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EFFECT OF TIMING OF BASAL FERTILIZER APPLICATION ON YIELD OF THREE RICE (*Oryza sativa L.)* VARIETIES IN GUINEA SAVANNA ECOLOGICAL ZONE

BY

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DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for the award of a degree in this University or elsewhere, except for the references to other people's work which I have duly acknowledged.

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Supervisors' Declaration

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

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DEDICATION

To my lovely wives Shawana and Faiza and also to my children, Rahama, Mudasir and Sharif.

ABSTRACT

A field experiment was conducted at Nyankpala, in the northern region of Ghana, during the 2018 cropping season. The experiment was a 3 x 4 factorial experiments which was conducted with three (3) varieties at four (4) different times of fertilizer application. This was conducted using Randomized Complete Block Design (RCBD). It was twelve (12) treatments and replicated three (3) times which sum up to thirty-six (36) experimental units. The study was aimed at investigating the response of three rice varieties (C93, Gbewaa and Tox 3107) to four fertilizer application timings. The fertilizer application timings were; (1) farmers practice (3WAP basal application + 6WAP top dressing), (2) 1WAP basal application + 5WAP top dressing, (3) 2WAP basal application + 6WAP top dressing and (4) 3WAP basal application + 7WAP top dressing, were combined factorial with three rice genotypes; C93, Gbewaa and Tox 3107. Parameters measured were plant height, chlorophyll content, leaf area, tiller count, number of seeds per panicle, 1000 grain weight, biomass yield, grain yield and harvest index. Yield components were grain yield of the genotypes were significantly affected by the fertilizer application timing. Average grain yields of C93 and Tox 3107, which are varieties yet to be released, were similar to Gbewaa. Averagely, 2 WAP basal application + 6 WAP top dressing recorded the highest influence on grain yield relative to the remaining fertilizer application timing. The varieties varied in their response to the various fertilizer application timing. Biomass and grain yield of C93 were maximised by 1 WAP basal + 5 WAP top dressing, yield of Gbewaa and Tox 3107 were maximized by 2 WAP basal + 6 WAP top dressing and 3 WAP basal + 7 WAP top dressing respectively. Grain yield was highly positive correlated with 1000 grain weight (r=0.76**). The study recommends 2 WAP basal + 6 WAP top dressing for optimize yield in the selected three rice varieties. However, 1 WAP basal + 5 WAP top dressing for C93, 2 WAP basal + 6 WAP top dressing for Gbewaa and 3 WAP basal + 7 WAP top dressing for Tox 3107 respectively of fertilizer are recommended for yield maximization in rice production.

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LIST OF ACRONYMS

ACRONYM	**MEANING**
ADP	Adenosine Diphosphate
AJAR	African Journal of Agriculture Research
ATP	Adenosine Triphosphate
BC	Before Christ
CGIAR	Consultative Group on International Agricultural Research.
CGR	Crop Growth Rate
CSIR	Council for Scientific Industrial Research
DNA	Deoxyribonucleic Acid
EC	Electrical conductivity
ERECON	Environmental Rehabilitation and Conservation
FAO	Food and Agricultural Organizations
FAOSTAT	Food and Agriculture Organization Statistical database
FYM	Farm Yard Manure
GDP	Gross Domestic Products
IFA	International Fertilizer Industry Association.
IRRI	International Rice Research Institute
JICA	Japan International Cooperation Agency
LAI	Leave Area Index
LSD	Least Significant Figures
MDAEGPR	Millenium Development Authority for Economic Growth and Poverty Reduction

MiDA	Millenium Development Authority
MoFA	Ministry of Food and Agriculture
NPK	Nitrogen Phosphorus Potassium
PFJ	Planting for Food and Agriculture
PPI	Potash and Phosphate Institute
PPIC	Potash and Phosphate Institute of Canada
RH	Relative Humidity
SARI	Savanah Agricultural Research Institute
SRID	Statistic Research and information directorate
UDS	University for Development Studies
UN	United Nations
USA	United States of America
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
WARDA	West African Rice Development Agency

CHAPTER ONE

INTRODUCTION

1.1 Background

Rice (*Oryza sativa L.)* is a grass family crop called *Gramineae* (Poaceae). Rice is one of the world's three main meat plants and is accepted as their staple diet by about quarter of the world's population. Its worldwide output is projected at 650 million tons and the rice-growing region is projected at 156 million tone's (FAOSTAT, 2012).

Zhang *et al*. (2014) said rice (*Oryza sativa L.*) after corn is the world's second-largest cereal crop. Rice is a significant staple food for most of the world's population, adding about 23 half of the world's weekly calorie consumption, according to Brar and Khush (2003). Rice is the primary nutritional calorie cause eaten by over 3 billion individuals worldwide (Fageria and Baligar, 2003). It supplied 49 % calories and 39 % sugar in people's diets (FAOSTAT, 2012). The average annual consumption per capita is around 197 kg in 2007, according to FAOSTAT (2012). In Asian nations around 90 % of the world's food is generated and eaten (Khush, 2005). For well over 4,000 years, Asian peoples have been supplied on rice, serving as their main meat (Manzanilla *et al*., 2011).

Dibba *et al.* (2012) also indicated that rice is the most significant cereal crop in sub-Saharan Africa. More also, rice is the second largest cereal crop after maize (Zea mays, L.) in Ghana (Anang *et al.*, 2011). According to FAO (2015) in Ghana, rice is mainly generated by smallholder producers, which is a significant food and cash crop. The area under rice production in Ghana was 27,518 ha^{-1} in 1961, while the area was 215,905 ha^{-1} in 2013, an increase of about eight times the area of 1961. Similarly, rice output in Ghana was 30.400

tons in 1961, while production was 569.524 tone's in 2013, an improvement of almost nineteen twice that of 1961.

Witt *et al.*, (2007) indicated that contemporary rice cultivars involve a sufficient quantity of essential nutrients to achieve elevated grain yields. In 2010–2011, 14.3 third (24.7 Mt) of the total 172.2 metric mass (Mt) fertilizer (N + P_2O_5 + K_2O) produced worldwide was used for fruit manufacturing. The percentages of added oxygen (N), carbon (P), and potassium (K) were 15.4 %, 12.8 %, and 12.6 %, respectively (Heffer, 2013).

Owing to its input to the Gross Domestic Product (GDP), rice manufacturing and consumption in Ghana has continuously risen. It acts as an revenue stream and offers the agricultural family with employment (Millennium Development Authority (MiDA), 2010). According to Osei-Asare (2010) the per capita consumption of rice in Ghana rose from 17.5 kg per year between 1999 and 2001 to 22.6 kg per year between 2002 and 2004. It had reached 38 kg annually by 2011 (Ministry of Food and Agriculture (MoFA), 2012). According to Oteng (1994), the landscape of Savannah is home to about 80 percent of rice manufacturing. Approximately 73 percent of Ghana's complete ground region used for rice manufacturing is discovered in the Northern, Upper East and Volta areas, while the rest 27 % are discovered in the southern areas (SRID/MoFA, 2013).

Dobermann and Fairhurst (2000) recognized that extensive rice manufacturing and potential requirements for rice will involve knowledge-intensive approaches for the effective use of all ingredients, including nutrients for fertilizers. Irrigated and rainfed coastal crop technologies represent approximately 80 % of the rice region grown globally and 92 % of complete crop manufacturing.

The plant is submerged for all or portion of the growing season in coastal rice ecosystems. Rice is distinctive among cereal crops as its root system is tailored to soil circumstances that are mainly anaerobic. The aquatic climate also changes the accessibility of several essential nutrients, affecting the absorption of nutrients and using effectiveness and fertilization methods. Knowledge of nutrient management under saturated soil circumstances has advanced quickly over the previous several centuries to generate upland flour (Chauhan *et al.*, 2017).

Brammer (1962) and Obeng (1975) indicated that rocks in the coastal areas of Guinea and Sudan, primarily Lixisols, Luvisols and Plinthosols, are small to moderately thick, moderate to light textured and develop over voltaic sandstones, sandstone, phyllite and schists.

1.2 Problem Statement

Despite the enormous contribution of rice to the livelihoods and GDP of the Ghanaian economy, grain yield in the Guinea Savannah agroecology still remains very low (JICA/CSIR, 2001). Local rice manufacturing in Ghana, characterized by bad performance and uneven supply arising from low returns, has struggled to meet the ever-increasing national requirement, increasing the divide between demand and manufacturing (MoFA, 2011). Despite the country having a huge potential in rice production to feed its people and export some, Ghana is only 46 % self-sufficient. The 54 % gap in demand is bridged annually with rice importation, which is estimated at about USD 600 million (Duffuor, 2010). Such imports exhaust the country's foreign exchange and result in intense and unbalanced local manufacturers' rivalry and Most of whom follow adverse system yields (FAO, 2006). Pertinent constraints to enhanced rice production and yield maximization include weed interference, poor water management, predominant use of local unimproved varieties and soil fertility management which entails (adequate supply of balanced nutrients at the appropriate time) (FAO, 2006).

The most costly components in rice production are fertilizers and pesticides. Environmental pollution caused by nutrient leaching, particularly N, from rice fields has become a significant problem (Fageria and Baligar, 2003). Therefore the determination of an appropriate time where crops can effectively utilize applied fertilizers is imperative for sustainable crop production. Nitrogen, together with phosphorus and potassium, are the most crucial elements that are required for the growth of rice plants. Nitrogen is involved in the photosynthesis, a principal constituent of chlorophyll, enzymes, proteins and vitamins, assists in the production and use of carbohydrates, and is required for the energy reactions taking place within the plants (Sara *et al.*, 2013). Phosphorus is a significant plant life-supporting macronutrient. Phosphorus performs an important part in root proliferation and standardized grain packing as well as being a component of energy-rich ADP and ATP bonds and is also engaged in numerous vital plant procedures such as cell division, photosynthesis, breathing, tissue growth and development. Potassium is required for rice plants in a relatively higher amount, even more than nitrogen. It is involved in short term maintenance of the electrical potentials across the cellular membranes and turgor related mechanisms including cell expansion and enlargement, plant movements, development of pollen tube, stomatal opening and closing (Bhattacharyya and Jain, 2000).

There is a great opportunity to increase rice output, but most producers ' inefficient use of nutrients is one of the most limiting factors. This can only be addressed by proper nutrient management, which has become an essential component of contemporary technology for rice production (Chauhan *et al*., 2017). Balanced nutrient application in adequate quantities and at the appropriate and critical periods of plant growth are essential components of plant nutrient management. Different varieties vary in their response to quantities of nutrients applied and the time of application of these nutrients. Critical periods of nutrient demands of genotypes vary significantly owing to their genetic variations and affects nutrient use efficiency and economics of rice production (Awan *et al*., 2011). Jayachandran *et al*. (2002) stated that different genotypes differ in nutrient uptake, translocation and assimilation, and accounts for the superiority of some genotype over the other and make them more nutrient efficient.

More also according to Wopereis *et al*. (2009) reproduction and maturity phases each normally last for thirty days except the vegetative phase which lasts longer or changes. In most varieties, vegetative phase accounts for the differences in varieties especially late varieties. However, most of the fertilizer recommendation, application rates and timing are generalized for all crops regardless of the genetic variations. This could lead to inefficiencies in nutrients uptake and utilization by plants, inhibit yield maximization and essentially reduce the net profit of farmers. Proper management of nutrients is vital to enhancing nutrient use efficiency and improve crop production (Bilbao *et al.*, 2004). Therefore, it is essential to determine the optimum nutrient amount and to evaluate the critical nutrient demand intervals, particularly for distinct genotypes, to improve rice output and performance (Mannan *et al*., 2009).

In the Ghanaian staple diet, rice is regarded a significant plant and its accessibility is of excellent importance throughout the year (God-fray *et al*., 2010). In the current conditions, however, achieving self-sufficiency in rice production will be very difficult for the state. This can be accomplished by expanding the region or increasing the production per unit region.

However, production constraints, such as land tenure issues, small quantities of input subsidies, bad water control schemes that result in high-risk and non-intensive crop methods has greater influence on rice production. Other issues include poor soil, yields, low profit combined with the liberalization of the Ghana rice agreement. More also rice produced locally is often unattractive to potential customers and sometimes not accessible to them (Kranjac-Berisavljevic, 2000).

With anticipated fast population growth, urbanization and development of infrastructure in the close future, at the cost of plant production, there would be many requirements on accessible soil for appropriate purpose. If noted, such conditions could have a negative effect on welfare and stop the accomplishment of essential objectives of declining nutrition safety and misery (Adu-Gyamfi, 2012). However, the effects of such incidences could be mitigated by improving the productivity of today's peasants ' areas to meet potential requirement.

Each crop has also got its critical period of nutrient demand which is also very important in enhancing crop performance. That is, it may either be too early or too late for some varieties which will automatically affect yield. Therefore critical nutrient demand period can only be identified if the researchers will narrow their research work onto the variety level than only at crop type.

For the fact that fertilizers are very expensive and should be used effectively and efficiently to enhance production that would lead to maximum profit to the farmer. Ghana spends a lot of money on fertilizer subsidies for farmers every year. Because of the periodic rise in fertilizer prices beyond the affordability of normal citizens, it has always been so. Farmers cannot afford the entire costs because they also do not get a large returns that will attain them enough revenue in that process. Notwithstanding that importing rice to meet Ghanaians demand has always been on the increase at the expense of our local low production. This also takes away some of our revenue for the country which could have been used for other infrastructural development.

1.3 Justification

Aamer *et al*. (2000) stated that one of the variables accountable for poor rice output is the insufficient fertilizer supplied by incorrect implementation method. In rice production, the availability of plant nutrients, especially nitrogen at different phases of plant growth, is of vital significance. It is very essential to increase the effectiveness of fertilizer use, especially in emerging nations where fertilizer costs are rather large and growing. The sensible use of fertilizers adds significantly to the improvement of grain output and performance.

Although a considerable number of effort has been put into increasing yields in the country low input use still keep average yields low (Belder *et al*., 2005). Therefore there is a need to experiment on adequate quantity and timely application of fertilizer (especially the basal) to solve the problem of low yields in rice production. Basal fertilizer application is similar to that of the foundation of the building. Thus the strength of the building in holding up to the roof depends on the strength of your foundation. The nutrients in organic carbon and nitrogen are usually small. In most crop production basal fertilizer contains the three major nutrient elements (NPK) and if it is timely applied at recommended quantities can positively affect crop performance (Stoop *et al*., 2002).

Among the three growth phases (vegetative, reproduction and maturity phase), vegetative phase varies among the rice varieties and so must the basal fertilizer timing vary according to the variety to ensure effective performance. That is late varieties are usually having longer vegetative period followed by medium and then early varieties have very short vegetative period. Therefore because of these differences, it will not be suitable to some varieties if we recommend the same time of basal application for all the three classes of varieties.

It will involve knowledge-intensive policies for effective use of all outputs, including fertilizer nutrients, for based rice production and potential requirements. As irrigated and rainfed coastal crop schemes account for approximately 80 % of the crop region cultivated globally and 92 % of complete crop production (Dobermann and Fairhurst, 2000)

1.4 Objectives of the Study

1.4.1 Main Objective

The main objective of the experiment is to determine the optimum timing of basal fertilizer for maximum performance of yield components and grains of the selected lowland rice varieties to improve farmer's production efficiency

1.4.2 Specific Objective

The specific objectives are;

1. To determine the effect of basal fertilizer timing application on growth and yield of rice.
2. To determine the influence of fertilizer application timing on the three rice genotypes.
3. To determine the interaction effect of basal fertilizer timing with varieties on plant growth and yield.

1.5 Hypothesis

1. Null Hypothesis: Timely application of basal fertilizer would not have an effect on the performance and yield of rice varieties.
2. Alternative Hypothesis: Timely application of basal fertilizer would have an effect on the performance and yield of rice varieties.

CHAPTER TWO

LITERATURE REVIEW

2.1 Origin of Rice

Rice (*Oryza sativa*) was domesticated about 10,000 – 14,000 years earlier from the *Oryza rufipogon* native crop. It was now thought that the two primary plant subspecies–indica (widespread in tropical areas) and *japonica* (common in East Asia's subtropical and coastal areas) –were extracted from autonomous domestication occurrences. Another species grown, *O. Glaberrima*, in West Africa, was domesticated much subsequently. Recent DNA evidence suggests that all kinds of Asian berries, both *indica* and *japonica*, came from a single domestication situation in the Pearl River Valley region of China 8,200–13,500 years ago (CGIAR, 2018).

African rice has been cultivated for 3,500 years. *Oryza glaberrima* was propagated from its initial core, the Niger River Delta, and expanded from 1500 to 800 BC to Senegal. However, it never developed far from its original region. Their production even fell in favour of the Asian species, quickly carried East Africa into the Common Era and spread westward. African rice helped Africa conquer its famine of 1203 (CGIAR, 2018).

2.2 Botany of Rice

Rice attaches to the *Oryza* group genus of *Gramineae* (Poaceae) and the tribe of *Oryzeae*. There are 25 known species in the *Oryza* genus, 23 of which are native and two, *O. Sativa* and *O. Glaberrima* are cultivated (Brar and Khush, 2003). It is a short-day self-pollinated crop and is also a semi-aquatic, *arenchynmatic* plant of tissue. *Arenchynmatic* cells on the top and root of the leaf carries oxygen from the airborne components down the stems. A maize crop has a fibrous root structure of seed rootlets, root fibers and seminal organs. The plant has adventitious roots which are real concrete roots from the decreased nodes of the culm (Yoshida, 1981).

Plant height can range from 1 to 1.8 m, rarely more or less depending on the soil's cultivated variety and fertility status. Leaves are 50 to 100 cm long and 2 to 2.5 cm wide. Rice generates tillers and blooms between 5 and 12 mm in a twisted column and 30–50 cm lengthy inflorescence (Swaminathan and Bhavani, 2013).

2.3 Climatic and Edaphic Requirement for Rice Production

According to Yoshida (2012), maize adjusted to develop successfully in varying settings due to man-made environmental changes through domestication and choice years. Rice's environment continues to change, particularly with present climate change developments that have an important impact on temperature and precipitation. Globally, temperature and rainfall are the two predominant components of climate variability. The seasonal and geographical variation in temperature and rainfall has a significant effect on agricultural sustainability and controls agricultural activities in many parts of the world to some extent (Courtois, 2007).

The optimum temperature required for successful rice growth and development is 25 °C and 35 °C, according to Zada *et al*. (2014). Temperature fluctuations have had a tremendous impact on rice production, particularly during critical periods of development. Krishnan *et al*. (2011) indicated that during breeding phases a rise in heat beyond the optimum could result in important reductions in output. Zhang *et al*. (2013) also noted that elevated night time temperatures have severe impacts on tillering and spikelet fertility, which in addition reduces overall output of biomass and grain output. As a cold sensitive plant, temperature below the optimum can also affect rice yield.

During growth stages, low temperatures below 15 °C can trigger severe harm to plant growth and development (Krishnan *et al*., 2011). Rice is ranked among the world's most water-loving cereals (Courtois, 2007). Rice needs an appropriate quantity of water for peak development and return fulfillment at each point of its development. For grain production, an average of 200 mm per month or 600 mm per plant summer is considered optimal (Zhang *et al*., 2013).

As a dryland crop and as a rain fed plant under alternatively moist and moist circumstances, and as a continually wet plant, it develops like corn (Zwart and Bastiaanssen, 2004). Farmers grow rice in drained rivers and enclosed mountains in alluvial grasslands (Datta, 1981). Although it has less drought tolerance than other cereals, rice is well developed in arid irrigated areas (Hirasawa *et al*., 1999). Rice grows on a varied soils, however, it is best grown on well-structured soils of texture ranging between sandy loam to clay loams. The sandy loam to clay loam therefore provides enough soil water, aeration and penetrability. These areas should be fine tilth, adequate density, adequate and regulated nutrient supply, good soil humidity without pathogens (Tripathi *et al*., 2011). The optimum soil pH in moist circumstances for plant development is 5.5 – 6.5. Under frozen circumstances, it may increase from 7.0 to 7.2 (Somado *et al*., 2008).

In north-eastern China, rice is grown at latitude 53 ° N in central Sumatra and at 35 ° S in New South Wales, Australia (Mae, 1997). According to Mae (1997), in most rice-growing regions it is cultivated below sea level in Kerala, India or close sea level; and in Kashmir, India, and Nepal at altitudes above 2,000 m. It can be cultivated in upland circumstances, in slightly immersed circumstances and in water of 1.5 to 5 m.

Rice is predominantly tropical and subtropical (Witt *et al*., 1999). Some temperate regions around the globe, however, such as Japan, Korea, and Italy, generate high plant nutrition yields (God-fray *et al*., 2010). Climatic conditions such as weather, relative humidity, heat radiation, plant species and dietary requirements may influence plant development and efficacy (Datta, 1981).

2.3.1 Temperature

Temperature is considered one of the most significant factors influencing the growth and production of rice (Kobata and Uemuki, 2004). Rice temperature requirements differ from one point of development to another (Zhang and Zhang, 1999). The small temperature in late phases of growth delays the development of production of seedling (Yoshida, 1976). Generally speaking, the impact of increasing temperature on rice growing capacity is positive. It reduces photosynthesis, improves breathing, shortens the holding span of vegetation and seeds (Shemahonge, 2013).

Any further increase in the optimum temperature especially during reproductive stages may cause significant yield and yield component losses (Krishnan *et al*., 2011). Zhang *et al*. (2013) also reported that high temperature during the night has serious effects on the tillering and spikelet fertility which, in turn, decreases the total biomass production and grain yield. Rice, on the other hand, is a tropical or subtropical cold-sensitive plant. If low temperatures during the growth phases are below 15 °C, the plant's growth and development can be adversely affected (Krishnan *et al*., 2011).

According to Yoshida (1981), rice germination temperature recommend that 10 ^{o}C is considered as low and at 4 ^{o}C as high temperature that may hinder germination however the optimal temperatures that will facilitate germination ranges between 20 and 35 ^{o}C. During the seed emergence temperatures range 12 ^{o}C to 13 ^{o}C are considered low and at 35 ^{o}C as high but 25 ^{o}C to 30 ^{o}C considered as optimal temperatures to enhance its emergence. The optimum temperatures to promote tillering ranges at 25 ◦C to 31 °C but considered low at 9 to 16 °C and high at 45 °C (Greer and Webster, 2001).

2.3.2 Rainfall

Rainfall is the primary cause of water in agriculture. Rain-fed rice depends mainly on current rainfall, whereas water is supplied for rice irrigation through a storage system that collects and maintains precipitation for later use (Deng *et al.*, 2006). The rates and trends of rainfall vary widely from place to place and year to year (Dai *et al.*, 2018). There is presently no technique for estimating the amount and composition of rainfall for a given region with sufficient accuracy (Yoshida, 1981).

2.3.3 Relative Humidity

According to Food and Agricultural Organization (2002) Relative humidity (RH) immediately impacts the rice plant's fluid connections and negatively impacts leaf development, photosynthesis, pollination, fungal diseases such as rice blast and leaf blast and ultimately financial output. The dryness of the environment as depicted by the saturation gap (100 % Relative Humidity) decreases the output of salt material in crop plants by controlling stomata and leaf humidity capacity. According to Mitani-Ueno *et al.* (2018) decreased transpiration affects translocation of food materials and nutrients, mildly elevated RH 60-70 % is useful for the growth and efficiency of rice crops.

2.2.4 Solar Radiation

Gupta and O'Toole (1986) indicated that solar radiation is the most significant cause of energy for growing crops and has a major impact on temperature and evaporation. However, credible radiation data is rarely accessible in upland rice areas. Amgain *et al.* (2006), reported on decreasing of both maximum and minimum temperature by 4 °C and increasing solar radiation by 1 MJ m^{-2} day^{-1}. Rice grain output increased by 18 times and development time by 24 days demonstrating the exciting impact of temperature and solar radiation. Amgain (2006) further noted that heat, thermal radiation and humidity immediately influence seed growth physiological mechanisms and negatively influence seed output by affecting disease and insect occurrence. Tunde *et al.* (2011) indicated that in the breeding and ripening stage, rice output is immediately linked to solar radiation.

2.3.4 Soil and Nutrient Requirement

According to Somado *et al*. (2008), rice is generated in all continents except Antarctica and thrives in a region between 530 and 400 latitude. As a wet soil plant, it develops much like corn or corn, as a rainfed plant under alternatively wet and moist circumstances, and as a continually drained plant (Morillas *et al.,* 2019). On alluvial lands, submerged rivers, and terraced hillsides, farmers develop paddy (Brammer, 2017). Despite having less sensitivity to rainfall than other cereals, maize develops well in dry irrigated regions such as Egypt and Pakistan (Fahad *et al*., 2017). Similarly, given the sensitivity of rice to low temperature it also does well in these regions.

It is well recognized that heavy soils with characteristics of the river valley are more preferred than lighter soils in rice cultivation (Landon, 2014). The best soil for rice should have fine fractions of silt and clay, while a difference in yield from one place to another may be due to greater variation in soil conditions and extension of rice cultivation to unsuitable soils (Datta, 1981). The optimum soil pH for rice growth in dry conditions is 5.5 – 6.5. It may rise from 7.0 to 7.2 under flooded conditions (Somado *et al*., 2008). In elevated rice producing settings where improved varieties are used, the distinction must be made in the shape of mineral fertilizer between the soil's indigenous nutrient production and plant nutrient requirement.

Results on soil analysis in three regions for chosen upland rice increasing areas, in a 2010 research (Mghase *et al*., 2010).

Zebarth *et al*. (2009) showed that total nitrogen (N) range from 0.1 to1.2 % was low to support the growth of rice, available phosphorous (P) was also low < 7 to medium 7 – 20 mg kg^{-1} P. While organic carbon was medium ranged between 1.26 to 2.50 % (Shemahonge, 2013). According to these results, the areas that were under study experienced low N and P values which were the elements that limits rice production. More also the use of fertilizer among farmers was very low, about 15 to 20 % farmers use fertilizer in their field (Mghase *et al*., 2010).

Nwilene *et al*. (2008) stated that, inorganic fertilizer such as Triple super phosphate (46 % P), Ammonium sulphate (21 % N), Urea (46 % N) and Calcium ammonium nitrate (26 % N) are straight (single) fertilizer that supply only one primary nutrient, and are widely used in some African countries. The suggestion for nitrogen fertilizer varied from 100 kg to 120 kg N ha^{-1} if soil has low N (less than 1.0 g total N kg^{-1} of soil). More also, 60 to 80kg N ha^{-1} is recommended when the soil has a medium N content (between 1.0 to 2.0 g total N kg^{-1} of soil) while less than 40kg N ha^{-1}, which is high N content in the soil (i.e greater than 2.0 g total N kg^{-1} of soil). Phosphorous application of 30 to 60 P for low P content soils, 15 to 30 kg P for medium and 15 kg P for high P contents soil (Heckrath *et al*., 1995).

Recommendation for potassium (K) is 30 to 60 kg K for low, 15 to 30 K for medium and 0 to 15 K for high K in the soil (Oikeh *et al*., 2008). Application of phosphorus and potassium should be performed one week before transplantation, while top dressing can be implemented in three equivalent divisions during transplantation/sowing, mid-tanning and introduction of panicles (Food Agricultural Organization, 2009; Somado *et al*., 2008).

2.3.5 Soil Moisture Content

Most terrace fields are situated in reduced scenery to allow simple transport moisture from greater cultivation or normal causes of precipitation (Ijumba and Lindsay, 2001). These regions of marsh cultivation may be flat hills or terraced and bundled hillsides of fields otherwise hillside. In alluvial plains, deltaic lowlands, coastal lowlands, tidal flats, marshes, and significant river basins, wetland rice is more commonly discovered (Brinson and Malvárez, 2002). In general, such regions are defined by a normal or caused "aquic" humidity system that means elevated humidity and poor oxygen requirements. As a result of this elevated necessity for low moisture humidity, the ground features of floating rice cultivation may differ less than those of alpine or dryland rice (Brady, 1981).

Only 4 % of the arable soil in Africa is now irrigated, 70% of which is in four nations: Egypt, Madagascar, Nigeria and Sudan (FAO, 1996). Although not all arable land in Africa can be irrigated due to bad soil or inappropriate place in terms of water resources and altitude, there is considerable capacity to increase meat and cash crop production through agricultural growth (WRI/IIED, 1986).

According to Kajiru (2006) Rainwater retention is one of the most prevalent and significant methods of soil management. It improves the level of accessible soil moisture for crop growth and development when rainfall water infiltrates and retains in the soil. Saito *et al.* (2005) disclosed a rise in output of improved varieties of upland rice when there is no water stress during the development phase.

Junge *et al.* (2008) noted that the quantity of precipitation and its allocation, groundwater and groundwater form fertility state are among the key reference fields for the efficient use of bind pads. Open ridges are very common in many areas especial in the Lake zone.

However, the technology is not effective in moisture conservation rather than a water drainage system. The nature of the ridges allows movement of water through furrow between ridges out the field, while flat cultivation exposes the field to the risk of soil erosion especially when the field is located on a slope (Kajiru, 2006).

2.4 Growth and Development of Rice

2.4.1 Germination of Seed

According to the International Rice Research Institute (2002) Rice plant growth is split into three stages: vegetative, sexual and maturing. To identify the growth stages of a rice plant, the development stages in each phase are further divided according to the numerical scale of 0-9. Each amount in the scale refers to a particular phase of development. Three development phases therefore comprise of a sequence of 10 separate stages.

Yoshida (1981) also indicated that the temperature mostly affects the germination of rice. Through influencing the mobilization phase and post germination development, the temperature has a deep impact on germination. The germination impacts of temperature can be examined in three dimensions: proportion of temperature, moment, and germination. For inhibition, moisture is also essential, allowing crops to emerge through the soil layer and the method of internode elongation. In addition, the emerging plant needs nutrient moisture and plant water supply.

2.4.2 Growth phases and stages of rice

According to Tripathi *et al*. (2011) vegetative which is the first growth phase start from the germination stage to panicle initiation. This includes four sub-growth phases from germination to development, thus starting from phase 0, while phase 1 includes seedling, tillering phase 2 and elongation phase 3 of the stem. The reproduction stage that lasted from the initiation of the panicle to the flowering has to finish three phases of development. Reproductive phase involves initiating panicle to boot as stage 4, then stage 5 is going or panicle exertion and stage 6 growing concerns. Phase of maturity which is the last stage of rice development which also has to go through three phases of development. As stage 7, the milky grain stage followed stage 8 at dough grain stage and the last stage of growth which is stage 9 mature grain stage.

2.5 Rice Production in Ghana

According to Glenna *et al*. (2012) rice is a major food product for Ghanaian crops and the country as a whole, accounting for about 15 % of GDP. Although maize continues to be Ghana's most important cereal crop, food production and consumption remain to rise, particularly in metropolitan regions. According to SRID/MoFA (2010) the Millennium Development Authority for Economic Growth and Poverty Reduction revealed that maize speaks for almost 13 % of Ghana's complete grain intake. It is increasingly leaving other traditional foods of rural and metropolitan residents as an increasing diet and main factor. Between 1989 and 1996, rice production in Ghana increased steadily at a pace of 13 percent per year owing to development of the region and increased yield from 0.9 kg ha^{-1} to 2.4 kg ha^{-1} (MiDA, 2010; MoFA, 2009).

The distribution and production dynamics of rice differ among different rice ecologies, with rainfed account for about 78 %, irrigated 16 % and inland valley account for 6 % (Oteng, 1994). Oteng (1994) reported that about 80 % of the production of rice is done in the interior savanna while 60 % is cultivated in the hydromorphic ecology. About 73 % of the total land area is situated within the Northern, Upper East and Volta regions. The remaining 27 % of land cultivated is distributed among other regions of the country (SRID/MoFA, 2010). The three regions also accounted for 80 % of the national rice output production in Ghana. An average yield of 2.96 mt ha^{-1} in these three regions exceeds the national average of 2.71 mt ha^{-1}, but is significantly lower than the average yield of 5.48 mt ha^{-1} in the Greater Accra region (SRID/MoFA, 2010). The land area harvested for 2013 was 215,905 hectares for total production of 569, 524 ton's. Recurrently, Ghana experienced (3 %) and (9 %) increase in harvested area and total production between 2012 and 2013 respectively (FAOSTAT, 2015).

The rice products have potential for being the focus of Ghana's import substitution strategies (Diao *et al*., 2017). Rice is now a staple food in Ghana's towns, as in other Western African nations, and most rice eaten in Ghana has been introduced since the 1980s, with exports primarily from East Asia (Andam *et al*., 2019). For the last decade, Ghana has been importing 60 percent of its rice consumption (Ragasa *et al*., 2014). Along with imports, local rice production and productivity has also increased (Ragasa *et al*., 2014). According to Andam *et al*. (2019), Majority of local rice consumption came from exports. However, rice local production has grown alongside imports, Given the growing importance of products such as rice in Ghanaian diets, it is not surprising that the policy dissertation on Ghana's agricultural development is broadly in favor of supporting local production and reducing reliance on imports (Andam *et al*., 2019). This will enable the local producers derive profits from the dietary changeover. Many interventions have been instituted in response to the apparent disadvantages accumulated in the country from imports of rice thus import bills (MoFA, 2017). The Ghanaian government's main policy intervention in the agricultural sector, the Planting for Food and Jobs (PFJ) program, is seeking to promote rice production by 49 percent to displace imported rice (MoFA, 2017). The current rates of production are small and there is a strong opportunity to increase rice output to self-sufficiency. This is possible considering the fact that in 1976 the country achieved 99.2 % food sufficiency due to the Operation Feed Yourself concept introduced by the then government (Bimpong, 1998). The current estimated per capita consumption for the year 2013 is 35 kg. The range of domestic production of milled rice between 2009 and 2013 is 270,000 to 405,000 MT and the area under cultivation is 160,000 to 218,300 ha (SRID/MoFA, 2013).

Household rice production in Ghana has been for an extended span of moment a smaller quantity than consumption demands. Dercon (1993) proposed that rates are the overall method by which financial strategies are probable to impact agricultural factors such as production, demand, sales and revenue. Analyzing the reaction of production to variable rates is a key factor in evaluating the impacts of growing economic openness. Although endowed with ample agricultural and natural resources, the returns of most Ghana-produced plants are well below their climate capacity (Van Oort and Zwart, 2018). With achievable yield potentials of 6.0 mt ha^{-1}, 2.0 mt ha^{-1}, 1.0 mt ha^{-1}, 49 mt ha^{-1} and 72 mt ha^{-1} for corn, millet, cocoa, yam and pineapple, has reduced to 1.7 mt ha^{-1}, 1.3 mt ha^{-1}, 0.4 mt ha^{-1}, 15.3 mt ha^{-1} and 50 mt ha^{-1} respectively were observed for these crops (MoFA, 2011). The nation noted 2.4 mt ha^{-1} in 2009, 2.72 mt ha^{-1} in 2010, and 2.71 mt ha^{-1} in 2011, with a climate capacity of 6.5 mt ha^{-1} for rice. This shows that Ghana achieved only 38 % of achievable output by the 2009 forecast, with returns of roughly 42 % of climate capacity found in the years between 2010 and 2012 (MoFA, 2011).

2.5.1 Rice Production in the Northern Region of Ghana

The Northern region is the highest producer of rice and accounts for 60 % of national production (Ministry of Food and Agriculture (MoFA) Japan International Cooperation Agency (JICA), 2012). Regardless, there remains a great discrepancy between the estimated yields and potential yields of rice in the region. According to MoFA (2011) the yield of rice is less than their climatic potential. Yield divide is the distinction between peasants lowest achievable return and real output. Maximum achievable output relates to the greatest output that a plant can achieve in a recognized setting; alternately, yield gap relates to plant model projections that suppose ideal leadership or the greatest returns in Agricultural Research Stations or peasants ' areas. There are reports that biophysical factors, socio-economic factors and institutional or political aspects affecting yield gaps cannot be exploited, but that gaps can be bridged mainly due to sub-optimal crop management practices through the deployment of more competent research and extension delivery that can be used.

Referring to the Statistics, Research and Information Directorate (SRID) of the Ministry of Food and Agriculture (2015), the Northern Region of Ghana has five months of food insecurity in rice crops, although it has plenty of agricultural and natural resources. According to the Ministry of Food and Agriculture (2011) annual report on facts and figures, rice output are less than its environmental capacity. Comparing the achievable yields of 7.0 mt ha^{-1}, 3.0 mt ha^{-1}, 15 mt ha^{-1} and 17 mt ha^{-1} respectively for maize, millet, yam and Cassava to the potential yield of 1.8 mt ha^{-1}, 1.8 mt ha^{-1}, 12.5 mt ha^{-1} and 13.3 mt ha^{-1} respectively indicates less yield for these crops. At a production yield capacity of 7.2 mt ha^{-1} for rice in terms of its climate, the region observed 2.61 mt ha^{-1} in 2009, 3.0 mt ha^{-1} in 2010, 2.33 mt ha^{-1} in 2011 and 2.36 mt ha^{-1} in 2012. Table 2 shows rice production per region in Ghana. Rice is grown in all ten regions of the country (Ministry of Food and Agriculture (MoFA), 2010). The Northern region is the highest producer of rice which accounts for 38 % of national production, Upper East being the second with 27 % and Volta region the third with 14 %

(Table 1). These three main rice producing regions produce between 45,000 tonnes to 60,000 tonnes per year each (USAID, 2009).

Table 1: Rice Production per Region in Ghana

Region	Production (%)
Northern	38
Upper East	27
Volta	14
Ashanti	6
Western	5
Eastern	4
Greater Accra	3
Brong Ahafo	1
Upper West	1
Central	1

Source: USAID (2009)

Rice production is largely dependent on the most hazardous economic variables among the various variables that influence output (Altieri, 2018). The output of rice relies on the highest input mixture to achieve an exceptional amount (Mueller *et al.*, 2012). Inputs are not restricted to acquainted production outputs, according to Tanko *et al.* (2016), but include differentiated economic variables that are supplied by design. The unique characteristics of the environment include rainfall characteristics that include duration and intensity, relative humidity and temperature that is responsible for rice yield variation (Altieri, 2018). Some of the variables have a direct impact, while others have a different connection to rice output (Tanko *et al*., 2016).

2.5.2 Characteristics of Rice Consumption in Ghana

Compared to most Western African nations, the view that Ghana has small median daily rice consumption per cent is a previous concept. This could be said to have been the situation when Ghana used about 9 kg per person, as the median was 25 kg in the same sub-region for other nations (Akanko *et al*., 2000).

Since the 1980s, rice imports have continued to increase gradually and contribute more than 50 % of all food eaten in the country. Rapid urbanization and easy food preparation and transport can be ascribed in big portion to the rise in supply (Bimpong, 1998). Imported rice is also revealed to be of superior performance for local rice and thus order greater rates. For a long time, local rice output in Ghana has been less than consumption requirements.

Rice demand began to surpass demand owing to population expansion and increased living standards. This scenario was also compensated for by unpredictable production and marketing arrangement. The state therefore exports up to 200 % of local consumption to compensate for the lack of supply (Dogbe, 1996).

2.5.3 Importance of Rice

According to Datta (2004) rice serves more than two billion individuals globally and is Asia's top one staple cuisine supplying 40 % to 70 % of the complete meat calories eaten. Rice is also used for animal feed and offers poor individuals with a significant source of revenue; high-quality rice adds extra revenue (Efferson, 1985). A quantum leap in rice yields has taken position over the previous three centuries because of the Green Revolution, although enhanced food production has not eliminated poverty and hunger (Tscharntke *et al.*, 2012). The rise in yields helped avoid famine and discourage further disturbance of meat production in Asia, unlike in some African nations, where the absence of infrastructure and political will led in Green Revolution methods not being used (Dada, 2006).

According to Gnanamanickam (2009) Rice is lives for most of Asia's individuals. Rice has influenced thousands of millions of people's societies, diets and markets. The United Nations selected the year 2004 as the International Year of Rice, taking into account its imperative position. It was distinctive in the past of the United Nations to devote a year to a commodity. The 57th meeting of the United Nations General Assembly, however, recognized that rice is the staple food of more than quarter of the world's population, confirmed the need to raise consciousness of the position of rice in alleviating poverty and malnutrition, and reaffirmed the need to concentrate country attention on the part rice can perform in food security and poverty eradication and the year 2004 was proclaimed the International Year of Rice (Gnanamanickam, 2009).

Although rice is the second largest nutrition supply for Asian nations due to the area it is grown, primarily in south-eastern areas where it is an economic crop for landowners and employees who develop it on millions of farms throughout the region (Gomez, 2001). Historically, rice was cultivated l0000 years ago in the river valleys of South and Southeast Asia and China since it served as the most important food for people. Although Asia is the main place of rice cultivation but it was harvested in other continents like Latin America, Europe, some parts of Africa and even USA (Gnanamanickam, 2009).

Since rice offers 21 % of energy and 15 % of protein, its quantity and quality required major attention (Gnanamanickam, 2009). While these two variables could be enhanced through biotechnological methods, the development of this economic plant globally is subject to important limitations. Rice pests and illnesses trigger important rice production losses every year. Several insects invade rice including Rice Water Weevil, Rice Stink Bug, Fall Armyworm, Chinch bug, Mexican corn borer, Grasshoppers, Blister Beetles and Leafhoppers. This is only half the issue, as many pathogens trigger serious damage such as fire, rice yellow mottle virus and bacterial blight (Reissig *et al*., 1985).

Many African nations have embraced rice production in their different nations to prevent food crises. It is anticipated that the six billion worldwide population of today will achieve eight billion by 2020. Therefore, we must generate 25-40 % more rice with less soil and air and less agrochemical use. Despite the improved varieties and techniques in location, rice output has stagnated for the last three centuries (Datta, 2004).

In several nations, Rice performs an imperative social function. The rice straws are used for other purpose depending on location; such as firewood, thatching, starch production, and artwork. Growing, buying and consuming rice is vital to many nations worldwide society. Rice has traditionally been a wealthy commodity in Japan and is now a highly prized plant. Many rituals involve rice bed preparing, plant seeding, and harvesting. In China, rice grain was produced for 3000 to 4000 years, where it grew rapidly but certainly to become a significant component of aristocratic lives. China's rural culture has urbanized around rice cultivation, and rice-prepared food is the basis for celebrations such as the Land Opening Festival, which signifies the start of the rice cultivation cycle, and the Spring Festival

(Leppman, 2005). Rice is an important component of the culture even in Western countries (Carney and Carney, 2009).

In Ghana rice is the most dominant crop products use in almost all festive and occasion gatherings and which is highly appreciated and recognized as special food dishes for our important guest/personnel (Office of the Gene Technology Regulator, 2005).

Rice is a nutritious cereal crop intended for individual use (Bhattacharya *et al*., 2012). It is the primary cause of energy and an important supply of protein that provides significant quantities of the suggested zinc and niacin nutrient consumption. Rice, however, is very small in calcium, zinc, thiamine, and riboflavin, almost without beta-carotene. Because of its elevated real digestibility (88 %) among plant enzymes, rice flour is the wealthiest in existence and also offers minerals and fiber (Bhattacharya *et al*., 2012). Rice calories are especially essential for the needy, accounting for 50 to 80 % of the weekly caloric consumption (Ahmed *et al*., 2012). To mention a few other purposes, rice can also be used in cereals, snack foods, brewed drinks, flour, petroleum (rice bran powder), syrup and spiritual rituals (Ali *et al*. 2014; Chavan *et al*.,1986). It is also thought that rice has medicinal properties and is used for the same in many nations, including India (Office of the Gene Technology Regulator, 2005)

2.6 Rice Production Constraints

The potential of Africa in meeting its demand for rice is hampered by numerous constraints attributed to biotic and abiotic stress, and crop management lapses (Johnson *et al*., 1998). According to Pradhan *et al*. (2015) for the continent to bridge the gap between demand and supply of rice, there is the need to urgently adopt strategies for mitigating these constrains.

High cost of inputs as a constraint have been considered serious problem that hinders rice production especially when in short supply traders take advantage of that and charge high price (Veeraswamy *et al.*, 2003). Even though sometimes there are subsidies on the most used fertilizers only a marginal number of farmers can access it for use. The amount of subsidy provided by the State and Central Governments is very small relative to the real selling cost suggested for multiple outputs (Singh and Varshney, 2016).

Non-availability of desired technology also account for low production. Consequently, suggested rice techniques may not be appropriate for all areas (Shigwan, Meshram and Dalvi, 2019). State Department of Agriculture's suggestions for achieving greater returns may not be applicable to circumstances at village stage. As a consequence, return decrease at farm stage is possible owing to different climate and soil variables. Lack of awareness and understanding of certain improve techniques regarding the local rice production by the farmers (Singh and Varshney 2016).

2.6.1 Traditional Rice Varieties

Traditional varieties of rice to a larger extent do not satisfy the required standard of genetic and physiological purity, good health and other attributes that are characteristic of quality seed (Dogbe *et al*., 2015). Improved varieties offer good quality seeds that are pure (of the chosen variety), full and uniform in size, viable (more than 80 % germination with good seedling vigour), and free of weed seeds, seed-borne diseases, pathogens, insects or other matter (International Rice Research Institute (IRRI), 2003). Such crops have elevated yield per unit region as the crop's genetic capacity can be fully utilized, promoting the use of lower seed rates with elevated seedling development (> 70 percent), lower replanting, more standardized plant displays, and stronger premature crop development. Early vigorous development decreases weed problems and improves plant strength to pests and illnesses of insects. A combination of higher crop emergence, vigorous early crop growth, and increased crop resistance to insect pests and diseases will result to a 20 % increase in yield of improved varieties over traditional genotypes (International Rice Research Institute (IRRI), 2003).

Traditional varieties have poor quality seeds that give rise to poor seedling vigour, non-uniform growth and maturity and further make rice seedlings prone to insects and disease, weed-pests, and adverse environmental conditions (Ellis *et al.*, 1995). Good performance plants have elevated yield per unit region as it is possible to fully exploit the genetic capacity of the plant. Planting good-quality seed is often one of the fields removed for granted as peasants perform plant development even from poor-quality seed saved by peasants. One of the most critical leadership choices of the farmer is the choice of the crop and seed supplier that could maintain grain output.

Improved varieties are being created to enhance farm output and decrease the growing requirement for meat owing to population growth. Hybrid maize adds 9 % to the crop output capacity relative to irrigated plains elite inbred strains (Peng *et al.*, 2009). Zhang *et al.* (2014) recorded a 12 % fold rise in output capacity compared to normal hybrid and inbred strains in the super hybrid rice ranges. Hybrid rice cultivars with multiple spikelets per panicle are marked by big panicles or extra-heavy panicle forms. Despite these types huge capacity for improving rice output, these cultivars often lack their elevated output capacity owing to bad grain filling owing to bad nutrient management (Peng *et al.*, 2009).

2.6.2 Pests and Diseases

Rice pests are known to devour and cause considerable damage to the crop throughout growth phases and also during the post-harvest and storage periods (Jahn *et al.*, 2007). Insects pest are the most prominent rice pests in the field and during storage. These pests attack all vegetative parts of the plant and cause considerable damage to reproductive parts during seed filling. About 800 different insect species have been identified and classified worldwide to constitute rice pests that cause considerable damage during production and at storage (Cohen *et al*., 1994). The damage caused by these species varies from country to country as influenced by prevailing conditions and crop management systems. Leafhoppers and planthoppers are the major insect pests among other species that solemnly cause significant yield losses in rice production. Stem borers and leaf defoliating species are also known to transmit diseases (Jahn *et al*., 2007). Pod sucking bugs also cause considerable yield loss during grain filing.

Weeds are economic important pests of rice that cause considerable yield loss through competition for ecological niche and allelopathy (Ze-Pu, 1996). The prime restrictions to rice cultivation in direct-seeded areas are the occurrence of red rice, which is widespread all over the world. West Africa Rice Development Association (WARDA) stated that about 27 % to 37 % of the entire labour for rice cultivation is due to weed control. As compared to cereals like sorghum and maize, rice is very slow in establishing its canopy thereby causing weed competition for soil nutrients, light and moisture (DeVries and Toenniessen, 2001). In West Africa *Oryza barthi* and *O. longistaminata*, are among different weed type that causes yield reduction in rice. According to WARDA (1999) weeds can lead to about 25 % to 40 % yield loss in rice and may also lead to total crop failure if they are left uncontrolled.

According to Dean *et al*. (2005) rice blast is a fungal disease that is very pronounced in rice-producing areas in Africa and causes significant yield loss. The disease can affect the leaf, sheath, neck, panicle, rachis, stem node and grains and is pronounced throughout the growth stages of rice. According to Candole *et al.* (2000) rice blast can cause a substantial decrease in grain bulk density and yield of rice. Sheath blight, rice ragged stunt and tungro are other major diseases that cause drastic yield reduction in rice (IRRI, 2012). Brown spot of rice has been overlooked as one of the most detrimental rice diseases. It is most common in rainfed and upland areas. This condition assaults the plant from the nursery seedling level to the field milk level. Spots differ in form and magnitude and occur on the leaves, leaf tissue, and glumes coleoptiles. Brown place is another yield-reducing factor also recorded in the world's rice-growing fields. Savary *et al.* (2000) also noted that about 5 % of output losses in South and Southeast Asia's coastal production fields occur from brown patch harm.

2.6.3 Fertility Status of Ghanaian Soils

Naturally, most of the Sub-Saharan Africa (SSA) surfaces are not very productive relative to other islands in the globe (Law-Ogbomo and Law-Ogbomo, 2009). African plants are characteristically small in nitrogen, sulfur, potassium and potassium accessible (Grant, 1981). These soils are strongly leached, with elevated acidity (pH < 5.5), poor organic soil content, and swap ability for cations (Alwis, 1995). In relation to acute deficiencies in macronutrients, micronutrients such as zinc and boron are supposedly restricted at sites undergoing constant cropping (Wendt *et al.*, 1996). Physically, plants in sub-Saharan Africa are small in organic soil, combined with bad soil cover, leading in bad soil structure, root density, and subsequent susceptibility to soil deterioration (Law-Ogbomo and Law-Ogbomo, 2009).

Ghana's sediments are extremely eroded with predominantly medium textured ground layers where the prevalent textural classes are rocky loams and loams (FAO, 2006). The B-horizons— subsurface horizons displaying growth characteristics or important changes — may comprise extensive crude content as either grass or stone or concretionary products. The ground's crudeness has an adverse effect on their physical characteristics, especially their ability to hold water. Thus, during the increasing summer, plant moisture pressure is not unusual (Loveland and Webb, 2003).

Input and output balances of nutrients are very important for keeping land nitrogen balance (Buri *et al.*, 2012). Removing and losing considerably more plant nutrients than being utilized, resulting in progressive soil impoverishment. There is still extensive use of traditional, soil-exhausting growing methods (Gerner *et al.*, 1995). Nearly all Ghana's crop balances indicate a nutrient deficit (the distinction between the amounts of plant nutrients employed and the amounts withdrawn or wasted). This reflects a reduction of prospective output and gradual soil degradation according to the FAO (2004).

2.7 Lowland Soils in Ghana

Soils of the lowland ecology of Ghana are deficient of some essential nutrient elements. The extent of deficiency in these elements vary considerably across different locations (Buri *et al.*, 2008). Lowland soils for rice cultivation in Ghana are constrained by drudgery in land preparation, water management constraints and inefficiencies, and soil fertility deficiency and nutrient management (Buri *et al.*, 2008). These constraints are major hindrance to rice yield maximization in lowland ecologies, even with the use of improved high yielding varieties. Efficient water and nutrient management are therefore imperative to yield maximization and sustainable rice production in the lowland ecology.

Lowland forests are characteristically extremely acidic with $pH < 0.5$ in drier savannah agro-ecological areas of Ghana. Despite the relative acidity of some of the materials within this area, this is on a restricted scale. In the savannah agro-ecology, exchangeable acidity is also greater (median 1.0 Cmol kg^{-1}), which possibly impacts fundamental cation balances, especially Ca and Mg, contributing to negative effects on crop development. Lowland plants complete oxygen and ammonia have small to mild organic carbon concentrations. Organic carbon levels at some sites could be as low as 4 g kg^{-1} and at some location as high as 37 g kg^{-1} (Buri *et al.*, 2008). The mean concentration is about 120 g kg^{-1}. However, organic carbon concentrations are relatively smaller within the agro-ecological savannah area with an overall average level of about 6.0 g kg^{-1} with a 50 percent coefficient of variation across the site. In soil agro-ecology, Total Nitrogen has a mean value of 1.1 g kg^{-1} with very little variation relative to forest ecology. Local mean concentrations are below 0.7 g kg^{-1} (Buri *et al.*, 2008). For all soil types and across all agro-ecological areas, available P is usually small (CSIR-SARI, 2012). Available P is the nutrient that is most restrictive. It differs widely between places within the agro-ecological areas of the forest. Mean forest concentrations are approximately 5 mg kg^{-1} but vary widely. The average P concentrations accessible for grasslands within the coastal areas are even smaller and also vary considerably with the rate of variability exceeding 60 %. The mean concentration is about 1.5 mg kg^{-1} (CSIR-SARI, 2012).

The use and accessibility of P is improved under hydromorphic circumstances. This allows present P concentrations very insufficient and therefore very limited because of their important consumption to use these plains for crop agriculture (Buri *et al.*, 2008). Most coastal forest regions in Ca, Mg and Na are comparatively sufficient, but other regions have temporary deficiencies in K (Buri *et al.*, 2008). However, exchangeable levels of cation within the agro-ecological zones of the savannah are generally low compared to those in the agro-ecological zone of the forest. For Volta sequence (2.2-5.8 Cmol kg^{-1}), the exchangeable calcium is mild and comparatively greater than the Lima sequence (1.76-2.24 Cmol (+) kg^{-}

^{1}). According to Buri *et al.* (2012) mean exchangeable concentrations of K (0.22 Cmol (+) kg^{-1}) and Mg (0.9 Cmol (+) kg^{-1}) are also quite small with variation coefficients above 74 %, 90 % and 77 % respectively. Therefore, there are comparatively effective amounts of cation exchange capacity.

Soils are comparatively small in clay material within the drier savannah agro-ecological areas and coastal nutrients. Most places display less than 10 % ceramic material, but again with higher variability with a ratio of variation greater than 60 %. However, the sediments indicate significant silt concentrations (average > 60 times) and are therefore mostly silt loam in shape, with sandy loam secluded fields. The silt generally occurs extensively and covers more of the plains (Bailey, 1980). The sediments are usually profound, but owing to poor clay content, the water holding capability may be small. The grounds are also comparatively small in carbon in the woodland environment. They also comprise comparatively greater concentrations of silt, according to Bailey (1980). Some are big and some are very small. Textures range from sandy loam to loam through silt loam. Compared to the Savannah, the water holding capability of these materials is greater (Buri *et al*., 2012).

According to Wakatsuki *et al*. (2004), Ghana's plains comprise mostly floodplains and river plains across the nation. In morphology, groundwater form, vegetation and hydrology, these planes were distinguished as heterogeneous. Therefore, lowland forests happen throughout the country's agro-ecological areas. These agro-ecological areas include the drier Savannahs (Sudan, Guinea, and Coastal) spanning the country's northern and mediterranean areas, and the Forest spanning the country's western, middle, and southern routes. According to predictions, in relation to the parts of areas used for annual cold plant production, the country has more than one million hectares of soil that can be produced for effective and sustainable plant production (Wakatsuki *et al.*, 2004).

Rice increasing in the agro-ecological fields of Savannah is common due to comprehensive poorly handled land. These waters are deep clay loams to gravel loams and comprehensive water resources from the primary rivers, including the Volta, Oti, Nasia, Daka, Kulda and their innumerable rivers that could be used for construction reasons. The soil is formed by shale / mudstone, sandstone, granites and phyllite (Adu, 1969, 1995b, 1995a; Dedzoe *et al.*, 2001).

2.8 Specific Nutrient Requirement of Lowland Rice

Grain yields decline as soil fertility decreases under rain fed circumstances (Fairhust and Witt, 2002). The decrease in land productivity in West Africa plains outcomes in poor plant production among tiny owned fields (Abunyewa and Karko, 2005). Fertilizers provide nutrients for growth and development to rice plants (Nayak *et al.*, 2018). Paddy groundwater scheme favours plant quality retention and organic material build-up and is the cornerstone of watershed cultivation projects ' long-term development (Sahrawat, 2004). However, this balance has been troubled by the outputs of mineral fertilizers now having an important part in present extensive rice monocropping schemes (Ladha *et al.*, 2000). Nutrients removed from the plant must be replenished in order to preserve soil fertility and efficiency and to avoid soil degradation, hence the need to use fertilizers to replenish those plants (Van Kauwenbergh, 2006). It is observed that it is possible to achieve sustainability in rice plant production by integrating chemical fertilizers and natural manures (Khan *et al.*, 2001). One of the easiest methods to boost productivity and rice production is to fertilize the rice plant. Rice is a strong eater and highly susceptible to ground nutrient quantity and equilibrium. The fertilization of the plant using accessible organic and inorganic fertilizers is therefore vital (WARDA, 2002).

In sub-Saharan Africa, fertilizer use is quietly small, weighing about 10 kg ha^{-1}, whereas Asia and Latin America have suffered important increases in use (Laegereid *et al.*, 1999). Rice reacts well to the most significant necessity in Guinea Savanna with oxygen and oxygen fertilizer (Kwarteng and Towler, 1994). Nitrogen is the main limiting nutrient in the production of modern rice varieties and its efficient use is important for the economic sustainability of cropping systems. Several trials have shown that applying N fertilizer to maize contributes to increased crop height, panicle amount, leaf volume, panicle amount and seed output (Balasubramanian *et al.*, 2002; Walker, *et al.*, 2008). Urea is now the leading N crop fertilizer (Huh *et al.*, 2019).

Phosphorus application is vital to allow the plant during the premature vegetative phase to resist aerial drying (Reddy *et al.*, 1991). Rice plants fertilized with both nitrogen and phosphorus withstand flooding and generate considerably greater grain yields than unfertilized or nitrogen or phosphorus alone fertilized plants (Reddy *et al.*, 1995). N is essential for all life processes in plants. N fertilizer application generally results in a fast graphic rise in plant development (Mengel *et al.*, 2001). Nitrogen is required by the rice plant during almost the entire vegetative process, but especially during the initiation phases of tillering and panicle (Becker *et al.*, 2003). Phosphorus has been shown to play an important part in rice's physiological development, although its impacts are not as noticeable as oxygen (Oikeh *et al.*, 2001). Phosphorus stimulates root growth, tillering, pollination and decreases the time to mature and is engaged in supplying and transferring energy to the rice plant for all biochemical procedures. It is possible to extract fast growing plants as much as 1 kg P ha^{-}

^{1} day^{-1}. A mild implementation speed of 20-40 kg P_2O_5 ha^{-1} in combination with 60 kg N ha^{-1} is therefore suggested at sowing moment in order to enhance population density, development and rice output under submergence circumstances (Rathore, 2005). Potassium is one of the three most important components of plant nutrients. To guarantee plant opposition to accommodation, illnesses and starvation, an appropriate stock is required (Laegereid *et al*., 1999). Application of K_2O to 30 kg ha-1 increases output (Rathore, 2005).

2.9 Nutrient Management in Rice

Chauhan *et al.* (2017) reported that nutrient management has become an essential part of modern rice production and sustainability. Nutrient management consisting mainly of an adequate and controlled supply of vital plant nutrient at the suitable plant-requested intervals. Rice is a heavy feeder and requires the timely, adequate and balanced application of essential nutrients (WARDA, 2002). The two most critical periods for nutrients application in rice production is at the four- leave stage and at panicle initiation stages. Application of the optimum nitrogen rate in different splits and timing has significant effects on grain yield and yield components (Wopereis *et al*., 2009).

Koffi *et al*. (2016) reported an optimized vegetative growth and enhanced yield component, grain yield and quality with NPK basal application before transplanting, and top dressing at panicle initiation and before flowering in aromatic rice. Janki and Thiyagarajan (2002) reported significant and consistent difference for nitrogen uptake, yield and synthesis of crude protein in 64 genotypes of rice that had received split nutrients at different stages of growth. Fageria (2010) recorded the largest crop output with N timing therapy of 1/3 for sowing + 1/3 for successful tillering and 1/3 for panicle introduction development for natural plants and 1/2 N for tillering + 1/2 N for inbred plants. Hirzel *et al*. (2011) verified the largest efficiency of perennial rice crops in Chile by applying 33 % N at sowing, 33 % at tillering and 34 % at panicle introduction, and the lowest efficiency for perennial plants by applying 50 % N at sowing and 50 % at panicle introduction.

Perez *et al.* (1996) indicated that several splits of nitrogen fertilizer recommendation are requirement for high yielding varieties. Blumenthal *et al*. (2008) reported 6% increase in rice yield and 25% increase in grain protein due to nitrogen applied two weeks after emergence and top dressing at flowering stage. Kenzo (2004)) reported that number of panicles along with number of grains per panicle and paddy yield was significantly affected by nitrogen application in splits at planting and at tillering stage. Raza *et al*. (2003) sated that number of grains per panicle and panicle lengths were significantly higher in N applied in two splits, that half at tillering and half at panicle initiation. Raza *et al*. (2003) also indicated that the weight, seed output, straw output and crop ratio of 1000 grains was considerably increased when oxygen was supply in three equivalent divisions, that is 1/3 at transplantation + 1/3 at panicle introduction. Krishnan *et al*. (2011) noted that when oxygen was introduced in three divisions at primary, effective tillering and panicle induction phases, a large amount of saturated seeds, crop coefficient and return were acquired. Earlier than needed or postponed implementation, inappropriate timing of implementation of nitrogen decreases output and protein concentrations (Jeremy, 2007). Sahoo *et al.* (1989) concluded that number of productive tillers per hill were maximum where nitrogen was applied in three splits, at planting, tillering and at flowering.

2.10 Rice Varieties Cultivated in Ghana

The predominantly grown rice genotypes in Ghana are clusters of Indica, Japonica and Javanica (Affram, 2000). Rice production was dominated by local or traditional variants until the 1960s (Akai, 2004). The gradual process of rice production, in the country received a boost in the 1970s and led the rapid increase in production with the North contributing significantly (Akai, 2004). While choosing a range to develop relies on a number of variables, rice ecology, variation output possibilities, and customer preference are essential (Akai, 2004).

Many scientists have demonstrated that rice customers prefer to buy rice for intake (Huh *et al*., 2019). This was ascribed to a number of variables including differences in physical features, type of nutrition and performance of dressing and cooking. Studies showed a greater requirement for long-grain noodles compared to brief, round seed kinds (GLG-SOFRENCO, 1997). Thus, rice research in the country has focused on the production of improved varieties with better production yields, grain quality and stress resistance (Adu-Kwarteng *et al*., 2003) Some other consumers preferred perfume rice for which the three selected varieties has those qualities (Calingacion *et al*., 2014).

In the other vain Ghanaian farmers' choice of varieties are based on how long a variety takes to mature and quantity of yields that it can produce. For these reasons, most of the rice varieties developed by researchers combine these traits. Varieties used for this study share these characteristics. The varieties were: Gbewaa, Tox3107 and C93.

2.10.1 Gbewaa Rice

Jasmine 85 also known as Gbewaa rice is an aromatic rice variety developed in Thailand in 1966 by Doctor Ben Jackson a rice breeder at the International Rice Research Institute. In 1989, the USDA in collaboration with IRRI, University of Arkansas, Louisiana State University, released Jasmine 85 to American farmers. This variety grows rapidly, gives high yield, and carries good resistance to pests in southern United States. It also suppresses the growth of weeds in the surrounding area. All these desirable features allow US farmers to grow Jasmine85 as Organic Rice, for which health-conscious US consumers are willing to pay a premium price (Tanasugarn, 1998). One main problem with Jasmine 85 is the many broken grains found after milling, which tend to drive the price down (Hagrove, 1997).

Gbewaa rice can be grown under either Irrigation or Lowland rice cultivation scheme that is rain-fed. It is an aromatic rice of mid-season with a long grain cultivar and awn-less (Abdul-Ganiyu *et al*., 2018). The crop have elevated tillers and stalks of horizontal flags, extremely susceptible to some pests and colored straw illnesses. It is a product of small consistency, smooth in consistency and very cohesive when boiled (IRRI, 1998).

According to Diako *et al*. (2011), this rice type was launched in their scheme by the Savanna Agricultural Research Institute (CSRI-SARI) in Ghana in 1998 to reduce milled rice imports in Ghana. This variety has been chosen because of the characteristics it has, especially its aroma, grain size and grain length.

2.10.2 C 93

This is one of the early maturing varieties of rice which takes an average of eighty (80) days to mature (Ohno *et al*., 2018). It also works well with a minimum quantity of moisture required in both Midland and Lowland environment. The crop can bear fourteen tillers per crop under favourable climate circumstances that can generate an estimate of twelve panicles per crop.

This variety has an average yield potential of five (5) ton's per hectare under favourable weather condition. The variety is yet to be released by Savannah Agricultural Research Institute (SARI) under the Council for Scientific and Industrial Research Institute (CSIR).

2.10.3 TOX 3107

This variety has it geographical origin from Africa Rice developed from *Oryza sativa* species which has institutional name known as SARI rice and was released in the 1998 by CSIR-SARI.

With reference to its agronomic traits, Tox 3107 is a deep lowland ecology which has a potential yield of 7.5 tons ha^{-1}. It is a variety which takes 115 days for 50 % days to heading and takes 145 days to mature. (Ragasa *et al.*, 2013). This variety has good resistances to diseases, insects and lodging. The average weight of the 1000 grain is 26.6 g. The magnitude of the panicle is medium and a very lengthy grain includes awns (Borale, 2014).

The organoleptic and technological characteristics has shown that it has intermediate threshability and medium consumer acceptability with good cooking quality but without aroma (CSIR-SARI, 2012).

2.11 Nutrients Requirements for Rice Production

For more than 100 years, mineral fertilizers have maintained good farming and thus population and prosperity development globally (Smil, 1999; Stewart *et al.*, 2005). This fertilizer provides the plants as a secure cause of nutrient production that generally compliments the soil's natural nutrient. Supporting fertilizers to increase plant production has prevented millions of tonnes of artificial habitats that would otherwise have turned into cultivation (Balmford, 2005). Nevertheless, lack of, imbalanced, inadequate or excessive nutrient use in agricultural systems continuous to be a problem. The removal of nutrients is a significant source of poor crop yields in creating global regions, especially in Africa. In other circumstances, substances such as oxygen and oxygen often migrate beyond the boundaries of the agricultural sector because water availability and plant resource requirement were not matched by leadership methods (van Noordwijk and Cadisch, 2002). Such losses, if survived unchecked, can bear important social expenses (Mosier *et al.*, 2001). Increasing the effectiveness of nutrient use therefore remains a significant task for global forestry (Principles, 2007). This has resulted to a call for the most suitable moment for study to provide nutrients to plants in an increasing sector and to which extent to allow effective and productive farming in the nation (Filippelli, 2018).

Nitrogen, phosphorous, potassium, sulphur and zinc are the most prevalent restricting ingredients for plants. Usually many synthetic fertilizers have been developed with this difficulty to provide those components to plant when implemented. Most study advises soil testing to understand the field's nutrient deficit before fertilizer suggestion is produced to guarantee efficient and effective use of plants (Mori *et al.*, 2018). Moreover, the age of the plant variation should also be understood as study indicates that; long-term range requires more fertilizer than short-lived variety.

2.11.1 Fertilizer Nutrient Supply

Application of fertilizers is needed to enhance crop output in West Africa's poor productive lands. This exercise may also boost pest stress in the crop sector, considerably lowering output (Koné *et al*., 2014).

Over-supply or undersupply of crop substances can have adverse effects, leading to inability to obtain the required outcomes (Parchomenko and Borsky, 2018). The idea of good fertilization includes eliminating this damaging effect by using fertilizers judiciously to keep economically viable and environmentally delicate plants that meet future requirements (Ernst and Mutert, 1995). Rice yields per unit region in Ghana are still very low, given recent efforts to promote or encourage increases in production (JICA/CSIR Joint Study Project, 2001).

Declining plant stabilization and the inability of farmers to use the required quantities of mineral fertilizers are among the acknowledged causes of bad yields (Moro *et al.*, 2008).

Rice can take advantage of fertilizer use to offset for oxygen transferred. It is projected that approximately 15 to 20 kg N, 2 to 3 kg P and 15 to 20 kg K are taken from the soil for each color of rice grain grown. With the emergence of fresh and low producing crop variants, groundwater nitrogen mining will improve if there are no or not appropriate quantities of mineral fertilizer inputs (Moro *et al.*, 2008).

If one or two nutrients are found to be yield-limiting, the use of single-element fertilizers or the modification of the compound fertilizer formula may be essential to correctly reflect the demands of the crop. Several writers noted the significance of N in determining output rises (Obigbesan, 1981). N and P were the most restrictive nutrients at both locations in the first year (2004). At both locations in the second year, all three components (N.P.K.) displayed the same degree of restriction > 0.2 cmol kg^{-1} land K and > 9–10 ppm groundwater sample concentrations. P cannot react to fertilization with P and K (Doberman and Fairhurst, 1999). It is evident that all cultivation of maize is limited at both locations, N, P, K. Results indicate that N implementation was allowed on both locations in 2004 and 2005 as output reductions without this resource were important. The lack of N substantially decreased returns at both locations in both years (Moro *et al*., 2008).

2.11.2 Grain yield response to Nitrogen

Nitrogen (N) is one of the most yield-limiting substances for crop production in most rice-producing areas of the globe (Fageria and Baligar, 2003). Mineral fertilizer has an impact on the output of crop grains (Moro *et al.* 2008). Mean grain output improved considerably with rising N levels for both years, achieving a maximum of 90 kg N ha^{-1}. The same 2-year pattern has been noted at both locations. Grain returns varied from 1.29 to 1.39 t ha^{-1} in (2004) and from 1.47 to 1.48 t ha^{-1} in 2005 without fertilizer N. Except for potassium, rice requires more N than other vital foods (Fageria and Baligar, 2003).

Across N levels, 23 kg of grain generated per kg N implemented for agronomic effectiveness and 146 kg of biological output (straw plus seed) per amount of N accumulated for physiological effectiveness (Fageria and Baligar, 2003). In grain and straw, agrophysiological effectiveness was 63 kg of grain generated per kg of N collected at N levels. The apparent effectiveness of regeneration was 39 % and the effectiveness of production was 58 kg of maize generated per kg of N used (Fageria and Baligar, 2003). Agronomic effectiveness in tropical upland cultivation is recorded to be between 15 and 25 kg of seed generated per kg of implemented N (Yoshida, 1981). This spectrum includes the results described in Table 2. Higher physiological effectiveness (146 kg kg^{-1}) over N levels relative to agrophysiological effectiveness (63 kg kg^{-1}) is owing to dry matter being included in the calculation of this effectiveness. (Singh *et al*., 1998) recorded an agrophysiological efficacy of approximately 64 kg of seed generated per kg of N intake and an agronomic efficacy of 37 kg of seed generated per kg of N in 20 upland chicken genotypes. An evident effectiveness of regeneration over N levels of 39 % is quite small. The proportion of N regeneration differs with soil properties, techniques, quantities, and timing of requests for fertilizer and other adjusted leadership practices. It usually ranges between 30 and 50 % in the tropics (Prasad and De Datta, 1979).

Table 2: Effects of Nitrogen Rates on Physiological Efficiency

Nitrogen Rates (kg ha^{-1})	Physiological Efficiency (kg kg^{-1})
30	156
60	166
90	182
120	132
150	146
180	126
210	113
Average	146
R^2	0.62^{**}

Source: Adapted from Fageria and Baligar, (2001) **Significant at 5 % probability level.

2.11.3 Grain yield response to Phosphorus

Moro et al. (2008) stated that, in both years, mean grain yield increased significantly with increasing P levels to 60 kg ha^{-1} and became similar thereafter. Paddy grain yields without fertilizer P ranged from 1.99 to 2.03 t/ha in 2004 and from 2.04 to 2.08 t/ha in 2005. Similarly, the addition of 30 kg ha^{-1} P_2O_5 increased grain yield by 51 % (2.06 t ha^{-1}) in 2004 and by the same margin (2.11 t ha^{-1}) in 2005.

Hedley *et al*. (1994) and Sanchez and Salinas (1981) clarified that phosphorus (P) deprivation was recognized as a significant limiting factor in the production of rice on many farms around the globe. In the Cerrado region of Brazil, phosphorus deficiency was the main variable limiting rice returns to about one t ha^{-1} (Fageria *et al*., 1982). P impairment may occur if P is heavily adsorbed in relation to a small complete ground P material (Dobermann *et al*., 1998;

Sanchez and Salinas, 1981). More than 90 % of the born fertilizer P can be converted quickly into types of P that are not readily accessible to crops. The creation of plant cultivars consisting of using a greater percentage of the set P already existing in crops can be an appealing and cost-effective option, with beneficial impacts on the long-term sustainability of agrarian structures (Wissuwa and Ae, 2001).

2.11.4 Grain yield response to Potassium

The use of potassium raises the amount of tillers hill^{-1} in cultivation considerably (Sarkar *et al*., 2001). In the growing season of the elongation phase, potassium uptake by rice population is maximized to the moving point. They indicated that one-time implementation of K as soil clothing relative to one-time implementation as top dressing improves crop K uptake and ratio from elongation phase to growth phase as well as amount of seeds per panicle. It is therefore necessary to give more thought to perform more studies in *Aus* rice cv with a suitable amount of K fertilizer (Qiangsheng *et al*., 2004).

De Datta and Gumez (1985) showed that K has additive influence on filled grain percentage per panicle and its deficiency cause sterility of pollen seeds at the reproductive stage and result in decreased number of filled grains. Qiangsheng *et al*. (2004) noted that in the growing phase of the elongation phase to the moving phase, K uptake by fish inhabitants is maximized. Non fertilizer and or excessive fertilizer application enhanced plant K uptake before the elongation stage, but reduced effective panicles. Also, with one-time application of K as basal dressing compared to one-time application as topdressing, K application as panicle fertilizer caused increases in plant K uptake and proportion from elongation stage to heading stage as well as number of filled grain. Combined application of K and N had a remarkable positive reciprocal effect on crops, and was an important approach in improving K use efficiency (Li *et al*., 2009). Kavitha *et al*. (2008) revealed that for effective tillering, panicle initiation, N and K were applied in four equivalent divisions.

Cropping prevents around 15.88 or 18.14 kg per Area, per Year (A^{-1} Yr^{-1}) (K_2O equal of 19.1 to 21.8 kg) in the grain, gently decreasing the land quantity accessible. Reaction to K implementation in tests has become more prevalent in latest years, and many growers in the region have started applying K regularly at 27.2 to 54.4 kg K_2O A^{-1} prices. Straw withdrawal from these poor K fields, which is essential due to decreased consumption, is probable to boost in the coming years, accelerating the pace of K suppression (Williams and Smith, 2001).

A comparable pattern in grain output with higher K prices was also noted for years (2004 and 2005) and at both sites. Increase in return of grain reached at 60 kg ha^{-1} K_2O after which output of grain became comparable. The outputs of paddy grain without fertilizer K varied from 2.98 t ha^{-1} to 3.09 t ha^{-1} in 2004 and from 2.31 t ha^{-1} to 2.52 t ha^{-1} in 2005. The excess of 30 kg ha^{-1} K_2O enhanced crop yields in 2004 by 44 % (2.27 t ha^{-1}) and in 2005 by 56 % (3.10 t ha^{-1}). The average rise was 50 % (2.68 t ha^{-1}). The projected rise in output from the second increase per level of fertilizer (30 to 60 kg ha^{-1}) was also considerably greater for the three components than the first amount (0 to 30 kg ha^{-1}) (Moro *et al*., 2008).

2.11.5 General grain yield response

The inclusion of the first 30 kg ha-1 N for both locations, according to Moro *et al*. (2008), led in important rises in the amount of tillers for both years. Increasing N concentrations above 90 kg ha^{-1} also resulted for both years to significant increases in plant height. However, this resulted only to higher biomass production with no related increase in grain production, showing lower harvest indices (HI) for medicinal products with higher N concentrations. The biggest plant results were recorded at 90 kg ha^{-1} N and between 60 and 90 kg ha^{-1} each of P_2O_5 and K_2O. Panicles with a tiny percentage of sterile crops make it possible to apply more nitrogen and produce more quickly (Chaturvedi, 2005).

Tillering is a significant feature of grain production, according to Siavoshi *et al*. (2011) and is thus a significant element of rice output. Due to the impact of various fertilizer mixes, Mirza *et al*. (2010) recorded a rise in the amount of tillers in rice plants.

According to Mirza *et al*. (2010) more number of tillers per square meter might be due to the more availability of nitrogen, which plays a vital role in cell division. Organic sources offer more balanced nutrition to the plants, especially micro nutrients which positively affect number of tiller in plants (Miller, 2007).

Siavoshi *et al*. (2011) noted out that leaves are significant organs in photosynthesis for any plant. Maximizing the leaf region to a large return is a significant consideration. In this inquiry, we discovered that natural fertilizer alone and considerably improved the duration of the banner leaves over untreated command in conjunction with chemical fertilizers. Similar results were revealed Mirza *et al*. (2010). The rise in leaf number and volume owing to sufficient nutrition can be described in aspects of feasible rise in plant nutrient absorption capacity as a consequence of improved root growth and enhanced carbohydrate translocation from origin to growth nodes (Singh and Agarwal, 2001). The output elements of rice plant panicle amount per square meter, amount of full grains per panicle, unfilled grain proportion and weight of 1000 grains indicates important variations owing to fertilizer implementation. Salem (2006) reported that the use of FYM with nitrogen fertilizer increased significantly the number of panicles per square meter, the length of the panicle, the weight of the panicle, the number of filled grains perpanicle and the weight of 1000 grains and the yield of grains in rice.

According to Siavoshi *et al.* (2011) the rise in plant height, amount of tillers per stand, amount of spikelets per panicle, output of grain and weight of 1000 grains in reaction to the use of organic and chemical fertilizers is likely owing to increased nutrient accessibility. Due to nutrient inputs, the change in plant height was regarded owing to variability in the supply of significant nutrients. Similar outcomes were noted with the use of natural manure and fruit compost (Muhammad, 2008). The accessible nutrients may have helped boost the region of the leaf, resulting in greater photo-assimilations and more production of dry matter. The findings of (Swarup and Yaduvanshi, 2000; Yadana *et al.*, 2009) have also revealed an rise in fresh weight (Sarwar *et al*., 2008).

Dakshina *et al.* (2015) recorded a noticeable rise in the number of tillers m^{-2}, panicles m^{-2} and wet material output per hectare by raising the N rate from 120 kg ha^{-1} to 180 kg ha^{-1} (50 % increase) and no important shift in the further rise.

2.11.6 Nutrient Deficiency

Jat *et al.* (2015) indicated that agricultural fields are now recovering from decreasing fertility condition, their physical and chemical properties are decreasing, and plant growth essential nutrients are steadily decreasing. The daily price of environmental degradation is projected to range from 4-17 times of gross national product in some nations (Jat *et al.* (2015).

It has been noted that N is important in determining output rises (Obigbesan, 1981). N and P were the most restrictive nutrients in the first year (2004) of experiment.in the second year, all three elements (N, P, and K) showed the same degree of limitation. Soil sample concentrations of > 0.2 cmolc kg^{-1} ground K and > 9–10 ppm P may not react to fertilization with P and K (Doberman and Fairhurst, 1999). P cannot react to fertilization with P and K (Doberman and Fairhurst, 1999). Site soil sample findings indicate that the concentrations of K and P are well below these critical concentrations. It is evident that all cultivation of maize is limited at both locations, N, P, K. Results indicate that N implementation in both (2004 and 2005) and at both locations was expected as output reductions without this nutrient were important. The lack of N considerably decreased returns at both locations in both years. The average return drop from withholding N was 2.94 t ha^{-1} in 2005 for both places coupled.

Nitrogen is one of the most important nutrients for rice production (Yoshida, 1981). In nitrogen-deficiency conditions, many agronomic traits, including crop growth rate, leaf area index, plant height, tillers, spikelets per panicle, and grain filling, are negatively affected and, as a result, grain yield and biomass decrease (Wei *et al*., 2012). Many physiological processes, including photosynthetic and respiratory systems, nitrogen and carbon metabolisms, and plant hormone metabolism, are also affected (Novoa and Loomis, 1981), including photosynthetic and cardiovascular structures, oxygen and coal dioxide, and crop nutrient production. For the two trials combined (2004 and 2005), yield loss due to withholding N (5.93 t ha^{-1}) was significant at $P < 0.001$. Thomas *et al*. (2001) stated that P fertilization boosted the median crop output in the Philippines by 20 %, complete consumption by 27 % and P uptake by 53 %. A comparable remark was produced in this research as P fertilization led in greater seed output rises under continental circumstances. Seasonal potassium uptake model of flooded-irrigated rice described on sufficient K substrates stated that adequate K during vegetative development must be available to enhance K uptake (Slaton *et al*., 2003).

Earlier surveys show that adequate use of fertilizers can significantly boost output and enhance crop performance (Chaturvedi, 2005). In view of the significance of nitrogen fertilization on the grain output from the rice plant, it is essential to understand what the finest treatment is for each variation, as well as its impact on the output elements and other agronomic parameters such as the grain process, crop height, accommodation and humidity material, in attempt to gain a clearer understanding of that efficient reaction.

2.11.7 Response to increasing rates of N, P, K

Chemical fertilizers are primarily used to boost crop productivity according to Liu *et al*. (2014). The grain returns acquired from the suggested amounts of NPK were 1.4 to 2.3 times greater than the returns achieved without chemical fertilizer in ongoing rice structures from long-term laboratory studies undertaken around the globe (Bi *et al*., 2009; Dobermann *et al*., 1998; Haefele *et al*., 2006). For crops like wheat and maize, the responses were usually higher than those obtained in rice. Comparatively low responses of 2.1 to 2.5-folds increases of maize yields observed in uplands in the Loess plateau of China and Germany (Fan *et al*., 2005; Lothar *et al*., 2000) were greater than the responses of rice yields observed in most of the paddy trials.

Rice output reactions to chemical fertilizer implementation were also generally smaller than that of wheat in a rice-wheat scheme (Gu *et al*., 2009; Nayak *et al*., 2012; Yadav *et al*., 2000). Accordingly, the implementation of chemical fertilizer (NPK) in all three of our studies considerably improved plant returns. The reactions to chemical fertilizer implementation from the returns of upland plants such as sweet potato, oilseed and corn were greater than those of rice. However, in subtropical China, owing to financial cause and the complexity of fertilizer travel, local peasants did not receive full exposure to fertilization in agriculture, particularly hill soil. According to Liu *et al*. (2014) research findings indicate that, the use of more chemical fertilizers in upland plants could gain the region's general economic efficiency.

Applying chemical fertilizer to the land along with natural manure produces 18 times greater than those achieved with chemical fertilizer alone. In addition, the mixed implementation of manure and chemical fertilizer revealed only restricted impacts on rice returns in another long-term experiment where complete N, P and K entry levels were equal (Bi *et al*., 2009).

Increasing N levels (> 90 kg ha^{-1}) led only in rises in plant height and complete biomass, according to Moro *et al*. (2008). Higher N levels enhance the tillering and creation of fresh leaves, triggering shading, a disease-friendly situation, accommodation, and productivity cuts. Even though no diseases were observed in this study, lodging was very severe in higher N rates. N fertilizer was generally beneficial and clear with increasing rates up to 90 kg ha^{-1} before flattening off. Witt *et al*. (2004) stated that a site-specific strategy to rice nutrient management offered adequate solid projections of long-term demands for fertilizer P and K to prevent depletion of nutrients. They also observed that long-term testing for fertilizer P and K may be essential to fine-tune on-farm suggestions. In addition, the same authors stated that soil management P and K gain greater visibility in Asia's comprehensive marine rice irrigation systems owing to problems that are not optimally adjusted to long-term demands with fertilizer concentrations P and K. A comparable situation may occur in Ghana as less focus is paid to both P and K fertilization (Moro *et al*., 2008).

Instead, too much importance is placed on N fertilization, leading to the use of mostly N-composed fertilizers. The response to both P and K was obvious from this study and should provide a useful basis for the various quantities required (Moro *et al*., 2008). Yamaguchi

(1989) observed that increases in Fe and decreases in K concentrations were prominent in bronzing of rice in Nigeria and suggested that proper fertilization and planting of resistant varieties may be the most suitable approach. Potassium predominates in rice straw and straw governance can have a major impact on the accessibility of K and therefore the amounts it requires as mineral inputs. Improvements in the management of rice grain can therefore contribute to decreases in the number of K components via mineral fertilizers.

2.11.9 Fertilizer Use and Efficiency

Efficient utilization of nutrients can be described as the greatest financial output per amount of nutrient component added and consumed by the plant for grain and straw production (Fageria and Baligar, 2003). Blair (1993) characterized nutrient effectiveness as the capacity of a genotype or cultivar to obtain nutrients from the growth medium and to integrate or use them in the production of shoot and root biomass or used plant material. Graham (1984) also described a genotype's nutrient effectiveness (individually for each component) as the capacity to generate a large output for a normal genotype in a soil that is restricted in that component.

Baligar *et al*. (2001) concluded that, higher nutrient use efficiency by plants could reduce fertilizer input costs, decrease the rate of nutrient losses, and enhance crop yields. Genetic and physiological components of plants have pro-found effects on their abilities to absorb and utilize nutrients under various environmental and ecological conditions. Genetic, morphological, and physiological plant traits and their interactions with external factors such as soil moisture and temperature, light, best management practices, soil biological, and fertilizer materials need to be more thoroughly evaluated to improve the nutrient use efficiency in plants.

Most rainfed upland rice producers use fertilizer N on their rice plants in much lower quantities than in irrigated rice schemes due to greater danger and decreased effectiveness. Smaller output opportunities and higher confusion due to environmental and abiotic pressure are two factors why entry use in plains and alpine rainfed settings is lower. K fertilizer is not commonly used for rainfed plain and upland cultivation, although there has been frequent reaction to K, especially on coarse-textured crops. For instance, the effectiveness of N use in rainfed structures is controlled primarily by economic variables such as drought and flooding that are beyond the reach of the farmer (Dobermann and Fairhurst, 2000). On acid fields in lowland crop structures, development and output are limited by P defect and Al poisoning. Reduced accessibility of Si under upland circumstances improves the susceptibility of rice plants to disease (e.g. shot), thus reducing the quantity of N that can be securely used. These constraints limit the returns to investments in N fertilizer in contrast to irrigated systems where N use efficiency is higher, more consistent, and more reliable (Li *et al.*, 2010). In addition, rain-fed soils are characterized by intermittent wetting and drying cycles, even during the wet season, which results in an accumulation of nitrate because of nitrification and the subsequent loss of N by de -nitrification or leaching. Slow-release fertilizers may have potential to increase N use efficiency in these environments (Rakshit *et al*., 2015).

2.11.10 Fertilizer Timing in Rice Production

Application timing for fertilizers is one of the leadership methods that can improve the effectiveness of plants using N (Randall *et al.*, 2005; Ruiz-Diaz *et al.* 2008). Abbasi *et al.* (2013) indicated that N fertilizer split requests are often suggested as a means of reducing N casualties and improving the effectiveness of nitrogen use. Regardless of the mechanism that increases the availability of phosphorus after flooding, the time required releasing phosphorus and the magnitude of the concentration of soil solution phosphorus varies between soils and can take several weeks to peak.

The implementation of fertilizers in crop production has two critical phases, the four-leaf stage (vegetative stage) and the panicle introduction stage (sexual stage) when the output increases are ignored (Wopereis *et al*., 2009). For the initiation of primordial leaves and florets, an appropriate amount of nitrogen to plant crops during their premature development cycle is very essential (Chaturvedi, 2005). Rice yield is increased with an increase of N fertilizer applied to both stages of the critical period of rice growth. When nitrogen is applied to rice at the four-leaf stage, a number of panicles increases directly proportional to tillers and number of flor*et al*so increases per panicle resulting in high grain yield of the rice. Apparently, the application of N fertilizer at panicle initiation leads to an increase in the dry matter at maturity and the number of florets per panicle (Dunn *et al*., 2016).

According to Jin *et al*. (2002), balanced fertilization improves rice production and a farmer income significantly if is timely and adequately applied. The standard best yields achieved with balanced NPK fertilization for rice cultivated in southern China, regardless of the planting season, increased substantially (Bijay-Singh *et al*., 2017). The agronomic demand for balancing fertilizer inputs has been acknowledged as requiring enhanced P and K levels to ensure elevated crop returns of excellent performance (Jin *et al*., 2002).

Peng *et al*. (2010) noted that the high rates of N fertilizer input and improper timing of N application in China have led to low recovery efficiency and agronomic N use efficiency.

2.13 Soil Type

Rice may be grown on different types of soil provided there is adequate water either from rain or irrigation. For lowland and irrigated rice, heavy clays and heavy alluvial soils of river valleys and deltas are very suitable because of their high water retention capacity. A pH range of 7.0 to 7.2 is considered optimum for paddy rice but the crop also grows on alkaline soils with a pH range of 8 to 9. The growth of the crop is inhibited at soil pH 0.4 or lower (Mengel *et al.*, 2001). Soil fertility and water retention characteristics are usually the most important soil properties affecting rice yield. Soil nitrogen is one of the most important nutrients for rice growth. Generally, rice responds positively to N and trials with lowland rice show that, the response to N fertilizer is usually higher than to either phosphorus (P) or potassium (K) (Yoshida, 1981).

2.14 Role of Plant Nutrients in Crop Growth

Plants needed seventeen components, called nutrients, to develop and finish their life cycle, according to Ali *et al*. (2008). Three of these nutrients originate from water or air, while the other 14 originate from the soil. Each of the nutrients conducts a particular role within the plant, and the quantity required by the plant is mainly dependent on feature. Limiting one nutrient may discourage other nutrients from being taken and eventually affect crop yield and performance (Ali *et al*., 2008).

Again, Ali *et al*. (2008) indicated that soil productivity depends on the significant and a few minor components accessible in plant areas. The main nutrient components needed by crops include a greater amount of nitrogen, phosphorus and potassium, while the micronutrient contains Fe, Mn, Zn, Cu, B, Mo, Cl, Ni, Co. needed in lower amounts.

Micro or macro nutrients are determined by the plant requirements rather than plant uptake quantities. Plants can bring up big quantities of Cl, for instance, but crops need less Cl than the macronutrients, so it is categorized as a micronutrient. (Ali *et al*., 2008).

However, when the elements are in equilibrium or sufficient amounts in demand for growth and development of crops, groundwater is regarded productive. Similarly, they are categorized as productive soil if they are insufficient or deficient in soil to improve plant growth and development. Our agrarian nutrients ' availability and sustainability relies on how regularly they are used for production. Low land productivity is connected with the rise in land-use frequency. These findings indicate the need for measures for agricultural sustainability to improve land health (Osman, 2013). The designs also provide a way to identify functional relationships in Ghana for in-depth analysis of land-use transition (Braimoh and Vlek, 2005).

Three nutrients N, P, and K are categorized as the main macronutrients, as N, P, and K deficiencies are most prevalent, according to Jones *et al*. (2011). For premature seedling vigor, small quantities of N are essential. High N levels, however, can harm seedlings and over-stimulate vegetative development soon in the summer that depletes soil moisture and depresses returns. Excess N may also stop the mature of the plant. Phosphorus is vital for power storing and exchange and for energetic development and plant development. It improves the age and performance of the plant, particularly in seed plants. Potassium retains water balance and stems power as a result. In fact, K encourages the production of energy needed to move nutrients in the plant, the absorption of N and the synthesis of proteins. Deficient K crops may have small complete N intake, output, and protein (Jones *et al*. 2011).

In relation to the increasing medium, the fertility of our rice fields can be enhanced with additional nutrients. Therefore, adding nitrogen fertilizer before continuous rain is the most effective use of oxygen irrespective of whether the plant is airborne or tool sown, adequate nitrogen fertilizer must be introduced with pre-permanent rain to achieve adequate vegetative development through panicle introduction to obtain a large output capacity for the plant. The quantity of nitrogen needed depends on the field crop culture and the level of organic nitrogen in the earth (Jones *et al.*, (2011). There is also an enhanced danger of failure of oxygen if in a few days after fertilizer implementation continuous humidity is not supplied. High nitrogen intakes above the target range boost the likelihood of freezing harm, while nitrogen intakes below the target range show that inadequate pre-permanent water nitrogen has been utilized and output opportunities may be lowered (Brian *et al*., 2016).

It is also necessary to complement phosphorus (P) when the component is recognized as deficient. High yielding plants extract from the land significant amounts of phosphate. Chemical procedures in the groundwater enable greater concentrations of carbon to become accessible for the plant on certain plant kinds when continuous rain is introduced to a rice ground. On prior plants or grasslands, inadequate phosphorus has been utilized. Phosphorus can enhance the vigor and output of plants (Brian *et al*., 2016).

Applied N at doses above the recommended rates produces excessive vegetative growth, shading, lodging, and a negligible increase in the number of panicles (Dobermann and Fairhurst, 2000). To preserve a nutrient equilibrium, micronutrients such as zinc, iron, manganese, sulphur and silicon are needed. Zinc deficiency has been recorded to decrease the output of rice, even if N is sufficient (Nathan *et al*., 2005; Yoshida *et al*., 1970). Highlighting the significance of soil testing in evaluating the nutrient position. With crop strength and or bad land governance, groundwater health generally decreases. To right bad soil fertility in rice production, inorganic and sometimes organic fertilizers are often used. The FAO (1997) has highlighted the need for field-specific fertilizer leadership, especially nitrogen, although it may seem costly. In the hills of Accra, the suggested fertilizer levels for rice are 90 kg N 1 ha^{-1}, 45 kg P 1 ha^{-1} and 35 kg K 1 ha^{-1} (Oteng, 1997).

2.15 Characteristics of Rice Soils in Northern Ghana

Northern Ghana's complete soil region is approximately 98,000 km^2, of which 16,000 km^2 are heavily farmed and about 8,000 km are farmed less intensively. The area's main waters are Alfisols and the integrated Plinthic Luvisols. Approximately 47 % of the lands are deemed unsuitable for industrial production, 25 % are poor and approximately 28 % are appropriate for cultivation. (Donkoh *et al*., 2011).

The agricultural scheme is largely dependent on real soil fertility and very little on inorganic fertilizers. The population growth pace is quoted as approximately 3 times (Ghana Statistical Service, 2002) as cited by (Braimoh and Vlek, 2005).

2.16 Savannah Agro-Ecological Zone

According to Amikuzuno and Donkoh (2014), Ghana's northern Savannah region lies between 8 ° N and 11 ° N latitudes and has 97702 km^2 of soil area. Northern Ghana's rainfall is characterized by a long humid period of about seven months from October and November to April / May called the dry period with no important rainfall and a rainy period from May to October with suitable rainfall levels for plant production.

Northern Ghana is located in Ghana's sub-humid to semi-arid Guinea Savannah and wet Sudan Savannah regions, spanning the North, Upper East and Upper West regions. This area has an estimated rainfall variety of between 400 and 1200 mm, and cultivation, which utilizes about 70 half of the inhabitants, is only rain-fed about 95 %. Amikuzuno and Donkoh, (2014) also indicated that Northern Ghana has been the poorest component of the nation since ancient moments due to its weakness to weather shift and precarious environmental circumstances such as the lengthy rain summer of about seven months accompanied by a five-month summer summer with recurrent, continuous droughts and or storms during the harvest period.

Based on their environment, the nation is split into six agro-ecological areas. The natural environment depends on the distinct weather circumstances and is affected by distinct kinds of land. These north-south agro-ecological areas are Sudan Savannah Zone, Guinea Savannah Zone, Transition Zone, Semi-deciduous Forest Zone, Rain Forest Zone and Coastal Savannah Zone (FAO, 2018).

2.16.1 Soils of Savannah agro-ecological zones

Lima and Volta group, which derive from sandstone and mudstone, are the largest coastal plants in the agro-ecological areas of Savanna. Lima series is the largest, followed respectively by Volta and Changnayili series (Dedzoe *et al.* 2001a, 2001b; Senayah *et al.*, 2001). These lands are usually plain (0-3 % elevation), wide and very vast coastal plains, usually appropriate for mechanization. In a catena, the valley fringes adjacent to the upland are occupied by the series Changnayili (Stagnic Plinthosol), followed by the series Lima (Endogleyi – Ferric Planosol) and the series Volta (Dystric or Eutric Gleysol) closest to the stream bed (Senayah *et al.*, 2001).

Brammer (1962) and Obeng (1975) indicated that rocks in the savannah areas of Guinea and Sudan, predominantly Lixisols, Luvisols and Plinthosols, are small to moderately thick, moderate to light textured, and develop over voltaic sandstones, rocks, phyllite and schists.

The nutrients in organic carbon and nitrogen are usually small. In the savannah areas, the availability of nitrogen and P is less than in the forest areas.

2.17 Effects of Basal Fertilizer Timing

The timing of the implementation of fertilizer has an important impact on crop yields, according to Sela (2018). Proper timing of the implementation of the fertilizer improves returns, decreases nutrient casualties, improves the effectiveness of nutrient use and avoids environmental harm. Applying fertilizers at the incorrect time could lead to loss of nutrients, fertilizer scrap and even harm to the plant. The processes by which failures happen rely on the nutrient's characteristics and their responses to the environment.

During their growth, plants involve a healthy availability of nutrients. Generally, most of their nutrients have collected between growing and ripening phases at some point. Approximately 50 to 90 times of N and P move from the leaves to the growing seed in the plant at birth. Consequently, small nutrient consumption in the premature development of a plant reduces the nutrient amount for the seed, influencing both output and performance.

Jones *et al*. (2011) indicated that it is critical to timing the implementation so that nutrients are accessible before the peak demand for nutrients that occur before crops achieve their peak volume. Before premature tillering, the second of divided apps on tiny grains should be implemented, although real timing will rely on a multitude of variables including soil nutrient concentrations and starter fertilizer concentrations. In rice plants, the ideal moment would be before or during tillering for additional in-season fertilization. The timing of fertilizer apps should normally be focused on plant growth phase, rather than calendar date, according to Jones *et al*. (2011), the ideal location of a second implementation or head fitting will differ depending on the crop and year. Regardless of the plant and year, appropriate nutrients are needed for peak manufacturing soon in development and to guarantee that particularly nitrogen and phosphorus are accessible for healthy grain or seed filling.

2.18 Timing of Fertilizer Application

The consumption of nutrients does not generally correspond to a rise in plant biomass. For instance, when tiny plants achieve 50 % of their complete energy, they have gained about 80 % of their needed N and K, 60 % P, and 70 % S. Therefore, in the growing season, it is essential to provide adequate nutrients soon. Seed (including grain) early in the growing season accumulates oxygen, either straight from nutrients.

Table 3: CSIR/MOFA recommended rate and timing of fertilizer application for rice

Location and type of rice	1st application NPK 15-15-15		2nd application SOA or urea		Total nutrients (kg)		
	Rate	**Timing**	**Rate**	**Timing**	**N**	**P**	**K**
Lowland areas Transplanted	400 kg	1 WAP	150 kg SOA or 75 kg urea	5–6 WAP (or just before booting)	95	60	60
Direct seeding	300 kg	2–3 WAP	150 kg SOA or 75 kg urea	5–6 WAP (just before booting)	80	45	45
Northern Savannah	200–300 kg	1 WAP (transplanted); 2–3 WAP (direct seeding)	150 kg SOA or 75 kg urea	7–8 WAP	60–80	30–45	30–45

Sources: Ragasa *et al.*, (2013) SOA = Sulfate of Ammonia; WAP = week(s) after planting

CHAPTER THREE

MATERIAL AND METHODS

3.1 Experimental Site

This experiment was conducted in 2018 at Savannah Agricultural Research Institute (SARI) lowland research fields under rainfed at Nyankpala in the Tolon District of the Northern Region of Ghana. This experimental field was ploughed and harrowed before planting was done. The field was already developed with permanent earth bonds at each hectare boundaries for which the field was also temporally bonded to each plot or experimental units since the experiment was a fertilizer trial.

3.2 Preparation of the Experimental Field

The experimental field was slashed, ploughed and two weeks later harrowed to a fine tilt and divided into three blocks. Each block was made up of twelve (12) treatments with the block size of 17 m x 23 m and between each of the three blocks was an alley of 2.0 m. Each plot was measured 5 m × 5 m with alleys of 1.0 m between the plots within a block.

3.3 Experimental Design and Treatments Combination

The experiment was a 3 x 4 factorial experiments which was conducted with three (3) varieties at four (4) different times of fertilizer application. This was conducted using Randomized Complete Block Design (RCBD). There were twelve (12) treatments and replicated three (3) times which sum up to thirty-six (36) experimental units.

The three rice varieties were selected from the three classes of maturity periods. The early rice variety selected was C90 which takes (80) days to mature. The medium variety selected for this experiment was Gbewaa rice that matures within (125) days and then, late variety selected was Tox 3107 which matures at (145) days. These three varieties were treated with four different levels of fertilizer application regimes (1WAP, 2WAP, 3WAP and farmer practice). The farmer practice is what they have adopted as old research recommendation for them. Initially, researchers recommendation was on crop base but silent on variety specific when we have long, medium and short duration crop varieties (Koné *et al*., 2014). Therefore the farmer practice (treatment) was on the 3rd week after planting for basal application and then top dress 6th week after planting.

The treatments used were:

F0 * C93

F1 * C93

F2 * C93

F3 * C93

F0 * Gbewaa

F1 * Gbewaa

F2 * Gbewaa

F3 * Gbewaa

F0 * Tox 3107

F1 * Tox 3107

F2 * Tox 3107

F3 * Tox 3107

The fertilizer recommendation was 60-60-30 kilogram per hectare (kg ha^{-1}) of NPK. It was 15-15-15 compound fertilizer mixed with TSP at the basal application.

The fertilizers were weighed NPK 500g/plot, TSP weighed 163g per plot and Sulphate of Ammonium weighed 357g per plot. The TSP and the NPK were mixed together and applied once as the basal. The top dressing was done with Sulphate of Ammonium four (4) weeks after basal application for each treatment except farmer practice which was on three (3) weeks after planting.

3.5 Sowing of Seeds

After having prepared the land adequately to a fine tilth, the sowing was done after a good rainfall to facilitate seedling emergence. The land was lined and pegged and sowing was done with the use of a dibbler and four to six seeds sown per hill at the depth of 3.0 cm.

All the treatments were randomly assigned to the various plots and blocks. The planting distance was 20 cm x 20 cm apart at a seeding rate of 50 kg per hectare. The plot size was 5m x 5m and each plot seed was weighed at 125 g per plot. With this, 4 to 6 seeds per hole were planted to cover the entire field at the recommended plant population per stand. The varieties planted were Gbewaa, Tox 3107 and C 93 and all were certified seed obtained, from Savanna Agriculture Research Institute (SARI), Nyankpala, Ghana. The total quantity of seed used for each variety was 1500g (1.5 kg) with a grand total of 4500g (4.5 kg) worth of seed.

Re-filling of seeds was done seven days after emergence. The whole planting exercise was done within a day for the entire experimental plot.

3.6 Cultural Practices

All cultural practices were employed as and when needed. Herbicides were applied a day after planting with both pre-emergence and post-emergence herbicides. The herbicides were applied at a rate of 300ml per 15L knapsack. Weeds were later controlled manually after seedlings emerged from the soil and at 14, 28, 42 and 56 days after emergence (DAE).

The mini bonds between plots were usually reshaped regularly after every breakage by rainfall to maintain its standards for the purpose.

3.7 Data Collection

3.7.1 Plant stand

The three spots (1m^2) quadrant sampling method were used, as a recommended procedure for plants stand sample per plot (IRRI, 2002). Three spots were identified in each plot by pegging and tiring a rope around each spot. Each spot was surrounded by a minimum of two rows to the plot boundary. In each 1m^2 quadrant the number of plants stand was counted manually and each quadrant added together then strike the average as a representative for the treatment.

3.7.2 Plant height

The plant height was taken from the third week after planting for three weeks' interval consistently for three times at vegetative period. The sampling of the plant height was randomly selected following the recommended basic research principles (IRRI, 2002). Each spot was surrounded by a minimum of four hills to the plot boundary. Five plants stands were tagged at different points within each treatment plot for the height measurements. The plant height was measured by a long rule from the base of the stem through to the tip of the uppermost leaves at vegetative phase. Similarly at maturity, measurements were taken from the base to the last grain tip of the longest plant within the stand at erectile position.

3.7.2 Tiller Count

The 1 m^2 Quadrants were pegged two weeks after planting before the due date of the vegetative and maturity count to ensure bias-free data collection. This was carried out by sampling three quadrants in each plot and each stage. The number of tillers per $1m^2$ was counted manually. All the tillers within the quadrant that had the prominent terminal buds were counted and take the average value as a representative fraction for the treatment.

3.7.3 Number of Panicles

The number of panicles produced in 1 m^2 yields plots was counted and the averages of the three (3) quadrants were determined. This was only done at maturity to know the number of panicles produced per meter square. It was also done on the same pegged three quadrants in each plot or treatments.

3.7.4 Chlorophyll content

A Spad Meter was used to measure the chlorophyll content of the various treatments at three different stages of plant growth and development. The Spad Meter is a simple hand held electronic device used to clip undetached fresh leave on the plant to know the chlorophyll content. Five leaves sample were measured for its chlorophyll content in each treatment plot and their averages were recorded.

3.7.5 Days to 50 % flowering

Days to 50 % flowering of each variety were determined when 50 % of the plots or treatment plants flowered. The count started from the date of sowing till the last date when 50 % of flowers were observed.

3.7.6 Maturity Days

Days to maturity of each variety were determined when 85 % of the plot plant population matured and a number of days calculated starting from the date of sowing. The signs of maturity indices were the brown colouration, hard grain, and moisture content of the grains.

3.7.7 Leaf Area Index (LAI)

These was to determine the canopy spread of the leaves per area at a time interval during the plant growth and development. The Leaf Area Index was determined at panicle initiation and beginning of grain filling stages using an electronic leaf area meter. The hand held septo meter which is an electronic device was used for this exercise. Five sampled spot leaves area were measured in each plot and strike the average per plot or treatment.

3.7.8 Thousand Grain Weight (g)

Thousand-grain weight was determined by counting and weighing 1000 grains from the $1m^2$ quadrant plants stands grain yield. The process was done by counting thousand grains each from each plot and weighed it separately with an electronic scale.

3.7.9 Number of Effective panicle

The number of effective tillers per m^2 was calculated for each plot just before harvesting the crop. The panicles having filled grains were recorded as effective panicles.

3.7.10 Grain yield

Three quadrants were sampled in each treatment harvested, threshed and sundried to an average moisture content of 15 %. These samples were weighed separately and calculated for average value representative for each treatment. The representative values were then also use to convert into hectare bases

3.7.11 Straw Yield

The straws obtained from the net plot area of each plot were sun dried for 3 - 4 days and weighed. The weights that were obtained were converted into tonnes per hectare.

3.7.12 Soil Sampling

The soil sampling was done in a zigzag pattern across the entire experimental field after the field was ploughed and harrowed. Thirty (30) core samples were taken from the experimental field. The composite soil sample was shade dried and prepared for analysis.

3.8 Statistical Analysis

The data collected were subjected to analysis of variance (ANOVA) using Genstat discovery 12 Edition. Means were separated by the least significant differences (LSD) at 5 % probability.

CHAPTER FOUR

RESULTS

4.1 The Physical and Chemical Properties of the Experimental site

The physical and chemical soil analyses were done at the Savanna Agricultural Research Institute (SARI) soil chemistry laboratory. Results of the soil analysis are presented in (Table 4). The soil was sandy loam in texture.r

Table 4: Pre-planting soil analysis

Soil Property	Value
pH	4.53
E.C (µS/cm)	80.06
O.C (%)	1.02
N (%)	0.01
P (mg/kg)	7.08
K (mg/kg)	43.00
Ca (Cmol+/kg)	1.72
Mg (Cmol+/kg)	0.44
CEC (Cmol+/kg)	3.26
Sand (%)	59.80
Silt (%)	31.92
Clay (%)	8.28
Class/Texture	Sandy Loam

4.2 Plant Height (cm)

Plant height was taken in three weekly intervals at three different stages during the rice growth cycle as shown in Table 5.

4.2.1 Interaction Effects of Fertilizer Timing and Variety on Plant Height (cm)

Table 5 shows the effects of fertilizer timing and variety on plant height, there was a significant (P = 0.001) difference for plant height. Weekly variation with plant height was also recorded highly significant (P = 0.001). However, fertilizer, weeks and variety combine interaction with plant height was not significantly (P = 0.607). From table 5 below, it can be seen that plant height for week three recorded the shortest height followed by week six and with week nine recording the tallest plant heights.

Table 5: Interaction Effects of Fertilizer Timing and Variety on Plant Height (cm)

Fertilizer Timing	Variety								
	Gbewaa			Tox 3107			C93		
	3WAP	6WAP	9WAP	3WAP	6WAP	9WAP	3WAP	6WAP	9WAP
F0	29.41	48.93	69.27	29.41	47.47	66.53	25.47	47.37	65.40
F1	25.14	52.03	72.60	25.14	55.20	69.27	24.78	48.97	71.87
F2	28.33	55.60	71.47	28.33	47.70	75.53	29.32	49.83	77.17
F3	29.49	46.53	69.40	29.49	51.17	75.60	27.13	44.57	72.53
LSD	4.092	6.230	4.994	4.092	6.230	4.994	4.092	6.230	4.994

F0=famer practice, F1= 1WAP, F2=2WAP, F3= 3WAP, where WAP=Week After Planting.

4.2.2 Effect of fertilizer timing on plant height

Table 6 shows the effects of fertilizer timing and variety on plant height which indicates significant (P = 0.001) difference for plant height in week 3. Weekly variation with plant height was also recorded highly significant (P = 0.001).

Table 6: The effect of fertilizer timing on plant height

	Plant height (cm)		
	3 WAP	6 WAP	9 WAP
Fertilizer timing			
F0	25.71	47.92	67.07
F1	25.17	52.07	71.24
F2	28.35	51.04	74.72
F3	27.07	47.42	72.51
LSD (5 %)	2.362	3.597	2.884

4.2.3 The effect fertilizer timing and variety on plant height

Table 7 shows the effect of fertilizer timing and variety on plant height, there was a significant difference (P = 0.01) between the treatments at each stage of measurement. For 3WAP, F2 recorded the highest and the lowest plant height in that same week was F1. The highest plant height at 6WAP was F1 and the lowest value with treatment F3. For 9WAP, F2 was also the highest plant height and the lowest. For the effect of plant height on varieties, for 3WAP there were significant difference (P < 0.016) between variety whereby Gbewaa had the highest plant height and the C93 had the lowest plant height. At 9WAP the records show that there was not a significant difference (P = 0.104) among the tested varieties. However, C93 variety were recorded the highest and least was Gbewaa.

Table 7: The effect of fertilizer timing and variety on plant height

		Plant height (cm)	
Variety	3 WAP	6 WAP	9 WAP
C93	24.97	47.68	71.74
Gbewaa	28.09	50.77	70.68
TOX3107	26.67	50.38	71.73
LSD (5 %)	2.046	Ns	Ns
% CV	9.1	7.4	4.1

4.3 Plant Stand

There was no significant (P = 0.833) difference when mean values are compared with the Probable (P) value across the various treatment combination. With treatment combination of F2*Gbewaa had the overall highest number of plants stand. F3*C93 was the second highest plants stand and the least plant stand recorded by F0*C93.

4.4 Chlorophyll content

Chlorophyll content of the treatment showed no significant difference (P = 0.234) between means. However, considering the treatment (F1*C93) had the highest chlorophyll content among all the treatment followed by treatment (F3*C93) as the second highest in the chlorophyll content. The least chlorophyll content mean value among the treatments was (F0*Tox 3107).

4.4.1 Effects of Fertilizer Timing and Variety on Chlorophyll

From the Table 8 it shows that the effect of chlorophyll content was highly significant (P<0.01). With reference to the mean values from the table shows that Variety C93 had the highest mean value as chlorophyll content which was followed by Gbewaa chlorophyll content. The least mean value of chlorophyll content variety was Tox3107 with the mean value.

Table 8: Effects of Fertilizer Timing and Variety on Chlorophyll

Variety	Value
C93	42.33
Gbewaa	36.07
Tox3107	34.28
P-value	0.01

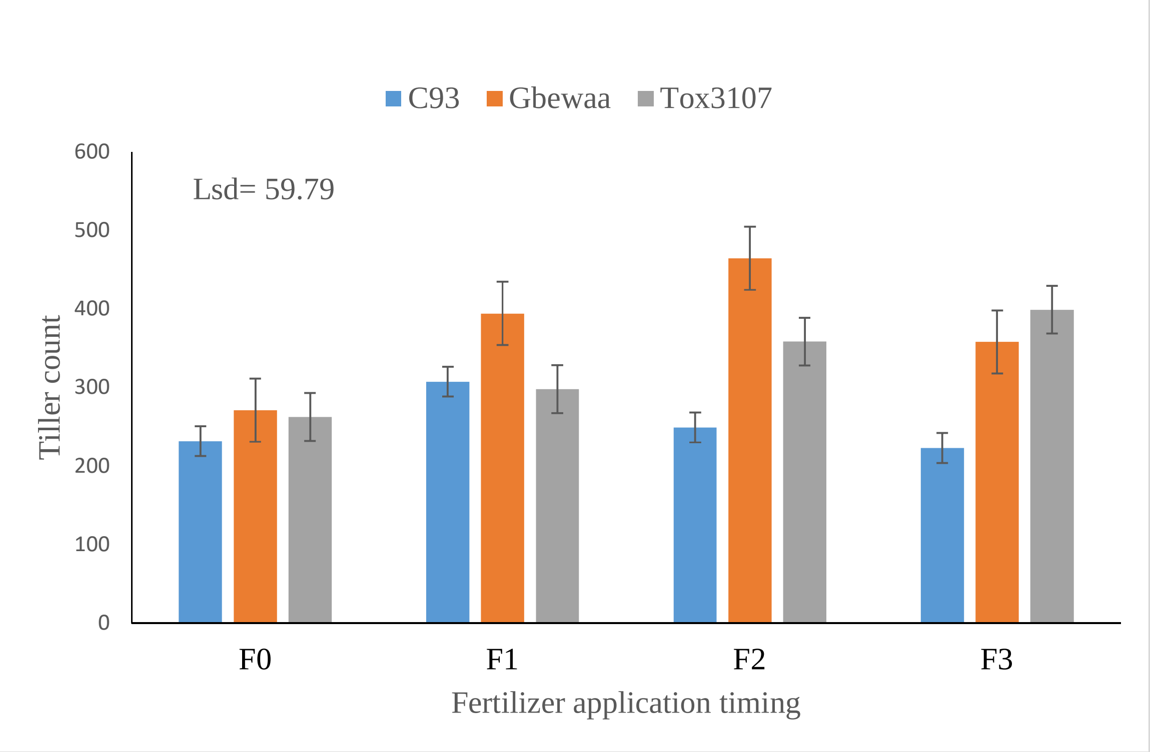
4.5 Tiller Count

From Figure 1, the graph shows the interaction effect of fertilizer timing and variety which was significantly affected (P = 0.001). It was realized that for F0*Gbewaa has recorded the highest number of tillers while F0*C93 which had the least number of tillers.

For fertilizer treatment, F1* Gbewaa still performed better than the other two selected varieties with the average tillers. Variety C93 also performed slightly higher than V3 as against V3.

For F2 fertilizer time interaction effect, it was realized from the graph that, variety Gbewaa still led to a maximum number of tiller counts. This was followed by Tox 3107 and C93 with the list performance variety under this treatment application.

For F3 application regime for the three varieties, Tox 3107 had the highest followed by the variety Gbewaa with an average.



F0 = Farmer practice, F1=1WAP, F2= 2WAP, F3= 3WAP

Figure 1: The interaction effect of fertilizer timing and variety on the tiller count.

4.6 Leaf Area Index (LAI)

From Figure 2, there was a significant difference (LSD = 0.3681) between treatments of fertilizer and variety on the LAI. In general, the main effect of fertilizer timing under Leaf Area Index (LAI) with respect to the four-week intervals for the three stages of data collection, the Gbewaa variety recorded the highest LAI value on the F3 fertilizer timing of application and followed by F2. The least LAI was recorded under Tox 3107 with F1 fertilizer application timing.

For 4WAP the fertilizer treatment F2 had the broadest growth rate in Leaf Area Index followed by F3 andF1 has the least LAI growth from the chart after farmer practice (F0). For 8 WAP, F2 still lead followed by F3 to F0 and then the least is F1. The third stage of the data did not show any significant (P = 0.383) difference.

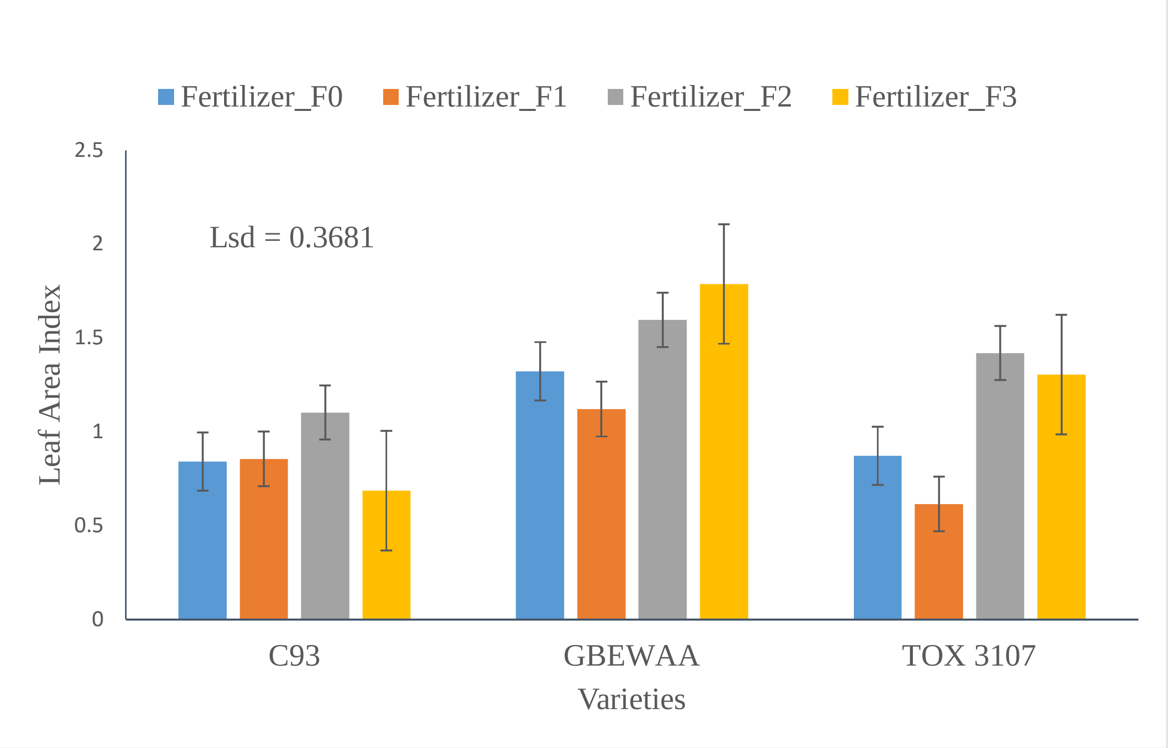


Figure 2: The effect of fertilizer timings and variety on the leaf area index.

From Figure 3, fertilizer treatment response under each stage of measured (4WAP, 8WAP and 12WAP), there was a significant difference (P = 0.008) in the Leaf Area Index of the rice. For week 4, the F2 treatment recorded higher Leaf Area Index (0.94) whiles F1 recorded lower Leaf Area Index of the rice varieties. A similar result was observed for week 8 after planting when F2 recorded higher (1.51) and F1 lower (0.88) Leaf Area Index for the rice varieties. F2 recorded higher leaf Area Index while F1 recorded lower Leaf Area index for week 12 after planting of rice. The results also show that generally F2 recorded the highest followed by F3, F0 and F1 in response to Leave Area Index.

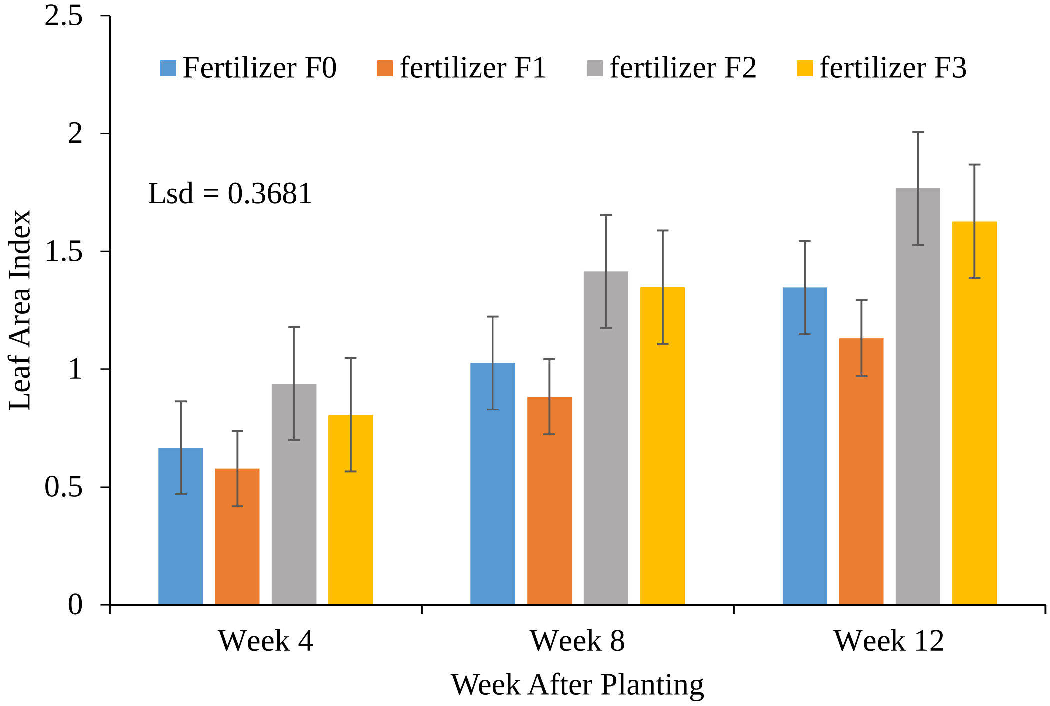


Figure 3: Effect of fertilizer timings on the leaf area index.

4.7 Number of Panicle Grain count

The figure 4 shows that, the three varieties interacted with fertilizer treatment (F0) and Gbewaa recorded the highest number of grains per panicle. The C93 and Tox3107 had the same number of panicle grain count except that C93 has insignificant margin higher than Tox 3107, that is C93 (83.1) and Tox3107 had (81.5). Gbewaa still had the highest number of grains per panicle but insignificantly higher than C93 with an average value (104.4) which is second to Gbewaa at (106.2) and Tox3107 had the least value (87.3).

For fertilizer treatment F3, Gbewaa was significantly higher than the other two varieties with a value (127) which followed by C93 with the value of (103.1) and the Tox 3107. F3 which also had the same varieties representation has the Tox 3107 being the highest with 99.7 average panicle grain count followed Gbewaa rice which had an average panicle count as (99.7). The least panicle count under this fertilizer treatment was C93 which has a value of (84.7).

Various varieties performance across the fertilizer treatments it was observed that C93 had its highest performance under F1 fertilizer timing regime and lowest panicle grain count in F0 fertilizer timing regime. Gbewaa produces the highest panicle grains under F2 and the least grain per panicle for F3 treatment. Tox3107 had the highest grain count in F3 and a least panicle grain count under F0 fertilizer treatment.

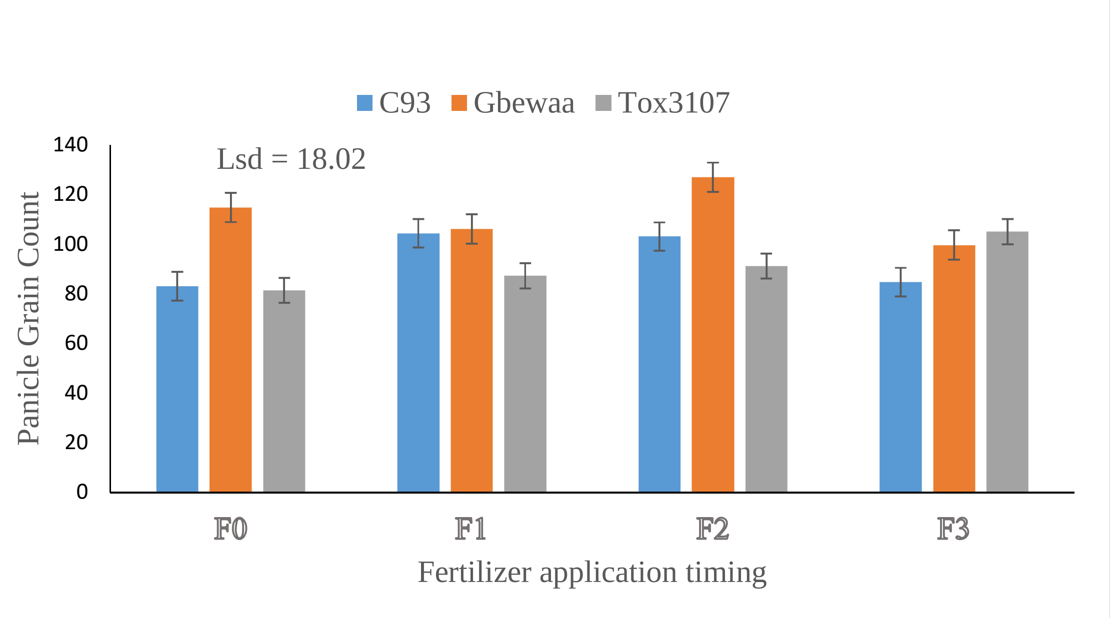


Figure 4: Interaction effect of fertilizer timing and variety on the panicle grain count.

4.8 Grain Yield

From Figure 5: Grain yield was significantly (P = 0.01) affected by fertilizer application timing against variety. The highest grain yield recorded was Gbewaa under the fertilizer treatment F2 and the second highest grain yield was Tox 3107 with fertilizer treatment F3 whiles the highest was C93 under fertilizer treatment F1.

However, looking at each variety poorly performed fertilizer treatments across, it’s realized that Gbewaa performs poorly under F3 treatment, Tox 3107 also performs poorly with fertilizer treatment F1 and C93 did not also gave good yield under the treatment F3.

More also the three varieties under each fertilizer treatment also has some clear performance disparities. From the figure 5, Variety C93 and Tox 3107 had almost the same grain yield whiles Gbewaa was the least performing variety under fertilizer treatment F0. Under the fertilizer treatment F1, variety C93 was the highest performing variety followed by Gbewaa and Tox 3107 the lowest grain yield. Fertilizer treatment F2 Gbewaa had the highest grain yield followed by C93 and Tox 3107 the least yield. From the same graph with fertilizer treatment F3, Tox 3107 was the best followed by Gbewaa and the C93 was the least grain yield.

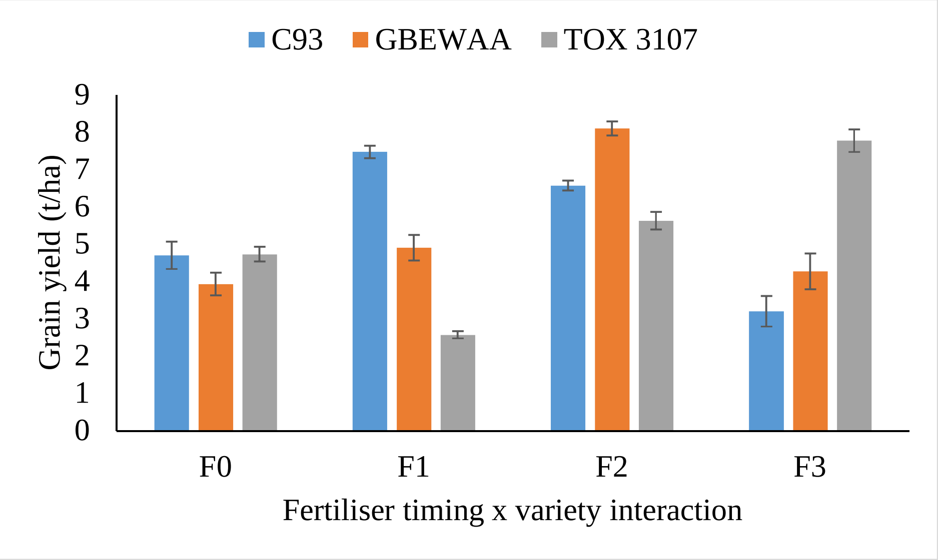


Figure 5: Interaction effect of fertilizer timing and variety on the grain yield of rice.

4.9 Thousand grain weight

From Figure 6. Thousand-grain weight was highly significantly (P < 0.001) affected by the treatments. Looking at the overall performance of varieties with fertilizer treatments from the graph. Tox 3107 was recorded the highest thousand-grain weight under Fertilizer treatment F3, it was followed closely by C93 with F1 and Gbewaa in F2. However, the poorly performed combination of varieties with fertilizer treatments specific as shown in figure 6, C93 performs poorly under fertilizer treatment F3. Gbewaa had the least thousand-grain weight recorded under fertilizer F0 treatment and Tox 3107 had the lowest weight under F1 across all the fertilizer treatments.

More also under each fertilizer treatment the same graph its observed that under fertilizer treatment F0 Tox 3107 was the highest followed by C93 and Gbewaa was least weight. Fertilizer treatment F1 C93 had the highest weight and followed by Gbewaa and the least was Tox 3107. Under fertilizer treatment F2 Gbewaa had the highest thousand grain weight followed by Tox 3107 and the C93 the least variety. The Tox 3107 was recorded the highest thousand grain weight under fertilizer treatment F3 followed by Gbewaa and C93 was the least weight.

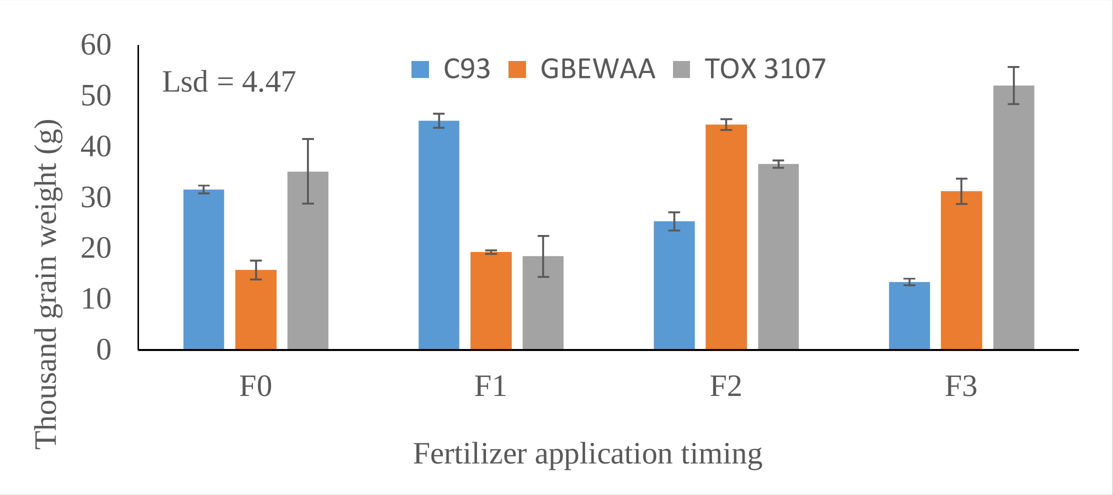


Figure 6: Effect of interaction of fertilizer timing and variety on thousand grain weight.

4.10 Straw Weight

Fertilizer application timing x Variety significantly (P = 0.019) affected biomass yield. The highest biomass yield was recorded by F2 in Gbewaa rice (Figure 6), followed by C93 under F1 and Tox 3107 under F3 as the third variety

Per independent varietal response to the various fertilizer treatments, Gbewaa variety performed much higher in F2 and the list straw yield at farmer practice, whiles F1 rank second highest straw yield per hectare within the variety. C93 variety had a very low straw yield and the highest straw yield attained for under F1 and then reduced slowly from F2 to F3 where it remained almost the same level with the farmer practices. The Tox3107 variety had a similar straw yield with farmer practice for F2 and F3 except F1 which had a very low straw yield with Tox3107 in terms of production field.

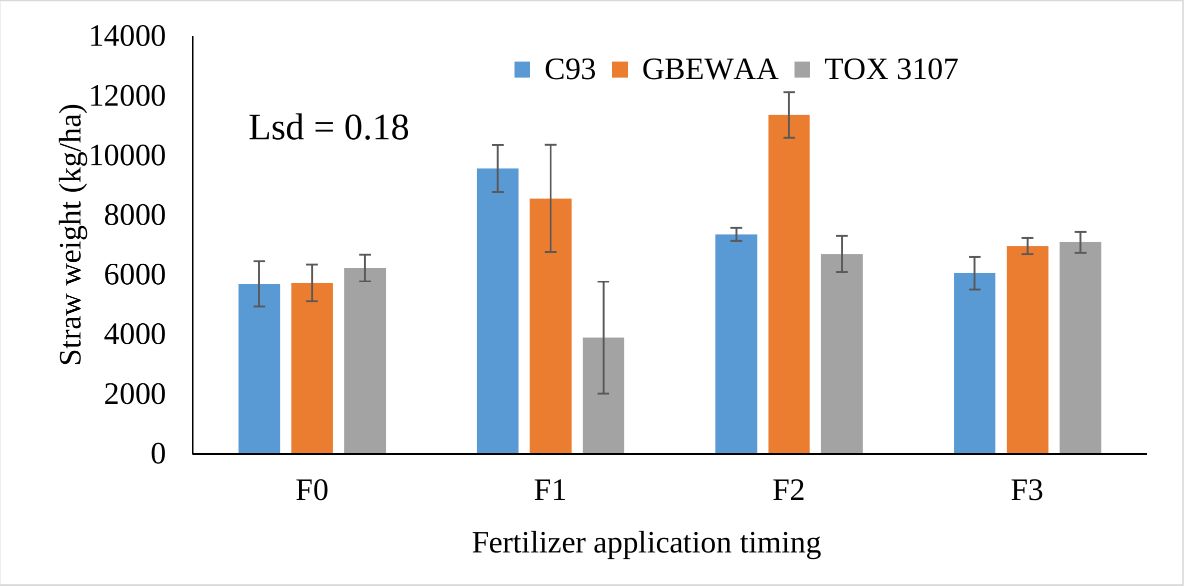


Figure 7: Effect of interaction of fertilizer timing on straw weight against varieties.

CHAPTER FIVE

DISCUSSION

5.1 Plant Height

According to Yang and Hwa (2008), in plant architecture, crop height is not only a crucial variable, but also an significant agronomic feature immediately related to the harvest indices and return ability.

For the combination of fertilizer regimes and rice varieties, plant height increased with an increasing number of weeks after planting. According to Morris (1980), intermediate rice plants have heights range from 75 cm to 160 cm. Therefore, the plant height recorded in this study fell within the range. The plant heights were not statistically significant for both week 3 (P = 0.158) and week 6 (P = 0.106). This observation confirms the results obtained by Álvarez-Herrera *et al.* (2017) who concluded that varying heights depended on the fertility and the environmental conditions of each of the soils. Plant height in week 9 was statistically significant (P = 0.001).

Also, the effect of fertilizer on the plant height also increased with an increasing number of weeks after planting. Here too, the shortest plant height was observed in fertilizer regime 1 WAP basal plus 5 WAP top dressing (F1) in the plants the third week after planting growth. While the tallest plant height was recorded in fertilizer regime 3 WAP basal plus 7 WAP top dressing (F3) also in week 9. The results are supported by Allahyar (2011) who reported that nitrogen fertilizer had significant influences on plant height. The plant height for all the fertilizer application regimes and heights measurement is taken during week 3, week 6 and week 9 were all statistically significant (P = 0.046).

Also, with the effect of rice variety on the plant height, plant height also increased as the number of weeks after planting also increased. For the rice varieties, the shortest plant height was observed for the C93 rice variety and this was during week 3 after planting, while the tallest plant height was also observed for the same rice variety and this was observed in the ninth week (week 9) after planting.

Generally, rice variety C93 recorded the tallest plant height among the three (3) rice varieties used in this study. This was followed by Tox3107 and with Gbewaa recording the shortest height observations in the study. Also, for the fertilizer regimes, 2 WAP basal plus 6 WAP top dressing (F2) recorded the tallest average plant height during week 3 and week 9. Plant height is one of the significant development parameters of any crop plant as it determines or modifies the yielding characteristics and ultimately forms the output of grain. For instance, characteristics associated with high yielding modern varieties, such as short stature and erect leaves, are considered to be unfavorable for weed suppression (Johnson *et al*., 1998).

5.2 Plant Stand

The effect of fertilizer and variety on the plant stand per meter square observed in this study was not statistically significant (P = 0.505). This implied that to get the optimum number of plant stand for medium varieties the best period is the second WAP for your basal application and top dressed in the sixth WAP to achieve the desired yield. This implies that some varieties still remain dormant for over one to two weeks before germination. The following could be the reasons for the delay germination; low moisture availability, poor sowing (deep burring or surface placement of seed) which confirm by Chauhan *et al.* (2008). F0 with C93 as early maturing variety had the least that signified that the basal fertilizer was applied very late denotes poor timing of application.

The effect of fertilizer had on the plant stand per meter square was not statistically significant (P = 0.505) (Table 2).

The type of rice variety too did not have any significant effect (P = 0.228) on the number of plant stands per square (Table 3). The study observed the highest number of plant stand per meter square can be rank as Gbewaa rice variety highest followed by Tox3107 rice variety and C93 variety had the least number of plant stand per meter square.

Overall, it was observed that fertilizer regime 2 WAP basal plus 6 WAP top dressing (F2) is highly recommended for Gbewaa rice variety as it was recorded the highest number of plant stand per meter square in the study.

5.3 Tiller Count

Rice tillering is one of the most important agronomic features in rice cultivation because the number of tillers per plant determines the number of panicles, a main element of seed output (Liu *et al*., 2011; Zhu *et al*., 2011). In addition, tiller count is generally used as an appropriate model feature for the research of behavioral features as it shifts over moment. The genetic elucidation of tiller numbers has thus become a concentrate of genetic studies on rice and reproduction (Liu, Shao, and Kovi, 2010).

The highest number of tillers was recorded in the combination of fertilizer regime 2 WAP basal plus 6 WAP top dressing (F2) and the Gbewaa rice variety while the least number of tillers were also recorded for the combination of fertilizer regime 3WAP basal plus 7 WAP top dressing (F3) and the C93 rice variety. The effect of both fertilizer and variety combination was statistically significant (P = 0.001) on the number of tillers per plant. Yoshida *et al*. (1970) indicated that there is a rise in the number of tillers per square meter as the amount of nitrogen taken by the plant rises. Experimental results show important impacts of soil fertilization and diversity on tillers m^{-2} (Mandana *et al*., 2014).

Fageria and Baligar (2001) also noted that the enhanced concentrations of nitrogen implemented led in a rise in an amount of tillers. Moro *et al*. (2008) also noted that adding the first 30 kg / ha N led in important rises in the amount of tillers. Statistically, fertilizer had a significant (P = 0.001) effect on the number of tiller counts in the study. The present results are also supported by Allahyar (2011) who reported that nitrogen fertilizer had significant influences on the number of tillers.

The effects of variety on the number of tiller counts are presented in Figure 3. The effect of variety had on the tiller count was statistically significant (P = 0.001). This is in agreement with Fageria *et al*. (1997) who stated that tillering characteristics among other factors is very much influenced by the genetic characteristics of the cultivars grown.

5.4 Chlorophyll Content

The effects of both fertilizer and variety on the chlorophyll content in these study shows that the highest amount of chlorophyll content found in 1WAP basal 5WAP top dressing (F1) fertilizer regime could be the combined effect of both fertilizer and the inherent seed endosperm nutrient with C93 rice variety confirmed by Kindred *et al.* (2008). Whiles the least amount of chlorophyll content under 3WAP basal plus 6WAP top dressing (F0) and Tox 3107 rice variety could account for delay fertilizer application or not fully utilized at time of measurements. More also the nutrient within the seed could have been exhausted before the fertilizer was applied. These could be possible since basal fertilizer was applied 3WAP. Though both fertilizer and variety did not have a significant (P = 0.234) effect on the chlorophyll content in this study. Implies fertilizer timing here hasn't got much effect on various treatment conducted.

Statistically however, the effect of variety on the chlorophyll content was highly significant (P = 0.001). This indicates that individual varieties have its own inherent genetic abilities of chlorophyll development level as to whenever nutrient requirement is supplied.

5.5 Number of Panicle Grain count

Rice grain output is a feature of panicles per unit region, a number of spikelets per panicle, weight of 1000 grains and sterility of spikelets (Fageria and Baligar, 2001). The amount of panicles is the consequence of producing a number of tillers and the percentage of efficient tillers that continued to generate panicle (Hossain *et al.*, 2008).

Statistically, the effect of fertilizer and variety combination on the number of panicle grain count had a significant (P = 0.014) effect on the panicle grain count. This implies that to achieve high number of grains per panicle in 2 WAP Basal and top dressed 6 WAP (F2) was applied or applied in the third week After Planting and top dress in the 5 WAP (F0). This can be applicable to Gbewaa variety. Whereas with C93 produces more panicle grains competitively high with Gbewaa for F1 (Basal 1WAP* Top dress 5 WAP) then also at better produce grains in F2 (Basal 2 WAP * Top dressed WAP). This can be applied to all early varieties for confirmation. The late or long maturity period varieties were also discovered to be performing well in delayed basal fertilizer application as shown from figure 6 above. Tox3017 performed higher in F3 (Basal 3WAP * Top dress 7WAP) and also performed averagely for F2 (Basal 2WAP * Top dress 6 WAP). This can also be recommended for long maturing varieties.

The effect of fertilizer on the number of grains per panicle showed that the highest number of grains per panicle was observed in fertilizer regime, F2 while the least number of panicle grain count was recorded for fertilizer regime F0. Artacho *et al*. (2009) found that with N fertilization a proportion of m^{-2} panicles improved and the connection was straightforward. Statistically, the fertilizer regime alone did not have any significant ($P > 0.018$) effect on the number panicle grain count of the rice plants.

Also, the effect of variety on the number of grains per panicle showed the highest number of grains per panicle was observed in the Gbewaa rice variety while the least was also recorded in Tox3107 rice variety. Variety alone had a significant ($P = 0.001$) effect on the number of panicle counts.

5.6 Thousand Grain Weight

The mass of actual plant grains immediately determines a population's output. As a final product of the interaction between many plant physiological and biochemical processes, the mass of plant grains depends on several properties, such as the number of panicles per plant, the number of grains per panicle and the weight of thousand grain (Verica *et al*., 2013). Rice grain output is a quantitative feature affected by other agronomic characteristics and cultural variables, the amount of spikelets per panicle being a significant element of rice grain output (Zong *et al*., 2012). It can be seen that the highest was recorded in the combination of fertilizer regime 3WAP basal plus 7WAP top dressing (F3) and Tox3107 rice variety. According to Sheehy *et al*. (1998) late maturing varieties require delay basal application since it has a very long period of vegetative phase of growth. This implies that to achieve good results per this parameter this treatment is recommended. Also, the least was recorded in the combination of fertilizer regime F1 and Tox3107 rice variety. Statistically, it can be stated that fertilizer and variety combination did not have a significant (P > 0.012) effect on the thousand grain weight.

Also, the effect of fertilizer on thousand grain weight showed that the highest thousand grain weight was recorded in fertilizer regime 2 WAP basal plus 6 WAP top dressing (F2) while the least thousand grain weight was also recorded in fertilizer regime 3 WAP basal plus 7 WAP top dressing F0. From the study, fertilizer too did not also have a significant (P = 0.061) effect on the thousand grain weight. Mandana *et al*. (2014) noted that the implementation of separate N fertilizer content had no important impact on the weight of thousands of grains, but it was discovered that the implementation of thousands of grains was considerably influenced by distinct types.

The variety alone had a significant (P = 0.001) effect on the thousand grain weight. Surekha *et al*. (2006) indicated that crop management methods did not substantially affect the weight of thousands of grains. Previous trials have identified seed weight as a hereditary characteristic (Mauad *et al*., 2003; Surekha *et al*., 2006) that may justify the incompatible reaction to soil fertilization and plant leadership methods (Kamara *et al*., 2011).

5.7 Leaf Area Index (LAI)

In rice, the perfect leaf areas for seedlings, perfect leaf forms to improve photosynthetic efficiency, profound, well-developed root systems, growing leaf zone indices (LAI) and plant development frequency (CGR) were recognized as the main output determinants during panicle introduction (Sun *et al*., 2005). The Leaf area index performs a key part in determining the ultimate output and competitiveness of rice against vegetation (Anyang, 2015).

The data revealed that, Gbewaa rice produced the maximum LAI at the three stages of measure (week 4, 8 and 12). Chaturvedi (2005) stated that, the increase in LAI might be due to improved nutrient availability and enhanced plant growth. Squire *et al*. (1987) found that N fertilizer's primary impact is to boost the frequency of leaf growth, contributing to enhanced interception by the canopy of regular solar radiation.

The effect variety had on the LAI is also presented in (figure 3). From the table, it can be seen that LAI increased with an increasing number of weeks after planting. Statistically, the variety had a significant (P = 0.008) effect on LAI of the rice plants.

5.8 Straw Weight

The straw yield obtained from the different treatments in this study ranged between 3900 to 11, 367 g m^{-2}. It was observed that, fertilizer regime F2 for Gbewaa rice recorded the highest straw weight (11,367 g m^{-2}). The lowest straw weight (3,900 g m^{-2}) was recorded for C93 rice variety for fertilizer regime F1. From the study again, the rice variety alone had a significant (P = 0.019) effect on the straw weight per meter square.

Islam *et al*. (2016) disclosed that fertilizer implementation had a marked impact in generating greater straw yields in rice. Due to fertilizer implementation, Azim *et al*. (1999) recorded a substantial rise in rice biological output.

5.9 Grain Yield

The effect of fertilizer and variety on the grain per meter square is presented in (Table 9). Statistically, fertilizer and variety did not have a significant (P = 0.543) effect on the number of grain per meter square.

The effect of fertilizer on the number of grain per meter square, the highest grain per meter square was recorded with fertilizer regime 2WAP basal plus 6WAP top dressing (F2) while the least grain per meter square was also recorded with fertilizer regime 3WAP basal plus 6WAP top dressing (F0). The effect of fertilizer on the grain per meter square was not significant (P = 0.061). Kamara *et al*. (2011) concluded that Nitrogen application increased rice grain yield and yield components with the highest grain yield. Previous studies showed that the proper use of fertilizer can increase the yield and improve the quality of rice significantly (Ahmed *et al*., 2005; Oikeh *et al*., 2008)

The effect of variety on the number of grains per meter square was also the highest number of grain per meter square was recorded for rice variety C93 while the least number of grain per meter square was also recorded for Tox3107 rice variety. Statistically, variety alone did not have any significant (P = 0.001) effect on the number of grains per meter square.

5.10 At Vegetative Growth Stage

The varieties exhibited variation in vegetative growth in response to the different fertilizer application timing. This can be attributed to the variation in genetic composition among the genotypes. According to Muhammad *et al*. (2015), plant growth and development is a function of their genetic composition, which interacts with their environment to influence growth and quality. Jayachandran *et al*. (2002) stated that different genotypes differ in nutrient uptake, translocation and assimilation, and accounts for the superiority of some genotype over others, making them more nutrient efficient. Muhammad *et al*. (2015) stated that characterization of rice genotypes based on efficient in absorbing, transporting and utilizing nutrients is of utmost importance in making nutrient recommendations and improving more vigorous in the vegetative phase, specifically at the seedling stage.

According to Bastia (2002) among various environmental factors that influence growth and development of plants, nutrient management is of the essence. Adequate and balanced nutrients applications at the appropriate time of crop requirement are the key components of crop nutrient management. The fertilizer application timing varied in their influence on vegetative growth among the genotypes. This is an indication of the variation in the critical period of nutrient requirement among the varieties. Several authors have reported different period of nutrient supply for different varieties for optimum growth. Koffi *et al*., (2016) recommended the basal application of NPK before transplanting of aromatic rice for optimum vegetative growth and split application of the remaining nutrients at panicle initiation and before flowering for enhanced yield components and yield. Vishwakarma and Kushwaha (2008), Mahajan *et al*. (2010) and Thomas and Lal (2012) made variable recommendations for nutrient application for different rice genotypes.

5.11 Yield Component and Yield

There was a difference in yield components and total yield among the varieties in response to the different fertilizer application timing. The difference in yield component and total yield of the genotypes indicated that the genotypes responded differently to the timing of the applied nutrients, and varied in nutrient uptake and use efficiency owing to the difference in the genetic composition of these genotypes. Exploitation genotypic variation for improving the utilization of soil and fertilizers applied is very crucial in rice crop production. It was observed that this variation in the ability of nutrient uptake among the genotypes is due to the diverse attributes such as genetic yield potential. This is similar to report by Muhammad *et al*. (2015) and Janki and Thiyagarajan (2002) who claimed that genotypes could vary in their capacity to digest soil nitrogen due to associative biological nitrogen fixation and the impact of rice plants on rhizosphere, nitrogen mineralization, subsoil nitrogen absorption, enhanced root mass density, and greater nutrient absorption per unit root size. This is supported by findings of Janki and Thiyagarajan (2002) who reported significant and consistent difference for nitrogen uptake, yield and synthesis of crude protein in 64 genotypes of rice that had received split nutrients at different stages of growth. According to Mae (1997), mineral uptake, transportation and consumption are linked to plant genetic personality, so distinct genotypes react negatively to the same fertilizers used.

Variation in the effect of the fertilizer application timing on the yield components and yield of the genotypes was attributed to the variation in critical periods of nutrients uptake and utilization among the respective genotypes. The current result confirms the finding of Fageria (2010) who reported highest grain yield with N timing treatment of one-third at sowing and one-third at active tillering and one-third at panicle initiation growth stage for hybrid rice and half N applied at the initiation of tillering and half N applied panicle initiation for inbred rice. Similarly, Hirzel *et al.* (2011) confirmed highest productivity of lowland rice crop in Chile with application of 33 % N at sowing, 33 % at tillering, and 34 % at panicle initiation, and highest productivity for upland rice with application of 50 % N at sowing and 50 % at panicle initiation.

It was also observed that when the timing of nutrient application does not coincide with the periods of the nutrient requirement by the respective rice genotypes, the applied nutrients are leached and volatilized, resulting in losses and inefficient in nutrient utilization. (Qiao-gang *et al.*, 2013) reported highest loss of applied nutrients to volatilization owing to nutrient misappropriation and improper timing of nutrient supply. This is also supported by Yoseftabar (2013).

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The purpose of this study was to determine the optimum timing of fertilizer for the maximum performance of yield components of Gbewaa, C93 and Tox3107 rice varieties to improve farmer's production efficiency.

In this study, it was realized that plant height increases directly proportional with the age and the time of fertilizer was applied the plants all thing being equal. The effect of plant height on variety was significantly different base the result analyzed. The number of plant stand per meter square was largely depended on the germination and plant resistant to drought, pest and disease on the growing field. The study reveals that the number of plant stands on rare occasion does increase or rather decreases at times by environmental influence thus either by drought or pest and diseases. The range and procedures did not differ significantly. The tiller number at the vegetative stage was completely different at the time of maturity. Some were increased as a result of the treatment differences or inherent varietal physiological development, whiles others reduce as a result of drought, failure to produce panicles etc.

Results of the study revealed that C93 and Tox3107 which are genotype yet to be released performed similarly to Gbewaa in terms of grain yield. Averagely, 2 WAP basal application + 6 WAP top dressing recorded the highest influence on grain yield relative to 3 WAP basal application + 7 WAP top dressing, 1 WAP basal application + 5 WAP top dressing and farmers practice. The varieties differed in their response to the various fertilizer application timing. Whiles biomass and grain yield of C93 was maximized by 1 WAP basal + 5 WAP top dressing, the yield of Gbewaa and Tox3107 were maximized by 2 WAP basal + 6 WAP top dressing and 3 WAP basal + 7 WAP top dressing respectively.

6.2.2 Recommendation

- The study recommends 3 WAP basal + 6 WAP top dressing gives optimize yield in rice for all varieties as being practice by most Farmers.
- However, 1 WAP basal + 5 WAP top dressing prove high yield in C93, 2 WAP basal + 6 WAP top dressing proved high yield in Gbewaa, and the 3 WAP basal + 7 WAP top dressing also yielded good with Tox3107.
- The study also specified that 1 WAP basal + 5WAP top dressing is recommended for Early Maturity Varieties, 2WAP basal + 6WAP top dressing recommended for Medium maturity variety and 3WAP + 7 WAP top dressing recommended for late maturity variety.

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LIST OF APPENDICES

Appendix 1: Plant height

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	57.331	28.665	3.01	
REP.*Units* stratum					
Fertilizer_F	3	273.770	91.257	9.57	<.001
Week	2	36152.460	18076.230	1895.08	<.001
variety_v	2	62.009	31.005	3.25	0.045
Fertilizer_F.Week	6	202.475	33.746	3.54	0.004
Fertilizer_F.variety_v	6	108.407	18.068	1.89	0.094
Week.variety_v	4	73.641	18.410	1.93	0.115
Fertilizer_F.Week.variety_v	12	259.278	21.607	2.27	0.017
Residual	70	667.694	9.538		
Total	107	37857.066			

Appendix 2: Plant stand

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	0.867	0.434	0.14	
REP.*Units* stratum					
Fertilizer_F	3	7.552	2.517	0.80	0.505
variety_v	2	9.909	4.954	1.58	0.228
Fertilizer_F.variety_v	6	8.576	1.429	0.46	0.833
Residual	22	68.893	3.131		
Total	35	95.796			

Appendix 3: Chlorophyll Content

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	12.22	6.11	0.50	
REP.*Units* stratum					
Fertilizer_F	3	32.27	10.76	0.87	0.471
variety_v	2	428.06	214.03	17.34	<.001
Fertilizer_F.variety_v	6	108.95	18.16	1.47	0.234
Residual	22	271.49	12.34		
Total	35	852.99			

Appendix 4: Tiller count

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	22452.	11226.	9.00	
REP.*Units* stratum					
Fertilizer_F	3	52234.	17411.	13.96	<.001
variety_v	2	87598.	43799.	35.13	<.001
Fertilizer_F.variety_v	6	52513.	8752.	7.02	<.001
Residual	22	27430.	1247.		
Total	35	242227.			

Appendix 5: Leaf Area Index

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	1.6876	0.8438	5.50	
REP.*Units* stratum					
Week	2	9.4472	4.7236	30.81	<.001
Fertilizer_F	3	4.3306	1.4435	9.41	<.001
variety_v	2	6.4695	3.2348	21.10	<.001
Week.Fertilizer_F	6	0.2751	0.0459	0.30	0.935
Week.variety_v	4	0.6209	0.1552	1.01	0.407
Fertilizer_F.variety_v	6	2.6030	0.4338	2.83	0.016
Week.Fertilizer_F.variety_v	12	0.2437	0.0203	0.13	1.000
Residual	70	10.7327	0.1533		
Total	107	36.4104			

Appendix 6: Panicle Grain Count

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	1220.7	610.4	5.39	
REP.*Units* stratum					
Fertilizer_F	3	955.2	318.4	2.81	0.063
variety_v	2	3044.2	1522.1	13.44	<.001
Fertilizer_F.variety_v	6	2384.4	397.4	3.51	0.014
Residual	22	2492.4	113.3		
Total	35	10097.0			

Appendix 7: Grain yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	227222.	113611.	0.28	
REP.*Units* stratum					
Fertilizer_F	3	27143056.	9047685.	22.25	<.001
variety_v	2	577222.	288611.	0.71	0.503
Fertilizer_F.variety_v	6	80242778.	13373796.	32.89	<.001
Residual	22	8946111.	406641.		
Total	35	117136389.			

Appendix 8: Thousand grain weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	10.14	5.07	0.24	
REP.*Units* stratum					
Fertilizer_F	3	401.18	133.73	6.39	0.003
variety_v	2	435.38	217.69	10.41	<.001
Fertilizer_F.variety_v	6	4381.08	730.18	34.92	<.001
Residual	22	460.07	20.91		
Total	35	5687.85			

Appendix 9: Straw yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	4273889.	2136944.	0.62	
REP.*Units* stratum					
Fertilizer_F	3	32183333.	10727778.	3.10	0.048
variety_v	2	28470556.	14235278.	4.12	0.030
Fertilizer_F.variety_v	6	67071667.	11178611.	3.23	0.020
Residual	22	76099444.	3459066.		
Total	35	208098889			