RESPONSE OF UPLAND RICE (NERICA-4) TO RATES OF NITROGEN AND PHOSPHORUS FERTILIZERS IN ABOLWOREDA, GAMBELLA, SOUTH WEST ETHIOPIA.

MSc Thesis

By

Dorar Tuoch Chiey

May 2015

Jimma, Ethiopia

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MSc Thesis

Submitted to the School of Graduate Studies, College of Agriculture and Veterinary Medicine

In partial fulfillment of the requirements for the degree of Master of Science in Agriculture (Agronomy)

By

Dorar Tuoch Chiey

May 2015

Jimma, Ethiopia

Jimma University College of Agriculture and Veterinary Medicine

Thesis Submission Request Form (F-05)

Name of Student: Dorar Tuoch Chiey: ID N$^{\underline{o}}$ 06024/06.

Program of study: MSc in Agronomy

Title**: Response of Upland Rice (NERICA-4) to Rates of Nitrogen and Phosphorus Fertilizers in Abol Woreda, Gambella, South West Ethiopia.**

I have completed my thesis research work as per the approved proposal and it has been evaluated and accepted by my advisers. Hence, I hereby kindly request the Department to allow me to present the finding of my work and submit the thesis.

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DEDICATION

This thesis manuscript is dedicated to my father Tuoch Chiey and my mother Nyayang Gach who helped and encouraged me during my educational career but was not destined to see the fruits of my efforts.

STATEMENT OF THE AUTHOR

First, I declare that this thesis is a result of my genuine work and that I have duly acknowledged all sources of materials I referred to for writing it. I submit this thesis to Jimma University in partial fulfillment for the Degree of Master of Science in Agronomy. The thesis is deposited at the library of the University to be made available to borrowers for reference. I solemnly declare that I have not submitted this thesis to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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BIOGRAPHICAL SKETCH

The author, Dorar Tuoch Chiey, was born on 2 January 1983 in Akobo woreda, Nuer Zone of Gambella Regional State of Ethiopia. He attended elementary school (grade 1-8) at Gog Elementary School from 1994 - 2001. After completing elementary education, he was enrolled at Itang Secondary School in Itang town, where he pursued and completed his Secondary Education from 2002 – 2004 (grade 9-10). After completing his secondary school, he attended his Preparatory school from 2005-2007 (grade 11-12) in Gambella town. Then, he joined Mizan-Tepi University in February 2008 and graduated with Bachelor of Sciences degree in Horticulture in July 2010. After graduation, he was employed by Gambella Agricultural Research Institute (GARI) and assigns him as a Researcher. After serving the GARI for three years, he joined the School of Graduate Studies of Jimma University in September 2013 to pursue a study leading to Master of Science degree in Agronomy.

ACKNOWLEDGEMENT

I would like to express my deepest gratitude to my research major advisor, Dr. Amsalu Nebiyu and Co-Advisor Mr. Merkeb Getachew for their unreserved guidance, encouragement, and support throughout the study period, which made the completion of this study smooth and successful. The constructive criticisms and valuable suggestions they gave me during the planning of the research work and throughout the period of the fieldwork and write up of thesis were critical for my ultimate success.

I would like to extend my acknowledgement to Horticulture and Plant Science Department head for his valuable comments and help he made during this research work. I would also like to thanks Mr. Binyam, Diriba and Kher Deng for their help they made in different ways. Wish you the best.

My sincere gratitude goes to Dr. Shiferaw Nesgea for his kind and scholarly help he offered me during the planning stage of the research work up to the completion, thanks once again. It is my great pleasure also to express my wholehearted indebtedness to the Director General of the Gambella Agricultural Research Institute (GARI) Mr. Pal Tut Gach and the staff of the Institute, for their kind cooperation and supports they gave me during the field research work. It is also my pleasure to express my gratefulness to my family members, especially to my beloved wife Nyachuol Tut and my children, Chie Dorar and Hannah Dorar and all my brothers Bol Tuoch, Lul Chuol, Dobuol Duany, Gatluak Biel and Gatwech Tuoch whose words of encouragement, affection, and prayers served me as a source of strength, inspiration, and impetus throughout the study period.

Above all, I am grateful to the heavenly father, the almighty God, without whose guidance and encouragement this study would have been impossible.

LIST OF ABBREVIATIONS AND ACRONYMS

EARO	Ethiopian Agricultural Research Organization
FAO	Food and Agricultural Organization
GLM	General linear model
ha	Hacter
JICA	Japan International corporation agency
LSD	Least significant different
m.a.s.l	Meter above sea level
MOARD	Minister of Agriculture and Rural Development
NERICA	New Rice for Africa
OC	Organic carbon
P	Probability level
r	Symbol for correlation
RCBD	Randomized complete block design
RNA	Ribonucleic acid
SAA	Sasakawa African Association
SAS	Statistical Analysis system
TSP	Triple super phosphate
WARA	West African Rice Development Association

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RESPONSE OF UPLAND RICE (NERICA-4) TO RATES OF NITROGEN AND PHOSPHORUS FERTILIZERS IN ABOLWOREDA, GAMBELLA, SOUTH WEST ETHIOPIA.

By

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ABSTRACT

*Decline in soil fertility is a major constraint in Abol Woreda of Gambella region due to the continuous cropping, removal of crop residues after harvest, poor application of organic manures to soils, etc. The scientific information available concerning the response of upland NERICA-4 rice variety to rates of N and P fertilizers in Gambella for its optimum productivity is limited. Therefore, a field experiment was carried out during the 2014 cropping season at Abol woreda, Gambella, southwestern Ethiopia to investigate optimum rates of N and P fertilizers for highest yield of rice. The treatments consisted of factorial combinations of four rates of N (0, 46, 92, and 138 kg N ha-1) and P (0, 23, 46, and 69 kg P ha-1) was laid out in a randomized complete block design (RCBD) with three replications. The effects of Nitrogen were significantly ($P \leq 0.05$) difference for harvest index and significantly ($P \leq 0.01$) differences for 1000-grain weight, plant height, panicle length, grain yield, straw yield, number of filled spiklets and unfilled spiklets, productive tillers, number of tillers and Dry grain weight. On the other hand, many growth, yield, and yield components did not differ significantly ($P > 0.05$) due to application of P except number of unfilled spikelets, straw yield, and grain yield. Conversely, the interaction of N and P was significant ($P \leq 0.01$) for all yield and yield components except straw yield, harvest index and panicle length. Application of N and P significantly ($P \leq 0.01$) increased grain yield of rice up to the level of 92 kg N and 69 kg P ha^{-1}. Highest grain yield (6.053 t ha^{-1}) was obtained with the combined application of 92 kg N and 69 kg P ha $^{-1}$, and the yield advantage over the control was 113.66% (3.22 t ha^{-1}). The economic analysis revealed that 92 kg N ha^{-1} with all rates of P (0, 23 and 46 kg) gave highest net benefits. Grain yield was significantly and positively correlated with straw yield (r = 0.66**), productive tillers (r = 0.423**), plant height (r = 0.632**), grain weight (r = 0.54**), panicle length (r = 0.453**), number of spikelets per panicle(r = 0.441**) and Number of filled grain (r = 0.362**). This indicates that N and P increase grain yield of rice by positively affecting the important yield components. Therefore, as a recommendation, farmers in the study area can apply 92 kg N ha^{-1} with no phosphorus application to improve the grain yield of rain-fed NERICA-4 rice as well as for highest economic benefit.*

Keywords: Grain yield; Nitrogen; Phosphorus; Upland rice.

1. INTRODUCTION

Rice (*Oryza sativa L.*) is an important food crop of the world. Rice is staple food for nearly half of the world's population, most of who live in developing countries (Metwally *et al.*, 2011). It is the main livelihood of rural population in tropical and subtropical Asia, Latin America, and Africa (Abadi Birhane, 2013). Rice is an annual grass in the grass family, *Graminacea (Poaceae).* NERICA is a group of rice varieties resulting from the inter-specific crossing between the Asian rice (*Oryza sativa*) and the African rice (*Oryza glaberrima*) (Naturland, 2002; Christopher *et al.*, 2012).

The total world rice production has risen steadily from about 200 million tons (t) of paddy rice in the 1960 to over 678 million tons in 2009. In 2010/2011 and 2011/2012, the world paddy productions were estimated at 691.3 and 713.8 million tons, respectively. Globally, 158.9 million hectare (ha) of rice was harvest in the 2011/2012 (FAOSTAT, 2012). It accounts 27% of the world cereal production, second to wheat with 30%. Rice can produce grain yield as high as 10-18 t ha^{-1} in countries advanced in its cultivation (CSA, 2012).

Rice in Ethiopia is of more recent history than its utilization as a food crop. Some evidences indicate that cultivation of rice in Ethiopia was first start at the Fogera and Gambella plains in the early 1970s. Currently, the Fogera, Gambella, Metema, and Pawe plains located in the northern, northwestern, and western regions are developing in to major rice-producing areas in Ethiopia (Helluf and Mulugeta, (2006); Mulugeta, 1999, 2000). Owing to its recent introduction to the country, the research and development effort undertaken so far on rice in Ethiopia is of limited scale (CSA, 2012). However, its productivity, varied uses, existence of vast suitable conditions (swampy, waterlogged, rain fed and irrigable land) and possibilities of growing it where other food crops do not perform well make rice among the promising alternative crops available for cultivation in Ethiopia. As a result, rice is among the target commodities of the millennium development goal of the country so named "Millennium crop" as it expected to contribute greatly towards ensuring household as well as national food security in the country (Shiferaw *et al.*, 2012).

Nitrogen deficiency generally results in stunted growth and chlorotic leaves with poor assimilate formation that leads to premature flowering and shortening of the growth cycle. The presence of nitrogen in excess amount promotes development of the above ground organs with abundant dark green (high chlorophyll) tissues of soft consistency and relatively poor root growth (Mohammadian *et al.,* 2011). This increases the risk of lodging and reduces the plants resistance to harsh climatic condition and foliar diseases (Mohammadian *et al.,* 2011).

Phosphorus deficit is a most important restrictive factor in plant growth and recognition of mechanisms that increase plant phosphorus use efficiency is important (Alinajoati & Mirshekari, 2011). Phosphorus is a major component in ATP, the molecule that provides ”energy” to that plant for such processes as photosynthesis, protein synthesis, nutrient translocation, nutrient uptake and respiration (Yuan, 2002).. Phosphorus is also a component of other compounds necessary for protein synthesis and transfer of genetic material DNA, RNA (Khuang *et al*., 2008). Rice may benefit from application of mineral and organic fertilizers to compensate for exported nutrients. With the introduction of new and high yielding rice varieties, soil nutrient mining will increase when mineral fertilizer additions are absent or not in adequate amounts (Moro *et al*., 2008). Bajwa and Rehman (1998) have found that imbalanced ratio of NPK nutrients promoted excessive vegetative growth and led to reduced yield and productivity of the soil. Judicious and proper use of fertilizers can markedly increase the yield and improve the quality of rice (Alam *et al*., 2009).

Since fertilizer is an expensive and precious input, determination of an appropriate dosage of application that would be both economical and appropriate to enhance productivity and consequent profit of the grower under a given situation needs intensive study Panda *et al*. (1995). At present, the world is facing the problem of shortage of major fertilizer nutrients, especially nitrogen (Manzoor *et al*., (2006). The application of nitrogen and phosphorus fertilizers either in excess or sub optimum rate affects both yield and quality of rice to remarkable extent, hence, proper management of crop nutrition is of immense importance (Moro *et al*., 2008). Judicial use and management of nutrients improves and maintains soil fertility while sustaining an economically viable and environmentally friendly agriculture that will meet the requirements of the future (Moro *et al*., 2008). Fertilizer type, level and time of application are among the prioritized rice production input constraints set in Ethiopia (MoARD, 2010). At the Fogera plain, northwestern Ethiopia, the highest rice mean yield obtained due to the applications of 60/13.2 kg N/P ha^{-1}, representing an increase of 38.5% over the control (Heluf and Mulugeta, 2006). Rehman *et al*. (2006) have studied the response of rice to different combinations of fertilizers in a farmer's field and found a significant improvement in paddy rice yield (3.30-4.35 t ha^{-1}) during the two experimental years with the application of recommended doses of N and P fertilizers.

Daniel and Solomon (2008) in their soil nutrient variability study in the Barro River basin, Gambella have reported that the amount of total nitrogen (N) ranged from 0.06 to 0.31%. They have also found that the amount of available phosphorus (P) ranged from absolutely deficit to excess levels. Soil variability in the regions is also one factor that can initiate further research in different areas. Endris and Alemayehu (2014) have reported that grain yield increased from 302-469 g m^{-2} and highest grain yield (510 g m^{-2}) was obtained at 7 and 10.5 g m^{-2} N rate, respectively and they recommend further study in different location. Shiferaw *et al*. (2012) have also reported that in the light of the significant response of rice to N and P fertilizer in the area, further studies aimed at formulation of fertilizers rates for different location would be important as the recommendation drawn was specific to one location, which is Gambella area district. Decline in soil fertility is a major constraint in Abol Woreda of Gambella region due to the continuous cropping, removal of crop residues after harvest, poor application of organic manures to soils, etc. Besides, rainfed rice production in the area, experiences considerable losses of applied N and phosphorus due to leaching, volatilization denitrification, and soil erosion because of intermittent flooding and/or water logging and drying of soils. Furthermore, information on optimum rates of N and P fertilizers for profitable rice production on different locations in the region is scant. Therefore, this field experiment was conducted with the following objective;

- To investigate the effect of N and P fertilizer rates and their interactions on growth and yield of upland rice (NERICA-4) at Abol woreda Gambella.

2. LITERATURE REVIEW

2.1. Rice as crop plant

Rice (*Oryza sativa* L.) is a plant belonging to the family of grasses, Gramineae (Poaceae). It is one of the three major food crops of the world and forms the staple diet of about half of the world's population. The global production of rice has been estimated to be at the level of 650 million tones and the area under rice cultivation is estimated at 156 million hectares (FAOSTAT, 2012). Asia is the leader in rice production accounting for about 90% of the world's production. Over 75% of the world supply is consumed by people in Asian countries and thus rice is of immense importance to food security of Asia. The demand for rice is expect to increase further in view of expected increase in the population. India has a long history of rice cultivation. Globally, it stands first in rice area and second in rice production, after China. It contributes 21.5 percent of global rice production. Within the country, rice occupies one quarter of the total cropped area, contributes about 40 to 43 percent of total food grain production and continues to play a vital role in the national food and livelihood security system. India is one of the leading exporters of rice, particularly basmati rice. *O. sativa* has many ecotypes or cultivars adapted to various environmental conditions. It grows in all continents except Antarctica. In fact, there is hardly any crop plant that grows under as diverse agro-climatic condition as rice does (FAOSTAT, 2012).

The morphology, physiology, agronomy, genetics, and biochemistry of *O. sativa* have intensely studied over a long time. More than 40,000 varieties of rice had reported worldwide. Crop improvement research in case of rice had started more than a century back. Extensive adoption of higher yielding varieties has enabled many countries in Asia to achieve sustained self-sufficiency in food. In India, rice grown under four ecosystems: irrigated, rain-fed lowland, rain-fed upland and flood prone (Naturland, 2002).More than half of the rice area (55%) is rain fed and distribution wise 80% of the rain-fed rice areas are in eastern India, making its cultivation vulnerable to vagaries of monsoon. Rice is a nutritious cereal crop, used mainly for human consumption. It is the main source of energy and is an important source of protein providing substantial amounts of the recommended nutrient intake of zinc and niacin. However, rice is very low in calcium, iron, thiamine, and riboflavin and nearly devoid of beta-carotene. Rice protein is biologically the richest by virtue of its high true digestibility (88%) among cereal proteins and also provides minerals and fibre. Calories from rice are particularly important for the poor accounting for 50-80% of the daily caloric intake. Rice can also be use in cereals, snack foods, brewed beverages, flour, oil (rice bran oil), syrup, and religious ceremonies to name a few other uses. Rice is also believed to have medicinal properties and used in many countries for the same including in India. Rice is classifying primarily based on its grain size and shape. Uniform standard grain classification is used in India for grouping the varieties into 5 groups based on the length/length-breadth ratio of the kernel (Naturland, 2002).

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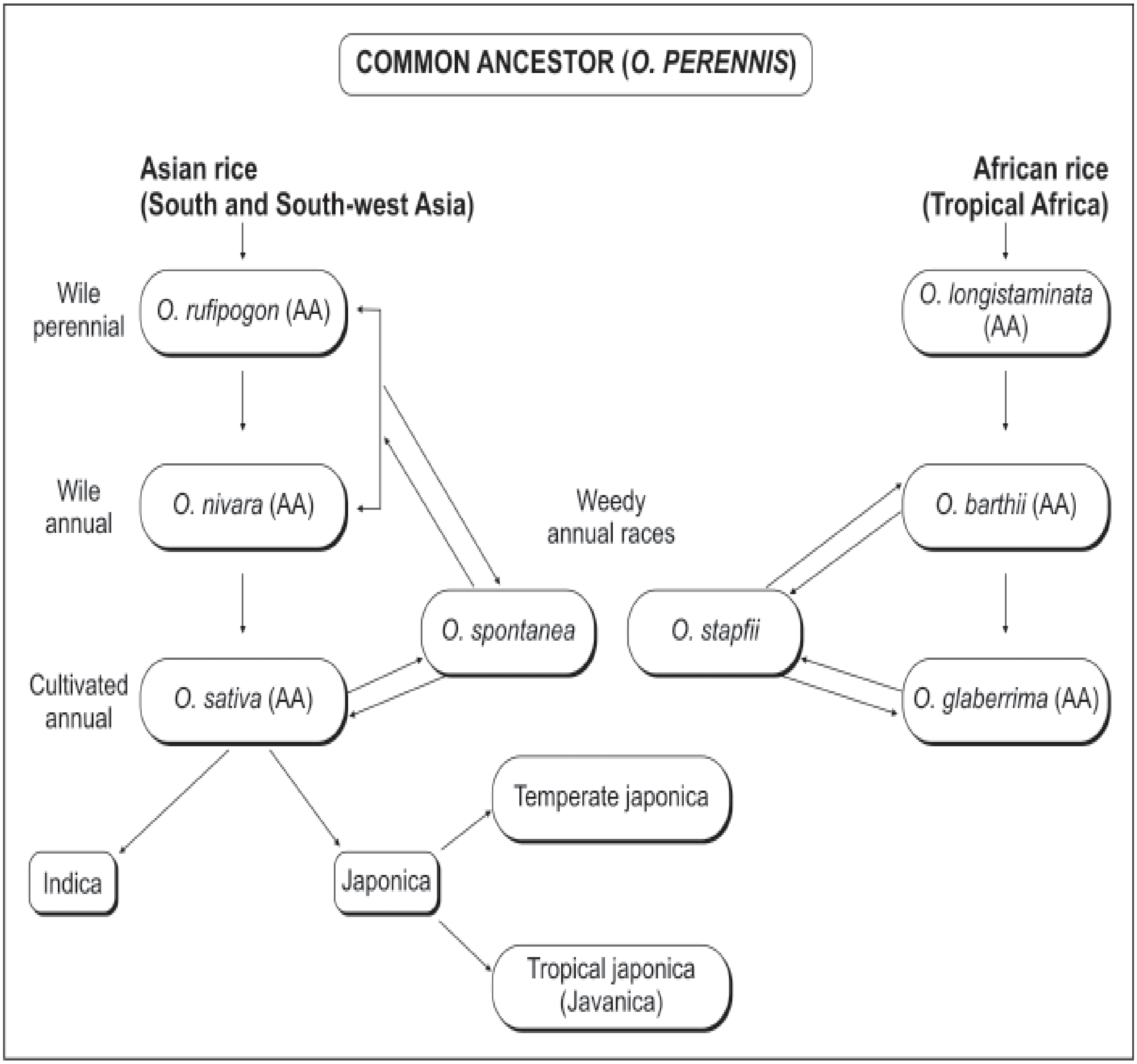
This classification has developed by the Ramaiah Committee in 1965, which appointed by Government of India. International Rice Research Institute (IRRI) has also developed similar international classification, Philippines which also take into consideration the grain length-width (breadth) ratio. As per Indian classification, rice varieties are grouped as Long Slender and Long Bold where the length is 6 mm and above and the length-breadth ratio is either 3 and above or less than 3 respectively. Likewise the varieties, which are classifying as Short Slender and Short Bold where the length is less than 6 mm and the length-breadth ratio is more than 3 or less than 2.5 respectively. A Medium Slender category has a grain length of less than 6 mm and the length-breadth ratio between 2.5 to 3. Amylose content varies from 2% to more than 25% and varieties with low (2-19%), intermediate (20- 25%) and high (>25%) amylase content are available in all grain types. However, only in case of japonicas, short bold or round grains in general have only low (<20%) and very low (2-8%) amylase content. Husk, bran and broken rice are the by-products of the rice milling industries. These by-products can be used in better and profitable manner both for industrial human and animal consumption. Rice husk constitutes the largest by-product of rice milling and one fifth of the paddy by weight consists of rice husk. Rice husk has a considerable fuel value for a variety of possible industrial uses. Hence, the major use of husk at the moment is as boiler fuel. Rice husk is also a rich source of silica. Rice bran is the most valuable by-product of the rice milling industry. It is obtain from the outer layers of the brown rice during milling. Rice bran consists of pericarp, aleurone layer, germ, and a part of endosperm. Rice bran can be utilized in various ways. It is a potential source of vegetable oil, feed, fertilizers etc. Rice bran oil is one of the healthiest oil for human consumption (Naturland, 2002).

2.2. Origin and diversity of rice (*Oryza sativa L)*

Archaeological and historical evidence points to the foothills of the Himalayas in the North and hills in the North-east of India to the mountain ranges of South-east Asia and South-west China as the primary centre of origin of *Oryza sativa*, and the delta of River Niger in Africa for that of O. glaberrima, the African rice *(*Randhawa *et al.,2006).* O. perennis is a common ancestor for both O. sativa and O. glaberrima. The wild progenitors of O. sativa are the Asian common wild rice (O. rufipogon) which shows wide variation ranging in their habit from perennial to annuals. O. sativa considered to have domesticated between 9000 and 7000 BC. The wild progenitor of the African cultivar O. glaberrima is O. longistaminata Chev.et Roehr endemic to West Africa. The primary centre of diversity for O. glaberrima is the swampy basin of Upper Niger (Randhawa *et al*., 2006). Oryza is a modest sized genus consisting of 20 well recognized wild species and two advanced cultigens, O. sativa which is grown worldwide and O. glaberrima grown in parts of West Africa (Yuan, 2002) but more species are reported by (Purseglove, 1972). Wild Oryza species are distributed throughout the tropics. They can be grouped into four complexes of closely related species among which two species, the tetraploid O. schlechteri Pilger and the diploid O. brachyantha Chev.et Roehr seem to be different from the others (OECD, 1999).Most of the species are diploid, having 12 pairs of chromosomes and seven species are tetraploids. Two species have both diploid and tetraploids sets of chromosomes. Complex consists of diploid and tetraploid species found throughout the tropics. All the species in these five complexes are perennial; some are rhizomatous and others form runners. They also differ in the habitats where they found. Some occur in full sun, others in partial shade. Variation exists within these species as shown by the responses of different populations to pests and diseases. The O. sativa complex consists of the wild and weedy relatives of the two rice cultigens as well as the cultigens themselves. The wild relatives of O. glaberrima in Africa consist of the perennial rhizomatous species O. longistaminata, which grows throughout Sub-Saharan Africa, and Madagascar, and the annual O. barthii A. Chev., which extends from West Africa to East and Southern Central Africa. The annual and weedy relatives of O. glaberrima are found primarily in West Africa (Purseglove, 1972).



Source: (OECD, 1999)

Figure 1: Schematic representation of the evolutionary pathways of Asian and African cultivated rice.

2.3. Rice Production Systems

2.3.1 Rice husbandry and suitable agro ecology

Rice was growing under such widely differing conditions that it is difficult to define the climate that is most suitable for its development. One of the main reasons for this wide range of climatic conditions is the great diversity of rice cultivars. Except for Antarctica, every continent on the planet produces rice. It was growing from the equator to latitude 530 N (in china) and 400 S and from sea level to 3,000 m in the Himalayas. The chief limiting factor to its growth is not climate but the water supply (Onwueme *et al*., 1991). Rice was growing on a variety of soils under varying climatic and hydrological conditions ranging from waterlogged and poorly drained to well-drained situations. Based on water regimes, rice can classified as irrigated and rain fed rice, the rain fed ecosystem may broadly categorized into upland and lowland ecologies. In the rain fed upland rice, there is no standing water in the field after few hours of cessation of rain. The lowland rice ecology depending on the water regimes may further categorized into three sub ecologies: - shallow lowland rice: water depth below 50 cm, semi-deepwater rice: - water depth between 50 to100 cm and deepwater rice: - water depth more than 100 cm in the field (Onwueme *et al*., 1991).

2.3.2 Overview of rice production in Ethiopia

Geographically, Ethiopia’s vast land area1.12 million square kilometers is defined by the Great Rift Valley system, which cuts the whole country diagonally from the Red Sea through to Kenya, creating mammoth depressions and mountain ranges. As a result, the country possesses unique and diverse geo-climatic zones. Agreeable weather conditions make the mid to high altitudes the predominant locations for human settlement and crop production. Consequently, population pressure and an archaic farming system at these altitudes have caused tremendous ecosystem degradation in the form of soil erosion and declining soil fertility. This situation, together with the Rift Valley’s typically erratic climate, means that prolonged cold and dry spells are challenging the country’s ability to achieve food self-sufficiency (producing enough food) and food security (ensuring that everyone has access to sufficient food) (Negusseie *et al*., 2008). Rice introduced to Ethiopia in the 1970s and has since been cultivated in small pockets of the country. It is a staple food in the country’s east, where rice is import through Somalia on the black market. Recent surges in demand, especially from city dwellers, are forcing the government to spend large am amounts of money on importing rice (WARDA, 2006).

The rice production system in the country has focused mainly on the introduction of improved varieties from a range of different sources, including the International Rice Research Institute (IRRI), the Africa Rice Center (WARDA), Guinea, and Madagascar. Federal and regional research centers are concentrating on the evaluation and release of new varieties for local producers. Three improved irrigated varieties from IRRI and four "New Rice for Africa" (NERICA) varieties from WARDA were released to farmers in 2005-07. In farmers' fields, the NERICA varieties grown in the rain fed uplands, where farmers do not have access to irrigation systems registered yields of 3–6 tons per hectare. The IRRI varieties, grown in lowland irrigated conditions, achieved 6–8 tons per hectare. The Sasakawa Africa Association (SAA) through its Sasakawa Global 2000 (SG2000) program has played a key role in promoting NERICA and other cultivated varieties to the country. In addition, the Japan International Cooperation Agency (JICA) and SAA have supported the introduction of essential postharvest (storing, milling, drying) technologies and processing machinery to rice-producing areas (WARDA, 2008).

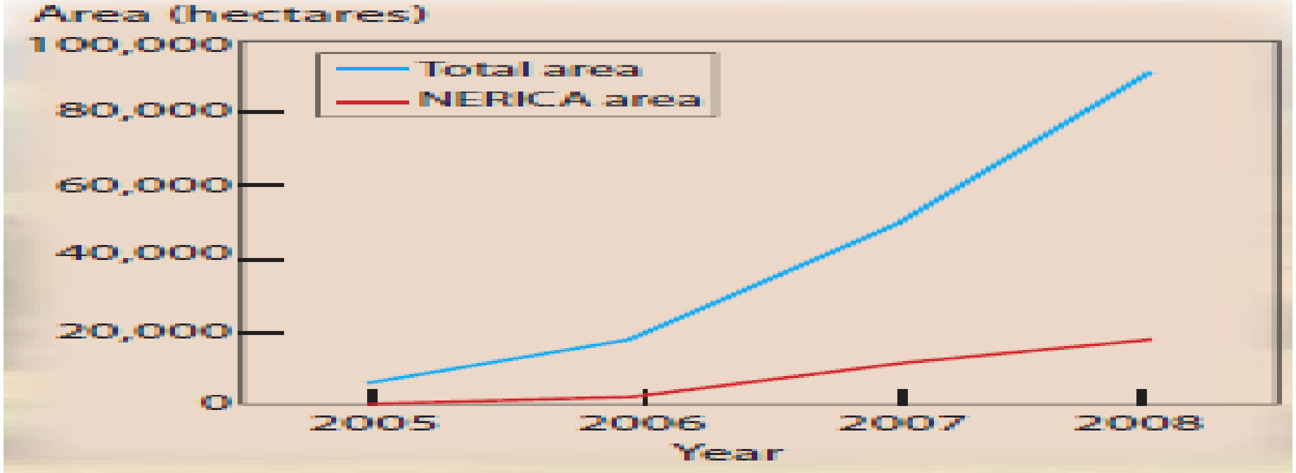
The recent surge in demand for rice combined with the skyrocketing import price challenged the country's policymakers to consider the country is potential to grow the grain for itself. Subsequently, successful lobbying has pushed rice to be classified as a fourth "National Food Security Crop" after wheat, maize, and the country's traditional staple cereal crop, tef. This move favors rice research and promotion on a larger scale. A national workshop was held on 21 August 2007 in the Ethiopian capital, Addis Ababa, where the National Rice Promotion Committee was formed, to facilitate the establishment of the National Rice Research and Development Steering Committee. Currently, 18 improved rice varieties (both NERICAs and *Oryza sativa*, conventional cultivated rice) were evaluate in different regions. Rice production is expects to cover about 90,000 hectares in 2008, up from 49,000 hectares in 2007. This figure is projects to reach 400,000 hectares by 2010, with NERICA varieties expected to dominate (Negusseie *et al*., 2008).

However, if rice is to contribute to the nation's food security, it must be grown on a larger scale in ecosystems not already devoted to traditional or cash crops preferred by local farmers. Fortunately, the country has more than 13 million hectares of waterlogged black-clay soil (known as Vertisol) in the mid and high altitudes. Resource poor subsistence farmers for whom growing rice presents good opportunities to supplement their current meager income occupy much of this land. The waterlogged nature of the soil and the characteristic cold climate of high altitudes are the major constraints to crop production in these areas. Nevertheless, rice grows well in waterlogged conditions and rice varieties exist that can grow at high altitudes in cold weather. Preliminary evaluation of a selection of local varieties revealed good vegetative growth but low night temperatures meant that most of the cultivars remained sterile or required a prolonged harvest time. Despite these early setbacks, the accessibility of many samples of cold-tolerant rice in IRRI's International Rice Gene bank and the large area of available fertile land mean that Ethiopia has great potential to become a major rice producing country (Negusseie *et al*., 2008).

2.3.3 Trends in NERICA rice Adoption

Rice production in the three sites increased at fast rates. In Guraferda, rice became one of the major cultivated crops. In terms of area cultivated in 2009, for example, rice covered 9,262 hectares as compared to 8,436 hectares under maize and 4,867 hectares for sorghum. Over the years, similar trends have been observed in selected areas of Fogera with rice progressively becoming the single most important crop, replacing tef, nug, and dagusa. While rice is not among the three major crops in Chewaka, there has been progressive adoption of NERICA with an increase in hectares under rice from 187 to 680 between 2007 and 2008 (MoARD, 2010).

Figure 2: RICE AREA trends in Ethiopia, 2005-08.



Source: Negusseie et al, 2008

2.4. Origin and Characteristics of NERICA varieties

NERICA originated from two species of cultivated rice; the African rice (*O. glaberrima* Steud) and Asian rice (*O. sativa*). NERICA also exhibit a very high yield potential of up to 6 tons per hectare under favorable conditions together with a protein content that is generally higher than most of the imported rice widely available in African local markets (WARDA, 2008). Initially, numerous conventional efforts were made to improve the performance of the Asian rice (*O. sativa*) for use in Africa farming systems but because the Asian rice lacks the resistance or tolerance to many African stresses, the limit were very limited in success. The best trails of the two cultivated varieties were used to produce progenies (Known as interspecifics), which are now referred to as NERICA. The Asian parent of NERICA is well known for its high yield potential, while, the African parent is highly recommended for its ability to thrive in harsh environment. Crossing both species was completely by incompatibility causing hybrid mortality hindering heterogenic recombination and progeny (F1) sterility (Second, 1984). Through back-crossings with the *O. sativa* parent coupled with another culture, this problem was overcome. The result was the first inter-specific rice progenies (Jones *et al*., 1997a, b, c). NERICA generally have a shorter duration than most of the traditional varieties and this attribute is in almost all cases the first cited by any NERICA adopter. Most of NERICA varieties are also known for their early vigor, which is a very important trait of a rice variety‘s ability to effectively compete with weeds, thereby improving the productivity of scarce labor. Furthermore, some NERICA varieties are tolerant to drought and soil acidity and exhibit good cooking and a good number of attributes that make them extremely desirable to the society characterizes consumption qualities that are acceptable to the local community Moreover, NERICA varieties.

2.5. Rain-fed upland Rice

The upland rain fed rice-based systems cover the largest area (44% of the total rice cultivated area), mainly in coastal areas in the humid and sub-humid agro-ecological zone (Defoer *et al*., 2002). Rice yields in upland systems average about one t ha^{-1}. Weed competition is the most important yield reducing factor (Johnson, 1997) followed by drought, blast, soil acidity and general soil infertility. Farmers traditionally manage these stresses through long periods of bush fallow. However, population growth has forced farmers to reduce the fallow periods and concentrate their farming activities towards the fragile upper parts of the upland slopes. The slash and burn method of land clearing has aggravated the weed pressure and a decline in soil fertility due erosion (Oldeman and Hakkeling, 1990). Farmers also face high risks of crop failure and generally lower productivity levels. In upland areas where the growing season is short, very early maturing varieties with tolerance to drought and blast like NERICA are those required. Traditionally, farmers use long-duration rice cultivars, which further undermine the fragility of the system and limit the cropping intensity. Thus, the resulting decline in productivity and income aggravate the incidence of poverty and environmental degradation (Cleaver, 1993; Cleaver and Schreiber, 1994).

2.6. Soil Fertility and Nitrogen Availability

Soil fertility is a complex quality of soils that is closest to plant nutrient management. It is the component of overall soil productivity that deals with its available nutrient status, and its ability to provide nutrients out of its own reserves and through external applications for crop production. It combines several soil properties (biological, chemical and physical), all of which affect directly or indirectly nutrient dynamics and availability. Soil fertility is manageable soil property and its management is of utmost importance for optimizing crop nutrition on both short-term and a long-term bases to achieve sustainable crop production (FAO, 2006).

Soil fertility decline considered as an important cause for low productivity of many soils. It has not received the same amount of research attention as soil erosion; possibly as soil fertility decline is less visible, less spectacular, and more difficult to assess. Assessing soil fertility status is difficult because most soil chemical properties either change very slowly or have large seasonal fluctuations; in both cases, it requires long-term research commitment. Growing agricultural crops implies that nutrients (N, P, K, etc.) removed from the soil through the agricultural produce (food, fiber, wood) and crop residues. Nutrient removal results in a decline of soil fertility when replenishment with inorganic or organic nutrient inputs is inadequate (Haftom *et al*., 2009).

The evidence is clear that the soils native ability to supply sufficient nutrients has decreased with the plant productivity levels and with increased human demand for food. One of the greatest challenges for our generation will be to develop and implement soil, water, and nutrient management technologies that enhance the quality of soil, water, and air. If we do not improve and/or sustain the productive capacity of our fragile soil, we cannot continue to support the food demand of our growing population (Tisdale *et al.*, 1995).

Systems of agriculture that rely heavily on soil reserve to meet the N requirements of plants cannot long be effective in producing high yields of crops (Stevenson, 1982). Except for legumes, which have the ability to fix their own N, N must supply to plants for growth. It is usually add as a fertilizer and is required for all types of soils (Alizadeh and Gadeai, 2006). Nitrogen is one of the most widely distributed elements required by plants but, paradoxically, it is the element that most often limits plant growth. This results from the relative inertness of elemental nitrogen in the atmosphere and of combined forms of nitrogen in minerals and organic matter. Since plants can use very little of these forms of nitrogen directly, they mostly depend on microorganism to fix elemental nitrogen or decompose organic nitrogen in to simpler forms. Although rocks and minerals contain larger amounts of nitrogen, the fraction that actively enters the nitrogen cycle is too small that it will not be consider (Alizadeh and Gadeai, 2006).

Most of the nitrogen in soils that is potentially available to plants is associated with organic matter. The accumulation of soil organic matter in natural ecosystem may require several thousand years to reach an equilibrium level. The level attained depends on such factors as climate, vegetation, topography, physical and chemical characteristics of the soil, and activity of micro flora and micro fauna. Since the system is very dynamic, any change in the environment may lead to a new equilibrium level of organic nitrogen. When the steady state conditions exist, the rate at which nitrogen is add to the soil equals the rate at which it is lost by such process as leaching and de-nitrification (Jeremy, 2007).

Type of vegetation is especially important in the accumulation, retention, and conservation of soil nitrogen. Other things being equal, organic matter and nitrogen content usually are higher in soils developed under grassland than in soils developed under forest type vegetation. Grass land soils contain a mass of fibrous roots that usually extend throughout the soil to a depth of several feet. These roots not only serve at absorptive organs for water and plant nutrients, but also contribute considerable debris to the soil in the form of excretions, sloughed-off root tissue, and dead root hairs that are continuous being produce during the regenerative process of root proliferation. This carbonaceous material utilized by wide variety of microorganisms that gradually transform part of the carbon and nitrogen in to stable forms of organic matter. In forest soils, however, plant debris added to the soil primarily as fallen leaves that accumulate on the surface. The organic layer that forms under these conditions remains at the surface and does not become distributed throughout the root zone. The main roots contribute little to the organic content of the soil, which remains light colored and contains relatively low amounts of nitrogen (Baldock *et al*., 2003).

2.7. Nitrogen Availability in Soils

The vast portion (about 98%) of the total N of the Earth is found in the lithosphere and 2% is in the atmosphere, with the portions in the hydrosphere and biosphere being insignificant relative to that in the lithosphere and atmosphere (Stevenson, 1982). Most of the N of the Earth, including the N in the rocks and in the atmosphere, is not available for plant nutrition. Plants obtain most of their N nutrition from the soil, which is a negligible component of the total N content of the world, and more than 90% of this N in most soils is in the form of OM, which is not available to crop plants (Stevenson, 1982).

Nitrate and exchangeable ammonium are important in plant nutrition. The other forms of N are generally not available for plant nutrition. Fixed ammonium, entrapped in clays, is a principal nitrogenous constituent of subsoil has and is resistant to removal from clay lattices and has little importance in plant nutrition. Exchangeable or dissolved ammonium is available to plants, but ammonium concentration in soils is low, usually in a magnitude of a few mg kg-1. According to (Brady and Weil, 2004) in well-aerated soils, ammonium is oxidize rapidly to nitrate by nitrification, so that nitrate is the major source of plant-available N in the soil. Most plants cannot tap into the large reserve of N in the atmosphere. Biological N fixation is the principal means of adding N to the soil from the atmosphere (Stevenson, 1982). More than 70% of the atmospheric N added or returned to soils is by biological fixation, and can exceed 100 kg of N ha-1 addition per year by N-fixing legumes. Most of this N enters into the organic fraction of the soils. Unless N-fixing legumes are growing, the addition of N to soils by biological fixation, averaging about 9.2 kg ha-1 annually, is too small to support crop production. The remainder is from atmospheric precipitation of NH4+, NO3-, NO2-, and organically bound N (terrestrial dust).

The plant available soil N fractions are vulnerable to different routes of losses; immobilization, denitrification, leaching, surface runoff and erosion, depending on the soil and climatic conditions (Bohn *et al.*, 2001). He or the same author also stated that soils have little capacity to retain oxidized forms of N, and NH4 accumulation in soils is small; consequently, most of the soil N is associated with OM. Release of N from OM is slow and unpredictable. If soil OM is depleted, as occurs in cultivated soils, N for plant growth is limited. Nitrogen is, therefore, usually the most deficient nutrient in cultivated soils of the world, and fertilization of these soils with N is required. To maintain or increase productivity of soils, worldwide consumption of N fertilizers continues to increase with time.

2.8. Role of Nitrogen in rice production

Rice contains more N than any other essential elements derived from the soil. Rice take up N from the time the roots begin to function until all uptake of nutrients ceases with maturity. Nitrogen is critically important to rice because of its presences in the structure of protein, the most important building substances from which the living material or protoplasm of every cell is made. In addition, N is also found in chlorophyll, which enables the plant to transfer energy from sunlight by photosynthesis.

Therefore, the N supply to the plant will influence the amount of protein, protoplasm and chlorophyll formed, which in turn influence cell size and leaf area, and photosynthetic activity (Mengel and Kirkby, 1996).Nitrogen is closely link to control the vegetative growth of plant and hence determine the fate of reproductive cycle. Mengel and Kirkby (1996) stated that N is an integral component of many essential plant compounds such as nucleic acids, amino acid, all protein, including enzymes, and chlorophyll. Therefore, a low supply of N has a profound influence on crop growth and may lead to a great loss in grain yield (Miller and Donahue, 1997). On the other hand, excess nitrogen supply causes higher photosynthetic activities, vigorous growth, weak stem, lodging, dark green color, reduced product quality; delayed 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).

Nitrogen is the most limiting nutrient for rice production in the world. Unlike nutrients such as P, K, and zinc (Zn), no suitable soil test method has been established and implemented for determining the N-supplying capacity for soils used to produce rice (Mengel and Kirkby, 1996). Instead, numerous N rate and application timing studies are conducting on experiment stations and farms to determine the optimum N rate by application timing for the various cultivars that are growing in the rice-producing country. In the United States, optimum N fertilizer use efficiency has been achieved by applying at least 50% of the total N immediately prior to permanent flood establishment, and the remaining N applied within the interval beginning with internodes movement to 10 days after internodes movement of 0.5 inch (Wilson *et al*., 1998). However, recent work in Arkansas has shown that some new cultivars produce yields that are comparable, and sometimes greater, when a single pre flood (PF) application is made as opposed to a two- or three-way split of the total applied N Rate and timing of N are critical in terms of their effect on yield. Nitrogen increases plant height, panicle number, leaf size, spikelets number, and number of filled spikelets, which largely determine the yield capacity of a rice plant. Panicle number is largely influenced by the number of tillers that develop during the vegetative stage *(DeDatta, 1986).* Spikelets number and number of filled spikelets are largely determined in the reproductive stage (DeDatta, 1986). Over fertilization, under fertilization, and improper fertilization timing have the potential to decrease rice yield.

Hence, it is important to determine the optimum rate and proper application timing of N fertilizers for individual rice cultivars. N fertility management is confounded by the widespread adoption of precision land leveling for irrigation purposes, the inability to establish and maintain a permanent flood within 5 to 7 days after fertilizer application, and high-pH soil conditions. Land forming in some areas requires the removal of the topsoil, which contains the highest percentage of organic matter. Less fertile subsoil is exposed and becomes the rooting media for the following rice crop. Thus, the organic fraction of the soil N-pool is often greatly decreased. The inability to establish and maintain a flood in a timely manner increases the likelihood of N losses through volatilization and de-nitrification once the flood is established. High-pH soil conditions increase volatility when urea (46-0-0) is used as the N-source *(*Tisdale *et al*., 1995). Each of these factors should be considered when creating an N budget. The source of N can increase N efficiency under certain situations. On newly precision-leveled fields, or on low-organic-matter soils, ammonium sulfate (21-0-0-24) may offer a yield benefit when compared with urea.

Numbers of grains per panicle were more (130.2) at a nitrogen level of 175 kg/ha which remained statistically at par with that obtained by nitrogen application levels between 125 to 225 kg per hectare. The lowest value of this parameter (121.1) was recorded in control treatment receiving no fertilizer (Manzoor *et al*., 2006). The more number of grains per panicle obtained in treatments receiving higher nitrogen rates were probably due to better nitrogen status of plant during panicle growth period. 1000 grain weight was highest (22.92 g) in treatment getting 175 kg/ha nitrogen level which was statistically similar with that produced by each of the nitrogen level of 150, 200 and 225 kg/ha. Zero kg/ha nitrogen (control) obtained minimum (19.13 g) grain weight. Increase in grain weight at higher nitrogen rates might be primarily due to increase in chlorophyll content of leaves which led to higher photosynthetic rate and ultimately plenty of photosynthetic available during grain development. The treatment where 175 kg nitrogen per hectare was applied produced a maximum (4.24 t/ha) of paddy (Manzoor *et al*., 2006).

2.9. Available phosphorus in soils

Phosphorus is among the most limiting nutrients for food production in the sub-humid and humid tropical highlands of East Africa. Next to N, P is the most limiting nutrient in most of clay loam, black clay etc and this holds true for Ethiopian soils and the problem in Ethiopia is further exacerbated by nutrient mining due to the prevailing low-input agriculture. Phosphorus is unique among the anions in that it has low mobility and availability, which is determined by soil pH and the consequent reactions of P with Al3+, Fe3+ and Ca3+. It is difficult to manage because it reacts so strongly with both solution and solid phases of the soil (Picolo and Huluka, 1985).

Studies show that the total P status of some representative major soil types in Ethiopia is low. Most of the Vertisols in the Ethiopian highlands, 70% of the cases, are reported low in available P content, below 5 ppm (Hubble, 1984; Berhanu, 1985). Phosphorus fractionation results show low levels of the available forms in the Ethiopian highland Vertisols. Phosphorus sorption studies indicated high sorption capacity of Vertisols and other soils in Ethiopia, which is mainly control by content of Fe and Al oxides (Tekalign and Haque, 1987). While P occurs in a multitude of inorganic and organic forms in the soil, the plant available forms of P are limited primarily to solution HPO_4-2 and H_2PO_4-, with the dominant forms determined by the soil pH (Tisdale *et al*., 1995).

2.10. Role of Phosphorus in rice production

Rice requires a considerable amount of phosphorus (P) for vigorous growth and high yield. Although in general response -to phosphorous in irrigated rice less marked than response to nitrogen, phosphorus is none the less a very important nutrient - one crop consumes approximately 15 kg of phosphorous for every ton of yield. Phosphorus is particularly important to the rice seedling du ring the time it is recovering from transplanting shock. Phosphorus greatly stimulates root development in the young plant, thus increasing its ability to absorb nutrients from the soil. When absorbed during the vegetative phase, phosphorus: - increases the number of root hairs, thus facilitating the uptake of other nutrients (enables the seedling to recover rapidly from transplanting shock) - stimulates extensive root growth, thus increasing the plant's resistance to drought - promotes tillering by facilitating nitrogen absorption - promotes early flowering and ripening (can be exploited to offset the effects of late planting) During the reproductive phase, the phosphorus intake of rice decreases considerably. When absorbed during the ripening phase, phosphorus: - increases the protein content of the grains thus improving the food value of the crop invigorates the germination power of the seed (as evidenced by an increase in the germination rate of the seed produced) (Tisdale *et al*., 1995). Phosphorus deficiency in rice can be recognized by: - small size of plants- short, underdeveloped root systems - low number of tillers - bluish green color of the leaves - purple color of the lower part of the culms (Note some traditional varieties have net rally purple culms) Hubble, 1984; Berhanu, 1985). Phosphorus is very important in the early vegetative growth stages. It is important to rice plants because it promotes tillering, root development, early flowering, and ripening. Rice plants that are deficient in P are stunted and dirty-dark green, and they have erect leaves, relatively few tillers, and decreased root mass. However, because rice is predominantly grown in rotation with soybean, the fertility management should consider both crops. A 50-bushel-per-acre soybean crop removes 40 pounds of P_2O_5 and 70 pounds of K_2O per acre with the harvested grain. Therefore, in a 1:1 rice/soybean rotation, approximately 85 pounds of P_2O_5 and 95 pounds of K_2O per acre are removed from the soil in a 2-year span. Depending on the soil type, the majority of these nutrients will be replenished by mineral weathering. However, to ensure that the current level of nutrients remains in the soil over an extended period of time, a maintenance application of P and K fertilizer equal to crop removal is recommended.

3. MATERIALS AND METHODS

3.1. Description of the study area

A field experiment was conducted under rain fed condition during the main rainy season (July to November of 2014) in order to investigate the response of upland NERICA-4 rice variety to N and P fertilizers in Abol Woreda, Gambella region. The study site is located in the region, around 797 Km away from the capital Addis Ababa, at $8^{0}21''$ latitude and $34^{0}39''$ longitude with elevation of 470 meters above sea level (m.a.s.l). The region is categorized in the sub-humid hot to warm agro ecological zone and is known for rice cultivation by the farmers. The experiment was conducted on clay soil with a pH of 6.5. Based on nine years (2006 to 2014) meteorological data, the average annual rainfall of the study area is 1245.8 mm with a monthly mean range of 46.4 mm to 114.7 mm and the average annual minimum and maximum temperatures are 20.1^{o}C and 35.7^{o}C, respectively. The study area is characterized by a uni-modal rainfall pattern, which starts in early April and extends to the end of November (National Meteorology Agency, Gambella Branch, 2014, unpublished report).

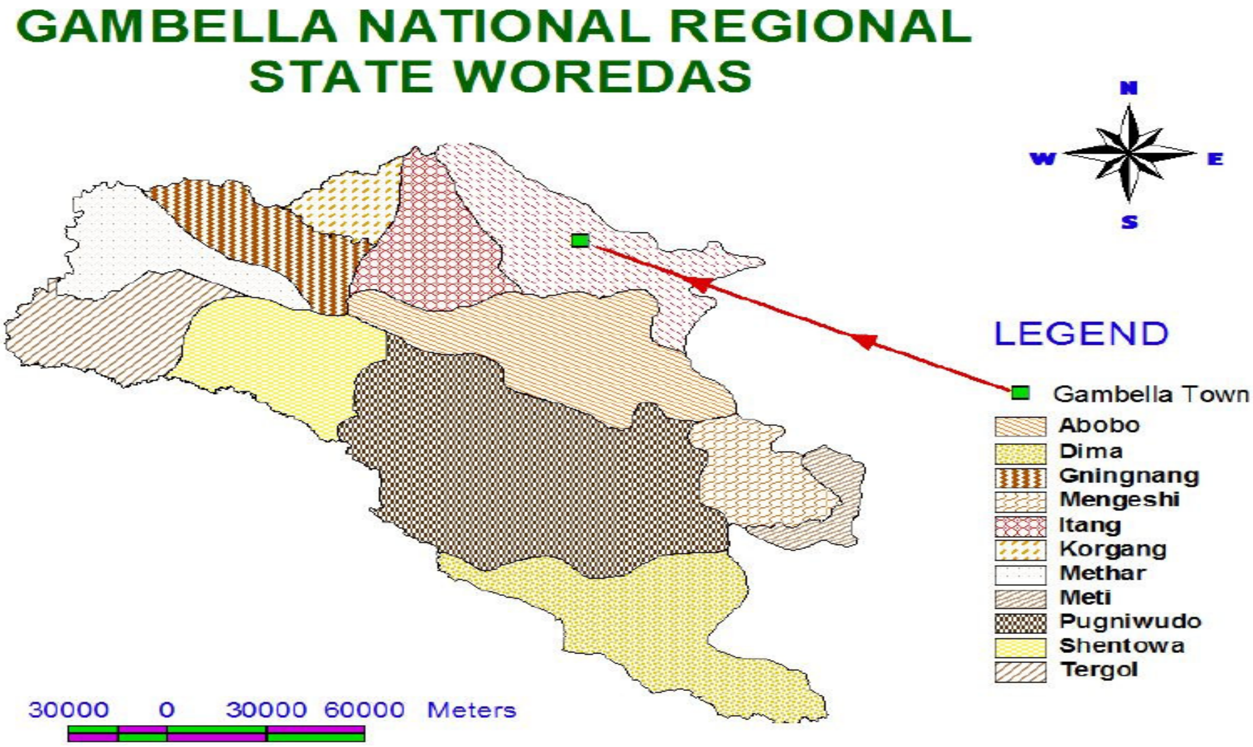


Figure 3: Map of Gambella Regional state showing the study area**.**

3.2. Experimental Materials, Treatments and Design

NERICA-4 rice variety, which was tested by Gambella Agricultural Research Institute (GARI), and adapted in the area, was used for the experiment. The fertilizer treatments considered in the study were consisted of factorial combination of four levels of N (0, 46, 92 and 138 kg N ha^{-1}) and four levels of P (0, 23, 46 and69 kg P ha $^{-1}$) consisting of 16 treatments laid down in a randomized complete block design (RCBD) with three replications. A 3 × 3m ($9m^2$) plot size was used as an experimental unit. There were 12 rows in each plot and 2 outer most rows were consider as borders. The second and third rows on both sides of the plots were used for destructive and non-destructive sampling respectively. A net plot size of 0.75m x 6 (4.5 m^2) was harvested when two-third of the length of panicle axis in 90% of the plant population attained yellow color. The blocks were separated by a two m wide-open space whereas the plots within a block were separated by a one m wide space. The plots were planted on July 2014 by hand drilling the seeds at a rate of 60 kg ha^{-1} in rows spaced 25 cm apart. Nitrogen applied in two equal splits as urea (46% N). The first half of the N rate was applying during planting, and the remaining half was top dressed at the maximum tillering stage, which occurred 32 days after emergence of the crop. The field was drain off before top dressing the second half of N, and Urea was hand drilled to the side of plant rows at 5-10 cm depth of the soil. Unlike N, the total dose of P was basal applied as triple super phosphate (TSP 20% P_2O_5) during sowing. Insecticide or fungicide was not applied because no serious insect or disease incidences occur. Harvesting manually done using hand sickles.

3.3. Soil Sampling and Analysis

A composite surface soil (0-30 cm) sample was collected with a gauge auger for analysis of physico-chemical properties of the soil of the experimental area before planting. Before plowing, the experimental field was blocked into three parts depending upon land uniformity. Plant residues on the soil surface were removed. These composite surface soil and core (undisturbed) samples per block were collected for analysis of selected physicochemical properties. The samples were analyzed for soil texture using hydrometer method (Jackson, 1967). Soil pH was determined in a 1:2.5 soil-water suspension using a combination of glass electrode. Organic carbon (OC) was estimate by the wet digestion method (Okalebo *et al.*, 2002) and organic matter (OM) was calculated by multiplying the percent organic carbon (OC) by a factor of 1.724. To determine the cation exchange capacity (CEC), the soil sample was first leached using 1 M ammonium acetate, washed with ethanol and the adsorbed ammonium replaced by sodium (Na). Then, the CEC was determining titrimetrically by distillation of ammonia that was displace by Na (Hesse, 1971). Total soil N was measure using the micro-Kjeldahl digestion, distillation, and titration procedure as described by AOAC (1994). After extraction of the soil sample by sodium bicarbonate solution as per the procedure outlined by Olsen *et al.* (1954), available P was determined by measuring its absorbance using spectrophotometer. The analysis result is in the table one below.

Table 1: Physico-chemical properties of the experimental soil (0-30 cm) before sowing in Abol woreda Gambella, 2014 crop season

Soil property	Value	Rating
Available P (mg kg-1)	65.00	Adequate
CEC (cmol kg-1)	35.60	High
Clay (%)	49.60	-
Organic matter (%)	7.03	Very high
pH 1:2.5 (H_2O)	6.5	Slightly acidic
Sand (%)	17.68	-
Silt (%)	33	-
Textural class	Clay	-
Total N (%)	0.50	Very high

3.4. Data Collections

Day to 50% flowering (DF): This parameter of the plant was determined by counting the number of days from sowing to the time when tip of panicles emerge on plants per plot.

Days to 90% physiological maturity (DPM): It was determined by counting the number of days from sowing to the time when 90% of rice change their color to yellow per plot.

Productive tillers (PT): The numbers of tillers were determined by counting the tillers from an area of 1mx1m by throwing a quadrate in to the middle portion of each plot at physiological maturity.

Number of tillers per plant (NTP): It was counted at physiological maturity of the rice plants in 1mx1m quadrate throwing in the middle harvestable plot.

Number of filled spikelets and unfilled spikelets (NFS and NUFS): This was determined by counting of spikelets filled with grain in a 1m*1m quadrate per plot.

Dry grain weight per panicle (DGW): was recorded in gram using 10 randomly selected plants per plot and weighed at 14% moisture content by using hygrometer.

Panicle length (PL): was measured from the neck node to the tip of panicle selecting 10 plants randomly just before physiological maturity.

Numbers of spikelets per panicle (NSP): was then obtained from the addition between the number of filled and the number of unfilled spiklets.

Plant height (PH): was determined by measuring the length of 10 plants randomly selected from the ground level to the tip of the panicle just before physiological maturity.

Thousand grain weights (TGW): was determined by counting and weighing 1000 seed samples randomly taken from each plot and drying to 14% moisture content.

Straw yield (SY): was determined as the difference between total above ground dry matter (straw plus grain) recorded after air-drying at harvest and the grain yield of the respective treatment.

Grain yield (GY): was measured by threshing the plants harvested from the middle rows of each plot to avoid border effects. The moisture content of the rice seeds was determined using a hygrometer at the time of measurement of the grain yield. Grain yield was then recorded at 14% seed moisture content.

Harvest index (HI): was calculated as the ratio of grain yield to grain plus straw yield of each plot and expressed as percentage.

3.5. Partial Budget Analysis

Partial budget analysis was conducted for economic analysis of nitrogen and phosphorus fertilizers application and was carried out using combined grain yield data. The potential response of rice towards the applied fertilizers was estimated, where price of fertilizers and other costs during planting determined the economic feasibility of fertilizer application. The price of N = Birr 10.5 per kg; P = Birr 12.5 per kg; Wage rate = Birr 20 per day; Retail price of grain = Birr 15,000 per ton; HTW = Harvesting, threshing and winnowing cost = Birr 1000 per ton; BMT= Bagging, material and transport cost = Birr 65 per ton. The partial economic analysis was compute using the procedure described by CIMMYT (1988). The following parameters were computed and used to estimate the cost and benefits of different treatment combinations. Gross average grain yield (kg ha^{-1}) (AvY) is an average yield of each treatment. Adjusted yield (kg ha^{-1}) (AjY) is the average yield adjusted downward by a 10% to reflect the difference between the experimental yield and yield of farmers. This is due to the assumption that under experimental condition there is optimum fertilizer application and use by plants, better crop management, and small plot size. Accordingly, AjY was calculated as AjY = AvY- (AvY*10%). Total cost is the cost of fertilizer used for the experiment. The price was estimated based on the situation during planting. The costs of other inputs and production practices, such as labor cost for land preparation, planting, weeding, crop protection, and harvesting were assumed to remain the same or the difference among treatments was insignificant. Gross benefit is calculated as adjusted yield times the unit price while net benefit is calculated as Gross benefit minus total cost.

3.5. Data Analysis

After having test of homogeneity of variances for each trait, all the data were subject to analysis of variance using statistical software package (SAS version 9.2). Means of significant treatment effects were compare using the Least Significant Difference (LSD) test at 5% and 1% probability levels (Gomez and Gomez, 1984). Genstat software was use to separate the interaction means for significant differences among the NXP treatments. Pearson correlation analysis was carried out using the same software to investigate associations among grain yield, and yield traits of rice crop.

4. RESULTS AND DISCUSION

4.1. Effect of nitrogen and phosphorus on yield and yield components

Analysis of variance revealed that there was a significant difference ($P \leq 0.01$) in yield and yield components of rice due to the treatments. However, the application of P was significant ($P \leq 0.01$) only for number of filled and unfilled spikelets, grain yield and straw yield. The mean N×P interactions were non-significant only for panicle length, straw yield and harvest index at both $P \leq 0.01$ and 0.05. The others parameters were significantly affected by the application of both N and P (Appendix Table 1).

Nitrogen is a major element determining crop yield. Analysis of variance showed that the effect of nitrogen fertilizer was significant ($P \leq 0.01$) for plant height, days to 50% flowering, number of tillers, dry grain weight, panicle length, number of spikelets, number of filled and unfilled spikelets, 1000 grain weigh, grain yield and straw yield and significant ($P \leq 0.05$) for harvest index and days to 90% physiological maturity (Appendix Table1). These results show that nitrogen is the most important factor that can limit yield and yield components if it is not obtained in sufficient amount. It has been reported that increase in fertilizer input, especially N fertilizer has significantly contributed to improvement of crop yield (Dastan *et al*., 2012). Maximum number of plant height, panicle length and number of tillers (113.85cm, 23.25cm, and 90.07, respectively) where recorded for 92 kg ha^{-1} and 138Kg ha^{-1} nitrogen (Table 2, 3 and 4). Irshad *et al.* (2000) showed that plant height and number of tillers per hill were significantly increased by nitrogen application. Optimum dose of nitrogen fertilization plays a vital role in growth and development of rice plant. Its growth seriously hampered when lower dose of nitrogen is applied, which drastically reduces yield (Alam (b) *et al*., 2009). Analysis of variance showed that the effect of phosphorus fertilizer was significant ($P \leq 0.05$) for grain yield, straw yield and number of unfilled spiklets and highly significant ($P \leq 0.01$) for number of filled grains. This result indicated that phosphorus was important to increase grain yield of rice from 2.83t/ha with 0kg/ha P to 3.9t/ha with 23kg/ha of P (Table 10). In agreement with this, it has been reported that Phosphorus is important for plant growth, promotes root development, tillering and early flowering, and performs other function like metabolic activities, particularly in synthesis of protein (Panhwar *et al.*, 2011).

4.1.1. Days to 50% flowering

The analysis of variance shows that there was a significant difference ($P \leq 0.01$) between N treatments and their interaction with P fertilizer for days to flowering (Appendix Table 1). Among the N and P treatment combinations, the maximum number of 50% days to flowering of rice (58.33) was attained at 0 kg N and 0 kg P ha^{-1} (Table 2). In contrast, the minimum number of days to 50% flowering was recorded for 138 kg N either 23 kg or 69 kg of Phosphorus favored early flowering of rice (Table 2). This result is in line with the finding of Sewnet (2005) who has reported early flowering with an increase in the rate of N application in rice. Shiferaw *et al.* (2012) have also reported that nitrogen and phosphorus effect was result in to promotion of rice days to panicle initiations. This fact indicated that when N applied before the onset of stem elongation and at first node stage, the total N uptake would be greater (Mossedaq and Smith, 1994). Accordingly, accelerated root (efficient uptake of nutrients and water) and vegetative growth might be a factor for resisting drought that delayed flowering and crop maturity (Hague *et al.*, 2006).

4.1.2. Plant height

Plant height responded highly significantly to the levels of N, and to the interaction of nitrogen and phosphorus levels (Appendix Table 1). Assefa *et al.* (2009) found significant effect on rice plant height by application of N and P. Without nitrogen application, phosphorus significantly increased plant height from 88.8 cm to 102.2 cm for 0 and 23 kg P ha $^{-1}$ respectively but no significant difference between control, 46 and 69 Kg P ha^{-1} (Table 2). Therefore, further increase of phosphorus levels resulted in decline of plant height. In contrast, without P application, N consistently increased plant height from 0-138 kg N^{-1} and there is significant difference between the control and the other treatments. Among the N and P treatment combinations, the maximum plant height of rice (122.2 cm) was attained at 138 kg N and 0 kg P ha $^{-1}$ (Table 2). In contrast, the shortest plant height (88.8 cm) was recorded for plots that received no nitrogen and phosphorus, which is also statistically the same with 0kg N in combination with 46 and 92 kg P ha $^{-1}$ (Table 2). This indicates that application of N fertilizer increased the growth of rice crop more than did P fertilizer. Shiferaw *et al*. (2012) reported that increase in plant height in response to N application was probably due to enhanced enlargement of leaf area that, in turn, enhanced photo assimilates and thereby resulted in more dry matter accumulation. Meena *et al*. (2003) have also reported similar results. According to Manzoor *et al.* (2006), the increase in plant height with increased N application might be primarily due to enhanced vegetative growth with more nitrogen supply to plant.

Table 2: Interaction effect of N and P fertilizers on plant height and days to 50% flowering of Nerica-4 rice variety in Abol woreda, Gambella 2014 crop season

Level 0f P(Kg/ha)	Level of N (Kg/ha)				
	Day to 50% flowering				
	0	**46**	**92**	**138**	Means
0	58.33*a*	54.67*b*	54.00*b*	54.67*b*	**55.42**
23	57.00 *a*	57.33*a*	54.67*b*	54.00*b*	**55.75**
46	58.33*a*	55.00*b*	54.00*b*	54.33*b*	**55.42**
69	57.67*a*	54.67b	54.00 *b*	54.00*b*	**55.09**
Means	**57.83**	**55.42**	**54.17**	**54.25**	
LSD (5%)	**1.427**				
CV%	**1.5**				
	Plant height				
0	88.8 *j*	100.6*ghi*	111.8*bcde*	122.2*a*	**105.85**
23	102.2*fgh*	100.3*ghi*	113.3*bcd*	116.7*ab*	**108.12**
46	92.8 *ij*	101.1*fgh*	108.8*cdef*	114.6*abcd*	**104.33**
69	94.9*hij*	107.5*defg*	115.5*abc*	104.4*efg*	**105.58**
Means	**94.68**	**107.38**	**112.35**	**114.48**	
LSD (5%)	**7.823**				
CV%	**4.4**				

Means within a rows and column followed by the same letter(s) for a parameter are non-significantly Different at P = 0.05.

4.1.3. Days to 90% physiological maturity

Days to 90% physiological maturity was significantly (P < 0.05) affected only by the main effect of nitrogen fertilizer while the main effect of phosphorus and its interaction with nitrogen did not affect this parameter (Appendix Table 1). Several research reports are available demonstrating significant effect of fertilizer N on days to physiological maturity (Zewdie, 2004). In fact, this phenological stage was reported to be promoted by N application (Zewdie, 2004. Application of nitrogen fertilizer in rice crop is found to be important for promotion of rapid growth through increasing height, tiller number, size of leaves and the length of roots according to the previous reports.

Table 3: Effect of Nitrogen fertilizer rates on days to 90% physiological maturity of upland Nerica-4 rice in Abol woreda, Gambella, 2014 crop season.

Level of N (kg/ha)	PM
0	125.58^{a}
46	125.75^{a}
92	126.67^{a}
138	125.0^{a}
LSD (0.05)	1.12
CV (%)	1.07

Means within a column followed by the same letter(s) are not significantly Difference at P = 0.05.

4.1.4. Panicle length

Panicle length was highly significantly ($P \leq 0.01$) influenced by the main effect of nitrogen fertilizer, but not by the main effect of phosphorus application as well as by the interaction of the two factors (Appendix Table 1). Increasing the rate of nitrogen further from zero to 138 kg N ha^{-1} markedly increased panicle length of the plants for about 12.6%. As a result, the maximum length of panicles (23.25 cm) was recorded from 138 kg N ha^{-1} and the minimum length (20.65 cm) was observed from control (no nitrogen applied) (Table 4). The difference between the control and 46 kg N ha^{-1} was non-significant, but it was significantly increased for 92 and 138 kg N ha^{-1} rice panicle length (Table 4). The result indicates that nitrogen is the most important factor that can increase panicle length. Panicle length is one of the yield attributes of rice that contribute to grain yield. Crops with higher panicle length could have higher grain yield. Since one of the most important functions of N is promotion of rapid growth, application of N fertilizer increased panicle length of rice crop more than P fertilizer did. The increment in panicle length due to application of low levels of N observed in the present study was in agreement with (Manzoor *et al*.,2006) who noted increases in panicle length of rice with increasing N fertilizer rates.

Table 4: Effect of Nitrogen fertilizer rates on panicle length (PL) of upland Nerica-4 rice in Abol woreda, Gambella 2014 crop season

Level of N (kg/ha)	PL(cm)
0	20.65^{b}
46	20.77^{b}
92	22.60^{a}
138	23.25^{a}
LSD(0.05)	**1.23**
CV (%)	**6.768**

Means followed by the same letter(s) with in a column are non-significantly Different at P = 0.05.

4.1.5. Total Number of tillers per plant

Tiller is an important trait for grain production. Analysis of variance showed total number of tillers was significantly ($P \leq 0.01$) affected by the main effect of nitrogen (Appendix Table 1). The interaction of N and P was also significant ($P \leq 0.05$). It was observed that nitrogen and phosphorus interaction resulted in higher numbers of tillers (81.33), which was obtained from 138kg N ha^{-1} and 46 kg P ha^{-1}. The lowest number of tillers was record from 0kg of phosphorus and 46 kg of nitrogen per hacter. This may be because there was deficiency of nitrogen, which is required for tiller production (Table 5). Enhanced tillering by increased nitrogen application might attribute to nitrogen supply at active tillering stage. The result was in agreement with the finding of (Zhu Defang *et al.*, (2002) who reported that the number of tillers increase exponentially with the number of phylochrons due to nitrogen application. This result was also in agreement with the findings of Yoseftabar (2013) who reported that application of nitrogen and phosphorus fertilizers showed increases in number of tillers, productive tillers and grain yield.

Table 5: Interaction effect of N and P fertilizers on number of tillers per plant of Nerica-4 rice variety in Abol woreda, Gambella 2014 crop season

Level 0f P(Kg/ha)	Level of N (Kg/ha)				
	0	**46**	**92**	**138**	**Means**
0	81.00*a*	72.33*e*	77.00*abcde*	79.00*abcd*	**77.33**
23	72.33*e*	74.00*cde*	79.67*abc*	77.67 *abcde*	**75.91**
46	75.00*bcde*	76.67*abcde*	79.67*abc*	81.33 *a*	**78.17**
69	73.67*de*	81.33*a*	79.67*abc*	80.33 *ab*	**78.75**
Means	**75.5**	**76.08**	**79.002**	**79.58**	
LSD (5%)	**5.841**				
CV%	**4.5**				

Means and column followed by the same letter(s) within a rows are non- significantly difference at P = 0.05.

4.1.6. Number of productive tillers

The analysis of variance showed that the effect of nitrogen and the interaction between N and P was highly significant ($P \leq 0.01$) for number of productive tillers (Appendix Table 1). The maximum number of tillers was recorded for 92 kg N and 23 kg of P (77.67) and the minimum value was obtained at control (0kg P) and 46kg of N/ha (Table 6). This result indicated that the enhancement of effective tiller development of plants that received nitrogen and phosphorus at higher rates supply in the soil might have synchronized for high uptake of applied N and P through the roots. Enhanced tillering by increased N and P application might attribute to more N supply to plant at active tillering stage. The current result is in agreement with that of Genene (2003) who reported higher tillering and maximum survival percentage of tillers with increasing N and P application. Corroborating the results of this study, Shiferaw *et al*. (2012) reported that stimulation of tillering with high application of nitrogen might be due to its positive effect on cytokines synthesis. Alam *et al*. (2009) have also reported 29% increase in effective tillers with the application of 72 kg P ha-1 over the control. The present finding supports the results of Jensen (2006); Madan and Munjal (2009) who have suggested that seed rate governs the number of tillers per panicle and all forms of N and P fertilizers interaction can perform equally well if applied appropriately.

Table 6: Interaction effect of N and P fertilizers on productive tillers per m^2 of rice in Abol woreda, Gambella 2014 crop season

Level of P (Kg/ha)	Level of N (Kg/ha)				
	0	**46**	**92**	**138**	**Means**
0	74.33*abc*	63.00 *e*	71.67*bcd*	75.67*abc*	**71.17**
23	66.67*de*	63.00*e*	77.67 *a*	76.67*ab*	**71.003**
46	68.00*de*	67.00 *de*	71.67*bcd*	73.67 *abc*	**70.085**
69	66.67*de*	77.33 *a*	76.67*ab*	71.00 *cd*	**72.918**
Means	**68.92**	**67.58**	**74.42**	**74.25**	
LSD (5%)	**5.207**				
CV%	**4.4**				

Means followed by the same letter(s) within a rows and column are non-significantly difference at p=0.05.

4.1.7. Number of spikelets per panicle

Analysis of variance showed that interaction effect of nitrogen and phosphorus was significant ($P \leq 0.01$) for number of spikelets per panicle (Appendix Table 1). The main effect of nitrogen fertilization also significantly increased ($P \leq 0.01$) number of spikelets per panicle when it was applied up to 138 kg ha^{-1} (Table 7), mainly due to an increase in panicle length. Similarly, number of spikelet increased from 105.3 to 126.3 m^{-2} with increasing P level from 0kg to 92 kg P ha^{-1}. However, the level of N increased number of spikelet from 105.3 to 162.9 for 0 kg N ha^{-1} and 138 kg N ha^{-1} respectively. The maximum numbers of spikelets (167.4 m^{-2}) recorded for 138 kg N ha^{-1} and 46 kg P ha^{-1}. In contrast, the lowest 105.3 m^{-2} obtained for both control plots. This result indicated that N and P fertilization increases the number of spikelets of rice crop by increasing number of panicles per m^{-2} and panicle length (Endris and Alamayehu, 2014). In contrast, Irshad *et al*. (2000) have reported that nitrogen application did not influence the number of spikelets per panicle of rice plants, which may be due to the genetic makeup of the species. On the other hand, it has been reported that application of P increases total number of spikelets per panicle in rice thereby contributing to increment in grain yield (Gebrekidan and Seyoum, 2006). Yoseftabar (2013) has also reported that application of P up to 26 kg of P/ha increase the number of spikelets per panicle. According to (Heluf and Mulugeta, 2006) application of more than 100 kg ha^{-1} of N reduced the number of spikelets's per panicle, which may be caused by an increase in competition for metabolic supply among tillers, thereby, decreasing the production of spikelets, or possibly due to vigorous vegetative growth and, hence, heavy drain off soluble carbohydrate, resulting in its reduced availability for spikelet formation. The present study however indicated that increasing the level of N resulted in higher number of total spikelets per panicle. Number of spikelets is one of the important yield-forming attribute of rice (Gebrekidan and Seyoum, 2006).

Table 7: Interaction effect of rates N and P fertilizers on number of tillers per m^2 of Nerica-4 rice in Abol woreda, Gambella, 2014 crop season

Level of P (Kg/ha)	Level of Nitrogen (Kg/ha)				
	0	**46**	**92**	**138**	**Means**
0	105.3 *g*	154.6*bc*	144.4*d*	162.9 *ab*	**141.8**
23	124.7 *ef*	120.5*ef*	120.5*ef*	164.4 *a*	**132.53**
46	123.0*ef*	115.1 *f*	144.5*d*	167.4 *a*	**137.5**
69	126.3*e*	117.0*ef*	149.7*cd*	162.0 *ab*	**138.75**
Means	**119.75**	**126.68**	**139.78**	**164.18**	
LSD (5%)	**9.800**				
CV%	**4.2**				

Means followed by the same letter(s) within a rows and column are non- significantly difference at P = 0.05.

4.1.8. Number of filled spikelets per panicle

The result of the analysis of variance revealed that there was a significant difference ($P \leq 0.01$) in number of filled spikelets per panicle for nitrogen and the interaction between N and P. The main effect of phosphorus was also significant ($P \leq 0.05$), (Appendix Table 1). Number of filed spikelet per panicle is a most importance yield components, which affects rice yield. The maximum number of filled grains was recorded for 138 kg N ha^{-1} and 23 kg of P ha^{-1} or 46 N and 0 P ha^{-1} (151.5), while the minimum value (105.1) was obtained from the control (no N and P) plots. Compared with the number of filled spikelets obtained from the control treatment of nitrogen, the increase due to application of 138 N kg ha^{-1} N was 43.76% (Tables 8). Thus, these results further revealed that N fertilization has more contribution than P does to the reduction of unfertility of grains in rice. The above result indicated that the enhancement of number of filled grains of plants that received higher rates of nitrogen and phosphorus might be attributed to and their availability. In agreement with this result, Fallah (2012) has reported that nitrogen promotes rapid growth and increases spikelet number per each panicle and percentage of filled spikelets per panicle. In contrast, it has been reported that increasing the levels of N and P fertilizers favored vigorous growth of the rice crop, which resulted in competition for metabolic supply among spikelets, thereby, affecting the production of fertile grains. Yoseftabar (2013) also reported similar results in that with increasing levels of soil fertility, the number of filled grain per panicle decreased with corresponding increase in unfilled spikelets.

4.1.9. Number of unfilled spikelets per panicle

Analysis of variance showed that interaction effect of nitrogen and phosphorus was significant ($P \leq 0.01$) for number of unfilled spiklets per panicle (Appendix Table 1). The minimum number of unfilled spikelets per panicle (13.20) was obtained from 0 kg N ha^{-1} and 0 kg P ha^{-1} and the maximum value (34.20) was obtained from 138 kg N ha^{-1} and 0 kg P ha^{-1} (Table 8). The increase of sterility from control (zero N and Zero P) to 138 kg N was 159.09% (Table 7). Alam (a) *et al. (*2009a) found that it is necessary to know the optimum dose of phosphorus fertilizer for maximum yield and to reduce spikelets sterility of rice. It has also been reported that with increasing levels of soil fertility, the number of filled spikelets per panicle decreased with corresponding increase in unfilled spikelets (Alam *et al.*, 2009a). On the other hand, reduction in the number of filled spikelets per panicle has contributed more to the negative yield response of rice under higher levels of N and P fertilizers. This study is in line with that of Heluf and Mulugeta (2006) who concluded that where the yield response to fertilizer application is negative, yield reduction is primarily cause by a reduction in the proportion of filled grains per panicle.

Table 8: Interaction effect of rates of N and P fertilizers on number of filled and unfilled spikelets per panicle of Nerica-4 rice variety in Abol woreda Gambella 2014 crop season

Level of P (Kg/ha)	Level of N (Kg/ha)				
	Number of filled spikelets per panicle				
	0	**46**	**92**	**138**	**Means**
0	105.1 *g*	151.5 *a*	137.7 *c*	148.3*ab*	**135.65**
23	122.0 *de*	109.7*fg*	140.4*c*	151.5*a*	**130.9**
46	122.4*d*	107.6 *g*	126.7*d*	141.4 *bc*	**124.53**
69	139.3*c*	114.9*ef*	135.9*c*	110.0*fg*	**125.03**
Means	**122.2**	**120.93**	**135.18**	**137.8**	
LSD (5%)	7.099				
CV%	3.3				
	Number of unfilled spikelets per panicle				
0	13.20 *b*	13.47 *b*	14.33 *b*	34.20 *a*	**18.8**
23	16.73 *b*	14.07 *b*	15.40 *b*	17.60 *b*	**15.95**
46	16.27 *b*	12.53 *b*	18.73 *b*	33.33 *a*	**20.22**
69	17.00 *b*	17.33 *b*	17.20 *b*	28.60 *a*	**20.033**
Means	**15.8**	**14.35**	**16.42**	**28.433**	
LSD (5%)	6.771				
CV%	21.7				

Means followed by the same letter(s) within a rows and column are non- significantly Different at P = 0.05.

4.1.10. Dry grain weight per panicle

The effects of nitrogen ($P \leq 0.01$) and interaction of nitrogen and phosphorus ($P \leq 0.05$) on mean of grain weight per panicle were significant, while the effect of phosphorus was non-significant (Appendix Table 1). Applied N levels exhibited significant positive effect up to 46 kg P ha^{-1} with the exceptions of 92 and 138 kg N ha^{-1} which significantly increased the grain weight (g) per panicle to 69 kg P ha^{-1} (Table 9). The highest mean of dry grain weight per panicle (4.09 g) was obtained with the applications 138 kg N ha^{-1} and 23 kg P ha^{-1}, representing an increase of 60.47% over the control treatment followed by 4.06g with the applications of 138 kg N and 69 kg P ha^{-1} (Table 9). Without P application, the grain weight increased from 2.533g to 4.067 g when the level of applied N increased from zero (control) to 138 kg N, while it increased from 2.533 g to 3.267g when the level of applied P increased from zero to 69 kg P ha^{-1} under no N (Table 9). This study was in line with the findings of Chaturvedi (2005), who found significantly highest grain weight per panicle with nitrogen application. The significantly higher panicle length and number of tillers due to nitrogen application might have resulted in a significant increase in grain weight per panicle. These results are in line with the work of (Manzoor *et al*.,(2006) who reported that increase in grain weight at higher nitrogen rates might be primarily due to increase in chlorophyll content of leaves, which led to higher photosynthetic rate and ultimately plenty of photosynthates available during grain filling. Shiferaw *et al*. (2012) have stated that grain weight increases due to the application of nitrogen up to 138 kg N ha^{-1}. Manzoor *et al*. (2006) have reported that more number of grains or grain weight per panicle was obtained from treatments receiving higher nitrogen rates, probably due to better nitrogen status of plant during panicle growth period. Similarly, Kamara *et al*. (2011) have also reported that N application had a significant effect on number of grains per panicle of rice.

Table 9: Interaction effect of rates of N and P fertilizers on dry grain weight (g) per panicle of Nerica-4 rice variety in Abol woreda, Gambella, 2014 crop season

Level of P (kg/ha)	**Level of N(kg/ha)**				
	0	46	92	138	**Means**
0	2.533 *f*	4.067*ab*	3.667 *bcd*	3.867*ab*	**3.534**
23	3.137 *def*	3.033d*ef*	3.600 *bcd*	4.400*a*	**3.543**
46	2.800*ef*	2.867 *ef*	4.067*ab*	4.033*ab*	**3.442**
69	3.267*cde*	2.767 *ef*	4.000*ab*	4.067 *ab*	**3.53**
Means	**2.934**	**3.184**	**3.834**	**4.092**	
LSD (5%)	**0.6799**				
CV%	**11.6**				

Means followed by the same letter(s) within a rows and column are non- significantly Different at P = 0.05.

4.1.11. Grains yield

The analysis of variance (Appendix Table 1) showed highly significant ($P \le 0.01$) difference in rice grain yield due to the main effect of N and the interaction of N and P. Phosphorus effect also showed significant difference ($P \le 0.05$). The highest mean grain yield (6.053 t ha $^{-1}$) was obtained with the applications of 92 kg N and 69 kg P ha^{-1}, representing an increase of 113.66% (3.22 t ha^{-1}) over the control treatment, followed by 5.96 t ha^{-1} with the applications of 92 kg N and 0 kg P ha^{-1} (Table 10). These findings were in agreement with the results obtained from mineral fertilizer studies by Heluf and Mulugeta, (2006). At the highest level of N, grain yields decrease. The decline in grain yield at the highest N rate relative to the linear increase in straw yield with the increase in N supply could be because of low sink strength to translocate extra assimilates from source or due to increased vegetative growth competing for assimilates available for grain formation and grain filling (Endris and Alemayehu, 2014).

Without P application, the grain yield increased from 2.833 to 5.96 t ha^{-1} when the level of applied N increased from zero (control) to 92 kg, while it increased from 2.833 t ha $^{-1}$ to 3.92 t ha^{-1} when the level of applied P increased from zero to 23 kg ha^{-1} with no N (Table 9). As compared to N, application of P increased rice grain yield through its effects on major yield attributes such as number of spikelets per panicle. Phosphorus is important for plant growth, promotes root development, tillering and early flowering, and performs other functions like metabolic activities, particularly in synthesis of protein (Panhwar *et al*., 2011). It has been reported that nitrogen application significantly increased grain yield over the control and that the highest grain yield recorded from 90 kg.ha^{-1} nitrogen fertilizer (Irshad *et al.,* 2000); (Azarpour *et al*., 2011). Shiferaw *et al*. (2012) have also reported similar response of rice yield and yield components to increasing rates of P and N fertilizers. Increase in the magnitude of yield attributes is associated with better root growth and increased uptake of nutrients favoring better growth and yield of the crop (Manzoor *et al*. 2006).

In line with this study, Singh *et al.* (2000) found that the response of rice to N averaged over P levels was curvilinear with significant response up to 80 kg ha^{-1}. Manzoor *et al.* (2006) have also noted higher paddy yield with 150 and 250 kg N ha^{-1}, respectively. Meena *et al.* (2003) also reported similar results with higher N rates. Further, Heluf and Mulugeta (2006) have found significant increase in grain yield of rice up to 60 kg N ha^{-1} and an increase in the number of spikelets per panicle may be an attribute of increase in grain yield. Fageria and Baligar, (2001) have reported that the grain yield of rice is a function of panicle length or number per unit area and 1000 grain weight. Yield increase (70-80%) of field rice could be obtained by application of nitrogen (Alam *et al*., 2009a). Earlier studies also reveal that judicious and proper use of fertilizers can markedly increase the grain yield and improve the quality of rice (Chaturvedi, 2005). Christopher *et al.* (2012) have reported that mean rice yield increased with increments in N and P rates.

Table 10: Interaction effect of *N* and *P* fertilizers on grains yield (t/ha) of rice in Abol woreda, Gambella, 2014 crop season

Level of P (kg/ha)	**Level of N (kg/ha)**				
	0	**46**	**92**	**138**	**Means**
0	2.833*g*	4.683*cde*	5.960 *a*	5.137 *abc*	**4.653**
23	3.920*ef*	3.523 *fg*	5.913 *ab*	5.797*ab*	**4.788**
46	3.600 *fg*	4.077*def*	5.943*ab*	3.593 *fg*	**4.303**
69	3.420 *fg*	5.373 *abc*	6.053 *a*	5.007 *bcd*	**4.963**
Means	**3.443**	**4.414**	**5.967**	**4.884**	
LSD (5%)	0.9459				
CV%	12.1				

Means followed by the same letter(s) within rows and column are not significantly Different at P = 0.05.

4.1.12. Thousand grain weight

Thousand grain weight of rice responded significantly to the main effects of nitrogen and P as well as their interaction ($P \leq 0.01$), (Appendix Table 1). Maximum 1000 grain weight (36g) was obtained with 0 kg/ha nitrogen and 69 kg/ha of phosphorus followed by (29g) from 92 kg of N and 0 kg of P/ha. The minimum 1000 grain weight (26.33g) was recorded for 46 kg N ha^{-1} and 23 kg P ha^{-1} and 92 kg N and 46 kg P/ha (Table 11). Similar results have also been noted by Manzoor *et al*., (2006) and Yoseftabar, (2013). Christopher *et al*. (2012) also reported that low to moderate P rates (30-60 kg ha^{-1}) enhanced 1000-grain weight of rice by 12% to 16% over zero P rate.On the other hand Heluf and Mulugeta (2006) reported that reduction in 1000 grain weight with increasing applied levels of N and P is probably the result of insufficient supply of carbohydrates to individual spikelets due to competition effect resulted from vigorous rice growth and the increased number of its spikelets. Increase in 1000 grain weight at higher nitrogen and phosphorus rates might be primarily due to the increase in chlorophyll content of leaves which led to higher photosynthetic rate and ultimately plenty of assimilates available during grain development. In addition, P is generally most available to plants when the soil pH is between 6.0 and 6.5. Singh *et al*. (2000) reported inconsistent 1000-grain weight response to applied P during the earlier stages of growth, however there was a consistent increase in yield later on. Similarly, George *et al.* (2001) reported that the application of P had only little effect on thousand grains weight in spite of increased P uptake by the plant. Thousand Grain weight is a genetically controlled trait, which is greatly influenced by environment during the process of grain filling, but it also appeared that the application of N increased the protein percentage, which in turn increased the grain weight (Shiferaw *et al*., 2012).

Table 11: Interaction effect of *N* and *P* fertilizers on thousand grain weights (gm) of rice in Abol woreda, Gambella, 2014 crop season

Level of P	Level of N (Kg/ha)				
(Kg/ha)	**0**	**46**	**92**	**138**	**Means**
0	28.00 *b*	27.33*b*	29.33 *b*	26.67 *b*	**27.833**
23	28.00 *b*	26.33 *b*	28.67 *b*	28.33 *b*	**27.833**
46	28.67*b*	28.67 *b*	26.33 *b*	27.33 *b*	**27.75**
69	36.00*a*	28.33 *b*	27.33 *b*	26.67 *b*	**29.583**
Means	**30.168**	**27.67**	**27.92**	**27.25**	
LSD (5%)	3.326				
CV%	7.1				

Means followed by the same letter(s) within a rows and column are not significantly Different at P = 0.05.

4.1.13. Straw Yield

The analysis of variance in the Appendix Table 1 shows that nitrogen has significant difference ($P \leq 0.01$) but the interaction effect of N and P is non-significant for straw yield. The data in Table 12 indicates that increasing the levels of N significantly increased straw yield of rice. The highest straw yield (13.16 t ha^{-1}) was recorded for 138 kg N ha^{-1}, while the lowest value (6.29 t ha^{-1}) was obtained from the control (No N) plot (Table 12). This implies that increasing levels of nitrogen may increase the straw yield of rice, with means values 6.29, 8.74, 12.58, and 13.16 t ha^{-1} obtained from 0, 46, 92, and 138 kg N ha^{-1} respectively. The highest straw yield was statistically similar with 12.58t ha^{-1} which was obtained from application of 92 kg ha^{-1} but significantly different from 0 and 46 kg N ha^{-1}. The increase in straw yield due to application of increasing rates of N fertilizer is apparently attribute to its effect in enhancing vigorous vegetative growth of the rice plant. Shiferaw *et al*. (2012) have reported that better straw yield could be explain as higher capability of rice to utilize more N through the expression of better growth by accumulating more dry matter. Manzoor *et al*. (2006) have indicated that among N application times used on fine rice, three equal splits showed maximum straw yield. Azarpour *et al*. (2011) reported that the highest straw yield was record for 90 kg ha^{-1} nitrogen fertilizer. Straw yield was significant ($P \leq 0.05$) for the effect of phosphorus. Increasing the levels of P from 0 to 23 kg ha^{-1}also increased rice straw yield up to 11.27 t ha^{-1}, but further increase of phosphorus level decreased straw yield (Table 12). Moreover, the response of rice straw yield above 23 kg P ha^{-1} was possibly affected by the adequate to higher amount of inherent Olsen extractable available P (68 mg l^{-1}) of the experimental field soils. Shiferaw *et al*. (2012) and Zia *et al.* (1992) have reported that the availability of both native and applied P increase in soils under flooded rice production. Similarly, Yoseftabar (2013) has stated that due to the increase in the availability of P, yield responses to P fertilization are not significant in upland crops and increased straw yield of aerobic rice was due to appropriate application of P and better growth in the absence of weeds and better water use efficiency.

Table 12: Effect of N and P fertilizers on the straw yield (SY) of upland rice (NERICA 4) variety in Abol woreda, Gambella, 2014 crop season

Level of P (kg/ha)	**SY(t/ha)**	Level of N (kg/ha)	**SY(t/ha)**
0	9.95^{ab}	**0**	6.29c
23	11.27^{a}	**46**	8.74b
46	8.71^{b}	**92**	12.58^{a}
69	10.83^{a}	**138**	13.16a
LSD(0.05)	1.88		
CV%	22.1		

Means followed by the same letter(s) within a column are not significantly Different at P = 0.05; SY = Straw yield (kg ha $^{-1}$).

4.1.14. Harvest index (%)

Harvest index was computed as the ratio of grain yield to the straw yield. Analysis of variance showed that it was significantly ($P \leq 0.05$) affected by N rates (Appendix Table 1). Phosphorus and interaction of N and P resulted in non-significant effect on the harvest index of rice crop. The results of application of nitrogen rates were 36.30, 34.73, 32.34, and 27.43% for 0, 46, 92 and 138 kg N ha^{-1} respectively. The highest (36.30%) harvest index was record for the control (no N) and the lowest (27.43%) obtained for 138 kg N ha^{-1}. As indicated in Table 13, harvest index consistently declined with increasing levels of N, through the difference between 0, 46 and 92 kg ha^{-1} was not significant. Generally, increasing the levels of N fertilizer from 0 to 138 kg ha^{-1} decreased the harvest index of rice from 36.30 to 27.43% (Table 13). Harvest index is an important physiological and agricultural factor indicating productivity of total plant (Vahed *et al*, 2012). Results from similar studies by Helluf and Mulugeta, (2006) have also revealed decreasing trends of harvest index with increased rates of applied N fertilizer. They also stated that harvest index in rice is closely related to the percentage of productive tillers which generally decreases with increase of N fertilizer. The application of 30 to 60 kg N ha^{-1} was found to increase harvest index by 4% to 6% over no N applied treatment (Christopher *et al*., 2012).

Table 13: Effect of N fertilizer on the harvest index (HI) of upland rice (NERICA 4) variety in Abol woreda, Gambella, 2014 crop season

Level of N (kg/ha)	**HI (%)**
0	36.30^{a}
46	34.73^{ab}
92	32.34^{a}
138	27.43^{b}
LSD	**3.58**
CV%	**13.20**

Means followed by the same letter(s) within a column are not significantly Different at P = 0.05; HI=Harvest index (%)

4.3. Correlation analysis

Correlation analysis between yield and yield components is presents in Table 15 below. The correlation analyses revealed that there was a significant ($P < 0.01$) positive correlation between grain yield and many yield related traits of rice. Grain yield was significantly and positively correlated with straw yield (r = 0.66**), productive tillers (r = 0.423**), plant height (r = 0.632**), dry grain weight (r = 0.54**), Panicle length (r = 0.453**), number of spikelets per panicle (r = 0.441**) and Number of filled spiklets (r = 0.362**) (Table 14). However, grain yield have negative relationship with days to 50% flowering (r = -0.681**) and non-significant with number of unfilled grains (-0.015 ns), thousand grain weight (r = -0.11 ns) and harvest index (r = -0.015ns) (Table 14). Different studies have also indicated positive associations of grain yield with yield related traits (Heluf and Mulugeta, 2006; Jaglan *et al*., 1997). Straw yield were also found to be significantly ($P < 0.01$) and positively associated with spikelets number per panicles (r = 0.614**), Panicle length (r = 0.41**), dry grain weight (r = 0.623**), number of unfilled grain (r = 0.373**), plant height (r = 0.70**), productive tillers (r = 0.31*), but had negative relation with days to 50% flowering (- 0.692**) (Table 14). However, there was no significant correlation between straw yield and number of tillers, number of filled spikelets and thousand grain weights. The study further revealed that panicle length was correlated positively and significantly with number of filled spikelets (*r* = 0.431**), number of spikelets (*r* = 0.681**), number of unfiled spikelets (r = 0.322**), dry grain weight (*r* = 0.622**), straw yield (*r* = 0.41**), plant height (*r* = 0.509**) and grain yield (*r* = 0.453**) of rice (Table 14). In accordance to the findings reported by Behera (1998), Heluf and Mulugeta (2006), panicle length has contributed to increment of rice grain yield indirectly by increasing the number of panicles and number of spikelets per panicle. In this present study, number of filled spikelets per panicle was positively associated with plant height, day to 50% flowering, and dry grain weight, and panicle length, number of spikelets per panicle and grain yield.

Table 14: Pearson's correlation coefficient (r) between yield and yield attributes of rice at Abol woreda , Gambella, 2014 crop season

Parameters	PH	DF	NTP	PT	DGW	PL	NSP	FS	UFS	TGW	GY	SY	HI
PH(cm)	1												
DF	-0.695**	1											
NTP	0.301*	-0.422**	1										
PT	0.509**	-0.382**	0.705**	1									
DGW(g)	0.609**	-0.592**	0.079ns	0.147ns	1								
PL(cm)	0.509**	-0.461**	0.221ns	0.251ns	0.622**	1							
NSP	0.667**	-0.636**	0.171ns	0.256ns	0.864**	0.681**	1						
FS	0.487**	-0.303*	-0.06ns	0.204ns	0.60**	0.431**	0.657**	1					
UFS	0.507**	-0.345**	0.302*	0.255ns	0.332**	0.322*	0.590**	0.189ns	1				
TGW(g)	-0.240ns	0.107ns	-0.15ns	-0.046ns	-0.125ns	-0.036ns	-0.209ns	0.115ns	-0.23ns	1			
GY(t/ha)	0.632**	-0.681**	0.209ns	0.424**	0.540**	0.453**	0.441**	0.362**	-0.015ns	-0.11ns	1		
SY(t/ha)	0.701**	-0.691**	0.223ns	0.319*	0.623**	0.410**	0.614**	0.194ns	0.373**	-0.259ns	0.66**	1	
HI	-0.534**	0.426**	-0.181ns	-0.141ns	-0.519**	-0.281*	-0.55**	-0.091ns	-0.522**	0.332**	-0.144ns	-0.78**	1

** = Significant at P = 0.05; ** = Significant at P = 0.01; DF=Day to flowering; NTP=Number of tillers panicle-1; PT= Productive tillers; DGW= dry Grain weigh; PL = Panicle length (cm); NSP = Number of spikelets's per plant; FS=Filled spikelets; UFS= Unfilled Spikelets; TGW = Thousand grains weight (g); GY =Grain yield (t ha −1); SY = Straw yield (t ha −1); HI = Harvest index*

4.4. Partial budget analysis of N and P Fertilizer Rates

The result of the partial budget analysis and the data used in the development of the partial budget were in Tables 15 below. As indicated in Table 15, net benefit obtained in response to application of 92 kg N ha^{-1} with 0, 23 and 46 kg P ha^{-1} were 73,126.6, 72224.1, and 72,324.7 Ethiopian Birr, respectively. Bekele (2000) has reported that the highest return is due to the use of inputs that result in maximum net benefits. Besides, findings from coastal Kenya on maize also showed that the application of 30 kg N ha^{-1} consistently gave acceptable economic returns (Saha *et al*., 1994). According to the manual of CIMMYT (1988) for economic analysis, the recommendation is necessarily base on the treatment with the highest net benefit, and not the treatment with the highest yield. Therefore, the treatments with 0, 23, and 46 kg P ha^{-1} with 92 Kg N ha^{-1} gives an economic yield response and sustained acceptable even under a projected worsening trade conditions in Abol woreda. On tentative basis, farmers could thus choose the first choice which is 92 kg N ha^{-1} because it is cost benefited fertilizer rates return.

Table 15: Partial budget analysis to estimate net benefit (Ethiopian Birr, ETB) for application of N and P fertilizer rates at current prices in Abol Woreda, Gambella, 2014 crop season

N	**P**	**Average grain yield(t ha^{-1})**	**Adjusted yield (t ha^{-1})**	**Total cost Varied (ETB ha^{-1})**	**Gross field benefit (ETB ha^{-1})**	**Net benefit (ETB ha^{-1})**
0	**0**	2.833	2.55	3,017.15	38,250	**35,232.9**
	23	3.920	3.528	4,482.3	52,920	**48,437.7**
	46	3.60	3.24	4,429	48,600	**44,171**
	69	3.420	3.078	12,467.3	46,170	**33,702.7**
46	**0**	4.683	4.215	5,582.4	63,225	**57,642.6**
	23	3.523	3.171	4,654.5	47,565	**42,910.5**
	46	4.077	3.669	5,532.00	55,035	**49,503**
	69	5.373	4.836	15,142.3	72,540	**57,397.7**
92	**0**	5.960	5.364	7,333.4	80,460	**73,126.6**
	23	5.913	5.321	7,590.9	79,815	**72,224.1**
	46	5.943	5.349	7,910.3	80,235	**72,324.7**
	69	6.053	5.447	16,257.5	81,705	**65,447.5**
138	**0**	5.137	4.624	6,919.9	69,360	**62,440.1**
	23	5.797	5.218	7,930.3	78,270	**70,339.7**
	46	3.593	3.234	5,870.6	48,510	**42,639.4**
	69	5.007	4.506	15,606.5	67,590	**51,983.5**

GFB = Gross field benefit; TCV = Total cost that varied; NB = Net benefit; Field price of N = Birr 10.5 per kg; Field price of P = Birr 12.5 per kg; EtB = Ethiopian Birr; Wage rate = Birr 20 per day; Labor to apply fertilizer per ha = 1 and 2 man-day; L Retail price of grain = Birr 15,000 per ton; HTW = Harvesting, threshing and winnowing cost = Birr 1000 per ton; BMT= Bagging, material and transport cost = Birr 65 per ton.

5. SUMMARY AND CONCLUSION

A field experiment was carry out during the 2014 main cropping season from July to November in Abol woreda of Gambella region at research field with the objectives of studying the response of upland NERICA-4 rice to nitrogen and phosphorus fertilizers rate and determining the most economic rate in the area. The experiment was laid out in a randomized complete block design in a factorial arrangement with three replications. The treatments consisted of factorial combinations of four levels of nitrogen (0, 46, 92 and 138 kg N ha^{-1}) and four level of phosphorus (0, 23, 46, and 69 kg P ha^{-1}).

All the yield and yield components of rice (grain yield, thousand grain weight, day to 50% flowering, dry grain weight per panicle, plant height, number of tillers, productive tillers, filled spikelets and unfilled spikelets) were significantly influenced by the interaction effect of nitrogen and phosphorus but, panicle length, harvest index and straw yield were significant only for nitrogen application while straw yield is significant only for phosphorus application. The maximum plant height of rice (122.2 cm) was attained at 138 kg N and 0 kg P ha^{-1}. In contrast the shortest plant height (88.8 cm) was recorded for plot that received no nitrogen and phosphorus, which was also statistically the same with 0kg N in combinations with 23, 46 and 92 kg P ha $^{-1}$. Panicle length is one of the yield attributes of rice that leads to high increment in grain yield. It affected only by the rate of nitrogen fertilizer. Increasing the rate of nitrogen from 0 to 138 kg N ha^{-1} markedly increased panicle length of the plants by about 12.6%. The maximum length of panicles (23.25 cm) was recorded from 138 kg N ha^{-1} and the minimum length (20.65 cm) was observed for the control. Days to 50% flowering was influence by the interaction effect of N and P. Increasing the rate of nitrogen significantly decreased the days to panicle emergence across all the rates. Nitrogen and phosphorus interacted significantly to influence plant height and number of effective tillers. The maximum number of tillers was recorded for 92 kg N and 23 kg of P (77.67) and the minimum was obtained at (0kg P) and 46kg of N/ha. However, the levels of N increased the number of spikelets from (105.3) to (162.9) in 0 kg N ha^{-1} and 138 kg N ha^{-1} respectively.

Number of filled spiklets was significantly affected by the N and P interaction ($P<0.01$). The maximum number of filled spiklets was record for 138 kg N ha^{-1} and 23 kg of P ha^{-1} (151.5) and the minimum was obtained at the control (no N and P). The highest straw yield (13.16 t ha^{-1}) was recorded for 138 kg N ha^{-1} and the lowest value (6.29 t ha^{-1}) was obtained from zero N. This implies that increasing levels of application of nitrogen may increase straw yield of rice. Nitrogen and phosphorus application influenced the grain yield of rice. The highest mean yield (6.053 t ha^{-1}) was obtained with the applications of 92 kg N and 69 kg P ha^{-1}, representing an increase of 53.19% over the control treatment, followed by 5.96 t ha^{-1} with the applications of 92 kg N and 0 kg P ha^{-1}. The highest (36.30%) harvest index recorded from the control (No N) and the lowest (27.43%) obtained from 138 kg N ha^{-1}. As indicated in the result, harvest index consistently declined with increasing levels of applied N up to the highest level 138 kg of N $ha^{-1.}$

Yield and yield components of rice variety NERICA-4 responded strongly to N fertilizer application than to P fertilizer. Accordingly, optimum magnitudes of increase in almost all the parameters were obtained with applied N fertilizer. However, the maximum grain yield and greater magnitude increase in yield and yield components were obtain with combined application of N and P fertilizers. In this study, it was observed that number of productive tillers per panicle, number of filled spiklets per panicle, panicle length, dry grain weight per panicle, number of tillers and spikelets per panicle were the most important yield forming attributes causing significant variation in grain yield of rice. From the range of treatments tested, 92 kg N ha^{-1} resulted in significantly higher grain yield even without phosphorus application. Phosphorus alone did not show any significant differences in yield and yield components of rice, but the interaction of the two exhibited highest significant differences. In general, treatments with 92 kg N ha^{-1} with 0, 23, 49 and 69 kg P ha^{-1} produced higher grain yield, coupled with the best economic benefit or profitability. Therefore, the results of the present study indicate that farmers in Abol woreda, Gambella region need to apply 92 kg N ha^{-1} irrespective of the amount of phosphorus in order to improve the grain yield and yield components of upland NERICA-4 rice grown under rain fed conditions.

5.1. Future line of work

Based upon the above conclusion, the following recommendations can be drawn;

- The optimum rate 92 kg of N ha^{-1} with 0kg P ha^{-1} fertilizer as tested in this study gave promisingly highest grain yield and economic profitability.
- N and P fertilizer recommendations drawn from the present study for rice should be further verified at different location in the area, and soil test based fertilizer rate determination studies should be conducted.
- Moreover, in the light of the significant response of rice to both N and P fertilizers, further studies aimed at formulation of fertilizer recommendation on soil test basis over locations are desirable.
- Market prices are ever changing and as such a recalculation of the partial budget using a set of likely future prices *i.e.*, sensitivity analysis, is essential to identify treatments which may likely remain stable and sustain satisfactory returns for farmers, despite price fluctuations.
- Further research on nitrogen and phosphorus uptake and use efficiency shall be good.

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APPENDICES

Appendices Table1: Mean square values of parameters of Upland rice as affected by rates of N and P in Abol woreda, Gambella region south west Ethiopia in 2014 season crop.

parameters	**N(3)**	**P(3)**	**NXP(9)**	**Rep(2)**	**Error(30)**	**CV%**
Plant height	1013.74**	30.34**ns**	96.59**	62.33**ns**	22.009	**4.4**
Day to 50 %flowering	35.055**	0.888**ns**	1.981**	12.020**	0.731	**1.5**
Days to 90% maturity	5.72*	0.67ns	1.54ns	13.94**	1.81	1.07
Number of tillers	50.36**	18.14ns	28.342*	57.645**	12.268	**4.5**
Productive tillers	151.63**	16.805ns	70.138**	5.051**ns**	9.751	**4.4**
Dry Grain weight	3.524**	0.026**ns**	0.565*	0.235**ns**	0.342	**11.6**
Panicles length	20.457**	1.382**ns**	1.910ns	3.638**ns**	2.180	**6.8**
Number of spikelets	4773.29**	41.96ns	442.89**	171.47ns	34.54	**4.2**
Number filled grain	907.19**	334.23**	903.09**	43.50**ns**	18.126	**3.3**
Number of Unfilled grain	509.10**	46.56*	53.93**	18.39**ns**	16.49	**21.7**
1000 Grain weight	21.722**	10.944**ns**	14.889**	4.645**ns**	3.979	**7.1**
Grain yields	13.195**	0.938*	1.392**	0.255**ns**	0.321	**12.1**
Straw yields	127.552**	15.196*	6.006**ns**	22.632*	5.088	**22.1**
Harvest index	83.674*	8.557**ns**	19.108**ns**	39.485**ns**	26.009	**13.2**

= significant at P=0.05, **= significant at P=0.01,* ***ns**= non-significant, Figures in parentheses =degree of freedom (DF)*

Table 2: Eexperimental material (rice genotype) description

Genotype	***Releasing Center***	***Release year***	***Adaptation***				***Maturity days***	***Yield (ton ha^{-1})***		***1000 seed wt(g)***	***Diseases resistance***	***Caryopsis color***
			Altitude (m.a.s.l)	**Rainfall (mm)**	**Ecosystem**	**Cultivation areas**		**farm**	**station**			
Nerica-4	Pawe	2006	600-1850	800-1300	Upland	Pawe and similar areas	110	3.0	4.8	29.5	Resistant	White