DETERMINATION OF NITROGEN RATE FOR OPTIMUM YIELD, N UPTAKE AND USE EFFICIENCY OF UPLAND RICE (*Oryza sativa* L.) VARIETIES AT GIMBO DISTRICT, SOUTHWESTERN ETHIOPIA

M.Sc. THESIS

MERKINE MOGISO

September 2016
Jimma, Ethiopia

DETERMINATION OF NITROGEN RATE FOR OPTIMUM YIELD, N UPTAKE AND USE EFFICIENCY OF UPLAND RICE (*Oryza sativa* L.) VARIETIES AT GIMBO DISTRICT, SOUTHWESTERN ETHIOPIA

A Thesis Submitted to School of Graduate Studies, Jimma University,
College of Agriculture and Veterinary Medicine

In Partial Fulfillment of the Requirements for the Degree of Masters of
Science in Agriculture (Agronomy)

Merkine Mogiso

September 2016
Jimma University

APPROVAL SHEET
SCHOOL OF GRADUATE STUDIES
JIMMA UNIVERSITY

Jimma University College of Agriculture and Veterinary Medicine
Department of Horticulture and Plant Science

Signature _____________ Date _______________

DEDICATION

I dedicate this thesis manuscript to my mother W/ro Desta Borena, her encouragement and good wishes vitalized me to this academic accomplishment.

STATEMENT OF THE AUTHOR

I declare and affirm that this thesis is the result of my own research work and that all sources of information used for this thesis writing have been correctly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for the award of the Degree of Master of Science at Jimma University College of Agriculture and Veterinary Medicine (JUCAVM). This thesis is retained in the library of the university to be made accessible to borrowers under the rules of the library. I affirm that this thesis has not been submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

Brief quotations from this thesis are acceptable without needing special permission only if a correct acknowledgement of source is made. Applications for permission for extended quotations from this document in whole or in part may be approved by the head of the department of plant sciences and horticulture or the dean of postgraduate program directorate when in his or her decision, the proposed use of the material is for a scholarly interest. Rather, in all other cases, the permission must be obtained from the author.

Name: …………………………………………..
Signature: ……………………………………….
Place: ……………………………………………
Date of submission: …………………………….

BIOGRAPHICAL SKETCH

The author was born on August 21, 1986 at Bedessa town, Damot Woyde district, Wolayta Zone in SNNPR. He attended his primary and secondary education at Bedessa elementary and secondary school, respectively. He joined Mizan ATVET College in 2003 academic year and graduated with Diploma in Plant science. Then he joined Wolayta Soddo University on August 15, 2006 to scale up his knowledge and graduated with B.Sc. Degree in Crop Science and Horticulture on October 23, 2010.

Soon after his graduation, he was employed by Southern Agricultural Research Institute (SARI) and stationed at Bonga Agricultural Research Center (BARC), and served as researcher in crop research process from 2011 to 2014 until he joined the school of graduate studies at Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) in 2014/15 academic year to study his M.Sc. degree in Agronomy.

ACKNOWLEDGEMENTS

At the beginning, I would like to thank the almighty God, his grace and mercy enabled me to pursue higher education in Agriculture and to complete the research work and the preparation of the thesis successfully for the degree of Master of Science in Agronomy.

I would like to express my heartfelt gratitude, sincere appreciation to my major research advisor Dr. Abush Tesfaye, and co-advisor Dr. Amsalu Nebiyu for their keen scholastic guidance, supervision, enthusiastic encouragement, constructive comments and valuable suggestions from the initial stage of thesis proposal development up to the completion of the thesis work.

I thank the Southern Agricultural Research Institute (SARI) for sponsoring and facilitating my thesis research work. I would like to express my great thanks to Jimma University, College of Agriculture and Veterinary Medicine (JUCAVM), for financial support in covering some expenses for my research work.

Special thanks, goes to Bayu Dume, and Abiyot Hunde (JUCAVM laboratory technicians) for their support and kind help during the laboratory work. My thanks are extended also to Aminat Hassen, Ejigu Mulatu, Minalu Gebeyehu, and Tesfaye Tarekegn for their contribution and supports during implementation of the experiment.

I would like to express my special thanks to my intimate friends and coursemates; Yohannis Derara, Ermias Assefa, Tefera Abebe, and Buchura Negesse for their memorable moments during the entire period of my post-graduate study.

Finally, I would like to express my deepest gratitude and indebtedness to my mother Desta Borena Herana for her great sacrifice, encouragement, endless prayers and blessings throughout my academic career.

LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
ANRE	Apparent N Recovery Efficiency
ANUE	Agronomic N Use Efficiency
BARC	Bonga Agricultural Research Center
CIMMYT	International Maize and Wheat Improvement Center
CSA	Central Statistical Authority
CV	Coefficient of Variation
FAO	Food and Agricultural Organization
FAOSTAT	Food and Agricultural Organization of the United Nations Statistics
GRiSP	Global Rice Science Partnership
IRRI	International Rice Research Institute
HI	Harvest Index
LSD	Least Significant Difference
MRR	Marginal Rate of Return
MoARD	Ministry of Agriculture and Rural Development
N	Nitrogen
NRRDSE	National Rice Research and Development Strategy of Ethiopia
NUE	Nitrogen Use Efficiency
PNUE	Physiological Nitrogen use Efficiency
RSDEA	Rice Sector Development in East Africa
SNNPR	Southern Nation Nationalities and Peoples Region
SSA	Sub Saharan Africa

TABLE OF CONTENTS

Contents Page

TABLE OF CONTENTS (*CONTINUED)*

LIST OF TABLES

Table **Page**

LIST OF FIGURES

LIST OF APPENDICES

Appendix Table **page**

Determination of Nitrogen Rate for Optimum Yield, N Uptake and Use Efficiency of Upland Rice (*Oryza sativa* L.) Varieties at Gimbo District, Southwestern Ethiopia

ABSTRACT

A field experiment was conducted at "Choba" on-farm, Gimbo district in Kaffa zone, Southwestern Ethiopia during the 2015 main cropping season to determine optimum rate of N application and the best variety based on N uptake, N use efficiency, and yield and yield components of upland rice. A 4x4 factorial experiment was carried out using split plot design with three replications. The treatments consisted of four rice varieties as main plot factor and four N rates considered as the sub-plot factor. The analysis of variance revealed that variety and N rate were significantly ($P \leq 0.05$) different for all parameters studied in the location. Moreover, the interaction between variety and N rate was significantly ($P \leq 0.05$) different for tiller and panicle numbers, total and filled spikelets per panicle, grain yield, biological yield, grain harvest index as well as N use efficiency parameters except N concentration in grain and straw at maturity. The interaction effect showed that highest number of tillers 266.0 and 260.7 per square meter recorded for NERICA-4 and Suparica-1, respectively at 69 kg N ha^{-1}. NERICA-4 produced the highest number of panicles (227.3) followed by Suparica-1 (220.0) at 69 kg N ha^{-1}. Likewise, these two varieties were also produced the highest number of filled spikelets per panicle at 69 kg N ha^{-1}, and gave 114.3 and 111.7 for Suparica-1 and NERICA-4, respectively. However, all tested varieties produced highest number of total spikelets per panicle when the N rate exceeds 46 kg N ha^{-1}indicating the higher production of unfilled spikelets at increased N rate in low yielded varieties. Besides, the highest grain yield of 4589.00 and 4575.00 kg ha^{-1} was also recorded for both NERICA-4 and Suparica-1, respectively at 69 kg N ha^{-1}. The application of N fertilizer increased total N concentration and uptake in grain and straw at maturity, while decreased agronomic (ANUE), physiological N use efficiency (PNUE) and Apparent N recovery (ANRE %) except Suparica-1. The highest ANUE, PNUE and ANRE (%) was obtained at the rate of 46 kg N ha^{-1} for Suparica-1and at 23 kg N ha^{-1} for NERICA-4. The correlation analysis was also indicated that positive and highly significant associations between grain yield with yield components and N uptake at maturity. Overall, varieties Suparica-1 and NERICA-4 were more efficient in producing grain yield with the highest ANUE, PNUE, as well as, ANRE as compared to other varieties in the location. However, based on partial budget analysis the highest Marginal Rate of Return (MRR) was recorded for Suparica-1 and NERICA-4 at 46 kg N ha^{-1}. Therefore, it is possible to conclude that varieties Suparica-1 and NERICA-4 at 46 kg N ha^{-1} recommended for cultivation in the study area. However, repeating the experiment over years by increasing the N levels would help to draw sound recommendations. Hence, future studies should look into these issues to validate the current results in the location.

Key words: Agronomic N use efficiency; Correlation coefficient; Marginal rate of return

1. INTRODUCTION

Rice (*Oryza sativa* L.) is a staple food crop for more than half of the world's population, most importantly in developing countries (Seck *et al.*, 2012). It is one of the world's principal crops in terms of economic value. More than 90% of the world's rice is grown and consumed in Asia where nearly 60% of the world's people live (GRiSP, 2013). It is the most widely consumed food for a large part of the world's human population. One fifth of the world's population or more than a billion households in Asia, Africa and America depend on rice systems for their main sources of employment and livelihoods (Seck *et al*., 2012; Siwar et al., 2014). Its production is currently extending across at least 114 countries in the world and the second most produced cereals in the world after maize. The production area in 2014 was approximately 162 million hectares with 738 million tons of paddy rice in the world with the average paddy rice yield of 4.5 tons per hectare (FAOSTAT, 2015). China is the largest producer and consumer of rice, globally (Seck *et al*., 2012; GRiSP, 2013; FAOSTAT, 2015). The productivity of the crop elsewhere in major rice producing countries includes: 3.6 t ha^{-1} in India, 5.1 t ha^{-1} in Indonesia, 5.8 t ha^{-1} in Vietnam, 6.7 t ha^{-1} in China and 9.5 t ha^{-1} in Egypt (FAOSTAT, 2015).

Rice belongs to the genus *Oryza* under the family *Poaceae*. The only two cultivated species of the genus in the world are the universally cultivated Asian rice (*O. sativa*) and the West African rice (*O. glaberrima*) (Chang, 1976; Linares, 2002). Based on broad historical evidences, researchers thought that African rice first originated in the upper river delta of Niger in West Africa (Chang, 1976; Sarla and Swamy, 2005). The Asian cultivated rice is domesticated in tropical Asia to South of China (Linares, 2002). After wards, the crop is rapidly distributed to different parts of the world as a staple food crop, especially in the developing world. Currently, it has also become a priority commodity for food security in Africa and grown over 75% of the African countries with a total production of 14 million tons and 16 million metric tons of consumption annually (MoARD, 2010).

Rice was introduced to Ethiopia in the 1970's and has since been cultivated in small pocket areas of the country. Ethiopia is situated in the tropical zone with a wide range of altitude from below sea level to over 3000 meter above sea level, which makes the country have a diverse agro-climatic condition. The wide adaptability of the crop coupled with the diverse agro-climatic condition of the country, more suited for the cultivation of different rice ecosystems in Ethiopia (MoARD, 2010). Currently, due importance is given for rice among other crops in enhancing its production and productivity, and consequently rice has received the name *Millennium crop* because of the expected potential contribution to the food security of the country (NRRDSE, 2010). At present rice is gaining the same importance, as some of the most common cereal crops in Ethiopia i.e., wheat and barley in different parts of the country for both domestic consumption as well as export market for economic development (Hedge and Hedge, 2013). Despite, the importance of the crop, the national productivity of rice is 2.8 t ha^{-1} (FAOSTAT, 2015) which is far below the productivity of the crop on research plots, which have reported up to 5.4 t ha^{-1}(Tadesse, 2015), and the crop potential in other major rice producing countries in the world.

Southwestern part of Ethiopia is one of the potential areas for rice production, mainly in rainfed upland ecology. The crop plays an important role for farmers, as food for home consumption, and source of income, as it is important crop in the local market. It is consumed at household level in various ways which includes: *injera, dabbo, asambusa, kinche,* and *shorba.* The production and utilization of upland rice is increasing in the lowland part of Gimbo district; especially at *Gojeb, Arguba, Choba* and *Shomba* areas. Recently, some upland rice varieties have been released nationally to be grown under rainfed conditions. Bonga Agricultural Research Center has also been conducting experiments on rice with major emphasis on selection of adaptive varieties in the area. Accordingly, several released varieties were evaluated and two varieties i.e., NERICA-4 and Suparica-1 were identified as the most adapted and recommended for production in Choba areas with yield of 3.8 and 4.1 t ha^{-1}, respectively. However, after few years of production, the productivity of the varieties, have been declining gradually, which is currently estimated to be less than 1.5 t ha^{-1} (BARC, 2015). This might be attributed to the use of inappropriate management practices, among which, soil fertility management, particularly nitrogen is the most important limiting factor. It is mainly because of the common farmer’s practice of continuous mono-cropping of cereals without nutrient replenishment might have resulted in the depletion of the essential plant nutrient of the soil. Besides, ever increasing cost of fertilizer, poor distribution system, low input purchasing capacity of subsistence farmers, and unavailability at the right time of applications are among some of the important factors that limited the use of fertilizers particularly nitrogen fertilizer. Despite the above mentioned factors, studies on nitrogen fertilizer recommendations for maximum economic yield and nitrogen use efficiency of these varieties were still limited in the study area. The rate of nitrogen fertilizer, time of application, seed rate, and sowing methods are among the major agronomic practices that critically affect rice production in Ethiopia (Kebebew *et al.*,2011).

In fact, nitrogen is one of the most yield-limiting nutrient in rice production and its uptake, use efficiency and yield response is affected by varietal difference, rates of fertilizer application, soil conditions, and environmental factors (Heluf and Mulugeta, 2006; Rahman *et al.,* 2007; Fageria and Baligar, 2003). The authors reported significant differences among the rates of N fertilizer application on the maximum economic yield in different areas. In addition, different crops and its cultivars at the same site responds differently to fertilizers and its responses are significantly varied across sites (Morris, 1991). Moreover, many studies have reported varietal differences in upland rice for grain yield; N uptake and N use efficiency (Fageria *et al*., 1995; Fageria and Baligar, 2003; Fageria, 2007). Moreover, soil N is commonly very low as a result of the loss of applied N fertilizer through leaching, volatilization, run off and denitrification. Hence, the use of N efficient varieties in combination with optimum application of N fertilizer may improve rice yield and helps to balance the loss of applied N. Thus, it is necessary to study the interactive effects of different varieties of rice with varying rates of N fertilizer on rice yield and yield components. Therefore, the objectives of the study are:

- To determine the optimum rate of N on the growth, yield and yield components of upland rice varieties under Gimbo condition
- To determine the best variety based on the performance of yield and yield components under Gimbo condition
- To determine the interaction effect between variety and level of nitrogen on the yield, N uptake and use efficiency of upland rice
- To determine the economically optimum rate of N application for maximum grain yield of the upland rice

2. LITERATURE REVIEW

2.1. Rice Ecosystem

Environmentally, rice is grown under different climatic conditions including the temperate, sub-tropical and tropical climates. Within climate, the weather shows difference from arid and semi-arid to humid and sub-humid conditions (Lukas, 2011). However, rice is highly adaptable and it can be cultivated in diverse ecosystems; irrigated, rainfed, upland and lowland, mangrove and deep-water ecosystems. Distribution of environments, where rice is grown is varying among countries. In contrast to Asia, most rice in SSA is grown under rainfed conditions. In SSA the land under rice cultivation is about ten million hectares, of which about 40% is located in the upland ecology, 37% in rainfed lowland ecology, 14% in the irrigated ecology and are contributing about 19%, 48% and 33% of the total rice production respectively. The remaining 9% is covered by deep water and mangrove rice (African Rice Center, 2011).

Rice is most commonly grown by the small land holding, subsistence farmers in the developing regions of the world (IRRI, 1977). Rice is productive in various environmental conditions, where other crops would be unsuccessful to adapt or grow. Moreover, it is exceptional food crop that adapt and grow under flooded or submerged conditions in enormous areas, even in low-lying tropical soils during the rainy season. This is because of the distinct feature of the crop that possesses aerenchymatic cellular structures in its leaves, stem and roots, which permit air to diffuse from the leaves to root surfaces providing the submerged roots with sufficient oxygen for normal respiration and nutrient absorption (De Datta and Patrick, 1986). However, about half of the rice areas in the world do not have sufficient water to maintain flooded conditions and rice yield is reduced to some extent by drought, a period of no rainfall or irrigation (Hanson *et al.*, 1990).

The rice can be grown in different environmental conditions depending on the availability of water and temperature (African Rice Center, 2011). It is a cold-sensitive plant that originated from tropical or subtropical zones. When low temperature occurs during the reproductive stages, it can decrease spikelet fertility (Satake and Hayase, 1970). Temperature is the most important factor which affects the rate and ability to photosynthesize effectively. Rice is more sensitive to nighttime temperature, in which each 1^0 C increase in nighttime temperature leads to decline of about 10% in rice yield (Peng *et al.,* 2004). However, the optimum temperature for the growth and higher yield of rice is between 25 - 35^0C and night temperature ranges from 15 to 20 ^{0}C are preferred (Yoshida and Parao, 1976).

Upland rice is grown in rainfed, naturally well drained soils without surface water accumulation like any other cereals (Fageria, 2001). The term also used as dry land rice, instead of upland rice, and defined as field grown-rice that is not bunded, and its land preparation as well as sowing under dry condition depends on rainfall for soil moisture (Huke, 1982). The upland rice has a high degree of drought tolerance and is able to withstand periods of water stress that occur in rainfed production (Fageria, 2013).

2.2. Overview of Rice Production in Ethiopia

Rice is emerging as one of the most important cereal crop cultivated in different parts of the country, even though its introduction to Ethiopia is recent. Rice research in the country was started informally by Koreans through the Tana Beles project, who had been in Ethiopia for development assistance. They introduced some promising rice varieties in the Western and Northern parts of the country and conducted research activities in selected parts of the country (Pawe, Adet, Gode and Gambella) (MoARD, 2010). In fact, there were various rice production systems and growing ecologies existed within the country. These includes: upland rice, rainfed lowland rice, and irrigated lowland rice. Besides the above fact, due to the productivity potential of the crop as compared to the other cereals grown in Ethiopia (teff, wheat and barley), farmers demand for rice production is showing increase over time (Kebebew *et al*., 2011). It plays a very important role for the country’s food security and also serves as an important source of income for small-holder farmers. Thus, the introduction and expansion of rice production in suitable agro-ecologies could be an option to achieve food security and self-sufficiency in the country (RSDEA, 2012). The potential rice growing areas in Ethiopia are, West central highlands of Amhara Region (Fogera, Gonder Zuria, Dembia, Takusa and Achefer), North West lowland areas of Amhara and Benshangul Regions (Jawi, Pawi, Metema and Dangur), Gameblla regional state (Abobo and Etang districts), South and

South West Lowlands of SNNPR (Beralee, Weyito, Omorate, GuraFerda and Menit), Somali Region (Gode), Southwestern highlands of Oromia Region (Illuababora, East and West Wellega and Jimma Zone) (MoARD, 2009).

Generally, the potential rice producing areas in upland and irrigated ecosystems estimated 30 and 3.7 million hectares (MoARD, 2010; Dawit, 2015), respectively. It is also reported at, production of rice in Ethiopia is showing rapid increase over time. Thus, the production increased from six thousand hectares in 2006 to 58 thousand hectares in 2013 with respective production increase from 11 to 184 thousand tons (Dawit, 2015). The observed increasing trend could be due to market related factors (high price of rice over other cereals and increasing demand), suitability of the area, long shelf life, acceptability of rice amongst rural population (Dawit, 2015).

2.3. Rice Response to Nitrogen Fertilizer

Nitrogen is one of the most essential plant nutrients for crop production and required by plants for growth and reproduction. It is the constituent of almost all plant structures. It is an essential component of chlorophyll, enzymes, and proteins (Brady and Weil, 2002; Hofman and Cleemput, 2004). Rice plant requires large amounts of nitrogen for their growth and development as well as uptake of other nutrients. The crop consumes approximately 20-25 kg of nitrogen to produce a ton of grain yield, making nitrogen the single most important rice nutrient. Of its fundamental importance in crop production and productivity many improved rice varieties cultivated around the world have been bred to show a marked response to the application of nitrogenous fertilizers (Morris, 1982).

Nutrient content is related to the photosynthetic activity of leaves, because of the essential nutrients are directly or indirectly involved in photosynthesis and respiration. For example, nitrogen is a constituent of proteins, which in turn is constituent of protoplasm, chloroplasts, and enzymes. It also aids in production and use of carbohydrates. Generally, dry plant material of rice contains between 1 to 4% N; while leguminous plants contains slightly higher N contents i.e., around 5%. In green plant material, protein N is by far the largest N fraction.

This is advantageous because many crops are cultivated, essentially to produce plant proteins (Hofman and Cleemput, 2004). Gueye and Becker (2011) reported varietal difference in rice in response to the applied rate of nitrogen fertilizer. However, at lower N levels, grain yield and most of the yield components did not differ significantly. This indicates the need to use optimum amount of N rate when screening upland rice for various purposes (Fageria *et al*., 2010). Moreover, the upland rice genotypes differ significantly in N uptake and utilization efficiency (Fageria *et al*., 1995; Fageria, 2007).

2.4. Nitrogen on Rice Growth

Nitrogen is necessary for cell division as well as the growth of plants. Plant height is one of the plant growth parameter and an important morphological characteristic of a plant that vary with the genetic makeup of the plant, fertility status of the soil, in which it is grown and the environmental conditions (Aslam *et al*., 2015). Nitrogen fertilization increases vigor, enhances the growth of rice and promotes the activities essential for carbohydrate utilization. One of the most important functions of nitrogen in rice is promotion of rapid plant growth through increase in height, tiller number, size of leaves and length of roots (Chatterjee and Maiti, 1985; Morris, 1982). Nitrogen enhances growth and development of rice plant. Application and uptake of nitrogen fertilizer at vegetative stage helps to synthesize chlorophyll which is important for photosynthesis; and promotes rapid leaf, stem, and root growth and speeds up the growth of the plant. Nitrogen fertilization during the reproductive and ripening phases; promotes the development of panicle, stimulates the absorption of nutrients and assimilation and increases the protein content of the grains, thereby, improving the quality of the crop (Morris, 1982). It also has the strongest influence on growth of rice among various essential plant nutrients (Ahmed *et al*., 2005). Hence, it is an important component of chlorophyll, which enhances photosynthesis that is important for increased production of assimilates that promotes vegetative growth (Luka *et al.*, 2013).

The application of fertilizers is one of the primary methods for improving the availability of soil nutrients to plants. Fertilization can change rates of plant growth, maturity time, size of plants parts, and seed capabilities (Mevi-Schütz *et al*., 2003). However, its growth is reduced when the demand of rice plant exceeds the rate of nitrogen fertilization (Islam *et al*., 2009). Nitrogen deficiency reduces plant height, tillering, leaf area index, leaf area duration, and crop photosynthetic rate which leads to lower radiation interception, and consequently lower radiation use efficiency (Fageria, *et al*., 2003). It also causes stunted plant growth, development of thin and spindle system, low protein, and high sugar content (thickening of cells) and formation of chlorosis as a deficiency symptom on older leaves, which may progress to necrosis under severe condition. Excess nitrogen supply causes higher photosynthetic activity, vigorous growth, weak stem, dark green color, reduced product quality, delay in maturity, increase in susceptibility to insect pests and diseases and building up of nitrate in foliage, which is harmful to animals (Mengel and Kirkby, 1996; Tisdale et.al, 1999; Brady and Weil, 2002). The highest plant height in rice was observed at maximum rate of N application, while the shortest plant height was obtained from unfertilized control treatment (Aslam *et al*., 2015).

2.5. Nitrogen on Yield Components of Rice

Rice needs fertilizer N at different growth stages of the crop for different functions. Increased nitrogen uptake and utilization by the crop resulted in increased number of tillers per unit area (Yoshida, 1981). Rice requires nitrogen during the vegetative growth stage to promote growth and tillering, which determines the number of panicles, which contributes to spikelet production during the early panicle formation stage. It also contributes to sink size by decreasing the number of degenerated spikelets and increasing hull size during the late panicle formation stage. The number of spikelets per unit area is the most variable yield component, accounting for about 74% of the variation in grain yield in rice (Koutroubas and Ntanos, 2003). Nitrogen contributes to carbohydrate accumulation in culms and leaf sheaths during the pre-heading stage, and in grain, during the grain-filling stage, as component of photosynthesis (Mae, 1997).

The realized increase in economic yield due to increased nitrogen fertilizer application was because of increased number of yield components. There is a tendency for panicle size to decrease as panicle numbers increases. Larger panicle size, coupled with tall plant heightpredisposes the crop to lodging, especially at high nitrogen levels. Thus, the nitrogen response of the high panicle number cultivar type is higher than that of the high panicle weight type. Increased yield can be achieved through heavy nitrogen application combined with dense planting (De Datta, 1981). Straw yield of a crop is closely related to the vegetative growth like plant height, tiller numbers, leaf numbers and final stand of the crop (Singh and Verma, 1971).

Significant varietal differences were reported in rice for most of the yield attributes in response to N fertilizer application (Sokat, 2006; Moro *et al.,* 2015). The application of nitrogen also increases plant height, panicle number, spikelet number and number of filled spikelet per panicle (Doberman and Fairhurst, 2000). In addition, it increases the number of plant population and panicles per square meter, and total number of spikelets, which might be reflected on overall productivity. Thus positive association was observed among yield related traits, when the rice variety received increased rate of nitrogen, but further increase have a negative impact on grain yield (Sikuku *et al*., 2015), which could be due to the genetic or environmental differences.

According to Yoseftabar (2013) the maximum number of tillers in rice obtained at 150 kg ha^{-1} rate of nitrogen application, whilst the lowest number at the rate of 50 kg N ha^{-1}. On the other hand, rice varieties were evaluated under different nitrogen levels and found that the maximum number of tillers per square meter was obtained at the rate of 220 kg ha^{-1} while the minimum was recorded in the control having no N application (Abou-Khalifa, 2012). Likewise, Moro *et al*. (2015) also reported highest total number of tillers per square meter with increasing the rates of nitrogen fertilizer in rice. The response of nitrogen differs among rice varieties, thus the variety having the capability of producing higher number of panicles requires high amount of nitrogen than that of variety with lower panicle number. The varieties with higher panicle weight are more prone to lodging at higher nitrogen rates, due to the increment in plant height. The existence of difference among varieties may be due to varying responses of varieties to nitrogen fertilizer depending on their agronomic traits (Rahman *et al*., 2007).

2.6. Nitrogen on Grain Yield of Rice

Nitrogen is one of the essential plant nutrients and is a key input for increasing crop yield (Kamara *et al.*, 2010). Rice varieties have high response to nitrogen fertilizer application and they responded differently to the applied N rate (Sokat, 2006). The increased rate of N application significantly increased grain yield in upland rice varieties up to the rate of 120 kg N ha^{-1}(Haque and Haque, 2016). However, the yield response varieties to the applied rate of fertilizer N was varied due to the difference in soil conditions, agro-ecology and the management practices to be applied. In contrast, the grain yield of rice was significantly increased with an increase in the level of N from unfertilized control to 60 kg N ha^{-1}, and then decreased with further increase (Heluf and Mulugeta, 2006). In contrast, non-significant effect of N application on grain yield was reported by Mahajan *et al*. (2010). Rice yield normally increases, when the amount of nitrogen application is increased. If there is little or no yield increase in response to increased nitrogen application, there may be some problems involving variety, soil, or climate (Yoshida, 1981). Plant height, shoot dry matter, panicle number, panicle length, grain harvest index, N concentration in shoot and grain, and N uptake in shoot and grain were having significant positive relationship with grain yield (Fageria *et al*., 2010).

Rice grain yield is a function of panicles per unit area, number of spikelets per panicle, thousand grain weight, and spikelet sterility or filled spikelets. Therefore, it is very important to understand the management practices that influence yield components, and consequently grain yield (Fageria *et al.,* 1997). Grain yield of rice is a combination of different yield components, such as number of panicles per unit land area, number of spikelets per panicle, percentage of filled spikelets and grain weight (Yoshida, 1983). The successive increase in N level significantly increased grain yield of rice varieties in different locations. However, there is significant effect of locations, cropping seasons, varieties and their interactions on their performance (Geoffrey *et al*., 2012).

2.7. Nitrogen on Rice Phenology

The date of heading differs not only within a plant, but also among plants in the same field. Heading in rice means the exertion (the base panicle is clearly above the flag leaf sheath) of panicle. Within a rice plant, some tillers usually head earlier than the main shoot. To complete the heading process, commonly it takes 10–14 days for all the plants in a field. However, the date for heading in rice varies among varieties and depending on the nutritional status of the soil, especially soil nitrogen (Yoshida, 1981).

The response of different varieties varies at different growth stages for different nitrogen rates. The days required to heading, flowering and maturity significantly increased with the increase in the amount of nitrogen applied in rice (Haque *et al*., 2006). Likewise, the same result was also reported from Tanaka (1995) that, when the rate of nitrogen fertilization increased in higher amount the date of heading, flowering as well as physiological maturity in rice is delayed.

2.8. Biological Yield and Harvest Index

The application of nitrogen fertilizer determines the level and time length or duration of dry matter production in rice after anthesis (Tanaka, 1969). Similarly, the efficiency of dry matter production depends, mainly on the varietal differences for photosynthetic activity in response to nitrogen. The characteristics are not only in dry-matter production but also in the percentage of ripened grains and yields (Murata, 1969). The application of nitrogen also influenced vegetative growth, in terms of plant height and number of tiller, per hill, which further resulted in increased straw yield (Rahman *et al*., 2007). The Increased rate of applied N increased the dry matter accumulation and straw yield of rice significantly up to 90 and 120 kg N per hectare, respectively; while further increment in N did not significantly increased both dry matter accumulation and straw yield (Heluf and Mulugeta, 2006). Total dry matter production was significantly influenced by the application of nitrogen fertilizer (Haque and Haque, 2016). The rate of nitrogen positively influenced grain yield and straw yield that in turn increased biological yield (Rahman *et al*., 2007; Moro *et al*., 2015).

The application of nitrogen fertilizer increases the grain harvest index in rice. It is one of the most important characteristics of high yielding genotypes of the crop. Use of nitrogen fertilizer also improves the grain harvest index, as well as nitrogen harvest index in rice. The supply of nitrogen fertilizer improves the grain harvest index, nitrogen harvest index and plant height which are also positively associated with grain yield (Fageria, 2007). The application of nitrogen fertilizer, not always increases harvest index in rice. Westcott (1986) reported decreased grain harvest index with increasing application of nitrogen fertilizer.

2.9. Soil Properties Affecting Nutrient Availability

Soil property is one the factors that affects nutrient availability to plants. It affects the movement of water in the soil, and then nutrient movement. Availability of soil nutrients is mostly dependent on soil water content, which further affects nutrient movement in the soil. It also affects the mobility of water in the soil plant system, and then nutrients. Soil texture is one of the soil physical properties that determines moisture and nutrient holding capacity of the soil. According to Moormann and Dudal (1965) soil texture affects moisture status of the soil more than any other properties, except topography. Soil texture is mainly important in upland rice fields, because, it can serve as a moisture reservoir (De Datta, 1981). It also affects the retention of nutrients in the soil (Fageria, 2008). Thus, clay and organic soil holds more nutrients and water than sandy soils (Mengel and Kirkby, 2001). This affects the transport of solutes from the soil to root surface, through affecting soil moisture and hydraulic conductivity (Vetterlein *et al.*, 2007), and have an effect on nutrient absorption.

The characteristics of soils on which upland rice is grown are broad with respect to soil texture, pH, organic matter content, slope, and soil fertility variations (De Datta, 1981). In fact, rice can be grown on a wide range of soils from sandy loam to heavy clay soils. However, the most appropriate soil for rice should have fine fractions of silt and clay, while difference in yield between different production areas might be due to greater variation in soil conditions (Shemahonge, 2013). Moreover, soil pH, CEC and SOM affects nutrient availability in soil (Marschner, 2011). Soil pH plays a very important role in nutrient availability and uptake of essential nutrients as well as volatilization of certain nutrients (Kissel and Sonon, 2008). It also accelerates the microbial conversion of ammonium to nitrate (nitrification) at near neutral pH. However on acid soils with pH of less than 6.0, nitrification is slow and plants take up N in the form of ammonium. In addition, at higher soil pH level, the applied urea fertilizer is subjected to higher losses (McKenzie, 2003). According to Somado *et al*. (2008), the optimum soil pH for rice growth in upland condition is 5.5 to 6.5.

The amount of organic matter in the soil tends to increase with the increase in clay content. Its amount has also a direct and indirect effect on the availability of nutrients for the plant. It serves as a reservoir of nutrients and water in the soil. Thus, one percent of organic matter in the soil releases 9.1 to 13.6 kg of nitrogen (Funderburg, 2010). Besides, high concentration of organic matter in the soil increases the rate of urea hydrolysis (Jones *et al.,* 2007). The cation exchange capacity of a soil determines the number of positively charged ions that the soil can hold. This in turn can have significant effect on the fertility management of the soil. In addition, it also indicates the amount of clay and organic matter present in the soil. The soils with higher CEC have more clay or organic matter and thus have higher water and nutrient holding capacity (Ketterings *et al*., 2007).

2.10. Soil Nitrogen and its Availability to Plants

Nitrogen is the most importantly used macronutrient in plants and the most deficient nutrient in most cultivated soils of the world. The soil inorganic nitrogen is commonly less than 2% of the total nitrogen of surface soils and undergoes rapid changes in composition and quantity. The amount of inorganic nitrogen varies widely among soils, with climate, and weather conditions (Kopsell and Randle, 2001). Most nitrogen in the soil is tied up in organic matter and taken up by plants as nitrate (NO_3^-) and ammonium (NH_4^+) ions from inorganic nitrate and ammonium compounds. These compounds can enter the soil as a result of nitrogen fixation by soil bacteria, the application of inorganic nitrogen fertilizer, or alteration of organic matter into ammonium and nitrate compounds. Actually, not all nitrates in the soil are taken up by crop plants, because it might be found below the root zone in sandy soils or transformed to nitrogen gas in wet, flooded soils. On the other hand, soil micro-organisms might supplement their N requirements from the soil's inorganic pool by reducing the availability of N pool to plants during decomposition by the process of immobilization. However, the C:N ratio of the decomposed material is less than that of decomposers the micro-organisms will liberate excess N as NH_4^+, adding to the soils inorganic N by the process of mineralization (Hodge *et al.,* 2000). The determination of total nitrogen in the soil only indicates the total amount of nitrogen exist in the soil rather than its availability. Because, much of which is held in organic matter, and might not be immediately available to plants and it may be mineralized to available forms over times (Hazelton and Murphy, 2007). Nitrogen taken up during early growth stages accumulates in the vegetative parts of the plant and utilized for grain formation at later growth stage. A large portion of nitrogen taken up by crop plants accumulated in leaves and stems (Milkkelson, 1982).

Nitrogen management in the soil is difficult, due to dynamic nature of its cycle in the soil-plant systems. The main components in the N cycling are the addition, transformation, utilization, and possible losses of N from soil-plant systems. The addition of N through inorganic source contributes the major part in the soil. However, it is also added to soil is through biological fixation, precipitation, gases adsorption and organic manures. The way of N transformation in soil-plant system includes fixation, mineralization, nitrification, and immobilization (Fageria and Baligar, 2005). In most environments, the movement of N from the soil to the plant and from the plant back to the soil through the microbial biomass. It undergoes many transformations, which are all included in the "nitrogen cycle". In natural ecosystems, this cycle is more or less closed, i.e. N inputs are in equilibrium with N losses. In agricultural ecologies, however, this cycle is disturbed by the export of substantial amounts of N with harvested products. As a consequence, the use of N fertilizers has been essential to keep and/or increase the productivity of the soil (Hofman and Van Cleemput, 2004). In the past fifty years, the increased use of N fertilizer and better management practices were the major contributors to the increment in global food production (Smil, 2001).

2.11. Nitrogen Uptake and Use Efficiency of Rice

The amount of nutrient uptake is influenced by the type, source, time and rate of fertilizer application, the availability of nutrient in the soil and plant growth stages (Fagaria, *et al*., 2003). It is influenced by soil, climate and cultural practices (IRRI, 1986). The absorption of most nutrients is generally vigorous during vegetative growth, but is limited by the root system (Fagaria, *et al*., 2003). The nutrient uptake rate stretches a peak before heading and declined afterwards. The rice plant requires adequate amount of N in the soil at the rapid growth period especially at tillering for their optimum growth and yield (Takenaga, 1995). The upland rice varieties were significantly varied in the nutrient uptake and the variation with different growth stages increased with the age of the plants. Therefore, timing of plant sampling had an effect on the results of nutrient uptake in crop plants (Musa *et al.,* 2009).

The rice genotypes are varying in nutrient use efficiency in different nitrogen levels may be due to the presence of genetic variation among varieties (Moll, 1982). The variation in nutrient use efficiency may be due to utilization efficiency and or the uptake efficiency. The utilization efficiency is that the genotypes may differ in the effectiveness with which the nutrients in the plant are consumed to produce yield, and the uptake efficiency implies that the variation in their effectiveness in absorbing nutrients from the soil (Sattelmacher, *et al.,* 2007). It can be defined in various ways and by different authors that the maximum economic yield produced per unit of nutrient applied, absorbed or utilized by the plant to produce grain and straw (Fageria, *et al*., 1997; Fageria and Baligar, 2001). The N utilization efficiency is more important than N uptake efficiency when evaluating the genetic potential among cultivars for efficient grain production, especially on soils that require high rates of N to maximize yield (Moll *et al.,* 1982). Utilization efficiency together with economic yield is a desired characteristic in crop plants. The evaluation of NUE is useful to differentiate plant species, genotypes and cultivars for their ability to absorb and utilize nutrients for maximum yields. The NUE is based on the amounts of a particular nutrient applied or present in the soil, transported to shoot and leaves and the remobilization (Baligar, *et al*., 2001). Nitrogen use efficiency is used to indicate the overall efficiency of N and defined as the ratio of economic yield to the fertilizer N used. The most commonly used nutrient use efficiency measures are: agronomic efficiency (AE), recovery efficiency (RE), and physiological efficiency (PE), computed by different methods (Ladha *et al.,* 2005).

Nutrient use efficiency in crop plants can be stated and explained in a number of ways. However, most of the researches on N fertilization of rice crop in various rice growing area has focused on calibration of N fertilizer rates, plant N uptake and utilization, and the magnitude of N loss mechanisms among different sources of N fertilizer, time and methods of application. It helps to develop best N management practices to obtain high crop yields with minimum N losses and costs of production. The nutrient use efficiency in crop plants can also be expressed in terms of crop biomass or economic yield efficiency per unit of nutrient uptake or application (Fageria and Baligar, 2003). The increased application of nutrient fertilizers in crop plant decreased the recovery efficiency of nutrients. Its low efficiency with increased rate may be related to the loss of the applied nutrients by leaching, volatilization, denitrification, and soil erosion (Fageria and Baligar, 2005). However, 50% and even more than 80% recovery efficiency of fertilizer N was reported by different researchers in different area (FLAR, 2001). The increment of shoot nitrogen uptake increased shoot dry weight up to flowering stage and it becomes declined at harvest due to the translocation of nitrogen from vegetative parts to the grain (Chaudhuri, 2015).

2.12. Losses of Nitrogen from Soil

Nitrogen is most dynamic in nature and is a key factor in maintaining higher yield in crop production and global economic viability of agricultural systems. Since it is the most dynamic and mobile element, its management in soil is so difficult (Delgado, 2002). It is continuously recycled through plant and animal waste, residues and soil organic matter. The extent and mechanism responsible for nitrogen losses depends upon the chemical and physical properties of a given soil (Provin, and Hossner, 2001). The annual decomposition of organic matter in the soil is about 1-3%, and it is the basic determinant of N supply. If a fertile soil contains 8000 kg nitrogen per hectare in the organic matter (2%), and this corresponds to 160 kg of N transformed from organic N into ammonia, which may then be converted into nitrate. However, only half percent of this may be utilized by crops, and some of which is taken up by micro-organisms, while the remaining is lost from the soil through various ways (Shand, 2007). The main reasons for N shortage in the soil are high quantity of uptake by crop plants compared to other macronutrients except K and through leaching, denitrification, immobilization by micro-organisms, volatilization, soil erosion and surface runoff (Fageria *et al.,* 2005).

The loss of nitrogen through runoff and erosion may include, nitrate, ammonium, and organic nitrogen. Likewise, the loss of nitrogen through leaching reduces the amount of nitrogen available to crops, which involves the movement of water down ward through in the soil below the root zone. It, most frequently, occurs with nitrate in areas, where there is high rainfall and excessive irrigation water as well as in soils with high infiltration capacity. Therefore, the rates and time of nitrogen application should be related to soil conditions and crop requirements in order to minimize leaching losses (Provin, and Hossner, 2001).

2.13. Bases for Fertilizer Recommendations

Generally, plants grown on soils with low N test values are usually responsive to fertilizer N application whereas plants grown on soils with very high soil N test values show only a small or no response to fertilizer N as the concentration of NO^{-}_{3}-N in the soil is very high (Mengel and Kirkby, 1987). Hence, the application of N fertilizer depending on the N status of the soil and the crop N requirement is very important for optimum productivity of rice. The optimum N rate is governed by yield level, soil properties, organic matter content, cropping system, disease pressure, water management, weed control, socioeconomic condition of farmers, and the price of rice (Fagaria, *et al*., 2003).

Diagnosis of fertilizer requirement is vital to decide the applied fertilizer amount in rice cultivation, since the rice plant needs nitrogen at all growth stages. Such diagnosis and determination of crop nutrient requirements are carried out based on soil test and plant tissue analysis (Sharif *et al*., 2003). Soil test provides some of the basic information necessary to make agronomically profitable and environmentally sustainable nutrient recommendations. In addition, it is an important diagnostic tool for estimating nutrient supplying capacity of soils for optimum crop production (Rakkar *et al*., 2015). The results obtained from analyses can provide information that is important for maximizing nutrient use efficiency and agricultural productivity. A historical record of soil properties provided by long-term soil testing is useful for determining the effectiveness of fertilizer management strategies in maintaining soil fertility and sustainable agricultural productivity. It is also a useful for identifying the causes of nutrient related plant growth problems (Walworth, 2006). Soils vary in their capacity to provide nutrients to crops and crops differ in their requirements, therefore, most soils cannot supply all essential nutrients to crops (Sharif *et al*., 2003). Many of the nutrients required by rice plants sourced from the soil. In most natural conditions the supply of nutrients from the soil alone is insufficient to meet the nutrient requirements for high rice yields. Hence, the use of commercial fertilizer is essential to fill the gap between the crop requirement for nutrients and the supply of nutrient from the soil and available organic inputs (Jata *et al.,* 2011). Therefore, fertilizer recommendations, should consider, the supply of the nutrient from soil at the beginning of the experiment or any development work.

3. MATERIALS AND METHODS

3.1. Description of the Study Site

The experiment was conducted in Gimbo District of Kaffa zone, Southwestern parts of Ethiopia in the Southern Nations, Nationalities and People’s Region (SNNPR). The specific experimental site is Choba farmer’s association, located 27.5 km from Gimbo town. The study area is located at 7^0 35” N latitude and 36^0 18” E longitudes with the altitude of 1350 masl. The area experiences long rainy season, lasting from March-April to October. The mean annual rainfall ranges from 1710 to 1892 mm. Over 85% of the total annual rainfall occurs within eight months of the rainy season**,** with mean monthly values in the range of 125-250 mm. The mean temperature ranges from 18.1 to 21.4^{0}C. The soil type is characterized under Vertisols (BOANRD, 2015).

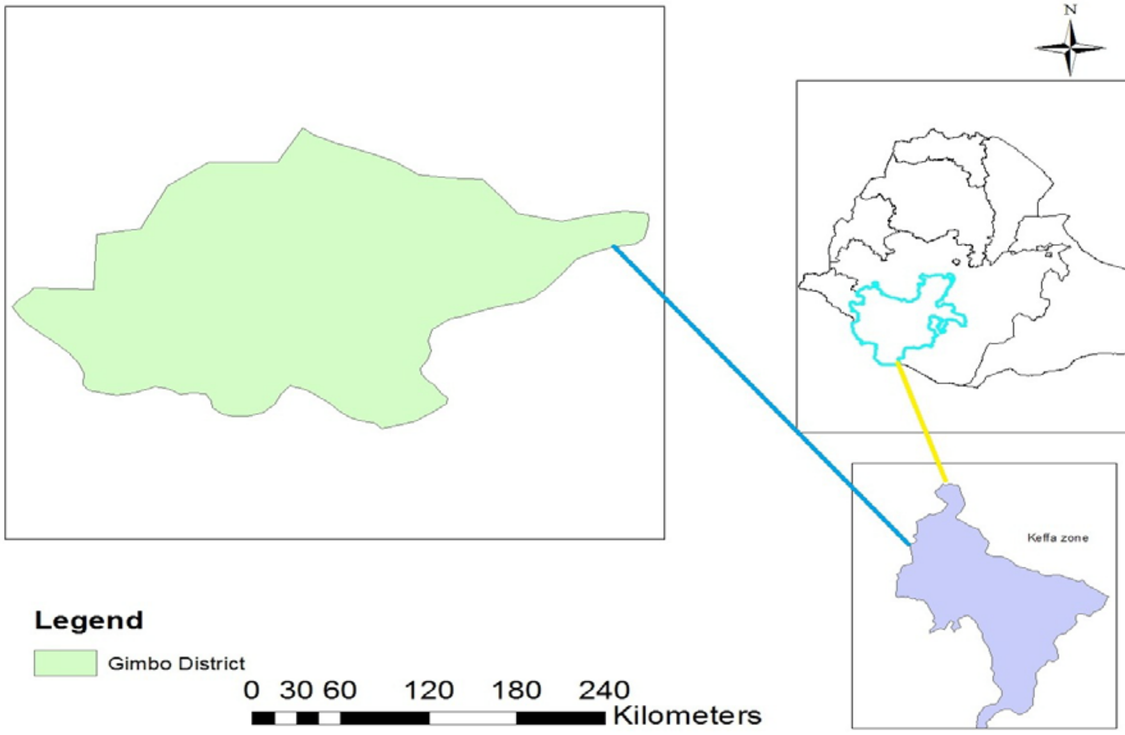

Figure 1: Map of the study district

The soil of the experimental site was analyzed for the physico-chemical properties: texture, pH, OC, total N, available P, and CEC and the results are presented in Table 1.

Table 1: Physico-chemical properties of experimental soil before sowing

Parameters measured (soil properties)	**Result**	**Rating**	**Source**
Sand (%)	17.00		
Silt (%)	24.00		
Clay (%)	59.00		
Textural class	Clayey		
pH 1:2.5 (H_2O)	5.6	Moderately acidic	Tekalign, 1991
Total N (%)	0.23	Medium	Tekalign, 1991
Available P (ppm)	12.50	Medium	Roy *et al*., 2006
Organic carbon (%)	2.83	Medium	Tekalign, 1991
Organic matter (%)	4.87	Medium	Tekalign, 1991
Catain exchange capacity	39.24	high	Roy *et al*., 2006

3.2. Experimental Design and Treatments

The upland rice consisted of four levels of varieties namely; NERICA-4, Suparica-1, Kokit and Kellafo-1. NERICA-4 and Suparica-1 were released in 2006 by Pawe Agricultural Research Center; while Kokit and Kellafo were released in 1999 and 2010 by Adet and Gode Agricultural Research Centers, respectively. They were high yielding and disease resistant varieties and well adapted to rainfed upland ecosystems. The varieties namely

The fertilizer treatments consisted of four levels of Nitrogen i.e., 0, 23, 46 and 69kg ha^{-1}) in the form of urea (46% N) were used. Nitrogen was applied in two equal splits; half of nitrogen was applied immediately after the establishment of seedlings and the remaining half at panicle initiation stage.

3.3. Experimental Procedures

Four levels of variety and four levels of nitrogen fertilizer, with a total of sixteen treatments were used in the study (Appendix Table 5). The experiment was laid out in split plot design with three replications. Varieties were set up as the main plot factor; while nitrogen fertilizer rates were considered as the sub-plot factor. The total experimental area was divided into three replications (blocks), each of which is further divided into four main plots. Following the procedure four main plots and replications were randomly assigned the four main plot treatments (varieties) to the four main plots in each of the three blocks. Then each of the twelve main plots divided into four subplots and four subplot treatments (Nitrogen rates) were assigned the four N rates to the four subplots in each of the twelve main plots.

The main plot size of the experiment was 60 m^2 (15 x 4 m) and the subplot size of the experimental unit was 12 m^2 (3 x 4 m) and 6 m^2 (2 m x 3 m) was used as a net plot size. The spacing between the blocks (replications) was 1.5 m; whereas plots were spaced 1m apart from each other. The experimental field was prepared following the standard practices for rice production before sowing. The field was ploughed, leveled, and rows were prepared 25cm apart from each other. Sowing was done on June, 2015 by hand drilling the seeds in the rows at the rate of 60 kg ha^{-1}. The total dose of phosphorus in the form of triple super phosphate (TSP) (46% P_2O_5) ha^{-1} was applied at sowing uniformly in all experimental plots. In addition, all other recommended agronomic practices were applied uniformly in all experimental plots.

3.4. Soil Sampling and Analysis

Representative surface soil samples (0-30 cm) were collected using Auger from 15 spots of the entire experimental field in a zigzag pattern to form one composite sample for soil fertility evaluation before sowing. The composite soil samples collected were air-dried, ground and sieved to pass through a 2 mm sieve in preparation for analysis. The soil was analyzed (twice) for physico-chemical properties: in JUCAVM soil laboratory for texture, pH, OC, total N, available P, and CEC.

Accordingly, soil pH was determined potentiometrically using a glass electrode attached to a digital pH meter in 1:2.5 soils to water ratio suspension as described by Carter (1993). Texture of the soil was analyzed by hydrometer method according to the procedure reported by Bouyoucos (1962). The cation exchange capacity (CEC) was measured after leaching the ammonium acetate extracted soil samples with 10% NaCl solution and then determining the amount of ammonium ion in the percolate, as per the procedure outlined by Kjeldahl and reported as CEC (Hesse, 1972). The soil organic carbon content was determined using wet digestion method, and percent soil organic matter (OM) was obtained by multiplying percent soil organic carbon by a factor of 1.72 (Walkley and Black, 1934). The determination of available P in the soil was done using sodium bicarbonate as extracting solution (Bray and Kurtz, 1945). The total N was determined using the Kjeldahl digestion and distillation method (Jackson, 1958).

3.6. Plant Tissue Analysis

The whole above ground plant part; (grain and straw) were collected at physiological maturity from each experiment unit to determine the nitrogen content in the rice plant, and a total of 48 samples each for grain and straw were prepared for chemical analysis in the animal nutrition laboratory of Jimma University College of Agriculture and Veterinary Medicine (JUCAVM). Grain and straw samples were dried in an oven at about 70 ^{0}C until it reaches constant weight, and then ground to pass through a 2 mm sieve. The ground plant materials (grain and straw) were stored in a small paper bags, separately.

Nitrogen content of the grain and straw were determined using micro-Kjeldahl method (Dewis and Freintus, 1970; Jackson, 1973). A 0.3 gram grain and straw samples and a 1.1 gram digestion tablet (K_2SO_4:$CuSO_4$+$5H_2O$: Se = 10:1:0.1) were placed in a digestion tube and then 5 mL concentration of H_2SO_4 were added to it. The flasks were taken to the digestion chamber and the block digester was adjusted at 420°C until it becomes color less. After completion of the digestion process, the tubes were cooled down for 30 minutes. The digest was moved to a volumetric flask and the volume was raised to 20 ml with distilled water and 40% NaOH solution. The distilled NH_3 was absorbed in H_3BO_3 indicator solution and titrated with 0.01N HCL. Likewise, a reagent blank was prepared in the same manner. Finally, the results were expressed as percentages.

3.7. Data Collection and Measurements

The agronomic parameters were determined according to the method of standard evaluation system for rice (IRRI, 1988; 2013).

3.7.1. Phenological parameters

Days to 50% heading: was recorded by counting the number of days from sowing to the time when 50% of the panicles begins to exert from the boot.

Days to 85% physiological maturity: days to 85% maturity was recorded as the number of days starting from the date of sowing to when 85% of the grains on the panicle was fully ripened.

3.7.2. Growth parameters

Plant height: was determined by measuring the length of ten randomly selected sample plants from the ground level to the tip of the panicle in each plot at physiological maturity.

Panicle length: done by measuring the length of the panicle from the node where the first panicle branch emerge to the tip of the panicle and determined from an average of ten randomly selected plants per plot.

3.7.3. Yield and yield components

Number of tillers (both productive and unproductive) per m^2: The numbers of tillers were determined by counting the tillers from an area of 0.5 m x 0.5 m row plants by using quadrant in each plot.

Number of panicles per m^2: The number of panicles was determined by counting the panicles from an area of 0.5 m x 0.5 m row plants of each plot.

Number of total spikelets per panicle: The number of spikelets was determined by counting all spikelets (filled and unfilled) from ten randomly selected panicles of ten sample plants in each plot and averaged.

Number of filled spikelets per panicle: The number of spikelets was determined by counting only filled spikelets from ten randomly selected panicles of ten sample plants in each plot and averaged.

Thousand grain weight: was determined by weighing randomly drown 1000 grains of well developed, whole or undamaged grains using a sensitive balance and adjusted to 14% MC.

Grain yield: grain yield was determined by harvesting the rice crop from the net middle plot area of 6m^2 and threshed cleaned and weighed using an electronic balance and then adjusted to 14% moisture content.

Straw yield: at maturity, the above ground plant parts excluding grains (leaves and stems) from the net plot area were harvested, sun dried and then measured.

Biological yield: at maturity, the whole plant parts, including grains and straw (leaves and stems) from the net plot area were harvested, sun dried and then measured.

Grain harvest index (%): was calculated as the ratio of grain yield to biological yield (grain plus straw) (Fageria *et al.,* 1997).

3.7.4. N uptake and use efficiency parameters

N uptake in grain: The uptake of N in grain was determined by multiplying N content with grain yield ha^{-1} and divided by 100.

$$\text{Grain N uptake} = \frac{(\text{N concentration of grain} * \text{Grain yield})}{100}$$

N uptake in straw: was determined by multiplying N content with straw yield ha^{-1} and divided by 100.

$$\text{Straw N uptake} = \frac{(\text{N concentration of straw} * \text{Straw yield})}{100}$$

Total N uptake: was obtained by summing up the N uptake by grain and straw (Husan *et al*., 2014).

$$\text{Total N Uptake} = \sum[\text{N uptak of grain} + \text{N uptake of straw}]$$

Nitrogen harvest index: was determined as the ratio of nitrogen uptake in grain to the total uptake of nitrogen (grain plus straw) (Fageria *et al*., 2003).

Determination of Agronomic, Physiological and Apparent N Fertilizer Recovery was computed as per the formula used by Pal (1991); Mengel and Kirkby (1996) and Fageria and Baligar (2005):

Agronomic N Use Efficiency (ANUE): was defined as the economic production obtained per unit of nutrient applied. It was calculated as follows:

$$\text{Agronomic N Use Efficiency} = \frac{(G_F - G_{UF})}{Na}$$

Physiological N Use Efficiency (PNUE): was defined as the grain yield obtained per unit of nutrient uptake. It was calculated as:

$$\text{Physiological N Use Efficiency} = \frac{(G_F - G_{UF})}{(U_F - U_{UF})}$$

Apparent N Recovery Efficiency (ANRE): the quantity of nutrient uptake per unit of N applied.

$$\text{Apparent N Recovery Efficiency} = \left[\frac{(U_F - U_{UF})}{Na}\right] X\ 100$$

Where:

G_F and G_{UF} stands for grain yield of the treatment receiving the applied N fertilizer and the grain yield in control having no N application, respectively. U_F and U_{UF} stands for nutrient uptake of the N receiving treatment and unfertilized or control treatment, respectively. ‘Na’ is stands for the quantity of N applied.

3.8. Statistical Analysis

The collected data were checked for ANOVA assumptions before analysis i.e. the treatment effects due to environmental must be additive, the experimental errors must all be independent, normal distribution of the experimental errors and the homogeneity of the experimental errors. Then the collected data were subjected to factorial analysis of variance (ANOVA) using General Linear Model (GLM) procedures of SAS version 9.2 (SAS Institute, 2002-2008) to determine the significance of the effect of nitrogen fertilizer levels on the upland rice varieties. The treatment means of significant treatment effects were compared using Least Significant Difference (LSD) test at 5% probability level ($P \leq 0.05$). Pearson correlation analysis was carried out using the same software to investigate associations between grain yield and yield components of rice varieties as well as between grain yield and nitrogen uptake in the rice plant.

The ANOVA model for split plot design:

$$\mathbf{Y}_{uvj} = \mu + \boldsymbol{R}_j + \boldsymbol{A}_u + \varepsilon_{uj} + \boldsymbol{B}_v + (\boldsymbol{AB})_{uv} + \varepsilon_{uvj}$$

Where:

$\mathbf{Y}_{uvj}$ = is the observation of v^th sub-plot treatment in u^th main plot treatment of j^th block;

$\boldsymbol{\mu}$ = is the overall mean

$\mathbf{R}_j$ = denotes the j^th block effect

$\mathbf{A}_u$ = is the main effect of u^th level of variety

$\mathbf{B}_v$ = is the main effect of v^th level of fertilizer

$\mathbf{(AB)}_{uv}$ = is the interaction effect of u^th level of variety and v^th level of fertilizer

$\boldsymbol{\varepsilon}_{uj}$ and $\boldsymbol{\varepsilon}_{uvj}$ = are the error terms, error 1 and error 2, associated with the main plots and the sub-plots, respectively.

3.9. Partial Budget Analysis

Partial budget analysis was performed for economic analysis of different rates of applied N fertilizer and carried out using the average grain yield. The yield response of rice varieties to the applied fertilizer rate was estimated, where price of fertilizer and costs that varied during cultivation determined the economic feasibility of fertilizer application. The main purpose of partial budget was to evaluate the differences in cost and benefits among different N rates. Meanwhile, the yields of all treatments were adjusted downward by 10% to reflect possible lower yields expected by the farmers due to differences in management factors. The price of N (ETB 1,421) per quintal, the local wage rate of (ETB 30) per person per day and the transport cost (ETB 0.3) per kg were considered under variable costs. The farm gate price of grain was (ETB 6.0) per kg. A gross farm gate benefit was obtained by multiplying adjusted yield (kg ha^{-1}) with farm gate price (ETB kg^{-1}); while the marginal rate of return for each N fertilizer treatment was calculated as change of benefit divided by change of cost and multiplied by 100 (CYMMYT, 1988). However, economic recommendations were made by arranging interaction effect of variety and rate of N fertilizer application in order of increasing costs and then considering MRR between each treatment. However, the decision was made taking into account both the acceptable minimum rate of return and sensitivity analysis. Thus, all treatments were subjected to sensitivity analysis for ability to withstand yield changes. In this analysis, the marginal rate of return was redone considering 20% yield reduction from current level. The acceptable minimum rate of return was used by considering 100% returns to management. The interest rate of the fertilizer in the area was 1.25% per month, and the period between land preparation and realization of income is seven months. The cost of capital is 8.75% (1.25% (15%/12) x 7 months). Finally, the treatment with the highest net benefit and MRR was recommended for further production in the study area.

$$MRR = \frac{\Delta NB}{\Delta TVC} * 100$$

Where;

MRR = Marginal rate of return in percentage, ΔNB = Change in net benefits,
ΔTVC = Change in total variable cost

4. RESULT AND DISCUSSION

4.1. Rice Phenology and Growth

Analysis of variance for two factors split plot design (Table 2) revealed significant difference ($p \leq 0.01$) for both of main effects i.e., variety and N rate of fertilizer application for all of the phenological parameters (days to heading and maturity) and growth parameters (plant height and panicle length) studied. However, none of the interactions of variety by N rate were significant for all of the phenological and growth parameters.

Table 2: Mean square values for phenological and growth parameters as affected by variety and N rates

Parameters	Mean squares			
	Var (3)	NR (3)	Var*NR(9)	CV (%)
Days to heading	416.50**	106.72**	3.37^{ns}	1.69
Days to maturity	171.35**	122.91**	0.45^{ns}	1.44
Plant height (cm)	92.54**	142.02**	5.56^{ns}	2.79
Panicle length (cm)	13.83**	35.65**	0.59^{ns}	4.79

Var = variety; NR = Nitrogen rate; Values put in parenthesis indicates the degree of freedom for respective source of variation; **, ^{ns} = significant, highly significant and non-significant at LSD (%) 0.05 probability level and CV (%) = coefficient of variation.

4.1.1. Days to heading

There was significant difference among the varieties for days to 50% heading. NERICA-4 and Kokit were the earliest to head with 87 and 88 days to heading (Table 3). The latest days to heading was recorded for variety Suparica-1 followed by Kellafo-1, with respective days to heading of 100 and 94. This difference might have come from genetic variation among the tested varieties.

Days to heading was also significantly affected by the rate of nitrogen fertilizer applied. The result showed that days to heading were linearly extended as the applied N fertilizer increased

(Table 3). The longest days to heading was recorded at the rate of 69 kg ha^{-1}, while the earliest was recorded for unfertilized control (89 days). The observed difference among varieties for days to heading might be due to the inherent genetic differences among the varieties. The increase in N rates significantly prolongs the duration of the vegetative period in plants, which further delays days to heading. This result is in agreement with the results of Tanaka (1995) and Abou-Khalifa (2012) who reported delayed days to heading at the highest rate of nitrogen fertilizer application over the control treatment.

4.1.2. Days to physiological maturity

The result showed that the longest days to maturity was recorded for variety kellafo-1 and Suparica-1, which took 125 and 124 days, respectively (Table 3). NERICA-4 and, Kokit were the earliest to mature or took shorter days to maturity with 118 days. The observed difference among varieties for days to maturity might be due to the inherent genetic differences among the varieties. The result revealed that maturity date showed linear increase with increased rate of N fertilizer application. Thus, when the rate of N application increased from the control to the highest rate of 69 kg N ha^{-1} days to maturity extended by seven days. The mean separation indicated that the longest days to maturity (124 days) was recorded at the rate of 69 kg N ha^{-1}, while the earliest (117 days) was recorded on the control treatment. In contrast, Sokat (2005) reported non-significant influence of increased rate of N on days to maturity among upland rice varieties, which might be due to the study was conducted under high soil total N conditions. This result is in agreement with Marschener (1995) and Tsedalu (2011) who reported that extended days to maturity at highest rate of N fertilizer application. The increase in N rates significantly delays the duration of the vegetative and reproductive period in plants (Namvar and Sharifi, 2011) and that prolongs the growth duration and delays maturity by encouraging excessive vegetative growth (Brady, 1988).

4.1.3. Plant height

The varieties showed significant differences in plant height (Table 3). Suparica-1 and Kellafo-1 produced the highest plant height of 84.6 cm and 83.1cm, respectively; whereas Kokit produced the shortest height of 78.6 cm. The observed difference in height between the varieties may be due to the inherent genetic difference among tested varieties. This result is in consistent with the results of Rahman (2003) and Jisan (2014) who observed difference in plant height among the varieties evaluated in their studies.

The plant height showed increase from 77.9 to 86.0 cm, when the rate of N application increased from 0 to 69 kg ha^{-1}. In fact, nitrogen is primarily responsible for vegetative growth of plants, which mediates leaf expansion through increase in cell number and enhancing the availability of assimilates (Sivasankar *et al.*, 1993). The rate of nitrogen fertilizer application increased the height of upland rice varieties. The increased height in response to increasing the rate of nitrogen application was likely due to the availability of more nitrogen in the soil, which may have promoted vegetative growth of the rice plants. This result is in agreement with the findings of Haque *et al.* (2012); Rahman *et al.* (2007); Sikuku *et al.* (2015) who reported that, increasing N fertilizer application increases plant height in rice. Several other authors also reported the same (Sharma, 1973; Fageria, 2007 and Ehsanullah *et al.*, 2012). It could be due to enhanced rate of nitrogen transport from culms to leaves that may lead to the production of photosynthate, which enhances the translocation of nutrients to the growing part of the plant (Singh *et al.*, 2014). This is most likely due to the availability of nitrogen in the soil, which may have encouraged the vegetative growth of upland rice varieties that promoted the growth of plants, through increasing the length as well as number of internodes (Gasim, 2001).

4.1.4. Panicle length

The panicle length of the varieties significantly increased with increasing level of nitrogen (Table 3). The longest panicle length was recorded for varieties NERICA-4, Suparica-1 and Kellafo with respective panicle length of 19.7, 19.3cm, and 18.8cms, respectively. But Kokit produced the shortest panicle length of 17.2cm.

The length of panicles was significantly and linearly increased with increasing nitrogen rate up to 46 kg N ha^{-1}, which was statistically similar to 69 kg N ha^{-1}. Thus, the increase in the rate of N application from the control to the highest rate of 69 kg N ha^{-1} increased the panicle length by 3.67 cm. This is probably due to better absorption of nitrogen by the rice plant during panicle growth period and this could be enhanced the length of panicle in rice (Manzoor *et al.*, 2006). This result is Similar with the result of Yoseftabar (2013) who reported increment of panicle length with increasing rates of nitrogen fertilization.

Table 3: Mean values of heading, maturity, plant height and panicle length as affected by variety and N rates

Variety	Days to		Plant height (cm)	Panicle length (cm)
	Heading (50%)	Maturity (85%)		
NERICA-4	86.8^{c}	117.6^{b}	80.02^{bc}	19.65^{a}
Suparica-1	99.6^{a}	123.6^{a}	84.62^{a}	19.33^{a}
Kokit	88.1^{c}	118.1^{b}	78.58^{c}	17.23^{b}
Kellafo-1	94.2^{b}	125.0^{a}	83.14^{ab}	18.83^{ab}
LSD (%)	3.31	3.25	3.14	1.64
CV (%)	3.60	2.68	3.86	8.74
Nitrogen rate				
0	88.8^{d}	117.0^{d}	77.92^{d}	16.58^{c}
23	91.2^{c}	120.3^{c}	80.13^{c}	18.18^{b}
46	92.9^{b}	122.6^{b}	82.31^{b}	20.03^{a}
69	95.8^{a}	124.4^{a}	85.99^{a}	20.25^{a}
Means	92.2	121.1	81.59	18.76
LSD (%)	1.31	1.47	1.92	0.76
CV (%)	1.69	1.44	2.79	4.79

Means with the same letter are not significantly different at 5% level of significance; ns = non-significant; LSD (%) = Least significant difference at $P \leq 0.05$; CV (%) = Coefficient of variation.

4.2. Yield and Yield Components

Analysis of variance for two factors split plot design (Table 4) revealed significant difference ($p \leq 0.01$) for the main effect of variety and N rate of fertilizer application on yield and yield components traits. Similarly, the interactions of variety with N rate showed significant difference on yield and yield related parameters, except thousand grain weight and straw yield ($p \geq 0.05$).

Table 4: Mean square values for yield and yield components as affected by variety and N rates

Parameters	Mean squares			
	Var (3)	NR (3)	Var*NR (9)	CV (%)
Grain yield	4922149**	18677865**	175484.7*	3.27
Straw yield	771429.91**	4143208.20**	60857.34^{ns}	5.16
Biological yield	5095774.00**	17660295.39**	317326.35**	2.31
Grain harvest index	28.427**	105.45**	15.841**	3.27
Filled spikelets Panicle^{-1}	451.534**	635.98**	25.200**	2.18
Total spikelets Panicle^{-1}	259.069**	1917.12**	33.613**	2.26
Tiller number m^{2}	636.667**	7938.67**	73.111**	1.66
Panicle number m^{2}	1316.750**	3776.31**	106.528**	1.69
1000-grain weight	32.695**	9.06**	0.285^{ns}	1.87

Var = Variety; NR = Nitrogen rate; values put in parenthesis indicates the degree of freedom for respective source of variation; *, **, ^{ns} = significant, highly significant and non-significant at LSD (%) 0.05 probability level and CV (%) = coefficient of variation

4.2.1. Tiller and panicle numbers per square meter

There was significant increase in the number of tillers in all tested varieties in each successive rate of fertilizer application up to 69 kg N ha^{-1}(Table 5). The comparisons of means indicated the highest number of tillers (266.0) per square meter was recorded in the treatment combination on NERICA-4 at 69 kg N ha^{-1} followed by Suparica-1 (260.7) at 69 kg N ha^{-1}. The lowest tiller number was recorded for variety Kokit (182.7) at control treatment.

The increased tiller number with increasing rates of N application might be due to more availability of nitrogen that favored cellular activities in rice plant and led to increased number of tillers. The increased N application in rice enhanced the production of tillers due to more nitrogen supply to plants at active tillering stage (Manzoor *et al.*, 2006). This result is in line with the findings of Fageria and Baligar (2001); Meenan *et al*. (2003); Singh *et al*. (2014) and Sikuku *et al.*, (2015) who reported the highest number of tillers at maximum rate of N fertilizer application over the control treatment. This result is agrees with those of Hossain *et al*. (2008); Jisan (2014) and Sikuku *et al*. (2015) who reported the same.

Table 5: Mean values of number of tillers per m^2 as affected by variety and N rates

Variety	Nitrogen rate (kg ha^{-1})				
	0	23	46	69	Mean
NERICA-4	206.67^{i}	236.00^{fg}	245.33^{de}	266.00^{a}	238.50
Suparica-1	208.00^{i}	237.33^{ef}	252.67^{bcd}	260.67^{ab}	239.67
Kokit	182.67^{j}	219.33^{h}	245.33^{de}	247.33^{cd}	223.67
Kellafo-1	200.00^{i}	228.67^{g}	252.67^{bcd}	255.33^{bc}	234.17
Mean	199.34	230.33	249.00	257.33	
LSD (%) = 8.19	CV (%) = 2.10				

Means with the same letter are not significantly different at 5% level of significance; LSD (%) = Least Significant Difference Test at P < 0.05; CV (%) = Coefficient of variation

Panicle number is one of the yield contributing components in rice production. The number of panicles per unit area is considered as one of the most important yield components, which increasing the rice yields (Fageria *et al.*, 2007). The interaction effect of variety and rate of N application was significantly varied for number of panicles per square meter (Table 6). The application of nitrogen fertilizer significantly increased number of panicles per square meter over the control treatment. Interaction of variety and N rate indicated that, highest (227.3) number of panicles per square meter was recorded for NERICA-4 at the rate of 69 kg N ha^{-1} followed by Suparica-1 (220.0) combined at the same N rate. However, the lowest (174.5) panicle number was recorded for Kokit at control treatment. NERICA-4 and Suparica-1 performed well under both low and high N rate. Thus, two varieties; NERICA-4 and Suparica-1 increased number of panicles at the maximum rate of N application (69kg ha^{-1}). On the other hand, Kokit and Kellafo-1 produced their maximum number of panicles at 46kg N ha^{-1}, and then decreased with further increase from 46 to 69 kg N ha^{-1}. This indicated the difference in the genetic potential of the varieties in responding to the rate of applied N. The increased number of panicles per square meter due to increased N rate in rice might be due to the contribution of adequate supply of nitrogen to the production of branches, which probably increased panicles. This result is in line with those of Artacho *et al*. (2009); Mannan *et al*.

(2010) and Jisan (2014). As stated by Gebrekidan and Seyoum, (2006), number of panicles per unit area is the most yield contributing trait, which had a direct effect on grain yield.

Table 6: Mean values of number of panicles per m^2 as affected by variety and N rates

Variety	Nitrogen rate (kg ha^{-1})				
	0	23	46	69	Mean
NERICA-4	184.00^{f}	208.00^{d}	212.67^{cd}	227.33^{a}	208.00
Suparica-1	182.67^{f}	206.67^{d}	218.67^{bc}	220.00^{b}	207.00
Kokit	156.67^{h}	188.00^{f}	208.00^{d}	189.33^{ef}	185.50
Kellafo-1	174.00g	196.00^{e}	212.67^{cd}	206.67^{d}	197.34
Mean	174.35	199.67	213.00	210.83	
LSD (%) = 6.76 CV (%) = 2.04					

Means with the same letter are not significantly different at 5% level of significance; LSD (%) = Least Significant Difference Test at $P < 0.05$; CV (%) = Coefficient of variation

4.2.2. Number of filled, and total spikelets per panicle

The interaction effect of variety and N rate indicated that NERICA-4 and Suparica-1 produced the highest filled spikelets per panicle, due to increased rate of N application up to 69kg N ha^{-1}, while Kokit and Kellafo-1 increased the number of filled spikelets per panicle up to 46kg N ha^{-1} (Table 7). The highest number of filled spikelets (114.3) per panicle was recorded for Suparica-1 at the rate of 69kg N ha^{-1}, which was statistically not different with Suparica-1 at 46 kg N ha-1 and also when NERICA-4 (111.7) received the highest rate of N (69 kg ha^{-1}). However, the minimum number of filled spikelets per panicle (80.1) was produced by variety Kokit at control having no nitrogen application. This result is similar with the findings of Kandil *et al*. (2010) highest number of filled spikelets per panicle were obtained at maximum rate of N application i.e. 69 kg N ha^{-1}; whereas the lowest was obtained from the control. The observed highest number of filled spikelets per panicle with increased rate of N might be due to the contribution of adequate nitrogen supply that might have favored filled spikelet formation, which probably increased the number of filled spikelets with increasing nitrogen application (Rahman *et al.*, 2007).

The optimum rate of nitrogen fertilizer that produce the highest number of filled spikelets but lowest number of unfilled spikelets per panicle, which is the most important trait in determining the performance of varieties for grain yield (Chaudhuri, 2015). The increase in filled spikelet at increased rate of N might be due to the increase in chlorophyll content of leaves, which leads to higher photosynthetic rate and ultimately plenty of photosynthate available during spikelet development (Kandil *et al*., 2010).

Table 7: Mean values of number of filled spikelets per panicle as affected by variety and N rates

Variety	Nitrogen rate (kg ha^{-1})				
	0	23	46	69	Mean
NERICA-4	97.47^{fg}	105.97^{cd}	109.63^{bc}	111.67^{ab}	106.19
Suparica-1	95.00^{gh}	102.27^{d}	112.27^{ab}	114.30^{a}	105.96
Kokit	80.10^{i}	95.80^{gh}	101.97^{de}	96.13^{g}	93.50
Kellafo-1	91.67^{h}	97.60^{efg}	103.97^{d}	101.63^{def}	98.72
Mean	91.06	100.41	106.96	105.93	
LSD (%) = 4.40 CV (%) = 2.62					

Means with the same letter are not significantly different at 5% level of significance; LSD (%) = Least Significant Difference Test at P < 0.05; CV (%) = Coefficient of variation

The varieties differed for the number of total spikelets produced per panicle in response to the applied N rate up to 46 kg ha^{-1}. However, when the N rate exceeded 46 kg ha^{-1} all the varieties produced the highest total number of spikelets per panicle (Table 8). Thus, all tested varieties produced the highest total number of spikelets per panicle i.e. Suparica-1 (140.6), NERICA-4 (138.0), Kellafo-1 (137.3) and Kokit (136.1) at the rate of 69kg N ha^{-1}. On the other hand, minimum number of spikelets per panicle (95.8) was produced for variety Kokit at the control. Besides, varieties NERICA-4 and Suparica-1 showed significant difference for total number of spikelets per panicle over Kokit at 46 kg N ha^{-1}. The observed varietal difference regarding spikelet production might be due to inherent genetic difference among tested varieties. In addition, higher number of total spikelets per panicle at higher nitrogen rate might be due to the absorption of higher nitrogen by rice plant that might have enhanced the formation of higher number of branches per panicle, which leads to the formation of more spikelets per panicle (Rahman *et al.*, 2007). This result is in agreement with the results of Singh and Singh (1993); Nori *et al.* (2008); Tsedalu, (2011) and Haque and Haque (2016).

Table 8: Mean values of number of total spikelets per panicle as affected by variety and N rates

Variety	Nitrogen rate (kg ha^{-1})				
	0	23	46	69	Mean
NERICA-4	115.13^{fg}	126.30^{cd}	130.63^{bc}	138.00^{a}	127.52
Suparica-1	111.00^{g}	120.60^{ef}	131.27^{bc}	140.63^{a}	125.88
Kokit	95.77^{h}	113.80^{g}	122.23^{de}	136.13^{ab}	116.98
Kellafo-1	111.00^{g}	119.60^{ef}	129.30^{c}	137.30^{a}	124.30
Mean	108.23	120.08	128.36	138.02	
LSD (%) = 5.59 CV (%) = 2.72					

Means with the same letter are not significantly different at 5% level of significance; LSD (%) = Least Significant Difference Test at P < 0.05; CV (%) = Coefficient of variation

4.2.3. Thousands grain weight

Variety Kokit produced highest (31.3gm) thousand grain weight among others (Table 9). However, the lowest 1000-grain weight (28.4gm) was recorded on NERICA-4. The other two varieties; Kellafo-1 and Suparica-1 were produced the same grain weight of 31gm. This result is consistent with the results of Hasan (2007) and Jisan (2014) who reported differences in thousand grain weights among rice varieties. The observed differences in thousand grain weight among varieties might be due to inherent genetic differences among the varieties.

The application rates of N had showed significant difference for thousand grains weight (Table 9). The highest thousand grain weight (31.6 gm) was recorded at the rate of 69 kg N ha^{-1}, but the value was statistically similar with the weight at the rate of 46kg N ha^{-1} which was 31.3 gm. However, the lowest grain weight was recorded for control N rate. Similar result was reported by Jisan (2014). In the contrary, several authors reported non-significant effect of nitrogen fertilizer on thousand grain weight in rice (Van Hach and Nam; Sokat, 2006; Mannan *et al.*, 2010; Heluf and Mulugeta, 2014), due to insufficient translocation of carbohydrates to individual spikelets, which has also resulted in the competition for growth and increased number of spikelets per panicle.

Table 9: Mean values of thousand grain weight as affected by variety and N rates

Variety	TGW (gm)	Nitrogen rate (Kg ha^{-1})	TGW (gm)
NERICA-4	28.4c	0	29.6c
Suparica-1	31.3b	23	30.6b
Kokit	32.2a	46	31.3a
Kellafo-1	31.2b	69	31.6a
LSD (%)	0.95**	LSD (%)	0.49**
CV (%)	3.08	CV (%)	1.87
Mean	30.78		

TGW= Thousands grain weight (gm); Means with the same letter are not significantly different at 5% level of significance; ns = non-significant; LSD (%) = Least significant difference at $P \leq 0.05$; CV (%) = Coefficient of variation.

4.2.4. Grain yield

The grain yield of all tested varieties was significantly and inconsistently increased across the increased rates of nitrogen application. The highest grain yield was produced by varieties NERICA-4 and Suparica-1 at the maximum rate of N application (69kg ha^{-1}) with grain yield of 4589.0 and 4575.0kg ha^{-1}, respectively. However, Suparica-1 at the rate of 46 kg ha^{-1} gave statistically the same grain yield with NERICA-4 and Suparica-1 at 69 kg N ha^{-1}. Kokit produced the lowest grain yield of 2307.3kg ha^{-1} at control plot. Furthermore, NERICA4 and Suparica-1 also surpassed the other two varieties in producing more number of tillers per square meter and filled spikelets per panicle, which might have direct effect on increased grain yield. The positive and strong associations between grain yield and yield components in rice was reported by Yoshida (1981).

NERICA-4 and Suparica-1 showed grain yield response to increased N rate of up to 69kg ha^{-1}; while Kokit and Kellafo-1 showed increment in grain yield up to 46kg N ha^{-1}, and declined when the N rate exceeded this rate. The decrease in grain yield with increasing the rate of N application might be due to the reduction in the number of panicles per square meter and filled spikelets per panicle for the varieties. The observed difference among varieties in response to applied N fertilizer might be due to inherent genetic difference among varieties. The increased grain yield with increased rate of N application might be due to the favorable growth with better N uptake resulted in the production of higher tiller number, panicle number and filled spikelets per panicle. This result is consistent with the results of Jayakumar and Krishnasamy (2005). The application of nitrogen fertilizer might be associated with the highest N uptake and accumulation of N in rice, which further leads to the production of increased number of panicles and filled spikelets per panicle. In addition, there were strong associations observed between yield components and grain yield. Thus, the increment in yield components of rice further increased the grain yield of rice (De Datta and Patrick, 1986; Heluf and Mulugeta, 2006; Fageria, 2007).

The association of yield components with grain yield is positive and strong as they have significant correlation of r= 0.87** with number of tillers, r= 0.93** with number of panicles, and r= 0.93** with number of filled spikelets r= 0.82** and total number of spikelets per panicle (Table 22). Meanwhile, grain yield had significant and positive correlation with grain N uptake (r= 0.99**) as well as total N uptake (r= 0.97**) in the study. This depicts that the contribution of nitrogen uptake to increased grain yield of rice is paramount important.

Table 10: Mean values of grain yield (kg ha^{-1}) as affected by variety and N rates

Variety	Nitrogen rate (kg N ha^{-1})				
	0	23	46	69	Mean
NERICA-4	2664.00^{h}	3567.70^{d}	4249.70^{b}	4589.00^{a}	3767.60
Suparica-1	2554.00^{h}	3301.00^{ef}	4494.70^{a}	4575.00^{a}	3731.18
Kokit	2307.30^{i}	2949.70^{g}	3468.00^{de}	3039.00^{g}	2941.00
Kellafo-1	2502.00^{hi}	3115.00^{fg}	3808.00^{c}	3516.30^{de}	3235.33
Mean	2506.83	3233.35	4005.10	3929.83	
LSD (%) = 219.08 CV (%) = 3.85					

TGW= Thousands grain weight (gm); Means with the same letter are not significantly different at 5% level of significance; ns = non-significant; LSD (%) = Least significant difference at P $\leq$ 0.05; CV (%) = Coefficient of variation.

4.2.5. Straw yield, biological yield and grain harvest index

The highest straw yield of 5178.80kg ha^{-1}, 4922.0 kg ha^{-1} and 4822.2 kg ha^{-1} was recorded for NERICA-4, Suparica-1, and Kellafo-1. However, the lowest straw yield was recorded for Kokit (4563.80kg ha^{-1}). The difference in straw yield production among varieties could be due to the tallest height of the plant coupled with greater number of tillers per square meter contributed the highest straw yield in rice. Thus, association of plant height and tiller number with straw yield is positive and significant as they have the correlation of r= 0.64** with number of tillers and r= 0.65** with plant height (Table 22). This result is similar with the result of Jisan (2014) who reported differences among varieties in producing straw yield.

The nitrogen rate showed significant difference for straw yield in rice. The highest straw yield of 5614.50kg ha^{-1} was produced at 69kg N ha^{-1}; while the lowest (4273.40kg ha^{-1}) was recorded at the control treatment. The increased straw yield with N rate might be due to enhanced vegetative growth of rice plant that might have resulted in higher straw yield. The straw yield is increased with the rate of N fertilizer in all the tested varieties. Rahman *et al.* (2007) reported that, influence of nitrogen application in vegetative growth in terms of plant height and number of tillers, which further increased the straw yield. This result is consistent with the results of Salam (2004); Mannan *et al.* (2010) and Jisan (2014), who reported increased straw yield as a result of increased rate of N application in rice.

Table 11: Mean values of straw yield (kg ha^{-1}) as affected by variety and N rates

Variety	Straw yield (Kg ha^{-1})	Nitrogen rate (Kg ha^{-1})	Straw yield (Kg ha^{-1})
NERICA-4	5178.80^{a}	0	4273.40^{d}
Suparica-1	4922.00^{ab}	23	4558.40^{c}
Kokit	4563.80^{b}	46	5038.90^{b}
Kellafo-1	4822.18^{ab}	69	5614.50^{a}
LSD (%)	383.07**	LSD (%)	211.85**
CV (%)	7.87	CV (%)	5.16
Mean	4871.31		

Means with the same letter are not significantly different at 5% level of significance; LSD **(%)** = Least Significant Difference Test at P < 0.05; CV **(%)** = Coefficient of variation.

The biological yield was significantly affected by the interaction effect of variety and N rate. The highest biological yield was recorded for NERICA-4 and Suparica-1, at the highest N rate of (69kg ha^{-1}), with respective mean biological yield of 10410.3 kg ha^{-1} and 10218.3 kg ha^{-1} (Table 12). The application of nitrogen fertilizer positively influenced grain, as well as, straw yield and, which further influenced biological yield in rice (Rahman *et al.*, 2007). The results showed that, biological yield increased progressively with each successive increment of nitrogen fertilizer in rice. This result is consistent with the results of Dutta (2002) and Sokat (2006).

Table 12: Mean values of biological yield (kg ha^{-1}) as affected by variety and N rates

Variety	**Nitrogen rate (kg N ha^{-1})**				
	0	23	46	69	Mean
NERICA-4	7261.70^{gh}	8550.70^{d}	9554.70^{b}	10410.30^{a}	8944.35
Suparica-1	7054.70^{gh}	7914.30^{ef}	9425.30^{b}	10218.30^{a}	8653.15
Kokit	6062.00^{i}	7193.00^{gh}	8380.70^{de}	8383.00^{de}	7504.68
Kellafo-1	6742.70^{h}	7509.00^{fg}	8815.30^{cd}	9165.70^{bc}	8058.18
Mean	6780.28	7791.75	9044.00	9544.33	
LSD (%) = 593.54 CV (%) = 4.31					

Means with the same letter are not significantly different at 5% level of significance; LSD **(%)** = Least Significant Difference Test at $P < 0.05$; CV **(%)** = Coefficient of variation

Grain harvest index of all the tested varieties increased with increasing the rate of N application up to 46 kg N ha^{-1}, and further increase to 69kg ha^{-1} had decreased grain harvest index in upland rice (Table 13). There were variations among rice varieties in grain harvest index. It could be due to the difference in partitioning of nutrients between panicle and straw (Yoshida, 1981). As it was indicated below the table (Table 13), Suparica-1 at the rate of 46 kg N ha^{-1} gave the highest grain harvest index of (47.7%) followed by Suparica-1 (44.8%) at the rate of 69kg N ha^{-1} and NERICA-4 (44.5%) at the rate of 46 kg N ha^{-1}. The highest value of harvest index obtained at 46 kg N ha^{-1} could be due to an increase in grain yield more than the increase in straw. Whereas, the recorded lower harvest index with the maximum N rate could be due to the influence of nitrogen application on the vegetative growth in terms of plant height and number of tillers, which further resulted in increased straw yield more than the increased grain yield. This result is in agreement with the findings of Moro *et al.* (2015), who reported the highest grain harvest index at increased rate of nitrogen application up to 90 kg ha^{-1} then decreased when the rate of N increased to 150 kg ha^{-1}. Furthermore, the existence of significant variation among rice genotypes in grain harvest index was also reported by Tadesse and Moro *et al.* (2015). On the other hand, Fageria *et al*. (2007) have reported improvement in grain harvest index due to application of nitrogen fertilizer in rice.

Table 13: Mean values of grain harvest index (%) as affected by variety and N rates

Variety	Nitrogen rate (kg N ha^{-1})				
	0	23	46	69	Mean
NERICA-4	36.69^{e}	41.72^{cd}	44.47^{b}	44.09^{bc}	41.74
Suparica-1	36.20^{e}	42.02^{cd}	47.69^{a}	44.81^{b}	42.61
Kokit	38.05^{e}	41.05^{d}	41.54^{d}	36.26^{e}	39.23
Kellafo-1	37.2^{e}	41.53^{d}	43.19^{bcd}	38.36^{e}	40.07
Mean	37.04	41.51	44.22	40.88	
LSD (%) = 2.38 CV (%) = 3.50					

Means with the same letter are not significantly different at 5% level of significance; LSD **(%)** = Least Significant Difference Test at P < 0.05; CV **(%)** = Coefficient of variation

4.3. N Uptake and Use Efficiency

The analysis of variance revealed variety and N rate significantly ($P \leq 0.01$) affected grain and straw N content, grain and straw and total N uptake, N harvest index, agronomic N use efficiency, physiological N use efficiency and apparent N recovery efficiency. The N rate X variety interactions was also significantly different except for grain and straw N content (Table 14).

Table 14: Mean square values for N uptake and N use efficiency as affected by variety and N rates

Parameters	Mean squares			
	Var (3)	NR (3)	Var*NR (9)	CV (%)
Grain N concentration	0.005**	0.014**	0.000^{ns}	1.75
Straw N concentration	0.012**	0.011**	0.002^{ns}	6.25
Grain N uptake	385.64**	1141.61**	51.803**	3.38
Straw N uptake	80.06**	257.60**	4.954*	4.81
Total N uptake	753.07**	2336.22**	31.26**	2.15
N harvest index	330.12**	2747.88**	66.24**	11.47
ANUE	206.18**	8846.60**	85.62**	7.67
PNUE	461.94**	8449.06**	86.24**	7.92
ANRE	753.07**	2336.22**	31.26**	2.15

Var = variety; NR = Nitrogen rate; ANUE = agronomic N use efficiency; PNUE = physiological N use efficiency; ANRE = apparent N recovery efficiency; values put in parenthesis indicates the degree of freedom for respective source of variation; *, **, ^{ns} = significant, highly significant and non-significant at LSD (%) 0.05 probability level and CV (%) = coefficient of variation

4.3.1. N concentration in grain and straw

All upland varieties were recorded the same amount of N concentration in grain and straw except Kokit (Table 15). Among tested varieties, NERICA-4 and Suparica-1 were significantly higher in grain N concentration than Kokit, which was 1.257% and 1.247%, for NERICA-4 and Suparica-1, respectively. Varieties Kellafo-1, Suparica-1 and Nerica-4 produced significantly the highest concentration of straw N with respective concentration of 0.572 and 0.522 for both NERICA-4 and Suparica-1. The concentration of N in the straw ranged from 0.498% - 0.572% for Kellafo-1 and Kokit, respectively.

The concentration of N in grain and straw increased with increasing the rate of N application at maturity (Table 15). However, the concentration of N in grain at 69kg N ha^{-1} was statistically similar with that of 46kg N ha^{-1}. Nitrogen concentration in grain ranged from 1.195 - 1.272%, when the rate of N increased from control to 69kg ha^{-1}. Thus, the grain N concentration was enhanced by 6.4% due to the increased N application of 69kg N ha^{-1} over control treatment. The application of N fertilizer significantly increased straw N concentration in rice. When the rate of N increased from control to 69kg ha^{-1}, the increase in straw N concentration was from 0.510% - 0.584%. The concentration of N was higher in grain than straw at maturity. Actually it is clearly stated by Yoshida (1981), as the concentration of nitrogen is higher in straw and low in grains at early growth stage and then it becomes decreased in straw and increased in grains at maturity. The increased N concentration in grain, as well as, straw at maturity might be due to the increased N application might have increased the concentration of N in the soil, and thus probably leads to more uptake of N from the soil. This result is in agreement with the previous results of Sewnet (2005) and Sokat (2006) who reported the increased grain and straw N concentration with increasing rate of N application.

Table 15: Mean values of grain and straw N concentration as affected by variety and N rates

Variety	Grain N (%)	Straw N (%)	Nitrogen rate (Kg N ha^{-1})	Grain N (%)	Straw N (%)
Nerica-4	1.257^{a}	0.552^{ab}	0	1.195^{c}	0.510^{d}
Suparica-1	1.249^{a}	0.552^{ab}	23	1.230^{b}	0.541^{c}
Kokit	1.210^{b}	0.498^{b}	46	1.257^{a}	0.541^{b}
Kellafo-1	1.237^{ab}	0.572^{a}	69	1.272^{a}	0.584^{a}
LSD (%)	0.029	0.064	Mean	1.238	0.544
CV (%)	2.34	11.76	LSD (%)	0.018	0.029
			CV (%)	1.753	6.247

Means with the same letter are not significantly different at 5% level of significance; LSD (%) = Least significant difference at $P < 0.05$; CV (%) = Coefficient of variation.

4.3.2. Total N uptake by rice at maturity

The highest grain N uptake was recorded at 46 and 69 kg N ha^{-1}. Nitrogen uptake in grain increased with increasing N application and reached the highest value at high N level i.e., 69 kg ha^{-1} for the two varieties i.e., NERICA-4 and Suparica-1. The grain N uptake for Kokit and Kellafo-1 was increased with each increment of N application at first, and reached the highest value at 46 kg N ha^{-1}, then decreased dramatically at 69 kg N ha^{-1}. The grain N uptake for suparica-1 at 69 and 46 kg N ha^{-1} was not significantly different. The highest grain N yield of 59.98 kg N ha^{-1} and 59.09 kg N ha^{-1} was recorded on varieties NERICA-4 and Suparica-1, respectively at 69 kg N ha^{-1}. Suparica-1 and NERICA-4 accumulated more N in grain than

Kellafo-1 and Kokit in response to applied N at maturity. The observed difference in grain N uptake among varieties might be due to the inherent genetic differences among varieties in grain and straw yield production per the applied N fertilizer. This result is in agreement with the findings of Caseman *et al*. (1996) who reported significant differences among varieties in nutrient uptake and grain yield production in a given environmental condition. Grain N uptake increased with increment of N rate up to 69 kg N ha^{-1}. This finding is consistent with the results of Mannan *et al*. (2010) and Endris and Balcha (2014) who reported increased grain N uptake with increased rate of N application. Thus, the application of N promoted the concentration of N in rice plant.

The straw N uptake significantly increased with increasing rate of N application up to the maximum rate of N application (69 kg ha^{-1}) (Table 16). Varieties were also significantly varied in straw N uptake efficiency in response to applied N rate. The highest straw N uptake of 36.04 kg N ha^{-1} was recorded for variety Kellafo-1 at the of 69 kg N ha^{-1}, which was statistically similar with NERICA-4 that produced 33.47 kg N ha^{-1} at the rate of 69 kg N ha^{-1}. The increased N uptake in straw might be due to the increased rate of N application that might have enhanced vegetative growth of the rice plant and production of more tillers, which further resulted in higher straw yield. This result is in agreement with the results of Mannan *et al.* (2010) who reported increased straw N uptake with increased rates of nitrogen fertilization in rice.

Table 16: Mean values of grain and straw N uptake at maturity as affected by variety and N rates

Variety	Grain N uptake (kg N ha^{-1})				
	Nitrogen rate (kg N ha^{-1})				
	0	23	46	69	Mean
NERICA-4	32.34^{gh}	44.43^{d}	53.59^{b}	59.98^{a}	47.59
Suparica-1	30.62^{h}	41.11^{de}	56.68^{ab}	59.09^{a}	46.88
Kokit	26.93^{i}	35.37^{fg}	43.2^{d}	37.36^{f}	35.72
Kellafo-1	30.00^{hi}	38.34^{ef}	48.04^{c}	44.34^{d}	40.18
Mean	29.97	39.81	50.38	50.20	
LSD (%) = 3.45	CV (%) = 3.38				

			Straw N uptake (kg N ha^{-1})		
NERICA-4	24.29^{fgh}	27.12^{def}	29.73^{cd}	33.47^{ab}	28.65
Suparica-1	23.09^{ghi}	25.84^{efg}	28.40^{cde}	31.45^{bc}	27.2
Kokit	17.50^{j}	20.41^{ij}	23.55^{ghi}	29.88^{cd}	22.84
Kellafo-1	22.37^{hi}	25.27^{efgh}	27.26^{def}	36.04^{a}	27.74
Mean	21.81	24.66	27.24	32.71	
LSD (%) = 3.43	CV (%) = 7.75				

NHI = Nitrogen harvest index; Means with the same letter are not significantly different at 5% level of significance; LSD **(%)** = Least Significant Difference Test at P $\leq$ 0.05; CV **(%)** = Coefficient of variation

Total N uptake showed increase with increasing rate of N fertilizer application in upland rice at maturity (Table 17). The mean comparison indicated that, highest total N uptake of 93.5kg N ha^{-1} was recorded for variety NERICA-4 at the rate of 69kg N ha^{-1}, which was statistically at far with Suparica-1 that gave 90.5 kg N ha^{-1} at the same N rate. The observed highest total N uptake with increased rate of N application in upland rice could be due to the increased grain and straw yield resulted from the increased vegetative growth and tiller production with increased N fertilization. This result is in harmony with the finding of Chaudhuri (2015) who reported increased total N uptake with successively increased rate of N fertilization in rice. The tested varieties were varied in nutrient uptake in the study. Similarly, Saleque *et al.* (2004) reported genetic differences among varieties in the ability to absorb inherent soil N, as well as, the applied N fertilizer in a given environmental condition.

Table 17: Mean values of total N uptake (kg N ha^{-1}) at maturity as affected by variety and N rates

Variety	Nitrogen rate (kg N ha^{-1})				
	0	23	46	69	Mean
NERICA-4	56.63h	71.55ef	83.32c	93.45a	76.24
Suparica-1	53.72h	66.95fg	85.07bc	90.54ab	74.07
Kokit	44.43i	55.78h	66.76fg	67.24fg	58.55
Kellafo-1	52.37h	63.61g	75.3de	80.38cd	67.92
Mean	51.79	64.47	77.61	82.90	
LSD (%) = 5.84	CV (%) = 5.07				

Means with the same letter are not significantly different at 5% level of significance; LSD **(%)** = Least Significant Difference Test at P < 0.05; CV **(%)** = Coefficient of variation

4.3.3. N harvest index

Nitrogen harvest index indicates the level of efficiency of crop plants to use acquired nitrogen for grain formation (Fageria and Baligar, 2005). The highest N harvest index produced for both NERICA-4 and Suparica-1 at both rate of 46 kg N ha^{-1} and 69 kg N ha^{-1} (Table 18). The nitrogen harvest index increased significantly with increased rate of N application up to 46 kg N ha^{-1}, then decreased when the rate increased to 69 kg N ha^{-1} for both varieties Kokit and Kellafo-1. The variation in N harvest index among the upland rice varieties might be due to the genetic difference in the utilization of N for grain formation. The higher N harvest index at the rate of 46 kg N ha^{-1} is might be due to the higher N mobilization from straw to grain at maturity. The higher N translocation from straw to grain ultimately results in higher grain yield (Boote *et al.,* 2003).

Table 18: Mean values of N harvest index as affected by variety and N rates

Variety	**Nitrogen rate (kg N ha^{-1})**				
	0	**23**	**46**	**69**	**Mean**
NERICA-4	57.11f	62.09^{cde}	64.34^{abc}	64.17^{abc}	61.93
Suparica-1	56.99f	61.41^{de}	66.64^{a}	65.31^{ab}	62.59
Kokit	60.64e	63.38^{bcd}	64.79^{ab}	55.59^{f}	61.10
Kellafo-1	57.32f	60.28^{e}	63.83^{bcd}	55.20^{f}	59.16
Mean	58.02	61.79	64.9	60.07	
LSD (%) = 2.91	**CV (%) = 2.92**				

Means with the same letter are not significantly different at 5% level of significance; LSD **(%)** = Least Significant Difference Test at P < 0.05; CV **(%)** = Coefficient of variation

4.3.4. Agronomic N use efficiency

The interaction of variety with the rate of N application significantly affected agronomic N efficiency in upland rice. The agronomic N efficiency varied from 10.6 to 42.2 kg grain yield/kg N applied. The highest agronomic N efficiency of 42.2 and 39.3 kg grain yield per kg N applied was recorded on Suparica-1 at the rate of 46 kg N ha^{-1} and NERICA-4 at the rate of 23 kg N ha^{-1} The existence of significant variation in agronomic N efficiency among rice varieties in response to the applied N rate is might be due to the genetic difference among varieties in producing grain yield per the applied N rate. This result is in agreement with the results of Ye *et al*. (2007) who reported significant difference among varieties in agronomic N use efficiency under different soil conditions. The significant difference among upland rice varieties in agronomic N use efficiency was also reported by Fageria *et al.* (2010). In contrast, Ye *et al*. (2007) and Tayefe *et al.* (2011) reported the lowest agronomic N use efficiency with increased rate of N application in rice. It might be due to the low nutrient absorption of varieties at maximum N supply.

Table 19: Mean values of agronomic N use efficiency as affected by variety and N rates

Variety	Nitrogen rate (kg N ha^{-1})			
	23	46	69	Mean
NERICA-4	39.29^{a}	34.47^{b}	27.90^{d}	33.89
Suparica-1	32.48^{bc}	42.19^{a}	29.29^{cd}	34.65
Kokit	27.93^{d}	25.23^{d}	10.60^{e}	21.25
Kellafo-1	26.65^{d}	28.39^{cd}	14.70^{e}	23.25
Mean	31.59	32.57	20.62	
LSD (%) = 4.25 CV (%) = 12.05				

Means with the same letter are not significantly different at 5% level of significance; LSD **(%)** = Least Significant Difference Test at P < 0.05; CV **(%)** = Coefficient of variation

4.3.5. Physiological N use efficiency

The physiological N use efficiency (PNUE) varied with increasing rate of N application depending on varietal differences. The highest PNUE was recorded by Suparica-1 (61.9 kg grain yield per kg N uptake) and NERICA-4 (60.55 kg grain yield per kg N uptake) at the rate of 46 and 23 kg N ha^{-1}, respectively (Table 20). Physiological N use efficiency first increased as the rate of N increased from 23 to 46 kg N ha^{-1}, and then declined at the rate of 69 kg N ha^{-1} and statistically remained the same with PNUE obtained at the rate of 23 kg ha^{-1} for Suparica-1. On the other hand, the PNUE was the same at 23 and 46 kg N ha^{-1}, and then declined significantly at 69 kg N ha^{-1} for NERICA-4, Kokit and Kellafo-1. It might be due to the inherent genetic differences among varieties in N requirement to transform the acquired N into grain yield. In consistent to this result Dobermann, (2007) reported the existence of genotypic difference among rice varieties in physiological N use efficiency. In addition, Craswell and Godwin (1984) and Sewnet (2005) obtained higher physiological N efficiency with increased rate of N application in rice.

Table 20: Mean values of physiological N use efficiency as affected by variety and N rates

Variety	Nitrogen rate (kg N ha^{-1})			
	23	46	69	Mean
NERICA-4	60.55^{a}	59.39^{abc}	52.28^{d}	57.41
Suparica-1	56.07^{bcd}	61.92^{a}	54.89^{cd}	57.63
Kokit	56.59^{abcd}	52.20^{d}	31.99^{e}	46.93
Kellafo-1	54.54^{cd}	57.00^{abcd}	36.21^{e}	49.25
Mean	56.94	57.63	43.84	
LSD (%) = 5.36 CV (%) = 8.14				

Means with the same letter are not significantly different at 5% level of significance; LSD **(%)** = Least Significant Difference Test at P < 0.05; CV **(%)** = Coefficient of variation

4.3.6. Apparent N recovery efficiency

The Apparent N recovery efficiency (ANRE %) of all varieties increased significantly and variably with increasing rate of N fertilizer application. Suparica-1 and NERICA-4 showed the highest ANRE of 68.2% and 64.8% at the rate of 46 and 23 kg N ha^{-1}, respectively (Table 21). The ANRE for NERICA-4 decreased significantly as the rate of N increased from 23 to 46 kg N ha^{-1}, and then, remained, statistically, the same with N rate of 69 kg N ha^{-1}. The ANRE of Superica-1, on the other hand, increased significantly as the rate of N increased from 23 to 46 kg N ha^{-1}, and then, remained, statistically, the same with N rate of 23 kg N ha^{-1}. Interestingly, Kokit and Kellafo-1 showed similar pattern of ANRE in which the ANRE remained the same for both Kokit and Kellafo-1 at both 23 and 46 kg N ha-1, and then significantly decreased at 69 kg N ha^{-1} for both varieties. The decrement of ANRE with the increased rate of N application might be due to inherent genetic differences among the varieties. However, the observed lowest N recovery efficiency of the tested varieties at maximum rate of N application (69 kg N ha^{-1}) is probably due to losses of N through leaching, denitrification. Similarly, the lowest ANRE of rice due to the highest rate of N application was reported by several authors in their previous findings (Sewnet, 2005 and Sokat, 2006).

Table 21: Mean values of apparent N recovery efficiency as affected by variety and N rates

Variety	Nitrogen rate (kg N ha^{-1})			
	23	46	69	Mean
NERICA-4	64.84^{a}	58.00^{b}	53.36^{bc}	58.73
Suparica-1	57.53^{b}	68.17^{a}	53.37^{bc}	59.69
Kokit	49.34^{c}	48.54^{c}	33.07^{e}	43.65
Kellafo-1	48.83^{c}	49.84^{c}	40.59^{d}	46.42
Mean	55.14	56.14	45.10	
LSD (%) = 4.96 CV (%) = 7.63				

Means with the same letter are not significantly different at 5% level of significance; LSD **(%)** = Least Significant Difference Test at P < 0.05; CV **(%)** = Coefficient of variation

4.4. Association between Yield and Yield Components of Upland Rice

Pearson's correlation coefficient analysis was done to show the association between grain yield and yield components of upland rice varieties (Table 22). The results indicated that significant and positive correlation were found for grain yield with all yield components i.e., with straw yield (r= 0.74), biological yield (r=0.94), grain harvest index (r= 0.83), total number of spikelets per panicle (r= 0.87), filled spikelets per panicle (r= 0.93), number of tillers per m^2 area (r = 0.87), number of panicles per m^2 (r= 0.93). Furthermore, the phenological as well as growth parameters were also showed positive and significant associations with grain yield; viz: days to maturity (r= 0.50), plant height (r= 0.62) and panicle length (r= 0.61).

Similarly, positive and significant association of grain yield was found with plant height and panicle length. Besides, positive and significant association was found between grain yield and phonological traits, growth and yield components among themselves and with traits of interest. Generally, strong and positive association was observed between grain yield and yield components and interrelationship of other traits among themselves. This indicated strong contribution of traits to increased grain yield. This result in agreement with the investigation of Fageria and Kayvan *et al*. (2007), Sabesan *et al*. (2009), Akinwale *et al*. (2011), Ranawake (2014) and Tadesse (2015) who reported significant and highly positive correlation of grain yield with yield components; number of total spikelets per panicle, number of spikelets per panicle number of tillers, days to heading, total number of tillers, days to maturity and plant height. In addition to this, different authors reported strong interrelationship of rice grain yield with yield components, which also indicated the direct contribution of yield components to the grain yield.

Table 22: Pearson’s Correlation coefficient between agronomic traits

	DTM	**PHT**	**PL**	**TGW**	**TN**	**PN**	**FSP**	**TSP**	**GYD**	**SYD**	**BYD**	**GHI**
DTM	1.00											
PHT	0.66**	1.00										
PL	0.30*	0.41**	1.00									
TGW	0.46**	0.29*	0.36*	1.00								
TN	0.63**	0.64**	0.69**	0.27^{ns}	1.00							
PN	0.55**	0.58**	0.60**	0.06^{ns}	0.93**	1.00						
FSP	0.48**	0.56**	0.55**	-0.05^{ns}	0.85**	0.95**	1.00					
TSP	0.60**	0.64**	0.61**	0.16^{ns}	0.93**	0.84**	0.84**	1.00				
GYD	0.50**	0.62**	0.61**	0.08^{ns}	0.87**	0.93**	0.93**	0.82**	1.00			
SYD	0.45**	0.58**	0.58**	0.06^{ns}	0.83**	0.75**	0.71**	0.86**	0.74**	1.00		
BYD	0.51**	0.65**	0.64**	0.08^{ns}	0.92**	0.91**	0.89**	0.89**	0.94**	0.92**	1.00	
GHI	0.38*	0.41**	0.42**	0.10^{ns}	0.61**	0.75**	0.76**	0.49**	0.83**	0.24^{ns}	0.61**	1.00

GYD=Grain yield; SYD = Straw yield; BYD = Biological yield; HI= Harvest index; TN = Tiller number per m2; PN = Panicle number per m^2; FSP = Number of filled spikelets per panicle; TSP = Total number of spikelets per panicle; DTH = Days to 50% Heading; DTM = Days to 85% maturity; PHT= Plant height; PL= Panicle length; TGW = Thousand grain weight; *, **, ^{ns} = non-significant, significantly different at 5% and 1% confidence interval.

4.5. Associations between Grain Yield and N Uptake of Upland Rice

The grain yield was highly significantly and positively associated with grain N uptake (r= 0.99), straw N uptake (r= 0.70), total N uptake (r= 0.96) and N harvest index (r= 0.66). This has clearly indicated that the highest contribution of absorbed nitrogen content in rice plant for the increment of grain yield in upland rice. This result is in agreement with Fageria *et al.* (2010) who obtained highly significant and positive association between grain yield and nitrogen concentration and uptake in upland rice. In addition to this the relationship between plant N uptake and yield related traits also indicated positive and significant relationship with total spikelets per panicle and grain N uptake (r= 0.82), straw N uptake (r= 0.88), and total N uptake (r= 0.90). The positive and highly significant association was also observed between grain N uptake and other yield related traits of upland rice; number of filled spikelets per panicle (r= 0.92), total spikelets (r=0.82), tiller number (r=0.88), panicle number (r=0.94), and biological yield (r= 0.95). Likewise, the straw N uptake also showed positive and significant association with grain yield (r= 70), biological yield (r= 0.83), tiller number (r= 0.79), panicle number (r= 0.72), filled spikelets (r= 0.70) and total spikelets (r= 0.88). The result showed interrelationship between N uptake in grain and increased grain yield. This result is in agreement with earlier findings of Tadesse (2015) who reported significant and positive correlation between grain N uptake with biological yield and nitrogen harvest index with correlation coefficient of r= 0.72 and r= 0.64, respectively. Similarly, the same positive association of nitrogen harvest index with grain yield was reported previously by Fageria (2007). The strong association between grain yield and nitrogen uptake indicated the enhancement of N uptake in grain, and shoot at maturity can improved the upland rice yield.

Table 23: Pearson's correlation coefficient between N uptake and agronomic traits

	GNU	SNU	NHI	TNU	TN	PN	FSP	TSP	GYD	BYD
GNU	1.00									
SNU	0.72**	1.00								
NHI	0.65**	-0.05^{ns}	1.00							
TNU	0.97**	0.86**	0.45**	1.00						
TN	0.88**	0.79**	0.42**	0.91**	1.00					
PN	0.94**	0.72**	0.57**	0.93**	0.93**	1.00				
FSP	0.92**	0.70**	0.55**	0.91**	0.85**	0.95**	1.00			
TSP	0.82**	0.88**	0.23^{ns}	0.90**	0.93**	0.84**	0.84**	1.00		
GYD	0.99**	0.70**	0.66**	0.96**	0.87**	0.93**	0.93**	0.82**	1.00	
BYD	0.95**	0.83**	0.45**	0.97**	0.92**	0.91**	0.89**	0.89**	0.94**	1.00

GY=Grain yield; SYD = Straw yield; BYD = biological yield; TSP = Total number of spikelets per panicle; FSP = Number of filled spikelets per panicle; TN = Tiller number per m^2; PN = Panicle number per m^2; GNU = Grain N uptake; SNU = Straw N uptake; TNU = Total N uptake; ** = significantly different at 1% confidence interval

4.6. Partial Budget Analysis

Partial budget analysis was used in this study to calculate the total costs that vary and the net benefits for each treatment. The results of the analysis showed that the highest gross farm gate benefit of birr 24,780.60 ha^{-1} was obtained from NERICA-4 at the rate of 69 kg N ha^{-1} followed by Suparica-1 at the rate of 69 kg N ha^{-1}, which was birr 24,705.00.

The dominated treatments were eliminated from further analysis. The marginal rate of return is important to compare treatments in view of economic profitability rather than only looking at the highest biological grain yield, because it may not be attractive, if they require very much higher cost (CIMMYT, 1988). This helps to remove unprofitable treatments before recommendation. Based on the results of variety X N rate interactions, the highest marginal rate of return of 731% was recorded for Suparica-1, followed by 375% by NERICA-4 at the rate of 46 kg N ha^{-1}. In addition, the sensitivity analysis was also made for each treatment. The variation of returns because of yield reduction under adverse weather conditions for each treatment was deliberated for sustainability of the recommendations in the location. Accordingly, the same varieties at the same N level were showed the highest MRR i.e. 480% and 267% for Suparica-1 and NERICA-4 at 46 kg N ha^{-1}, respectively.

The results showed that the existence of varietal differences among the tested varieties in response to the applied rate of nitrogen fertilizer. Similar result was reported by Fageria *et al*. (2008) and Maqsood *et al*. (2013) who reported maximum paddy yield with higher net economic benefit at the rate of 46 kg N ha^{-1}. The observed difference among varieties might be due to high photosynthetic rate of the varieties to the applied rate of N fertilizer as compared to other tested varieties in the study. High yielding varieties have high capacity in storing more nitrogen, in leaves as well as increasing stomatal conductance to the applied rate of N fertilizer (Hirasawa *et al.*, 2010).

Table 24: Partial budget analysis for the variety and N rate on upland rice yield

Variety	N Rate (kg N ha^{-1})	Average grain yield (kg ha^{-1})	Adjusted grain yield (kg N ha^{-1})	Gross farm gate price (ETB ha^{-1})	App. cost for fertilizer (ETB ha^{-1})	Fertilizer cost (ETB ha^{-1})	Total variable cost (ETB ha^{-1})	Net benefit (ETB ha^{-1})	Marginal rate of return (%)
N4	0	2664.0	2397.6	14385.60	0.00	0.00	0.00	14385.60	
	23	3567.7	3210.9	19265.58	400.00	725.50	1125.50	18140.08	334
	46	4249.7	3824.7	22948.38	450.00	1451.00	1901.00	21047.38	375
	69	4589.0	4130.1	24780.60	500.00	2176.00	2676.00	22104.60	136
S1	0	2554.0	2298.6	13791.60	0.00	0.00	0.00	13791.60	
	23	3301.0	2970.9	17825.40	400.00	725.50	1125.50	16699.90	258
	46	4494.7	4045.2	24271.38	450.00	1451.00	1901.00	22370.38	731
	69	4575.0	4117.5	24705.00	500.00	2176.00	2676.00	22029.00	D
K	0	2307.3	2076.6	12459.42	0.00	0.00	0.00	12459.42	
	23	2949.7	2654.7	15928.38	400.00	725.50	1125.50	14802.88	208
	46	3468.0	3121.2	18727.20	450.00	1451.00	1901.00	16826.20	261
	69	3039.0	2735.1	16410.60	500.00	2176.00	2676.00	13734.60	D
K1	0	2502.0	2251.8	13510.80	0.00	0.00	0.00	13510.80	
	23	3115.0	2803.5	16821.00	400.00	725.50	1125.50	15695.50	194
	46	3808.0	3427.2	20563.20	450.00	1451.00	1969.54	18593.66	343
	69	3516.3	3164.7	18988.02	500.00	2176.00	2676.00	16312.02	D

N4 = NERICA-4; S1 = Suparica-1, K = Kokit; K1 = Kellafo-1; N = Nitrogen; App = Application and D = Dominated treatments

Table 25: Sensitivity analysis for the variety and N experiment at different yield levels

Variety	N Rate (kg N ha^{-1})	Adjusted grain yield (kg N ha^{-1})	Decrease in adjusted yield (20%)	Gross farm gate price (ETB ha^{-1})	Total variable cost (ETB ha^{-1})	Net benefit (ETB ha^{-1})	Marginal rate of return (%)
NERICA-4	0	2397.6	2397.6	14385.60	0.00	14385.60	
	23	3210.9	2568.7	15412.46	1125.50	14286.96	D
	46	3824.7	3059.8	18358.70	1901.00	16457.70	267
	69	4130.1	3304.1	19824.48	2676.00	17148.48	89
Suparica-1	0	2298.6	2298.6	13791.60	0.00	13791.60	
	23	2970.9	2376.7	14260.32	1125.50	13134.82	D
	46	4045.2	3236.2	19417.10	1901.00	17516.10	480
	69	4117.5	3294.0	19764.00	2676.00	17088.00	D
Kokit	0	2076.6	2076.6	12459.42	0.00	12459.42	
	23	2654.7	2123.8	12742.70	1125.50	11617.20	D
	46	3121.2	2497.0	14981.76	1901.00	13080.76	80
	69	2735.1	2188.1	13128.48	2676.00	10452.48	D
Kellafo-1	0	2251.8	2251.8	13510.80	0.00	13510.80	
	23	2803.5	2242.8	13456.80	1125.50	12331.30	D
	46	3427.2	2741.8	16450.56	1901.00	14549.56	134
	69	3164.7	2531.7	15190.42	2676.00	12514.42	D

N = Nitrogen; D = Dominated treatment

5. SUMMARY AND CONCLUSION

Use of appropriate rate of N fertilizer and N efficient variety is an important strategy to boost rice yield and reduce cost of production in rainfed condition. Growing improved rice varieties continuously without the need of any fertilizer, particularly nitrogen fertilizer coupled with poor soil management practices on farmer’s field are some of the major constraints resulting in low rice yield in Ethiopia. The experiment was conducted at Choba on-farm, in Gimbo district, during June to November 2015 under rainfed conditions with a view to determine optimum rate of N application and the best variety based on N uptake, N use efficiency, and yield and yield components of upland rice under Gimbo condition. The experiment consisted of four upland rice varieties viz. NERICA-4, Suparica-1, Kokit and Kellafo-1 and four levels of nitrogen fertilizer viz. 0 (control), 23, 46, 69 kg N ha^{-1}. The experiment was laid out in split plot design in factorial arrangement with three replications.

Results of the experiment showed that variety had significant effect on rice phenological characters i.e. days to heading and maturity. The latest days to heading was recorded at the the highest rate of N application, while the control treatment headed earlier. The longest days to mature were recorded on varieties kellafo-1 and Suparica-1. NERICA-4 and Kokit were earliest to attain their maturity. Likewise, variety and N rate were significant for growth parameters i.e. plant height and panicle length. Level of nitrogen had also significant effect on measured traits. The increased rate of N application had significantly increased days to heading, maturity, plant height and panicle length in rice. The longest days to heading and maturity were found at 69kg N ha^{-1}, while the lowest at control treatment (no N application).

The interaction between variety and N rate was significantly ($P \leq 0.05$) different for tiller and panicle numbers, total and filled spikelets per panicle, grain yield, biological yield, grain harvest index, as well as, most of N use efficiency parameters. Accordingly, the highest number of tillers (266.0) and (260.7) per square meter were recorded on NERICA-4 and Suparica-1, respectively at 69 kg N ha^{-1}. NERICA-4 produced the highest number of panicles (227.3), followed by Suparica-1 (220.0) at 69 kg N ha^{-1}. Likewise, these two varieties also produced the highest number of filled spikelets per panicle at 69 kg N ha^{-1}, and recorded

114.3 and 111.7 for Suparica-1 and NERICA-4, respectively. However, all tested varieties produced the highest number of total spikelets per panicle when the N rate exceeded 46 kg N ha^{-1}, indicating the higher production of unfilled spikelets at increased N rate in low yielded varieties.

The application of nitrogen fertilizer plays a very important role in rice production; meanwhile, using fertilizer efficient variety is the most important strategy to improve rice yield and simultaneously decrease cost of production. The production of grain and biological yield was significantly varied due to variety X applied rate of N fertilizer interaction in the study. The highest grain yield (4589.0 and 4575.0kg ha^{-1}) and biological yield (10410.3 and 10218.0kg ha^{-1}) were recorded for NERICA-4 and Suparica-1, respectively at the rate of 69 kg N ha^{-1}. Furthermore, the highest grain harvest index was also recorded for Suparica-1 followed by NERICA-4 at 46 kg N ha^{-1}.

Variety X N rate had significantly influenced N uptake and use efficiency in rice at maturity. The uptake of N in grain increased with increasing rate of N application from 0 kg N ha^{-1} to 69 kg N ha^{-1} at maturity. The comparison of means indicated that the highest grain N, straw N uptake, as well as, total N uptake was recorded on varieties NERICA-4 and Suparica-1 at 69kg N ha^{-1}. However, agronomic N use efficiency (ANUE), physiological nitrogen use efficiency (PNUE) and apparent N recovery efficiency (ANRE %) showed significant differences, for the variety X N levels interaction at maturity in upland rice. The application of N fertilizer significantly increased agronomic (ANUE%), physiological N use efficiency (PNUE) and Apparent N recovery (ANRE) (%) for Suparica-1 and ANUE and ANRE% for NERICA-4 up to 46 kg N ha^{-1}, but beyond this rate the efficiency of all the parameters declined. The highest ANUE, PNUE and ANRE (%) was obtained at the rate of 46 kg N ha^{-1} for Suparica-1 and at 23 kg N ha^{-1} for NERICA-4. The ANUE ranged from 10.60 to 42.19 kg grain yield per kg N applied. Significantly higher ANUE recorded for Suparica-1 at 46 kg N ha^{-1} and NERICA-4 at 23 kg N ha^{-1}. The higher ANUE due to the application of N fertilizer showed the ability of producing higher grain yield with the applied level of N fertilizer. Thus, NERICA-4 and Suparica-1 were performed better and produced higher N yield and use efficiency as compared to others. The higher uptake of nitrogen in case of NERICA-4 and Suparica-1 had significant effect on grain yield and yield components.

The increased grain yield with increasing rate of N application might be due to the increased N uptake, N utilization efficiency and the increased yield components. The observed positive and strong relationship between grain yield and N uptake showed the contribution of absorbed N to increased grain yield. In addition, the association between grain yield and yield related traits indicated positive and significant. The increased grain yield with the increased N uptake in NERICA-4 and Suparica-1 indicated the transformation of absorbed nitrogen to grain formation. Generally, before recommending any alternative technology, checking its economic advantage is beneficial. Thus, comparing treatments with regard to their economic higher yield rather than considering only the highest biological yield is important strategy for economic profitability of crop production, as considering only biological yield may not be attractive if it requires very much higher cost. Suparica-1 and NERICA-4 produced the highest net benefit and marginal rate of return of 731 and 375% at 46 kg N ha^{-1}, respectively. In addition, the sensitivity analysis was also made for the ability to withstand the variation of returns under adverse weather conditions. Similarly, the same varieties were also showed the highest marginal rate of return at the same level of N application. Therefore, growing Suparica-1 and NERICA-4 at 46 kg N ha^{-1} produced optimum grain yield coupled with the highest economic benefit in the study area. Therefore, it can be suggested for cultivation by farmers in the upland ecosystem of Choba.

The experiment was conducted in one season and one location. In addition, variety NERICA-4 showed significantly higher grain yield and yield components with the increased rate of N application in the location. So that, it could not be known whether the grain yield for this variety would decrease or increase, when the rates of N increases further. Therefore, repeating the experiment over years by increasing N levels would help to draw sound recommendations in the location. Hence, future studies should take these issues into consideration in order to validate the current results.

6. REFERENCES

Abou-Khalifa, A.A.B. 2012. Evaluation of Some Rice Varieties under Different Nitrogen Levels. *Advances in Applied Science Research* **(3):**1144-1149.

Africa Rice Center, 2011. Boosting Africa's Rice Sector: A research for development strategy 2011-2020. *Cotonou, Benin*, 75p.

Ahmed M, Islam M.M, Paul S.K. 2005. Effect of nitrogen on yield and other plant characters of local T. Aman Rice, Var. Jatai. *Res. J. Agric. Biol. Sci*. **(1):** 158-161.

Akinwale, M.G., Gregorio, G., Nwilene, F., Akinyele, B.O., Ogunbayo, S.A. and Odiyi, A.C. 2011. Heritability and correlation coefficient analysis for yield and its components in rice (Oryza sativa L.). *African Journal of Plant Science* **5(3):** 207-212.

Alagesan, A. and Babu, R. 2011. Impact of different nitrogen levels and of application on grain yield and yield attributes of wet seeded rice, *International Journal of Food, Agricultural and Veterinary science* **1(1):** 15.

Alimi, T. and Manyong, V.M., 2000. *Partial budget analysis for on-farm research*, IITA. **65**: 1-52.

Artacho, P., Bonomelli, C. and Meza, F., 2009. Nitrogen Application in irrigated rice grown in mediterranean conditions: Effects on grain yield, dry matter production, nitrogen uptake, and nitrogen use efficiency. *Journal of Plant Nutrition*, ***32*****(9):** 1574-1593.

Aslam, M.M., Zeeshan, M., Irum, A., Hassan, M.U., Ali, S., Hussain, R., Ramzani, P.M.A. and Rashid, M.F., 2015. Influence of Seedling Age and Nitrogen Rates on Productivity of Rice (Oryza sativa L.): A Review. *American Journal of Plant Sciences*, ***6*****(9):** 1361-1369.

Baligar, V.C., Fageria, N.K. and He, Z.L., 2001. Nutrient use efficiency in plants. *Communications in Soil Science and Plant Analysis*, ***32*****(7-8):** 921-950.

Boote, C., Dennis, S., Newton, R.H., Puri, H. and Meek, K.M., 2003. Collagen fibrils appear more closely packed in the prepupillary cornea: optical and biomechanical implications. *Investigative ophthalmology & visual science*, ***44*****(7):** 2941-2948.

BOANRD (Berue of Agriculture and Natural Resource Development), 2015. Meteorological data of the destrict.

Bouyoucos, G.J. 1962. Hydrometer method improved for making particle size analyses of soils. *Agronomy Journal*, ***54*****(5):** 464-465.

Brady B. N. C. and R.R Weil, 2002. *The Nature and Properties of Soils*, 13th ed. Person Education Ltd, USA 621p.

Bray, R.H. and Kurtz, L.T., 1945. Determination of total, organic, and available forms of phosphorus in soils. *Soil science, **59***(**1**)**:** 39-46.

Cassman, K.G., De Datta, S.K., Amarante, S., Liboon, S., Samson, M.I., Dizon, M.A., 1996. Long-term comparison of agronomic efficiency and residual benefits of organic and inorganic nitrogen sources for tropical lowland rice. *Exp. Agric*. **32**, 427-444.

Chang, T.T., 1976. The origin, evolution, cultivation, dissemination, and diversification of Asian and African rices. *Euphytica, **25***(**1**)**:** 425-441.

Charron, C.S., Kopsell, D.A., Randle, W.M. and Sams, C.E., 2001. Sodium selenate fertilisation increases selenium accumulation and decreases glucosinolate concentration in rapid-cycling Brassica oleracea. *Journal of the Science of Food and Agriculture, **81***(**9**)**:** 962-966.

Chatterjjee, B. N. and S. Maiti, 1985. Principles and Practices of Rice Growing, 2nd ed. New Delhi. *Oxford and 1BH publishing Co*. 226p.

Chaudhuri P.B, 2015. *Nitrogen Nutrition in Rice***,** *Indian Journal of Plant Sciences **4(3):** 28-37, New Delhi, Indian*

CIMMYT. 1988. From Agronomic Data to Farmer Recommendations: *An Economics Training Manual,* Completely revised edition. Mexico, D.F, CIMMYT, 79p.

Craswell ET, Godwin DC., 1984. The efficiency of nitrogen fertilizers applied to cereals in different climates. In: Tinker B, Launch A. (Eds.), Advance in Plant Nutrition, Preager, and New York. 1: 1-55.

CSA 2012. Report on Area and Production of Crops, (Private Peasant Holdings, Meher Season),' Ethiopian Agricultural Sample Survey (2012/13 (2005 E.C.)) – Volume I, Statistical Bulletin 532, Central Statistical Agency (CSA), Addis Ababa, Ethiopia.

Dawit Alemu, 2015. Rice in Ethiopia: Progress in Production Increase and Success Factors, review on 6th CARD General meeting (power point slides). Retrained from http://riceforafrica.net/images/stories/PDF/5-4EN.pdf

De data, S.K. 1981. Principles and Practices of Rice Production, Wiley,New York. 507p.

De Datta, S. K. and Patrick Jr. W. H., 1986. Nitrogen economy of flooded rice soils, Martinus Nijhoff, the Netherlands. 186p.

De Datta, S. K., and Beachell H.M., 1972. Varietal response to some factors affecting production of upland rice. International Rice Research Institute, Rice breeding. Los Baños, Philippines. 685–700.

Delgado, J.A., 2002. Quantifying the loss mechanisms of nitrogen. *Journal of Soil and Water Conservation*, **57(6):** 389-398.

Dewis, J. and Freitas, F., 1970. Physical and chemical methods of soil and water analysis. *FAO Soils Bulletin*, (10): 275p.

Doberman, A. and Fairhurst, T. 2000. Rice Nutrient disorders and nutrient management, IRRI, Philippines, PPI, USA. and PPIC, Canada, 190p.

Dutta, D., Sarker, M. A. R., Samad, M. A. and Paul S. K. 2002. Effect of row arrangement and nitrogen level on yield and yield components of transplant Aman rice, Online J. Biol. Sci. **2 (10):** 636-638.

Ehsanullah, Jabran, K., Asghar, G., Hussain, M. and Rafiq, M., 2012. Effect of Nitrogen Fertilization and Seedling Density on Fine Rice Yield in Faisalabad, Pakistan. Soil & Environment **31:**152-156.

Fageria, N. K. and Baligar, V. C., 2003. Methodology for Evaluation of Lowland Rice Genotypes for Nitrogen Use Efficiency, *Journal of Plant Nutrition* **26(6):** 1315-1333.

Fageria, N. K., and V. C. Baligar. 2005. Enhancing nitrogen use efficiency in crop plants, *Advances in Agronomy* **88:** 97-185.

Fageria, N. K., E. P. Santana, and O. P. Morais. 1995. Response of favourable upland rice genotypes to soil fertility, Pesquisa Agro-pecuaria Brasileira **30**:1155-1161.

Fageria, N. K., O. P. Morais, and dos Santos A. B. 2010. Nitrogen use Efficiency in Upland Rice Genotypes, *Journal of Plant Nutrition*, **33**:1696-1711.

Fageria, N.K. and Baligar, V.C. 2001. Lowland rice response to nitrogen fertilization, *Commun. Soil Sci. Plant Anal*. **32:**1405–1429.

Fageria, N.K. and Baligar, V.C., 2005. Enhancing nitrogen use efficiency in crop plants. *Advances in agronomy*, ***88*****:** 97-185.

Fageria, N.K., 2007. Yield physiology of rice. *Journal of Plant Nutrition*, ***30*****(6):** 843-879.

Fageria, N.K., 2008. The use of nutrients in crop plants. CRC press, 419p.

Fageria, N.K., Baligar, V.C. and Bailey, B.A., 2005. Role of cover crops in improving soil and row crop productivity. *Communications in soil science and plant analysis*, ***36*****(19-20):** 2733-2757.

Fageria, N.K., Baligar, V.C. and Zobel, R.W., 2007. Yield, Nutrient Uptake, and Soil Chemical Properties as Influenced by Liming and Boron Application in Common Bean in a

No-Tillage System. *Communications in soil science and plant analysis*, ***38*****(11-12):** 1637-1653.

Fageria, N.K., De Morais, O.P. and Dos Santos, A.B., 2010. Nitrogen use efficiency in upland rice genotypes. *Journal of plant nutrition*, ***33*****(11):** 1696-1711.

Fageria, N.K., Filho, M.B., Moreira, A. and Guimaraes, C.M., 2009. Foliar fertilization of crop plants. *Journal of plant nutrition*, ***32*****(6):** 1044-1064.

Fageria, N.K., Santos, A.B. and Cutrim, V.A., 2008. Dry matter and yield of lowland rice genotypes as influence by nitrogen fertilization. *Journal of Plant Nutrition* ***31*****(4):**788-795.

Fageria, N.K., Slaton, N.A. and Baligar, V.C., 2003. Nutrient management for improving lowland rice productivity and sustainability. *Advances in Agronomy*, ***80*****:** 63-152.

Fageria, N.K., Zimmermann, F.J.P. and Baligar, V.C., 1995. Lime and phosphorus interactions on growth and nutrient uptake by upland rice, wheat, common bean, and corn in an oxisol. *Journal of plant nutrition*, ***18*****(11):** 2519-2532.

Fageria, N.K.; Baligar, V.C.; Jones, C.A. 1997. Growth and Mineral Nutrition of Field Crops, Marcel Dekker, Inc.: New York; 624p.

FAO, 2013. FAO statistical yearbook 2013.World Food and Agriculture. Food and Agriculture

FAOSTAT., 2015. FAO Statistics Division, available at: http://faostat3.fao.org/home/E

Funderburg, E., 2010. What does organic matter do in soil. *Retrieved from The Samuel Roberts Noble Foundation Web Site: www. noble. org/ag/soils/organicmatter*.

Gasim, S.H. 2001. Effect of nitrogen, phosphorus and seed rate on growth, yield and quality of forage maize (*Zea mays* L.). M.Sc. Thesis, Faculty of Agric., University of Khartoum.

Gebrekidan H. and Seyoum M. 2006. Effects of Mineral N and P Fertilizers on Yield and Yield Components of Flooded Lowland Rice on Vertisols of Fogera Plain, Ethiopia. *Journal of Agriculture and Rural Development in the Tropics and Subtropics* **107(2):**161-176.

GRiSP (Global Rice Science Partnership). 2013. Rice almanac, 4th edition. Los Baños (Philippines): International Rice Research Institute. 283p.

Gueye, T. and Becker, H. 2011. Genetic variation in nitrogen efficiency among cultivars of irrigated rice in Senegal. *Journal of Agricultural Biotechnology and Sustainable Development* 3(3):35.

Hanson A D, Peacock W J, Evans L T, Arntzen C J, Khush G S, 1990. Drought resistance in rice, *Nature* 234: 2.

Haque, K. M. S., Khaliq, Q. A. and Aktar, J. 2006. Effect of Nitrogen on Phenology, Light Interception and Growth in Aromatic Rice, *Int. J. Sustain. Crop Prod.* **1(2)**:01-06.

Haque, M.A. and Haque, M.M. 2016. Growth, Yield and Nitrogen Use Efficiency of New Rice Variety under Variable Nitrogen Rates. *American Journal of Plant Sciences*, **7(03):**612.

Hasan, S.M., 2007. Effect of level of urea super granules on the performance of T. aman rice. MSc. Thesis, Dept. Agron., Bangladesh Agril. Univ. Mymensingh, 30-52.

Hazelton, P.A. and Murphy, B.W., 2007. Interpreting soil test results: what do all the numbers mean?. CSIRO publishing, 151p.

Heluf Gebrekidan and Mulugeta Seyoum, 2006. Effects of Mineral N and P Fertilizers on Yield and Yield Components of Flooded Lowland Rice on Vertisols of Fogera Plain, Ethiopia, *Journal of Agriculture and Rural Development in the Tropics and Subtropics* **107:** 161–176 .

Hesse, P.R., 1971. A textbook of soil chemical analysisChemical Publishing Co. *New York*, 520p.

Hirasawa, T., Ozawa, S. Taylaran, R. and Ookawa, T. 2010. Varietal differences in photosynthetic rates in rice plants, with special reference to the nitrogen content of leaves. *Plant Production Science*, **13(1):** 53-57.

Hofman Georges and van Cleemput Oswald. 2004. Soil and Plant Nitrogen, *International Fertilizer Industry Association (IFA), Paris, France, 48p.*

Hossain, M.B., Islam, M.O. and Hasanuzzaman, M., 2008. Influence of different nitrogen levels on the performance of four aromatic rice varieties. *Int. J. Agri. Biol*, ***10*****(6):** 693-696.

Huke, R.E., 1982. *Rice area by type of culture: South, Southeast, and East Asia*. Int. Rice Res. Inst. 64p.

International Rice Research Institute. 1977. Annual report for 1976 (in process).

Jackson, M. L. 1973. Soil Chemical Analysis. Prentice Hall Grice. Englewood Cliffs, USA. 284p.

Jackson, M.L., 1958. Nitrogen determinations for soil and plant tissue. *Soil chemical analysis* 183-204.

Jata S K, Nedunchezhiyan M and Laxminarayana K. 2011. Site specific nutrient management for rice. *Orissa review,* 62 p.

Jayakumar, M. and Krishnasamy, S. (2005) Effect of Irrigation Regimes, Mid Season Drainage and Time of Application of Nitrogen on Hybrid Rice. Madras Agricultural Journal, **92**: 415-421.

Jisan, M.T., 2014. Influence of variety and level of nitrogen on the yield performance of transplant aman rice. MSc. thesis presented to the School of Graduate Studies of Bangladesh Agricultural University, Mymensingh, 98p.

Jones, C.A., Koenig, R.T., Ellsworth, J.W., Brown, B.D. and Jackson, G.D., 2007. Management of urea fertilizer to minimize volatilization. *MSU Extension*, 1-12.

Kamara AY, Ekeleme F, Omoigui L, Oikeh, OS, Chikoye D, and Tegbaru A., 2010. Responses of upland rice cultivars to nitrogen fertilizer in the Savannas of Nigeria Agronomy. **102(1):** 333-339.

Kandil, A.A., El-Kalla, S.E., Badawi, A.T. and El-Shayb, O.M. (2010) Effect of Hill Spacing, Nitrogen Levels and Harvest Date on Rice Productivity and Grain Quality. Crop and Environment, **1:** 22-26.

Kayvan A, Mohammad F, Ezatollah F. 2007. Correlation and path coefficient analysis for some yield-related traits in rice genotypes (Oryza sativa L.). *Asian Journal of Plant Sciences* **6(3)**:513.

Kebebew A., Dawit A., Shiratori, K. and Abebe K., 2011. Challenges and Opportunities of Rice in Ethiopian Agricultural Development. *Addis Ababa: Ethiopian Institute of Agricultural Research. Accessed on January, 15,* 2015. 23-24.

Ketterings, Q., Reid, S. and Rao, R., 2007. Cation exchange capacity (CEC). *Fact sheet*, *22*p.
Kissel, D.E. and Sonon, L.S., 2008. Soil test handbook for Georgia. 90p.

Kopsell D.A. and Randle W.M., 2001, Genetic variances and selection potential for selenium accumulation in a rapid-cycling Brassica oleracea population. *J. Am. Soc. Hortic. Sci.* **126:**329–335.

Ladha J K, Pathak H, Krupnik T J, Six J and Kessel C van, 2005. Efficiency of fertilizer nitrogen in cereal production: retrospect's and prospects, Adv. Agron. **87**: 85-156.

Linares, O.F., 2002. African rice (Oryza glaberrima): history and future potential. *Proceedings of the National Academy of Sciences*, ***99*(25):** 16360-16365.

Luka G.L, Yahaya R.A, Mahmud M., Babaji B.A, Arunah U.L, Hinjari A.D and Isah A. S. 2013. Growth Response of Upland Rice (Oryza Sativa L.) Varieties to Nitrogen and Seed Rates in the Northern Guinea Savahah. *Journal of Biology, Agriculture and Healthcare*, 3: 20.

Lukas Kilcher, 2011. African Organic Agriculture Training Manual, A Resource Manual for Trainers. FiBL, Research Institute of Organic Agriculture, Switzerland, 14p.

Mae T, 1997. Physiological nitrogen efficiency in rice: Nitrogen utilization, photosynthesis, and yield potential. *Plant Soil* 196: 201-210.

Mahajan G, Sekhon N K, Singh N, Kaur R, Sidhu A S.,2010. Yield and nitrogen-use efficiency of aromatic rice cultivars in response to nitrogen fertilizer, *J New Seeds* **11**: 356-368.

Mannan, M.A., Bhuiya, M.S.U., Hossain, H.M.A. and Akhand, M.I.M., 2010. Optimization of nitrogen rate for aromatic Basmati rice (Oriza sativa L.). *Bangladesh Journal of Agricultural Research*, ***35*****(1):** 157-165.

Manzoor, Z., Awan, T.H., Zahid, M.A. and Faiz, F.A. 2006. Response of rice crop (super basmati) to different nitrogen levels. *J. Anim. Pl. Sci*. ***16*****(1-2):** 52-55.

Maqsood, M., Shehzad, M.A., Ali, S.N.A. and Iqbal, M. 2013. Rice cultures and nitrogen rate effects on yield and quality of rice (Oryza sativa L.). *Turkish Journal of Agriculture and Forestry,* **37(6):** 665-673.

Marschner, H., 1995. Mineral nutrition of higher plants. 2nd. *Edn. Academic Pres*. 889p

Marschner, H., 2011. *Marschner's mineral nutrition of higher plants*. Academic press, 645p

McKenzie R. H., 2003. Soil pH and plant nutrients, *Agri-facts* 1-2. Accessed on August 19, 2016.

Mengel, K, and E.A. Kirkby, 1996. Principles of plant Nutrition, *Panama Publishing Corporation, New Delhi, India*. 314p.

Mengel, K., Kirkby, E.A., Kosegarten, H. and Appel, T., 2001. Nitrogen. In *Principles of plant nutrition*, 397-434. Springer Netherlands.

MeviSchütz T, Goverde JM, Erhardt A., 2003. Effects of fertilization and elevated CO_2 on larval food and butterfly nectar amino acid preference in Coenonymphapamphilus L, Behavioral Ecology and Sociobiology. **54:** 36-43.

Mikkelson, D.S., 1982. Timing and method of nitrogen applied for rice. Proceeding second National Rice, 175p.

MoARD, 2010. National rice research and development strategy of Ethiopia, Ministry of Agriculture and Rural Development, Addis Ababa, Federal Democratic Republic of Ethiopia, 48p.

Moll RH, Kamprath EJ, Jackson WA., 1982. Analysis and interpretation of factors which contribute to efficiency of nitrogen utilization. *Agronomy Journal* **74:**562–564.

Moormann, F.R. and Dudal, R., 1965. *Characteristics of Soils on which Paddy is Grown in Reloation to Their Capability Classification*. Kingdom of Thailand, FAO and Soil Survey Division.

Moro, B.M., Nuhu, I.R. and Martin, E.A., 2016. Effect of Spacing on Grain Yield and Yield Attributes of Three Rice (*Oryza sativa* L.) Varieties Grown in Rain-fed Lowland Ecosystem in Ghana. International Journal of Plant & Soil Science, **9(3):** 1-10, 2016.

Morris M.L., 1982. Rice Production. A Training Manual and Field Guide to Small-Farm Irrigated Rice Production. Appropriate Technologies for Development. Reprint No. R-40.

Mulugeta S. and Heluf G.K., 2014. Inherant properties and fertilizer effects of flooded rice soil. *Journal of Agronomy* **13:** 72-75.

Murata, Y. 1969. Physiological responses of nitrogen in plants, pages 235-259 in American Society of Agronomy and Crop Science Society of America. Physiological aspects of crop yield. Madison, Wisconsin, *Agronomy & Horticulture -Faculty Publications*, Paper 197.

Musa, M.H., Azemi, H., Juraimi, A.S. and Tengku Muda Mohamed, M. 2009. Upland rice varieties in Malaysia: agronomic and soil physico-chemical characteristics. *Pertanika Journal of Tropical Agricultural Science* **32(3):** 225-246.

Namvar, A., Sharifi, R.S., Sedghi, M., Zakaria, R.A., Khandan, T. and Eskandarpour, B., 2011. Study on the effects of organic and inorganic nitrogen fertilizer on yield, yield components, and nodulation state of Chickpea (Cicer arietinum L.). *Communications in soil science and plant analysis*, ***42*****(9):** 1097-1109.

Nori, H., Abdul Halim, R. and Ramlan, M.F., 2008. Effects of nitrogen fertilization management practice on the yield and straw nutritional quality of commercial rice varieties. *Malaysian Journal of Mathematical Sciences*, ***2*****(2):** 61-71.

NRRDSE, 2010. Federal Democratic Republic of Ethiopia Ministry of Agriculture and Rural Development (MoARD), 1-39, Addis Ababa

Organization of the United Nations (FAO), Rome, 978-92-5-107396-4.

Pal U.R. 1991. Effect of source and rate of nitrogen and phosphorus on yield and uptake and apparent fertilizer nutrient recovery by maize in southern guinea savanna of Nigeria, *J. Agric. Sci. Technol*. **1**: 21-34.

Peng, S., Huang, J., Sheehy, J.E., Laza, R.C., Visperas, R.M., Zhong, X., Centeno, G.S., Khush, G.S. and Cassman, K.G., 2004. Rice yields decline with higher night temperature from global warming. *Proceedings of the National Academy of Sciences of the United States of America*, ***101*****(27)**: 9971-9975.

Provin, T.L. and Hossner, L.R. 2001. What Happens to Nitrogen in Soils?. AgriLife Extension, Texas A&M System. E-59p.

Rahman, M. H., Ali, M. H., Ali, M. M. and Khatun, M. M. 2007. Effect of Different Level of Nitrogen on Growth and Yield of Transplant Aman Rice cvbrri dhan32, *Int. J. Sustain. Crop Prod*. **2(1**): 28-34.

Rahman, S., 2003. Profit efficiency among Bangladeshi rice farmers. *Food Policy*, ***28*(5**): 487-503.

Rakkar, M.K., Franzen, D.W. and Chatterjee, A., 2015. Evaluation of Soil Potassium Test to Improve Fertilizer Recommendations for Corn. *Open Journal of Soil Science*, ***5*(05):** 110.

Ranawake, A.L. and Amarasinghe, U.G.S., 2014. Relationship of yield and yield related traits of some traditional rice cultivars in Sri Lanka as described by correlation analysis. *Journal of Scientific Research and Reports* **3**: 2395-2403.

Ren, F., Lu, B.R., Li, S., Huang, J. and Zhu, Y., 2003. A comparative study of genetic relationships among the AA-genome Oryza species using RAPD and SSR markers. *Theoretical and Applied Genetics*, ***108*(1**), pp.113-120.

Rice Sector Development In East Africa (RSDEA), 2012. Accessed on oct 07, 2015. Availableat: http://commonfund.org/fileadmin/user_upload/Illustrations/CFC-Rice-Sector Development-in-East-Africa-2012.pdf

Sabesan, T., Suresh, R. and Saravanan, K., 2009. Genetic variability and correlation for yield and grain quality characters of rice grown in coastal saline low land of Tamilnadu. *Electronic Journal of Plant Breeding*, ***1*(1):** 56-59.

Salam M. A., Lucy Fouzia Kabir M.H. and Khan A.R., 2011. *Effect of different doses of fertilizers on yield and yield components of two varieties of boro rice*. J. Agrofor. Environ. **5 (2)**: 53-56.

Saleque, M.A., Naher, U.A., Islam, A., Pathan, A.B.M.B.U., Hossain, A.T.M.S. and Meisner, C.A., 2004. Inorganic and organic phosphorus fertilizer effects on the phosphorus fractionation in wetland rice soils. *Soil Science Society of America Journal*, ***68*(5):** 1635-1644.

Sarla, N. and Swamy, B.M., 2005. Oryza glaberrima: a source for the improvement of Oryza sativa. *Current science-bangalore-*, ***89*(6)**: 955.

SAS Institute. 2002. The SAS system for windows, V.9.2. SAS Institute, Carry, NC, USA.

Satake T, and Hayase H., 1970. Male sterility caused by cooling treatment at the young microspore stage in rice plants. Variability Estimation of pollen developmental stage and the most sensitive stage to coolness. *Proc Crop Sci Soc Jpn* **39**:468–473.

Sattelmacher, B. and Horst, W.J. eds., 2007. The apoplast of higher plants: compartment of storage, transport and reactions: the significance of the apoplast for the mineral nutrition of higher plants. Springer Science & Business Media, 3-12.

Seck, P.A., Diagne, A., Mohanty, S. and Wopereis, M.C., 2012. Crops that feed the world 7: rice. *Food Security, **4***(**1**)**:** 7-24.

Sewenet A., 2005. Effects of nitrogen and seed rates on grain yield and yield components and nitrogen uptake of rainfed rice (Oryza sativa L) in Fogera, South Gonder. MSc Thesis presented to the School of Graduate Studies of Alemaya University. 132p.

Seyoum, M. and Gebre-Kidan, H., 2014. Inherent Properties and Fertilizer Effects of Flooded Rice Soil. *Journal of Agronomy, **13***(**2**)**:** 72-75.

Shand, C., 2007. Plant Nutrition for Food Security. A Guide for Integrated Nutrient Management. By RN Roy, A. Finck, GJ Blair and HLS Tandon. Rome: Food and Agriculture Organization of the United Nations; 348p.

Sharif Z.M., Hussain F., Aslam M., Akhtar E.M. and Hamid A. 2003. Basis for Formulation of Fertilizer Recommendations for Crop Production. International Journal of Agriculture & Biology 392–396.

Sharma, R.K. 1973. Response of maize to nitrogen fertilization. *Madras Agric. J*. **60**: 399-440.

Shemahonge, M.I. 2013. Improving upland rice (oryza sativa L.) perfomance through enhanced soil fertility and water conservation methods at Ukiriguru Mwanza, Tanzania (Doctoral dissertation, Sokoine University of Agriculture).

Sikuku P. A., Kimani J. M., Kamau J. W. and Njinju S, 2015. *Evaluation of Different Improved Upland Rice Varieties for Low Soil Nitrogen Adaptability. International Journal of Plant & Soil Science, **5(1):** 40-49.*

Singh M. and Verma S. C., 1971. Effect of different rates of nitrogen and phosphorus application on the yield and yield contributing characters of TN-1 rice. *Indian J. Agron.* **16(3):** 257–260.

Singh, G. and O. P. Singh. 1993 Effect of method of seeding and level of nitrogen on yield and yield attributes of rice (Oryza sativa L) under flood affected condition. *Indian J. Agron.* **38(4):** 551-554.

Singh, H., Verma, A., Ansari, M.W. and Shukla, A. 2014. Physiological response of rice (Oryza sativa L.) genotypes to elevated nitrogen applied under field conditions. *Plant signaling & behavior* **9(7):** 29015.

Sivasankar, A., Bansal, K.C. and Abrol, Y.P., 1993. Nitrogen in relation to leaf area development and photosynthesis. *Proceedings-Indian National Science Academy part B*, *59*: 235-235.

Siwar, C., Diana, N., Yasar, M. and Morshed, G., 2014. Issues and challenges facing rice production and food security in the granary areas in the East Coast Economic Region (ECER), Malaysia. *Research Journal of Applied Sciences, Engineering and Technology*, ***7*****(4):** 711-722.

Smil V., 2001. Nitrogen in crop production. An account of global flows, Global Bio-geochemical Cycles **13**: 647-662.

Sokat Yiech. 2006. Nitrogen uptake and yield responses of rainfed rice (*Oryza sativa* L.) varieties to fertilizer N on fluvisols of Gambella region. An Msc Thesis presented to the School of Graduate Studies of Haramaya University, Ethiopia.

Somado, E.A., Guei, R.G. and Nguyen, N., 2008. Over view: Rice in Africa. *NERICA: The new rice for Africa—A compendium. Africa Rice Center (WARDA), Cotonou, Benin* 1-9p.

Taddesse L., 2015. Estimation of Genetic Variability and Trait Association in Nitrogen Use Efficiency of Upland Rice Varieties in North Western Ethiopia. *International Journal of Research and Review*, **2(9):** 527-535.

Takahashi, R. and Yasuda, S., 1956. Genetic studies of spring and winter habit of growth in barley. *Berichte des Ohara Instituts für landwirtschaftliche Biologie, Okayama Universität*, ***10*****(4):** 245-308.

Takenaga, H., 1995. Nutrient absorption in relation to environmental factors. *MATSUO, T. et al. Science of the rice plant: physiology. Tokyo: Nosan Gyoson Bunka Kyokai*, 278-294.

Tanaka, K. 1995. Physiology of Ripening: The Science of the Rice Plant, **2**: 97-118. Food and Agriculture Policy Center. Tokyo.

Tayefe M., Gerayzade A., Ebrahim A. and Zade A.N. 2011. Effect of nitrogen fertilizer on nitrogen uptake, nitrogen use efficiency of rice. *International Conference on Biology, Environment and Chemistry,* ***24****: Singapoore.*

Tekalign Tadesse, 1991. Soil, plant, water, fertilizer, animal manure and compost analysis. Working document No.13. International Livestock Research Center for Africa (ILCA), Addis Ababa. Ethiopia.

Tisdale, S. L., W. L. Nelson, J. D. Beaton and J. L. Havlin, 1999. Soil Fertility and Fertilizers. Macmillan Publ. Co., New York. 456p.

Tsedalu J. and Alamirew, T., 2011. *Effects of Deficit Irrigation and Nitrogen Fertilizer Rates on Yield and Yield Components of Upland Rice in Woreta, North Western Amhara Region, Ethiopia*. An MSc Thesis presented to Graduate Studies of Haramaya University.

Van Hach, C. and Nam, N.T., 2006. Responses of some promising high-yielding rice varieties to nitrogen fertilizer. *Omonrice*, ***14*****:** 78-91.

Vetterlein, A., 2007. Economic growth, poverty reduction, and the role of social policies: The evolution of the World Bank's social development approach. *Global Governance: A Review of Multilateralism and International Organizations*, ***13*****(4):** 513-533.

Walkley, A. and I.A. Black, 1934. An examination of the degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci., **37**: 29-38.

Walworth, J., 2006. Soil sampling and analysis. The University of Arizona Cooperative, Extension, 1-5p.

Westcott, B., 1986. Some methods of analysing genotype-environment interaction. *Heredity*, ***56*****(2**): 243-253.

Ye, Q., Zhang, H., Wei, H., Zhang, Y., Wang, B., Xia, K., Huo, Z., Dai, Q. and Xu, K. 2007. Effects of nitrogen fertilizer on nitrogen use efficiency and yield of rice under different soil conditions. *Frontiers of Agriculture in China*, **(1):** 30-36.

Yesuf, E. and Balcha, A., 2014. Effect of Nitrogen Application on Grain Yield and Nitrogen Efficiency of Rice (Oryza sativa L.). *Asian Journal of Crop Science* ***6*****(3):** 273.

Yoseftabar, S., 2013. Effect Nitrogen Management on Panicle Structure and Yield in Rice (Oryza sativa L.). *International Journal of Agriculture and Crop Sciences* 5(11): 1224.

Yoshida, H., 1983. Necessary condition for the existence of algebraic first integrals. *Celestial mechanics*, ***31*****(4):** 381-399.

Yoshida, S. 1981 Fundamentals of Rice Crop Science. IRRI, Los Banos, Philippines, 268p.

Yoshida, S. and Parao, F.T., 1976. Climatic influence on yield and yield components of lowland rice in the tropics. *Climate and rice*, 471-494.

7. APPENDICES

Appendix Table 1: Mean squares for agronomic traits of upland rice

	Mean squares						
Parameters	**Rep (2)**	**Var (3)**	**Var*Rep (6)**	**NR(3)**	**Var*N (9)**	**Error (24)**	**CV (%)**
GYD	296111.08	4922149**	286906.08	18677865**	175484.7*	73411.5	3.27
SYD	156227.31	771429.91**	147051.03	4143208.20**	60857.34^{ns}	63215.9	5.16
BYD	547340.25	5095774.00**	241810.25	17660295.39**	317326.35**	36652.44	2.31
GHI	3.52	28.427**	2.60	105.45**	15.841**	1.786	3.27
FSP	13.94	451.534**	13.18	635.98**	25.200**	4.874	2.184
TSP	4.48	259.069**	27.61	1917.12**	33.613**	7.776	2.255
TN	73.00	636.667**	44.67	7938.67**	73.111**	15.083	1.660
PN	59.08	1316.750**	22.75	3776.31**	106.528**	11.389	1.692
UFSP	3.37	59.180**	2.95	147.22**	15.949**	2.374	8.537
TGW	0.80	32.695**	0.90	9.06**	0.285^{ns}	0.332	1.87
DTH	19.40	416.500**	10.98	106.72**	3.370^{ns}	2.417	1.69
DTM	0.06	171.354**	10.56	122.91**	0.447^{ns}	3.021	1.44
PHT	37.96	92.536**	9.91	142.02**	5.563^{ns}	5.169	2.79
PL	0.97	13.828**	2.69	35.65**	0.593^{ns}	0.809	4.79

Rep = replication; N = Nitrogen rate; GY = grain yield; SYD = straw yield; BYD =biological yield; HI = harvest index; TN = tiller number; PN = panicle number; TSP = total spikelets per panicle; FSP = filled spikelets per panicle; UFSP = unfilled spikelets per panicle; TGW = thousand grain weight; DTE = days to emergence; DTH (50%) = days to heading; DTM (85%) = days to maturity; PHT = plant height; PL = panicle length and ** highly significant at LSD (%) 0.05 probability level and CV (%) = coefficient of variation

Appendix Table 2: Mean squares for the N uptake and N use efficiency of rice

				Mean squares			
Parameters	**Rep (2)**	**Variety (3)**	**Var*Rep**	**N(3)**	**Var*N (9)**	**Error (24)**	**CV (%)**
GN	0.001	0.005**	0.001	0.014**	0.000ns	0.00	1.75
SN	0.001	0.012**	0.004	0.011**	0.002ns	0.00	6.25
GNU	14.98	385.642**	9.69	1141.606**	51.803**	2.074	3.38
SNU	3.29	80.055**	15.038	257.598**	4.954*	1.638	4.81
TNU	31.24	753.072**	46.402	2336.218**	31.255**	2.207	2.15
NHI	9.35	330.123**	8.031	2747.883**	66.241**	5.908	11.47
AEN	8.38	206.178**	15.675	8846.595**	85.623**	9.237	7.67
PEN	8.21	461.938**	6.395	8449.064**	86.243**	9.575	7.92
ANR	31.24	753.072**	46.402	2336.218**	31.255**	2.207	2.15

Rep = replication; N = Nitrogen rate; GN = grain N concentration; SN = straw N concentration; GNU = grain N uptake; SNU = straw N uptake; TNU = total N uptake; NHI = nitrogen harvest index; ANE = agronomic N efficiency; PNE = physiological N efficiency; ANR = apparent N recovery; UEN = utilization efficiency of N; *, **, ^{ns} = significant, highly significant and non-significant at LSD (%) 0.05 probability level and CV (%) = coefficient of variation

Appendix Table 3: Treatment Combinations

Treat.	**Main-plot factor**	**Sub-plot factor**	**Treat.**	**Main-plot factor**	**Sub-plot factor**
	Varieties	N rates		Varieties	N rates
1	NERICA-4	0	**9**	Kokit	0
2	NERICA-4	23	**10**	Kokit	23
3	NERICA-4	46	**11**	Kokit	46
4	NERICA-4	69	**12**	Kokit	69
5	Suparica-1	0	**13**	Kellafo-1	0
6	Suparica-1	23	**14**	Kellafo-1	23
7	Suparica-1	46	**15**	Kellafo-1	46
8	Suparica-1	69	**16**	Kellafo-1	69

Trt no = treatment number and N rates = nitrogen fertilizer rate (kg N ha^{-1}).

Appendix Table 4: Soil rating for laboratory results

$pH^{(T)}$ and ratings		**$CEC^{(R)}$ ($cmol\ kg^{-1}$)**	**Av. $P^{(R)}$ $Mg\ kg^{-1}$**	**OC $^{(T)}$ (%)**	**OM $^{(T)}$ (%)**	**Total $N^{(T)}$ (%)**	**Ratings**
< 4.5	Extremely acidic	> 40	> 25	-	-	-	Very high
4.5 - 5.2	Strongly acidic	25 - 40	18 - 25	> 3.0	> 5.17	> 0.25	high
5.3 - 5.9	Moderately acidic	12 - 25	10 -17	1.5 - 3.0	2.59 - 5.17	0.12 - 0.25	Medium
6.0 - 6.6	Slightly acidic	6 - 12	5 - 9	0.5 - 1.5	0.86 - 2.59	0.05 - 0.12	Low
6.7 - 7.3	Neutral	< 6.0	< 5	< 0.50	< 0.86	< 0.05	Very low
7.4 - 8.0	Moderately alkaline						
> 8.0	Strongly alkaline						

Source: Tekalign (1991) **(T)**, and Roy *et al*. (2006) **(R)**