Compost × Fertilizer	4	10.296	2.574	0.5	0.739
Compost × Variety	2	4.037	2.019	0.39	0.681
Fertilizer × Variety	2	41.37	20.685	3.98	0.028
Compost × Fertilizer × Variety	4	5.185	1.296	0.25	0.908
Residual	34	176.63	5.195		
Total	53	1408.148			

Appendix 13: Effect of compost application rate, time of fertilizer application and variety on panicles per m^2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	2513	1256.5	8.75	
Compost	2	1163.2	581.6	4.05	0.026
Fertilizer	2	655.4	327.7	2.28	0.118
Variety	1	10072.3	10072.3	70.14	<.001
Compost × Fertilizer	4	199.7	49.9	0.35	0.844
Compost × Variety	2	439.8	219.9	1.53	0.231
Fertilizer × Variety	2	374.7	187.4	1.3	0.285
Compost × Fertilizer × Variety	4	688.7	172.2	1.2	0.329
Residual	34	4882.8	143.6		
Total	53	20989.6			

Appendix 14: Effect of compost application rate, time of fertilizer application and variety on plant height

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	127.44	63.72	1.52	
Compost	2	131.44	65.72	1.57	0.223
Fertilizer	2	102.78	51.39	1.22	0.306
Variety	1	48.17	48.17	1.15	0.292
Compost × Fertilizer	4	373.78	93.44	2.23	0.087
Compost × Variety	2	44.33	22.17	0.53	0.594
Fertilizer × Variety	2	61.44	30.72	0.73	0.488
Compost × Fertilizer × Variety	4	306.89	76.72	1.83	0.146
Residual	34	1426.56	41.96		
Total	53	2622.83			

Appendix 15: Effect of compost application rate, time of fertilizer application and variety on grain yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	492589	246295	6.31	
Compost	2	297211	148606	3.81	0.032
Fertilizer	2	241085	120543	3.09	0.058
Variety	1	7022909	7022909	180.04	<.001
Compost × Fertilizer	4	18621	4655	0.12	0.975
Compost × Variety	2	152	76	0	0.998
Fertilizer × Variety	2	101292	50646	1.3	0.286
Compost × Fertilizer × Variety	4	5867	1467	0.04	0.997
Residual	34	1326279	39008		
Total	53	9506005			

Appendix 16: Effect of compost application rate, time of fertilizer application and variety on straw yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	237348	118674	4.43	
Compost	2	749570	374785	13.99	<.001
Fertilizer	2	119393	59696	2.23	0.123
Variety	1	444630	444630	16.6	<.001
Compost × Fertilizer	4	12741	3185	0.12	0.975
Compost × Variety	2	48415	24207	0.9	0.415
Fertilizer × Variety	2	11481	5741	0.21	0.808
Compost × Fertilizer × Variety	4	29274	7319	0.27	0.893
Residual	34	910919	26792		
Total	53	2563770			

Appendix 17: Effect of compost application rate, time of fertilizer application and variety on dry matter accumulation

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	14116.1	7058	8.65	
Compost	2	19906.3	9953.1	12.2	<.001
Fertilizer	2	318.7	159.3	0.2	0.823
Variety	1	110017.1	110017.1	134.88	<.001
Compost × Fertilizer	4	501.4	125.3	0.15	0.96
Compost × Variety	2	529.3	264.6	0.32	0.725
Fertilizer × Variety	2	619.9	310	0.38	0.687
Compost × Fertilizer × Variety	4	286.9	71.7	0.09	0.986
Residual	34	27732.2	815.7		
Total	53	174027.8			

Appendix 18: -Effect of compost application rate, time of fertilizer application and variety on thousand grains weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	2	18.37	9.185	0.94	
Compost	2	25.926	12.963	1.33	0.277
Fertilizer	2	37.926	18.963	1.95	0.158
Variety	1	50.074	50.074	5.14	0.03
Compost × Fertilizer	4	44.296	11.074	1.14	0.355
Compost × Variety	2	31.259	15.63	1.61	0.216
Fertilizer × Variety	2	2.37	1.185	0.12	0.886
Compost × Fertilizer × –					
Variety	4	17.63	4.407	0.45	0.77
Residual	34	330.963	9.734		
Total	53	558.815			