RESPONSE OF RICE YIELD AND NUTRIENT USE EFFICIENCY TO DIFFERENT SOURCES OF NITROGEN AND PHOSPHORUS FERTILIZERS IN HMAWBI

PHYU HNIN SHWE

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PHYU HNIN SHWE

A thesis submitted to the post-graduate committee of the Yezin Agricultural University in partial fulfillment of the requirements for the degree of Master of Agricultural Science (Soil and Water Science)

Department of Soil and Water Science
Yezin Agricultural University
Nay Pyi Taw, Myanmar

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The thesis attached here to, entitled **"Response of rice yield and nutrient use efficiency to different sources of nitrogen and phosphorus fertilizers in Hmawbi"** was prepared under the direction of the chairperson of the candidate supervisory committee and has been approved by all members of that committee and board of examiners as a partial fulfillment of the requirements for the degree of **Master of Agricultural Science (Soil and Water Science).**

………………………………

Dr. Nang Ohn Myint
Chairperson of Supervisory Committee
Professor
Department of Soil and Water Science
Yezin Agricultural University

………………………………

Dr. Yi Yi Cho
External Examiner
Assistant Director
Myanmar Rice Research Center
Department Of Agriculture

………………………………

Daw Kyi Kyi Shwe
Member of Supervisory Committee
Assistant Lecturer
Department of Soil and Water Science
Yezin Agricultural University

………………………………

Daw Phyu Thaw Tun
Member of Supervisory Committee
Lecturer
Department of Agronomy
Yezin Agricultural University

………………………………

Dr. Kyaw Ngwe
Professor and Head
Department of Soil and Water Science
Yezin Agricultural University
Yezin, Nay Pyi Taw

Date …………………….

This thesis was submitted to the Rector of the Yezin Agricultural University and was accepted as a partial fulfillment of the requirements for the degree of **Master of Agricultural Science (Soil and Water Science).**

………………………………

Dr. Myo Kywe

Rector

Yezin Agricultural University

Nay Pyi Taw

Date …………………….

DECLARATION OF ORIGINALITY

This thesis represents the original work of the author, except where otherwise stated. It has not been submitted previously for a degree at any other University.

………………………………

Phyu Hnin Shwe

Date …………………….

DEDICATED TO MY BELOVED PARENTS,

U KYAW MYINT AND DAW HAN TIN

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ABSTRACT

The field experiments were conducted in Myanmar Rice Research Center, Hmawbi Township, in Yangon region during dry and wet seasons to compare the effect of two sources of nitrogen and phosphorus fertilizers on growth and yield of rice, to observe the effect of the combination of nitrogen and phosphorus fertilizers on rice and to examine nutrient use efficeiency of each fertilizer. The experimental design was 3x3 factorial arrangements in randomized complete block design with four replications. Treatments were nitrogen (N) sources; N_0- nitrogen omission, N_1- prilled urea (PU) (80 kg N ha^{-1}) and N_2- urea super granule (USG) (80 kg N ha^{-1}) and phosphorus (P) sources; P_0- P omission, P_1- triple super phosphate (TSP) (22 kg P ha^{-1}) and P_2- diammonium phosphate (DAP) (22 kg P ha^{-1}). In both seasons, USG significantly increased plant height, total dry matter, number of panicles $hill^{-1}$, number of spikelets $panicle^{-1}$ leading to more yield as compared with PU. The application of USG increased yield by 26% and 25% over PU in dry and wet seasons respectively. In the tested P sources, DAP fertilizer gave the better yield by 7% in dry season and 6% in wet season than TSP fertilizer. When PU combined with any tested P sources, the combination of DAP resulted not only in higher grain yield by 16% in dry season but also in saving 25% PU fertilizer than that of TSP. In the case of USG combining with any P sources, USG with DAP gave the greater grain yield by 8% and 5% than USG with TSP in dry and wet seasons respectively. In both seasons, the best nitrogen use efficiency (NUE) was obtained by using DAP among treatments and the higher NUE value was obtained from USG than PU fertilizer. Moreover, application of USG with any tested P sources gave the higher NUE than PU combination in dry season. Even though non-significant difference, the higher phosphorus use efficiency (PUE was obtained by using DAP alone or combining with any tested nitrogen fertilizers than using TSP. Nutrient use efficiency were superior in combined application of any tested N and P fertilizers when compared with applying N or P fertilizer alone. The use of USG and DAP fertilizers resulted the best growth parameters, yield components, yield, NUE and PUE. It can be concluded that using the combination of USG and DAP fertilizers was efficient and effective for Sinthukha rice production.

Key words: Prilled Urea, Urea Super Granule, Triple Super Phosphate, Diammonium Phosphate, Rice Yield, Nitrogen Use Efficiency, Phosphorus Use Efficiency

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CHAPTER I
INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important cereals in the world and staple food for more than half of the world population. Rice is one of the leading food crops in the world (Manzoor et al. 2006) and it represents a primary source of nourishment. Rice can be grown almost anywhere due to its adaptability and can be easily distributed to any part of the world (Expo Milano 2015).

In Myanmar, rice is the staple food of about 51 million people. It is a major source of income, employment, foreign exchange earnings, and an important contributor to the economic growth of the country. The total rice sown area is 7.17 million ha with the annual production of 28.19 million MT and the average yield is 3.94MT ha^{-1} in 2014-2015 (MOAI 2015). Rice yield in Myanmar is very low compared to China (6.8 ton ha^{-1}), Japan (6.7 ton ha^{-1}) and Vietnam (5.7 ton ha^{-1}) (FAO stat 2014). This may be due to many factors and one of the reasons is due to low soil fertility and inadequate nutrient management.

Fertilizers are one of the main inputs in rice production. Therefore, proper fertilization is an important management practice that can increase the yield of rice. Judicious and proper use of fertilizers can markedly increase the yield and improve the quality of rice (Alam et al. 2009). The profitability of rice production systems depends on yield and input quantities. Therefore, the appropriate fertilizer input is not only for getting high grain yield but also for attaining maximum profitability (Khuang et al. 2008).

The major nutrients for plants are nitrogen, phosphorous and potassium. Nitrogen and phosphorus fertilizers are major essential plant nutrients and key input for increasing crop yield (Dastan et al. 2012). These fertilizers are fundamental to crop development because they are essential for the basic component of many organic molecules, nucleic acids and proteins (Lea and Miflin 2011).

Nitrogen fertilizer is a major essential plant nutrient and key input for increasing crop yield (Dastan et al. 2012). Nitrogen fertilization increased the number of stems and panicles per square meter and the total number of spikelets, resulting in increasing grain productivity. Effective N management involves selecting an application rate, source, timing and placement combination that match N availability with crop demand to maximize N use efficiency, optimize crop production and minimize the negative impact of N on the environment (Malhi et al. 2001).

Phosphorus is an essential constituent of adenosine triphosphate, nucleotides, nucleic acids, and phospholipids. Its major functions are energy storage and transfer within the plant (Dick 2011). Phosphorus promotes root development, early flowering, and ripening. It is particularly important in early growth stages. Phosphorus is also a component of other compounds necessary for protein synthesis and transfer of genetic material (DNA, RNA) (Zhang and Raun 2006).

There are many different types of nitrogenous fertilizers available in the market of Myanmar. Among them, urea is the most commonly used nitrogenous fertilizer for rice cultivation. But, nitrogen derived from urea fertilizers that are not taken up by plants may be immobilized in soil organic matter or may be lost to the environment. The N losses from applied urea were estimated at 30 to 60% in tropical soil (Khalil et al. 2003).

To improve nitrogen use efficiency in order to favor farmer's profitability and reduce negative environmental impacts, many researches have been carried out previously on the fertilizer N recovery under different N managements (Sun et al. 2012). Many N saving application patterns (site-specific N management, balanced N fertilization, integrated N management, use of nitrification/urease inhibitors and slow/controlled-release fertilizers, etc.) have been developed (Spiertz 2010). Among them, urea super granule (USG) is one of the improved fertilizer products and it stops denitrification process and minimizes urea concentration in irrigation water. Urea super granule is a fertilizer that can be applied in the root zone of the rice plants at 8-10 cm depth of soil (reduced zone of rice soil), which can save 30% nitrogen compared to prilled urea (Rahman et al 2016).

There are many sources of phosphorus fertilizers such as triple super phosphate, single super phosphate, di-ammonium phosphate. The most commonly used P fertilizers are single and triple superphosphates, diammonium phosphate and ammonium phosphate. The choice of P fertilizer to be used depends on several soil factors, climate conditions, crop characteristics, economy and secondary effects of fertilizers. Triple super phosphate fertilizer contains P_20_5 46%, however, it does not nitrogen. In the case of diammonium phosphate fertilizer, it contains P_2O_5 46% and ammonium nitrogen 18%. Diammonium phosphate is an excellent source of ammonium-nitrogen and phosphate nutrients. Ammonium-nitrogen (NH_4^+- N) is the dominant form for plant uptake and rice produced better growth and high yield when fertilized with ammonium rather than nitrate nitrogen (Kirk 1994).

Keeping the above facts in view, the sources of nitrogen and phosphorus fertilizers have great impact in increasing the rice yield. There has been limited research done in combination of the improved nitrogen and phosphorus fertilizers. Therefore, the experiment was conducted with the following objectives;

1. To compare the effect of two sources of nitrogen and phosphorus fertilizers on growth and yield of the rice
2. To observe the effect of the combination of the nitrogen and phosphorus fertilizers on rice
3. To examine the nutrient use efficiency of each fertilizer

CHAPTER II
LITERATURE REVIEW

2.1 Importance of Rice

Cereals are the principle food source for growing human population and approximately 50% of calories consumed by the whole population depend on wheat, rice and maize (Gnanamanickam 2009). Gomez (2001) reported that rice provides the most important food source for Asian countries especially in south-east parts where it is grown on millions of hectares as an economic crop by farmers and workers throughout the area. Moreover, rice is an excellent food to help keep our body healthy. Rice provides 35–60% of the dietary calories consumed by nearly 3 billion people (Guerra et al. 1998). Rice also provides 21% of global human per capita energy and 15% of per capita protein. Rice also provides minerals, vitamins, and fiber, although all constituents except carbohydrates are reduced by milling (IRRI 2007).

Since rice provides as the most important food for people, it was historically cultivated 10000 years ago in the river valleys of South and Southeast Asia and China (Gnanamanickam 2009). At least 114 countries grow rice and more than 50 countries have an annual production of 100,000 tons or more. Among them, Asia, India, and China are mainly rice producing and consuming countries. In addition, global rice demand continues to be driven by population growth and economic growth in Asia and Africa. Globally, farmers will need to produce an extra 8-10 million MT paddy each year to meet demand (IRRI 2010).

Rice also plays an important role as a wage commodity for workers in the cash crop or non-agricultural sectors (Calpe 2006). It also plays an important cultural role in many countries. Products of the rice plant are used for a number of different purposes, such as fuel, roofing, industrial starch and artwork. Growing, selling and eating rice is integral to the culture of many countries (Hla 2017). In future, rice production continues to grow at least as rapidly as the populations to meet the food demand of growing population. The promotion of domestic rice production is a key element in the strategies for improving food security, stimulate economic growth and increase rural income (NRDS 2009).

2.2 Rice Production in Myanmar

Rice is a critical issue in the developing countries in the world and nearly half the world's populations are dependent on rice for survival. Much of the population in Asia consumes rice in every meal (Jirawut 2012). Myanmar is an agricultural based country and has tradition of rice production. Rice is the main staple food crop. Myanmar, with an abundance of land and water resources is well positioned to respond to market opportunities by increasing supply. In Myanmar, people eat an average of half a kilogram of rice every day. Rice and its by-products are used for making straw and rope, paper, wine, crackers, beer, cosmetics, packing material, and even toothpaste (FAO 2004). In Myanmar, cereals are sown on 8.7 million ha, which constitutes 52.1% of the total 16.7 million hectares sown in 2009. Among these crops, rice governs the agricultural sector, which is the largest and most productive part of the economy. The major rice-producing regions of Myanmar are Ayeyarwady, Bago, Sagaing and Yangon areas (MOAI 2011).

Rice is grown in monsoon and summer seasons with cultivated acres of 19 million or 33% of total crop sown areas. Monsoon rice is grown in 16 million acres and summer rice is grown in 3 million acres (Hlaing 2014). The total production of rice is 31.45 million tons including average production of 25.80 million tons from monsoon rice and 5.65 million tons of the summer with an average production of 3.93 ton ha^{-1} (MOAI 2009). Rice yields (4 ton ha^{-1}) in Myanmar are lower than in many other Asian countries such as Japan (6.7 ton ha^{-1}) and Vietnam (5.7 ton ha^{-1}) (FAO stat 2014). The major agronomic and environmental factors stagnating in growth and yield are thought to be mismanagement in the use of inputs such as fertilizer application, lack of potential varieties, and poor quality seeds. Among these factors, fertilizer application is one of the most important variables affecting growth and yield (Muhammad 2008).

2.3 Rice Growth, Development and Nutrient Requirement

Rice is an annual grass with round, hollow, jointed culms, narrow, flat, sessile leaf blades joined to the leaf sheaths with collars, well-defined, sickle-shaped, hairy auricles, small acute to acuminate or two cleft ligules and terminal panicles. The rice plant can be divided into three agronomic stages of development;

(1) Vegetative (germination to panicle initiation)

(2) Reproductive (panicle initiation to heading) and

(3) Grain filling and ripening or maturation (heading to maturity) (Yoshida 1981).

According to the Olembo et al. (2010), all these stages are quite important because they influence the three main yield components that determine grain yield that are number of panicles per unit land area, the average number of grain produced per panicle and the average weight of the individual grains (Yoshida1981).

Nitrogen provides dark green appearance of plant parts which promotes rapid growth or increased plant height and number of tillers as well as increases the size of leaves and grains. Rice plants require higher amount of nitrogen during tillering stages to ensure maximum number of panicles. At panicle initiation stage, the application of nitrogen may increase number of spikelets panicle^{-1}. At the ripening stage little amount of nitrogen is also required (De Datta 1981).

Latchanna et al. (1989) stated that application of phosphorus also resulted in increased number of filled grains panicle^{-1}, 1000 grain weight, grain and straw yields. Phosphorus absorbed after tillering is not used by plant for increasing grain production. However, phosphorus absorbed during tillering stage is most efficiently utilized for grain production. The maximum amount of phosphorus can be fixed in the soil by nature which will be released gradually. The whole amount of recommended phosphorus is used to crops either at final ploughing or mixed with the seed. If phosphorus is applied a little below the seed in the soil, the emerging roots will be able to use this phosphorus easily, so better results are obtained (Chandy 2011).

2.4 Soil Requirement for Rice

Worldwide, rice occupies almost 150 million hectare and very high proportion of the world's rice is grown under the wetland system. This system contains primarily of submerged or waterlogged conditions for whole growth period of the crops. Wetland rice soils vary greatly in their nutrient status. Regardless of their initial reaction, the pH of such soils moves towards neutrality after submergence. The soils on which rice grows are as varied as texture ranges from sand to clay, pH from 3 to 10; organic matter content from 1 to 50%, salt content from almost 0 to 1% and nutrient availability from acute deficiencies to surplus (Surajit and De Datta 1981). Moreover, rice is the only major annual food crop that thrives on land that is water saturated or even submerged during part or all of its growth cycle. A suitable pH for normal growth is 5.0-8.0 (Jose 2002).

2.5 Effects of Submergence on Soil Properties

Paddy soils denote soils in irrigated and rainfed lowland rice production systems with a prolonged period of submergence (Buresh and Haefele 2010). Soil submergence leads to a unique sequence of chemical and microbial transformations related to the changes in soil water content that occur during a cropping cycle (Dobermann and Fairhurst 2000).

When a soil is submerged, the supply of oxygen (O_2) in soil is greatly reduced because the diffusivity of O_2 in water is about 10,000 times less than in air. Plants adapted to submerged soils have developed gas exchange processes enabling O_2 and other gases to pass through the plant's emergent parts into the root zone. In the rice crop, O_2 is transported through porous internal aerenchyma tissue to roots, where most of the O_2 is consumed in root respiration (Buresh et al. 2008).

Submerging a soil brings about a variety of electrochemical changes. These include (a) a decrease in redox potential, (b) an increase in pH of acid soils and a decrease in pH of alkaline soils, (c) changes in specific conductance and ionic strength, (d) drastic shifts in mineral equilibria, (e) cation and anion exchange reactions, and (f) sorption and desorption of ions. Unlike a well-drained soil, submerged soil is in a reduced state. Submerged soil is gray or greenish and has a low oxidation-reduction potential. It contains the reduced counterparts of nitrate (NO_3^-), sulphate (SO_4^{2-}), manganese (Mn^{4+}), ferric (Fe^{3+}) and carbon dioxide (CO_2): ammonium (NH_4^+), hydrogen sulphide (H_2S), manganese (Mn^{2+}), ferrous (Fe^{2+}) and methane (CH_4). Reduction of the soil is a consequence of anaerobic respiration by soil bacteria. During anaerobic respiration organic matter is oxidized and soil components are reduced (Ponnamperuma 1972).

As a result of flooding, the pH of acidic soils increases and alkaline soils decreases. Soil pH is an important chemical property since it influences nutrients availability to plants. The overall, pH of most soils tends to change toward neutral with an equilibrium pH range 6.5 to 7.5 after flooding (Patrick and Reddy 1978).

2.6 Role of Nitrogen and Effects of Nitrogen in Rice Production

Nitrogen is an essential nutrient for all living things on earth and plays a major role in regulating the composition, structure, and function of ecosystems (Leip et al. 2008). It is crucially also important component for all biological life, particularly sensitive to human activities, such as fertilization and cultivation (Zhang et al. 2008).

It is an integral component of many essential plant compounds such as amino acids, which are the building blocks of all proteins including enzymes, nucleic acid and chlorophyll (Brady and Well 2002). Nitrogen is present in so many essential compounds and it is not surprising that even slight deficiencies can result in reduced growth and productivity (Mutters et al. 2006).

Nitrogen is essential to the growth of the rice plant and about 75% of leaf N is associated with chloroplasts, which are essential to dry matter production through photosynthesis (Fageria 2009). Dobermann and Fairhurst (2000) reported that N increases plant height, panicle number, leaf size, spikelet number, and number of filled spikelets, ultimately determining the yield potential of rice plant.

Modern agricultural production requires efficient, sustainable and environmentally sound management practices and moreover increasing crop yields per unit area through use of appropriate nitrogen management practices has become an essential component of modern crop production technology (Fageria and Filho 2001). Therefore efficient management of nitrogen resources is a very critical factor for high yield and it largely depends on the choice, dosage, timing and mode of application of the nutrient carrier or fertilizer (Prudente et al. 2009).

2.7 Role of Phosphorus and Effects of Phosphorus in Rice Production

Phosphorous is essential for growth, cell division, root lengthening, seed and fruit development, and early ripening and it is also a part of several compounds including oils and amino acids. Since phosphorus is a fundamental constituent of adenosine triphosphate, nucleotides, nucleic acids, and phospholipids that are energy carriers within the plants, it is important for energy storage and transfer in plants, (Shenoy and Kalagudi 2005).

Phosphorus is mobile within the plant and promotes tillering by facilitating nitrogen absorption. It promotes root development, early flowering, ripening and particularly important in early growth stages. Phosphorus mainly stimulates root development in the young plant, thus increasing its ability to absorb other nutrients from the soil (Dobermann and Fairhurst 2000). Phosphorus not only enhances the yields but also reduces spikelet sterility (Alam 2009).

Phosphorus (P) availability in soil is closely related not only to soil P content but also to soil physico-chemical and biological properties, which are closely associated with P sorption and biochemical transformation (Guo et al. 2009).

De Datta, 1981 presented that paddy soils are characterized by a sequence of chemical and microbial transformations related to the changes in soil water content. These changes control the availability of phosphorus which is closely related to the degree of soil reduction.

Phosphorus must be in the soluble orthophosphate (HPO_4^{2-}, $H_2PO_4^-$) form to be taken up by plants. Flooding generally increases the availability of P to rice crops. The increase in P availability to rice under flooded conditions involves the reduction of ferric (Fe^{3+}) phosphate to ferrous (Fe^{2+}) phosphate and the release of P from insoluble iron and aluminium compounds and some dissolution of calcium phosphates at higher carbon dioxide levels in the soil solution. It may take several weeks after flooding until P is released by these processes (Reetz 2002).

Although the increase in availability of P is regarded as a benefit of flooding rice soils, the effect on rice growth may not be appreciable in acid clays high in active Fe (IRRI 1985). The beneficial effect of flooding on P depends on the intensity of redox condition of submerged soil and Fe content (De Datta 1981). According to Snyder (2002), phosphorus behavior is not the same in soils that are continuously flooded compared to soil alternately dried and flooded. The duration and depth of flooding affects soil oxygen levels, soil pH, P availability, and levels and forms of some micronutrients. Extractable soil P levels, generally decrease after a flooded field is drained.

2.8 Nutrient Losses in Paddy Soil

The excessive use of nitrogen and phosphorus fertilizers with decreasing fertilizer use efficiencies in agriculture has resulted and N and P elements are loss in large amounts entering ambient water bodies and the atmosphere through various means (Chirinda et al. 2010). Nitrogen fertilizer is important for improving grain yields of cereal crops. However, excessive amounts and inappropriate application methods lead to low N efficiency and high fertilizer losses through volatilization, denitrification, runoff, and leaching (Richter and Roelcke 2000) resulting in a series of environmental problems.

Ammonia volatilization is the conversion from ammonium (NH_4^+) to the ammonia (NH_3) form in flooded water under conditions of high pH and temperature. In the wetland soils, rice plants take up N mainly as NH_4^+, requiring less energy to assimilate into amino acids than nitrate (NO_3^-) (Kennedy 1992). Application of prilled urea under either saturated or submerged conditions raise the pH of soil and flood water for a short period during which losses of NH_3 is maximized (De Datta 1981). When prilled urea fertilizer are applied to the surface of soil, it is hydrolyzed to form NH_4^+ and one or more inorganic carbon species. Ammonia volatilization losses in the flooded soils range from negligible to almost 60% of the applied N (Xing and Zhu 2000). Fillery et al. (1984) highlighted that NH_3 loss accounted for a 30-50% loss of the N applied to floodwater 2-3 days after transplanting. Unlike nitrogen, phosphorus is not found in a gaseous form and so the cycle does not have an atmospheric component. It is most commonly found in rock formations and sediments as phosphate salts. Over-application can lead to the buildup of phosphorus in the soil (Sharpley et al. 1999).

In lowland rice, large denitrification events occur when the soil is reflooded and then proceeds during flooding in the reduced soil layer (Buresh and De Datta 1991). Denitrification occurs in the flooded rice soils following the nitrification of ammonium into NO_3^-. In this process, NO_3^- is reduced by a series of steps to nitric oxide (NO), nitrous oxide (N_2O), and nitrogen (N_2) gases, which are then released into the atmosphere (Reddy and Patrick 1986). Factors contributing to denitrification include pH, temperature, organic matter, wet-dry cycles, and fertilizer management (Stevenson and Cole 1999; Mutters et al. 2006).

Nitrogen loss by surface runoff can occur through over flown flood water in undulating lands. Rain followed by application of fertilizers washed out nitrogen either through over flown or seepage. Excess irrigation encourages runoff loss over narrow and short height field bunds. Rain or irrigation water easily flows through the gradient and causes loss of nitrogen along with surface of soil. Annual N loss through erosion was 18.3 kg N ha^{-1} from upland rice fields in China (Peng et al. 1995).

Dissolved phosphorus from farm fields to lakes, rivers, and streams can lead to excessive aquatic plant growth, resulting in eutrophication. Generally, the factors that cause phosphorus movement are similar as those that cause nitrogen movement. Transport mechanisms are erosion, surface water runoff from rainfall and irrigation, and leaching. When water moves over the soil surface, as it does in runoff events, or passes through the soil profile during leaching, soluble phosphorus will be transported with the water. Applying phosphorus fertilizer or manures on the soil surface will subject them to both runoff and erosion, particularly if the application takes place just before a rainfall, irrigation, or wind event that can carry the phosphorus material off site (Steven et al. 2006).

The downward movement of NO_3^- in the soil profile is called nitrate leaching. When we apply fertilizer in soil for obtaining maximum yield, a significant amount of nutrients is lost through leaching, which might hamper the crop production and pollutes the environment. Nitrogen fertilizers are completely water soluble and a significant portion is lost through leaching. In well-drained sandy soils, much of the nitrate can be lost by leaching as water moves nitrate down through the soil profile (Camberato et al. 2008). Leaching loss of N occurs in the form of NO_3 and NH_4 from rice fields and the extent of loss by NO_3-N is more than 90%. Application of nitrogen fertilizers at higher doses cause higher leaching loss (Sahu and Samant 2006).

Phosphorus in the soil exists as the negatively charged phosphate ion, but unlike nitrate, it does not leach easily with the downward movement of water. Phosphate is extremely reactive and binds with aluminum, iron, calcium, and other elements, which are present in all soils at relatively high levels. This causes the phosphorus to form new chemicals in the soil that bind tightly with the soil clay and organic matter. Thus, P leaching losses from agricultural fields are usually insignificant (Zhang et al. 2011).

2.9. Nitrogen Fertilizers Application for Rice Production

Efficient use of nitrogen (N) fertilizer is a critical factor in receiving high and stable yield, while reducing negative effects to the environment in rice (Tylaran et al. 2009). Fertilizer N is used efficiently when a large proportion of the applied fertilizer is taken up by the crop termed recovery efficiency, and there is a reasonable increase in yield for each kilogram of fertilizer N applied termed agronomic efficiency. In the case of rice, N fertilizer use efficiency varies widely depending upon the fertilizer source, the N application time, or both. The recovery efficiency of N fertilizer by rice generally ranges from 20 to 80% (Fageria et al. 2003) with an average of about 30-40% (Cassman et al. 1993).

The rate, source, time of application, and method or placement of N fertilizer determine N recovery efficiency in the above-ground biomass of lowland rice. Many of the principles that govern N-use efficiency are the same for transplanted, dry direct seeded or direct-water-seeded rice cultures (Fageria etal. 2003). Numerous nitrogen-response experiments have shown that the nitrogen recovery efficiency of rice crop seldom exceeds 30-40%. Even with the best agronomic practices and strictly controlled conditions, it is seldom more than 60-65% (De Datta et al. 1968).

Although nitrogen fertilizer is important for increasing production grain yields of cereal crops, excessive amounts and inappropriate application methods lead to low N efficiency and high fertilizer losses through runoff, leaching, denitrification, and volatilization (Kirda et al. 2001), resulting in a series of environmental problems. Low N efficiency also increases production costs, leading to lower net returns for farmers (Wang et al. 2001). Thus, efficient N utilization should be realized in agriculture for environmental and economic reasons (Stevens et al. 2005, Delin et al. 2008).

Many scientists have tried to make several techniques and ways to reduce or minimize N losses and improve N use efficiency in the rice cultivation. In Asia, most farmers broadcast urea directly onto the flood water within two to four weeks after transplanting rice. Vlek and Fillery (1984) reported that the main problem with broadcast application of N fertilizers was the development of high concentrations of urea and/or ammonium in the flooded water and surface layer of soil where the major loss mechanism - ammonia volatilization, nitrification-denitrification, and surface runoff-operated. They also suggested that the concentration of fertilizer N in the floodwater might be reduced by deep placement of the fertilizer, use of slow-release fertilizer, nitrification inhibitors or urease inhibitors, incorporation of the N into the soil, or split application of the fertilizer dose.

Tian and Saigusa (2002) conducted that various kinds of slow and controlled release nitrogen fertilizers have been invented, produced and utilized. These fertilizers can provide to reduce environmental pollution while maintaining high crop productivity. Important considerations of rice growers for selecting nitrogen sources are availability, economy, convenience in storage and handling and effectiveness of the carrier (Fageria 2014).

2.9.1 Prilled urea (PU)

Prilled Urea is the most popular and economical of the nitrogenous fertilizers used worldwide. In general, urea is one of the top fertilizers. Compared to other nitrogenous solid sources, PU has a nitrogen (N) content of 46%, the highest concentration of available N. It permits considerable savings in shipping and distribution costs. These factors have made urea attractive to a large number of farmers at the lowest cost and fertilizer manufacturers. Prilled urea fertilizer might be used for all types of crops and soils and has no harm the soil. Urea currently constitutes 80% of the nitrogenous fertilizer that is used on rice (Vlek and Craswell 1982).

The high solubility of urea in the water, particularly in areas with high rainfall, makes it be easily leached from the soil before plants have a chance to assimilate it. It is reported that approximately 70% of the applied urea fertilizer maybe lost in regions with high, intermittent precipitation (Allison 1955; Lundt 1971). Moreover, about 20-70% of the applied urea fertilizer is lost to the environment, causing serious pollution and increasing costs. The losses are due to leaching, decomposition and ammonium volatilization in soil, handling and storage (Shaviv and Mikkelsen 1993).

2.9.2 Urea super granule (USG)

Basically, USG fertilizer is a simple physical modification of ordinary urea fertilizer. It consists of large discrete particles of urea $CO(NH_2)_2$ containing46% N as NH_2, an amide form. Weight may vary considerably, but the general range that has been evaluated is 1-3 grams per particle. USG can be placed efficiently by hand soon after transplanting of rice seedlings at the rate of one USG near the center of each four rice hills at a 7-10 cm soil depth. According to Crasswell and De Datta (1980) broadcast application of urea on the surface soil causes losses up to 50% but deep placement of USG in point may result in negligible loss. The use of urea supergranules could synchronise N release with plant requirements and provide sufficient N in a single application to satisfy plant requirements while maintaining low concentrations of mineral N in the soil throughout the growing season (De Datta and Patrick 1986).

Savant and Stangel (1990) reported that deep placement of USG essentially cuts off NH_3 volatilization and also significantly reduces denitrification N loss compared to surface application of PU. Furthermore, the N concentration of flooded water is greatly reduced when USG is deep placed, so that any water runoff from rice paddies does not contribute to N loss or to potential eutrophication problems. The reason for producing USG is that it makes it easier for farmers to apply USG by hand. Use of USG has one great advantage in that it requires only one-time application after rice transplanting, whereas surface application of PU requires two to three split applications that can still result in significant N loss through NH_3 volatilization.

According to the sources of International Fertilizer Development Center (IFDC) , benefits of urea super granules are (1) minimize costs for urea by 20%-25%, (2) increases rice yields by 15%-25%, (3) reduces hired weeding labor by 26%-35%, (4) increases efficiency of fertilizer use in submerged rice due to reductions of loss through gaseous emissions and floodwater runoff (With broadcast application of urea, volatilization losses alone could account for 30%-50% of applied fertilizer), (5) encourages algal biological nitrogen fixation because of low floodwater nitrogen concentration (6) encourages better water management and line transplanting (instead of random), thus, weeding and pest control is made easier, (7) reduces the number of ineffective tillers in rice plants and results in bigger panicles and (8) ensures nitrogen availability beyond the flowering stage when applied at an appropriate rate.

2.10 Phosphorus Fertilizer Application for Rice Production

The most commonly used P fertilizers for lowland rice are single and triple superphosphates, diammonium phosphate and ammonium phosphate (Sanyal and De Datta 1991). Generally, P fertilizers for rice should be applied at transplanting, but it may also be applied later, before the vigorous tillering stage (De Datta 1981). Split-application of P has not been effective. Nelson (1980) reported that applying the total dose as basal at transplanting is the best time and method of P fertilization for rice due to the following: more P is required by the rice during the early growth stage; available P from the soil cannot meet the requirement at this early stage; adequate P supply may be conducive to better root development and tillering.

2.10.1 Triple super phosphate (TSP)

Triple superphosphate (TSP) is the third most widely used high-analysis phosphate product. It contains only phosphate because it is produced by reacting phosphoric acid with additional high-grade phosphate rock. It also is a solid plant nutrient product, but it is hydroscopic or absorbs moisture and therefore cannot be blended with some products such as urea (Borlaug 2009).

Triple superphosphate has several agronomic advantages that made it such a popular P source for many years. It has the highest P content of dry fertilizers that do not contain N. Over 90% of the total P in TSP is water soluble, so it becomes rapidly available for plant uptake (www.ipni.net). Moreover, triple superphosphate (TSP) is a great phosphorus fertilizer and has a several agronomic advantages and a popular phosphorus source for many years. It has the highest phosphorus content of dry fertilizers that do not contain nitrogen. Triple superphosphate also contains 15% calcium (Ca), providing an additional plant nutrient (www.ipni.net).

2.10.2 Di-ammonium phosphate (DAP)

Diammonium phosphate (DAP) is the world's most widely used phosphorus (P) fertilizer. It is made from two common constituents in the fertilizer industry and it is popular because of its relatively high nutrient content and its excellent physical properties. (www.ipni.net)

When nitrogen is provided as an ammonium or ammonium-producing fertilizer, the acidifying effect could enhance nitrogen concentrations in plants (Malhi and Nyborg 1988) and phosphorus solubility in soil (Prasad and Power 1997), thus providing a positive interaction. Diammonium Phosphate (18-46-0) is the most widely used high-analysis phosphate product worldwide. Diammonium phosphate is produced by first combining phosphoric acid with anhydrous ammonia in a reaction vessel. This initial reaction creates a slurry that is then pumped into a granulation plant where it is reacted with additional ammonia to produce DAP. It is a solid phosphate product that is applied directly or blended with other solid plant nutrient products such as urea and potassium chloride (Borlaug 2009).

2.11 Nitrogen and Phosphorus Interaction in Rice

Nitrogen and phosphorus are fundamental to crop development because they form the basic component of many organic molecules, nucleic acids and proteins (Lea and Miflin, 2011). Numerous workers have reported positive interaction between nitrogen and phosphorus which leads to increase in P absorption and higher yields (Adam F, 1980). Wilkinson et al. 1999 reported that N can increase P uptake in plants by increasing root growth, by increasing the ability of roots to absorb and translocate P, and by decreasing soil pH as a result of absorption of NH_4 and thus increasing solubility of fertilizer P. Generally, phosphorus has positive significant interaction with N absorption and plant growth. It is commonly held view that increased growth requires more of both N and P, the inference being that mutually synergistic effects result in growth stimulation and enhanced uptake of both elements (Sumner and Farina 1986).

The reduced yields under single applications P and N alone, implies that these nutrients were poorly utilized and the increasing tillering without enhancing tillers to bear panicles and encourage grain formation is wasteful as nitrogen is essential for increase plant height and production of panicle bearing tillers while phosphorus promotes grain formation consequently increasing gain yield (Ochwoh et al. 2015).

It has frequently been described that in a highly phosphorus-deficient soil, application of nitrogen alone has little impact on crop yields but N × P application can dramatically increase the response to applied fertilizer. The contribution of a synergistic interaction between nitrogen and phosphorus in cereals can be 13 to 89% of the yield response to N × P and 14 to 96% of NUE, depending on the yield potentials, level of soil fertility and nutrient application rates. Grain yield response per kilogram nutrient was higher by 11% when 120 kg nutrients ha^{-1} were applied as 90 kg N + 30 kg P_2O_5 as compared to only 120 kg N ha^{-1} (Sharma and Tandon 1992). Therefore, in soils that are severely deficient in phosphorus, application of nitrogen alone will produce only a small increase in yield, much below the potential.

CHAPTER III
MATERIALS AND METHODS

3.1 Experimental Site and Growing Season

The field experiments were conducted at the Myanmar Rice Research Center (MRRC), Hmawbi Township in Yangon Region. This place represents not only low-land rice but also irrigated rice area of lower Myanmar. It is situated at 17˚06´35.0" N latitude and 98˚00´ 52.9" E longitude with the elevation of 21 meters above sea level near Yangon, about 32 miles. Two experiments in two consecutive rice growing seasons (dry and wet season experiments) were conducted from December 2016 to May 2017 and from June to October 2017.

3.2 Experimental Design and Treatments

The experimental design was 3x3 factorial arrangements in randomized complete block design. There were 36 experimental plots comprising 9 treatments and 4 replications.

Treatments

The treatment details are as follows and show in Table 3.1.

Factor A – Nitrogen Source (N)	**Factor B – Phosphorus Source (P)**
N_0 - N omission	P_0 - P omission
N_1 - Prilled Urea (PU)	P_1 - Triple Super Phosphate (TSP)
N_2 - Urea Super Granule (USG)	P_2 - Diammonium Phosphate (DAP)

According to the treatments, all amounts of phosphorus fertilizers (triple superphosphate and diammonium phosphate) were applied as basal. Prilled urea fertilizer was applied at 7 day after transplanting (DAT), panicle initiation stage and heading stage. In the case of USG, each granule of USG (2.7 g weight) was applied only once at 7 DAT to a depth of 7-10 cm into the soil between four hills (Appendix 4.). Potassium fertilizer was applied at all experimental units as muirate of potash (MOP) with the rate of 42 kg K ha^{-1} by three split application at the time of PU fertilizer application.

Table 3.1 Rates of different sources of nitrogen and phosphorus fertilizers applied in the experiments

Treatments	N% (kg ha^{-1})	P% (kg ha^{-1})	Fertilizer (kg ha^{-1})			
			PU	USG	TSP	DAP
N_0P_0 0	0	0	-	-	-	-
N_0P_1 (TSP)	0	22	-	-	109	-
N_0P_2 (DAP)	20	22	-		-	109
N_1P_0 (PU)	80	0	174	-	-	-
N_1P_1 (PU + TSP)	80	22	174	-	109	-
N_1P_2 (PU+ DAP)	60+ 20	22	130	-	-	109
N_2P_0 (USG)	80	0	-	174	-	-
N_2P_1 (USG + TSP)	80	22	-	174	109	-
N_2P_2 (USG + DAP)	80+20	22	-	174	-	109

Table 3.2 Physicochemical properties of the experimental soil before experiment

Parameters	Values	Range
Soil Texture		
Sand (%)	4.20	Silt Loam
Silt (%)	72.70	
Clay (%)	21.70	
Soil pH	5.08	strongly acid
Total N (%)	0.14	Low
Available N (ppm)	78.00	Medium
Total P (%)	0.36	-
Available P (ppm)	8.79	Low
Available K (ppm)	12.90	Medium
Cation Exchange Capacity (meq/100g)	9.34	Low
Organic carbon (%)	2.64	Medium
Exchangeable Fe (ppm)	238.00	Mean

3.3 Land Preparation and Crop Management

The soil samples were collected randomly at 0-15 cm depth from MRRC, Hmawbi. The sample was air-dried, crushed and sieved through a 2 mm sieve. Some physicochemical properties of soil such as soil texture, soil pH, total N, available N, total P, available P, available K, exchangeable Fe, CEC and organic carbon of soil sample were analyzed at land use division in Department of Agriculture before growing the plant. The analyzed soil physical and chemical properties including with their determination methods are shown in Table 3.2 and Appendix 1.

The whole size of the experimental area was (45 m x 25 m) and each plot size was (5 x 4) m^2. Double bands were separated between plots and treated plots were separated from the surrounding field about 1m apart to prevent the contaminations that may effect on treatments such as mixing fertilizer during irrigation or drainage. Sin Thu Kha was used as a tested variety for this experiment. Twenty days old seedlings were transplanted at the space of 20cm × 20cm. The plots were irrigated whenever necessary. Weed control and other managements were done regularly, especially at the early stages of growth.

3.4 Data Collection

3.4.1 Measurement parameters for agronomic characters

(a)Plant height and number of tillers hill^{-1}

Growth parameters such as plant height and number of tillers hill^{-1} were recorded from eight randomly selected hills for each plot. Plant height was measured from the base to uppermost growing point of the plant. The number of tillers hill^{-1} recorded in 2-week intervals from 14 DAT until heading stage.

(b)Chlorophyll meter measurement

The SPAD readings were measured by a chlorophyll meter (SPAD-502, Minolta Co., Japan), starting from 14 DAT to 84 DAT. It was measured from three sample leaves hill^{-1}. From each plant, SPAD readings were taken from the uppermost fully expanded leaf, one side of the midrib of the leaf blade. SPAD value was measured three points at tip, middle and base of the leave.

(c)Dry matter weight

Three hills from each plot were collected for measuring dry matter at 20 DAT (active tillering), 50 DAT (panicle initiation), 80 DAT (heading stage) and 110 DAT (harvesting stage). Three plant samples which taken from 20 DAT, 50 DAT, 80 DAT and 110 DAT were dried in the shade and then put in an oven at 65℃ ± 5℃ for 48 hours. After cooling to room temperature, the dry weight was recorded and computed.

3.4.2 Measurement parameters for yield and yield components

The grain yield was determined from a central $5m^2$ harvested areas in each plot at harvestable maturity and then weighted by using a digital balanced and adjusted to 14% moisture content. Grain moisture meter (GMK-303RS, JICA) was used for taking moisture data. Five hill samples from each treatment were collected to determine yield components parameters such as number of panicles $hill^{-1}$, panicle length, number of spikelets $panicle^{-1}$, filled grain% and 1000 grain weight.

(a)Number of panicles $hill^{-1}$

The number of panicles $hill^{-1}$ was counted from five hills collected and the collected data was averaged.

(b) Panicle length (cm)

Panicle length was measured as a linear distance from the neck-node of the panicle to the tip of the panicle.

(c) Number of spikelets $panicle^{-1}$

Total number of spikelets present on each panicle were counted from sampled five hills and averaged. The spikelet number included filled and unfilled spikelets.

(d) Filled grain percentage

The percentage of filled grains was calculated as the ratio of the number of filled grains to the total number of spikelets.

(e) 1000 grain weight (g)

Fully developed grains were randomly selected and their weights were recorded.

3.4.3 Calculations

(a) Harvest index (HI)

Harvest index of each treatment was calculated by the following equation.

$$\text{Grain Harvest Index} = \frac{\text{Economic yield (grain yield)}}{\text{Biological yield (grain+straw yield)}}$$

(Fageria 2009)

(b)Nutrient use efficiency

Nitrogen and phosphorus use efficiencies was calculated with the following formula.

$$\text{Fertilizer Use Efficiency} = \frac{\text{Grain yield (kg ha}^{-1}\text{) in fertilized plot- Grain yield in control plot}}{\text{Amount of fertilizer applied (kg ha}^{-1}\text{)}}$$

(Dobermann and Fairhurst 2000)

3.5 Weather Data

Climate influences the rice crop distribution over different regions of the world, while weather influences the corresponding rice crop production potential. Among abiotic stress, weather plays the significant role in influencing the growth and yield of rice. All weather data for the seasons of both experiments were obtained from MRRC, Hmawbi, (Appendix 2 and 3).

3.6 Statistical Analysis

All data were analyzed by the Analysis of Variance (ANOVA) procedure using statistix software (8^{th} edition). Where significant differences were detected, the means were separated by the least significant difference (LSD) at 5 percent probability level.

CHAPTER IV
RESULTS AND DISCUSSION

4.1 Field Experiment in Dry Season, 2017

This experiment was conducted to know the response of the different sources of nitrogen and phosphorus fertilizers on growth parameters, grain yield and nutrient use efficiency. The experimental results are presented and discussed in this chapter.

4.1.1 Growth parameters

4.1.1.1 Plant height (cm)

The plant height was measured at 14-days intervals from 14 to 84 days after transplanting (DAT). Plant height in all treatments continuously increased from 14 DAT to 84 DAT (Figure 4.1). The different sources of nitrogen, phosphorus fertilizers and their combined effects on plant height were presented in Table 4.1 and 4.2. Highly significant differences of plant height were found at 42 DAT, 56 DAT, 70 DAT, and 84 DAT. Nitrogen application treatments gave the taller plant height than N omission. This finding was similar with Irshad et al. (2000), who showed that the plant height was significantly increased by nitrogen application. In the types of nitrogen fertilizer application, the higher plant height was resulted from urea super granule (USG) treatments than that of prilled urea (PU) fertilizer at 84 DAT.

Plant heights were progressively increased by the application of P fertilizers regardless of sources. Phosphorus fertilizer applications gave the higher plant height than P omission. Dobermann and Fairhurst (2000) stated that phosphorus stimulates root development in the young plant, thus increasing its ability to absorb other nutrients from the soil. When compared the two types of phosphorus fertilizers, DAP fertilizer produced the higher plant height in numerical than TSP fertilizer. According to the results of Ali et al. (2012), they reported that there were non-significant differences in plant height among different phosphorus sources.

Although the combined effect of the different sources of nitrogen and phosphorus fertilizers were not significantly effect on plant height, the tallest plant height (91.97cm) was resulted from (USG + DAP) and the shortest (75.72cm) was recorded from no applied nitrogen and phosphorus fertilizers.

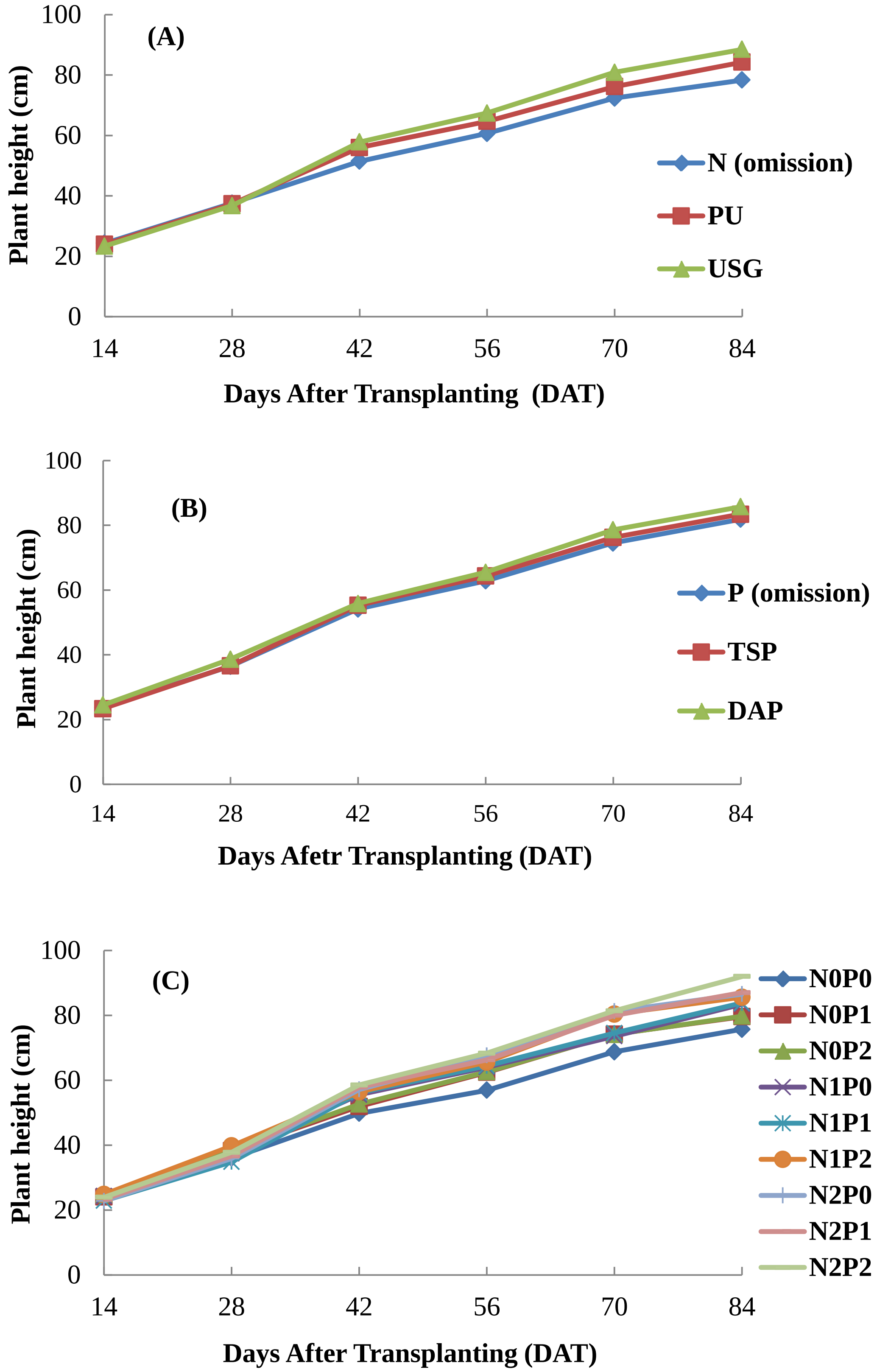


Figure 4.1 Mean value of plant height (cm) as affected by different sources of (A) nitrogen fertilizer, (B) phosphorus fertilizer and (C) their combination during dry season, 2017

Table 4.1 Mean effects of different sources of nitrogen and phosphorus fertilizers on plant height of rice during dry season, 2017

Treatments		Plant height (cm)					
Nitrogen (N)		**14 DAT**	**28 DAT**	**42 DAT**	**56 DAT**	**70 DAT**	**84 DAT**
N_0	N(omission)	24.31	37.585	51.48 b	60.67 b	72.37 b	78.37 c
N_1	PU	23.98	37.36	56.03 a	64.68 a	76.18 ab	84.29 b
N_2	USG	23.37	36.79	57.86 a	67.43 a	80.91 a	88.51 a
$LSD_{0.05}$		2.35	2.07	2.48	3.22	5.22	3.89
Phosphorus (P)							
P_0	P (omission)	23.74	36.46	54.17	62.87	74.55	81.92
P_1	TSP	23.40	36.59	55.31	64.39	76.26	83.47
P_2	DAP	24.53	38.68	55.87	65.52	78.64	85.78
$LSD_{0.05}$		2.35	2.07	2.48	3.23	5.22	3.89
Pr>F							
Nitrogen (N)		0.7085	0.7183	0.0001	0.0009	0.0092	0.0001
Phosphorus (P)		0.6025	0.0652	0.3681	0.2538	0.2868	0.1414
N x P		0.9692	0.2663	0.9660	0.4617	0.6824	0.8090
CV %		11.66	6.61	5.35	5.96	8.09	5.52

In each column, means followed by a same letters are not significantly different at LSD test 5% level.
PU- Prilled Urea, USG - Urea Super Granule, TSP - Triple Super Phosphate, DAP - Diammonium phosphate

Table 4.2 Combined effects of different sources of nitrogen and phosphorus fertilizers on plant height of rice during dry season, 2017.

Treatments	Plant height (cm)					
	14 DAT	**28 DAT**	**42 DAT**	**56 DAT**	**70 DAT**	**84 DAT**
N_0P_0	24.11	36.00 bc	49.82 d	56.94 c	68.78 b	75.72 d
N_0P_1	24.03	38.28 abc	51.94 cd	62.44 bc	74.19 ab	79.59 cd
N_0P_2	24.79	38.47 ab	52.64 bcd	62.63 b	74.13 ab	79.79 cd
N_1P_0	24.28	37.47 abc	55.54 abc	64.03 ab	73.59 ab	83.47 bc
N_1P_1	22.87	34.85 c	56.16 abc	64.41 ab	74.56 ab	83.82 bc
N_1P_2	24.83	39.77 a	56.41 ab	65.59 ab	80.38 a	85.59 abc
N_2P_0	22.84	35.89 bc	57.16 a	67.63 ab	81.28 a	86.57 ab
N_2P_1	23.32	36.66 abc	57.85 a	66.31 ab	80.03 a	87.00 ab
N_2P_2	23.96	37.80 abc	58.56 a	68.34 a	81.41 a	91.97 a
$LSD_{0.05}$	4.06	3.59	4.29	5.59	9.03	6.74
CV %	11.66	6.61	5.35	5.96	8.09	5.52

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

N_0P_0 = Control, N_0P_1 = 22 kg P ha^{-1} as TSP (Triple Super Phosphate), N_0P_2 = 22 kg P ha^{-1} as DAP (Diammonium phosphate),

N_1P_0 = 80 kg N ha^{-1} as Prilled Urea (PU), N_1P_1 = PU+ TSP, N_1P_2 = PU+ DAP

N_2P_0= 80 kg N ha^{-1} as USG (Urea Super Granule), N_2P_1 = USG +TSP, N_2P_2 = USG + DAP

4.1.1.2 Number of tillers hill^{-1}

Number of tillers hill^{-1} were counted at various growth stages from 14 DAT to 84 DAT, was continually increased (Figure 4.2). Numbers of tillers hill^{-1} were highly significant influenced within N application treatments in all growth stages except 14 DAT. The greater number of tillers hill^{-1} was resulted from nitrogen fertilization than N omission. In tested N sources, the maximum numbers of tillers hill^{-1} were found from USG in 28 DAT, 42 DAT, 56 DAT and 70 DAT which was followed by PU. It may be the continuous obtainability of N from USG that helped in increasing the number of tillers. This results was line with Mishu, F.R. (2014) who stated that the highest number of total tillers hill^{-1} was observed when 2.7g wt. of USG application.

Numbers of tillers hill^{-1} were regularly increased by the application of phosphorus fertilizers (Table 4.3). There were significant difference phosphorus application at 5% level in 28, 56 and 84 DAT and highly significant in 70 DAT. Phosphorus fertilization produced the higher tiller number than P omission treatment. According to Panhwar et al. (2011), they reported that phosphorus is essential for plant growth and encourages root development, tillering, and early flowering. The maximum tiller number was recorded from DAP which was followed by TSP. It may be due to effect of DAP fertilizer that contains NH_4 nitrogen (18%) over P content. Sharma et al. (2009) observed the number of tillers hill^{-1} increased significantly with the application of DAP at 35 kg ha^{-1}.

The combined effect of different sources of nitrogen and phosphorus was not significantly difference as shown in Table 4.4. At 84 DAT, the maximum number of tillers hill^{-1} (18.19) was obtained from the combined effect of USG + DAP and the minimum number of tillers hill^{-1} (11.38) was obtained from the no nitrogen and phosphorus fertilizers. Yoseftabar (2013) also reported that the total tiller increased with nitrogen and phosphorus fertilizer.

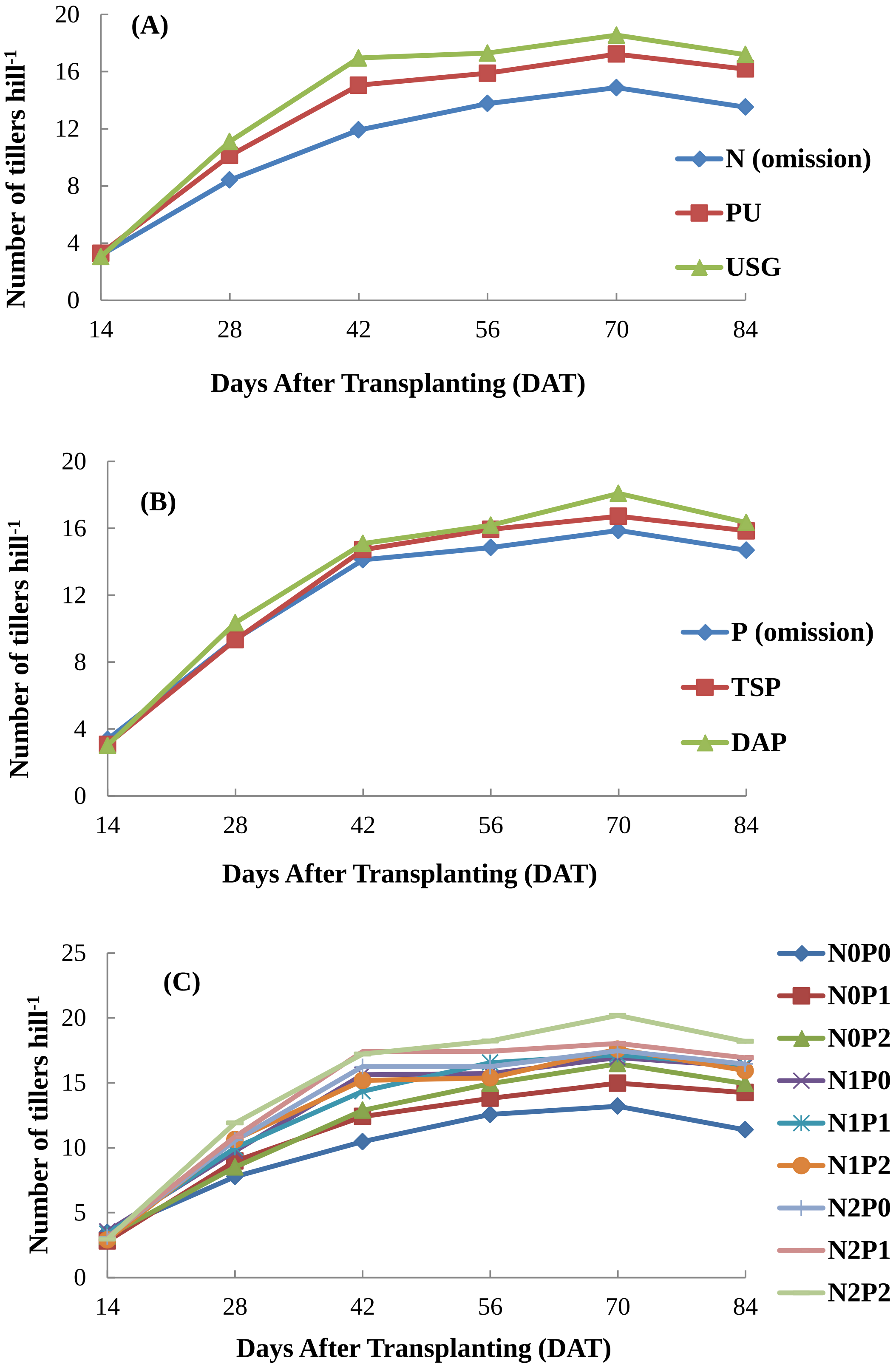


Figure 4.2 Mean value of number of tillers hill^{-1} as affected by different sources of (A) nitrogen fertilizer, (B) phosphorus fertilizers and (C) their combination during dry season, 2017

Table 4.3 Mean effects of different sources of nitrogen and phosphorus fertilizers on tiller number hill^{-1} of rice during dry season, 2017

Treatments		No. of tillers hill^{-1}					
		14 DAT	28 DAT	42 DAT	56 DAT	70 DAT	84 DAT
Nitrogen (N)							
N_0	N (omission)	3.15	8.42 c	11.92 c	13.77 c	14.88 c	13.52 b
N_1	PU	3.28	10.13 b	15.05 b	15.89 b	17.23 b	16.19 a
N_2	USG	3.05	11.11 a	16.96 a	17.30 a	18.56 a	17.19 a
$LSD_{0.05}$		0.38	0.67	0.92	1.07	0.86	1.28
Phosphorus (P)							
P_0	P (omission)	3.38	9.37 b	14.12 b	14.85 b	15.87 b	14.69 b
P_1	TSP	3.08	9.34 b	14.72 ab	15.94 a	16.72 b	15.85 ab
P_2	DAP	3.02	10.35 ab	15.09 a	16.18 a	18.09 a	16.35 a
$LSD_{0.05}$		0.38	0.67	0.92	1.07	0.86	
Pr>F							
Nitrogen (N)		0.4730	0.0000	0.0000	0.0000	0.0000	0.0000
Phosphorus (P)		0.1288	0.0211	0.1060	0.0374	0.0001	0.0377
N x P		0.36455	0.4020	0.0447	0.2181	0.1113	0.1368
CV %		14.23	8.08	7.44	8.09	6.06	9.73

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

PU - Prilled Urea, USG - Urea Super Granule, TSP - Triple Super Phosphate, DAP - Diammonium phosphate

Table 4.4 Combined effects of different sources of nitrogen and phosphorus fertilizers on tiller number hill^{-1} of rice during dry season, 2017

Treatments	No. of tillers hill^{-1}					
	14 DAT	**28 DAT**	**42 DAT**	**56 DAT**	**70 DAT**	**84 DAT**
N_0P_0	3.47 ab	7.78 e	10.47 f	12.57 e	13.20 e	11.38 d
N_0P_1	2.81 b	8.97 cd	12.41 e	13.81 de	14.97 d	14.25 c
N_0P_2	3.19 ab	8.51 de	12.89 de	14.94 cd	16.47 c	14.94 bc
N_1P_0	3.56 a	9.75 bc	15.63 bc	15.72 bc	16.94 bc	16.25 abc
N_1P_1	3.38 ab	10.00 bc	14.35 cd	16.56 abc	17.16 bc	16.37 abc
N_1P_2	2.91 b	10.63 b	15.19 bc	15.38 cd	17.59 bc	15.94 bc
N_2P_0	3.13 ab	10.56 b	16.25 ab	16.25 bc	17.47 bc	16.45 abc
N_2P_1	3.07 ab	10.85 ab	17.41 a	17.44 ab	18.03 b	16.93 ab
N_2P_2	2.97 ab	11.91 a	17.22 a	18.22 a	20.19 a	18.19 a
$LSD_{0.05}$	0.67	1.17	1.58	1.85	1.49	2.22
CV %	14.23	8.08	7.44	8.09	6.06	9.73

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

N_0P_0 = Control, N_0P_1 = 22 kg P ha^{-1} as TSP (Triple Super Phosphate), N_0P_2 = 22 kg P ha^{-1} as DAP (Diammonium phosphate),

N_1P_0 = 80 kg N ha^{-1} as Prilled Urea (PU), N_1P_1 = PU + TSP, N_1P_2 = PU + DAP

N_2P_0= 80 kg N ha^{-1} as USG (Urea Super Granule), N_2P_1 = USG +TSP, N_2P_2 = USG + DAP

4.1.1.3 SPAD reading

SPAD value was recorded two weeks intervals until 84 DAT and varied significantly with the application nitrogen fertilizers (Figure 4.3). They were significant difference in 28 DAT at 5% level and 42, 56, 70 and 84 DAT at 1 % level (Table 4.5).The higher SPAD value was found in N application plots than N omission. Varvel et al. (1997) demonstrated that N fertilizer significantly increased SPAD reading. When compared the two types of N fertilizers, the greater SPAD value was obtained from USG between 42 DAT and 70 DAT than PU fertilizer however the SPAD value of USG was gradually decreased until 84 DAT. At 84 DAT, PU fertilizer treatment obtained the increased SPAD reading again in 80 DAT that may be due to the split applied of PU fertilizer as the third time in this stage. The increase in SPAD value by the application of N fertilizers is probably due to enhanced availability of nitrogen which enhanced more leaf area resulting in higher photo assimilates.

The means of SPAD value of P treatment were not significantly different however P fertilization plots gave the higher SPAD value than P omission. The more SPAD value were obtained by DAP when compared TSP treatment. This result may be due to the effect of nitrogen containing DAP fertilizer.

No interaction was found in SPAD value between the effect of nitrogen and phosphorus fertilizers. The combination of nitrogen application treatments produced the more SPAD value than no nitrogen fertilizer application treatments.

4.1.1.4 Total dry matter (TDM)

Total dry matters (TDM) were recorded at active tillering, panicle initiation, heading and harvesting stages. The total dry matter continuously increased from active tillering to harvesting stages (Figure 4.4). Wajid et al. (2012) reported that TDM production was increased progressively after crop established and continued until maturity. Nitrogen fertilizer applications were significantly differed on TDM at 5% level. Total dry matter at heading and harvesting stages were highly significant by nitrogen fertilizer application (Table 4.7). Nitrogen applications produced the higher total dry matter than N omission. The higher total dry matter was observed by USG than PU fertilizer. This finding was similar with that using slow-release fertilizer might have the potential to get higher dry matter production in rice (Nguyen quang co, 2015).

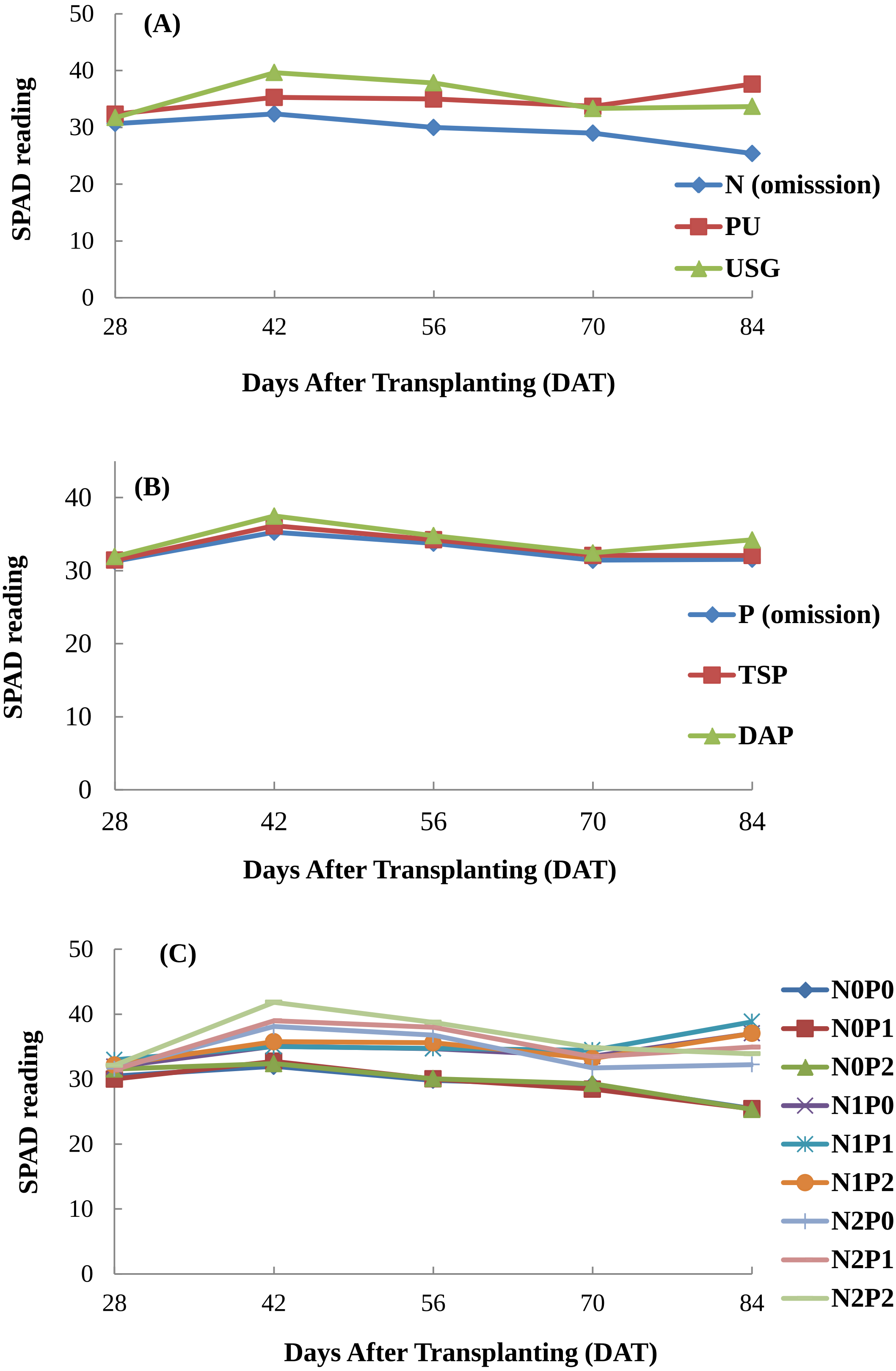


Figure 4.3 Mean value of SPAD reading as affected by different sources of (A) nitrogen fertilizer, (B) phosphorus fertilizers and (C) their combination during dry season, 2017

Table 4.5 Mean effects of different sources of nitrogen and phosphorus fertilizers on SPAD value of rice during dry season, 2017

Treatments		SPAD reading				
		28 DAT	42 DAT	56 DAT	70 DAT	84 DAT
Nitrogen (N)						
N_0	N (omission)	30.66 b	32.35 c	29.96 c	28.96 b	25.39 c
N_1	PU	32.32 a	35.28 b	34.99 b	33.69 a	37.62 a
N_2	USG	31.71 ab	39.63 a	37.83 a	33.32 a	33.68 b
$LSD_{0.05}$		1.29	1.87	1.02	1.19	1.51
Phosphorus (P)						
P_0	P (omission)	31.30	35.28	33.76	31.44	31.56
P_1	TSP	31.46	36.14	34.24	32.11	32.08
P_2	DAP	31.94	37.49	34.79	32.43	34.21
$LSD_{0.05}$		1.29	1.87	1.02	1.19	1.51
Pr>F						
Nitrogen (N)		0.0427	0.0000	0.0000	0.0000	0.0000
Phosphorus (P)		0.5771	0.2113	0.1326	0.2385	0.1370
N x P		0.6516	0.5070	0.6462	0.0869	0.5652
CV %		4.86	6.19	3.52	4.43	5.56

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

PU - Prilled Urea, USG - Urea Super Granule, TSP - Triple Super Phosphate, DAP - Diammonium phosphate

Table 4.6 Combined effects of different sources of nitrogen and phosphorus fertilizers on SPAD value of rice during dry season, 2017

Treatments	SPAD reading				
	28 DAT	**42 DAT**	**56 DAT**	**70 DAT**	**84 DAT**
N_0P_0	30.45 b	31.96 e	29.81 e	29.12 c	25.45 e
N_0P_1	30.00 b	32.72 e	30.02 e	28.44 c	25.43 e
N_0P_2	31.53 ab	32.37 e	30.05 e	29.31 c	25.31e
N_1P_0	31.89 ab	35.04 cde	34.69 c	33.49 ab	37.02 ab
N_1P_1	32.95 a	35.03 cde	34.71 c	34.44 a	38.83 a
N_1P_2	32.17 ab	35.76 bcd	35.59 bc	33.16 ab	37.03 ab
N_2P_0	31.59 ab	38.09 bc	36.77 abc	31.71 b	32.22 d
N_2P_1	31.42 ab	38.97 ab	37.99 ab	33.44 ab	34.92 bc
N_2P_2	32.12 ab	41.83 a	38.74 a	34.83 a	33.90 cd
LSD $_{0.05}$	2.24	3.23	1.76	2.07	2.61
CV %	4.86	6.19	3.52	4.43	5.56

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

N_0P_0 = Control, N_0P_1 = 22 kg P ha^{-1} as TSP (Triple Super Phosphate), N_0P_2 = 22 kg P ha^{-1} as DAP (Diammonium phosphate),

N_1P_0 = 80 kg N ha^{-1} as Prilled Urea (PU), N_1P_1 = PU + TSP, N_1P_2 = PU + DAP

N_2P_0= 80 kg N ha^{-1} as USG (Urea Super Granule), N_2P_1 = USG +TSP, N_2P_2 = USG + DAP

Total dry matter (TDM) of the different sources of phosphorus fertilizers at active tillering stage were significant difference at 5% level however at the other collected stages there were no significant difference (Table 4.7). The significantly higher total dry matter was obtained from DAP which was followed by TSP fertilization. The minimum was resulted from no phosphorus fertilization.

There was no interaction among TDM by the combined effect of the different source of nitrogen and phosphorus fertilizers in Table 4.8. However, the combination of USG with DAP fertilizers gave the highest TDM of rice plant**.**

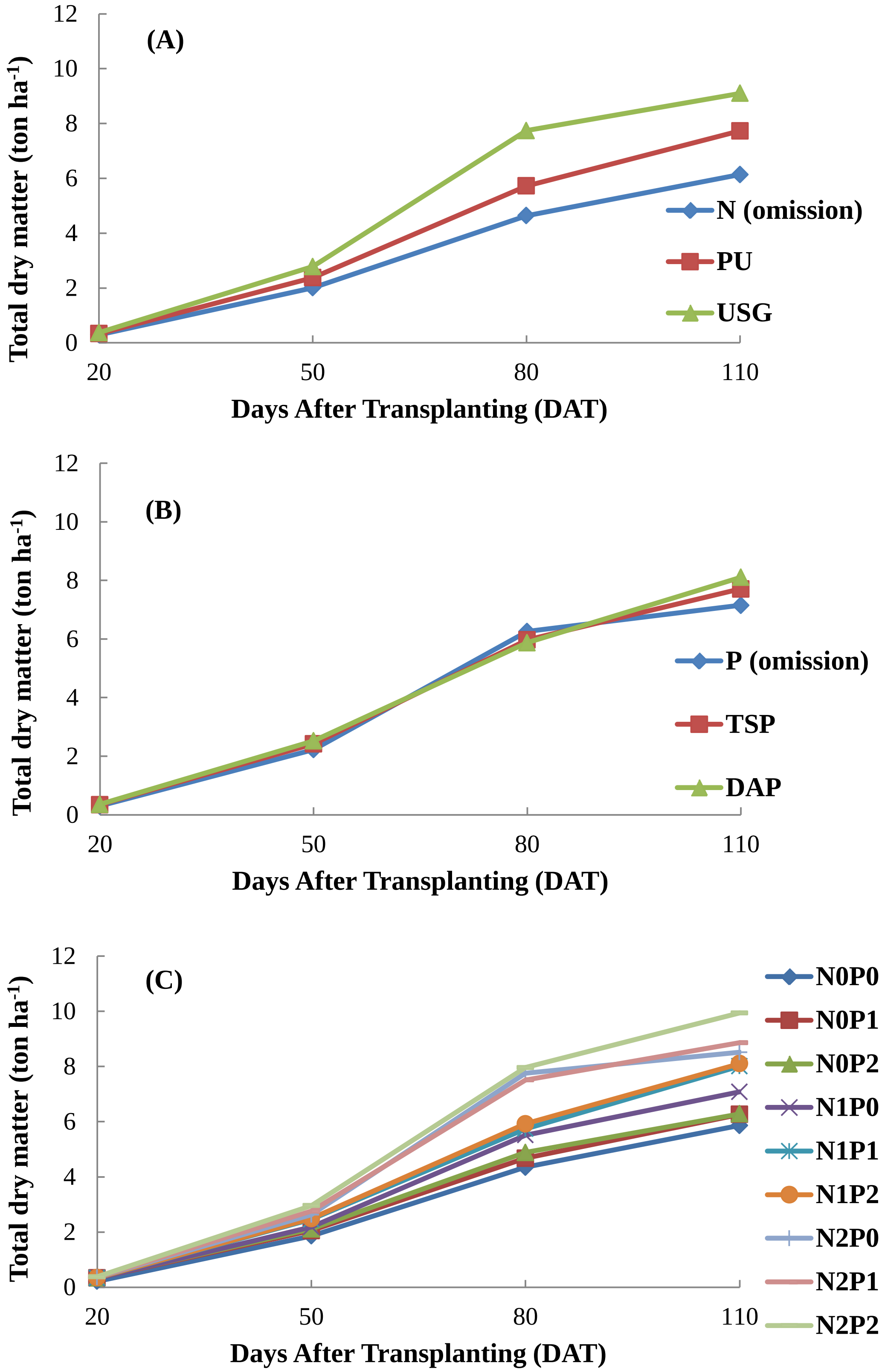


Figure 4.4 Mean value of total dry matter as affected by different sources of (A) nitrogen fertilizers, (B) phosphorus fertilizers and (C) their combination during dry season, 2017

Table 4.7 Mean effects of different sources of nitrogen and phosphorus fertilizers on total dry matter of rice during dry season, 2017

Treatments		**Total Dry Matter (ton ha^{-1})**			
		Active tillering	**Panicle Initiation**	**Heading stage**	**Harvesting stage**
Nitrogen (N)					
N_0	N (omission)	0.29 b	2.01 b	4.64 c	6.14 c
N_1	PU	0.34 ab	2.38 ab	5.72 b	7.73 b
N_2	USG	0.38 a	2.78 a	7.74 a	9.10 a
$LSD_{0.05}$		0.04	0.44	1.06	0.91
Phosphorus (P)					
P_0	P (omission)	0.30 b	2.23	5.87	7.15
P_1	TSP	0.35 a	2.42	5.97	7.71
P_2	DAP	0.36 a	2.52	6.26	8.11
$LSD_{0.05}$		0.04	0.44	1.06	0.91
Pr>F					
Nitrogen (N)		0.0077	0.0056	0.0000	0.0000
Phosphorus (P)		0.0324	0.3865	0.7436	0.1112
N x P		0.1869	0.9969	0.9931	0.8044
CV %		15.65	21.98	20.85	14.03

In each column, means followed by a same letters are not significantly different at LSD test 5% level.
PU - Prilled Urea, USG - Urea Super Granule, TSP - Triple Super Phosphate, DAP - Diammonium phosphate

Table 4.8 Combined effects of different sources of nitrogen and phosphorus fertilizers on total dry matter of rice during dry season, 2017

Treatments	Total Dry Matter (ton ha^{-1})			
	Active tillering	Panicle Initiation	Heading stage	Harvesting stage
N_0P_0	0.22 b	1.86 c	4.35 d	5.86 d
N_0P_1	0.34 a	2.05 bc	4.68 d	6.27 d
N_0P_2	0.34 a	2.12 bc	4.89 d	6.29 d
N_1P_0	0.32 a	2.19 bc	5.5 d	7.08 cd
N_1P_1	0.34 a	2.46 abc	5.74 cd	8.01 bc
N_1P_2	0.35 a	2.49 abc	5.92 bcd	8.11 bc
N_2P_0	0.36 a	2.63 ab	7.75 ab	8.51 abc
N_2P_1	0.37 a	2.76 ab	7.51 abc	8.86 ab
N_2P_2	0.38 a	2.96 a	7.96 a	9.94 a
LSD $_{0.05}$	0.08	0.77	1.84	1.57
CV %	15.65	21.98	20.85	14.03

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

N_0P_0 = Control, N_0P_1 = 22 kg P ha^{-1} as TSP (Triple Super Phosphate), N_0P_2 = 22 kg P ha^{-1} as DAP (Diammonium phosphate),

N_1P_0 = 80 kg N ha^{-1} as Prilled Urea (PU), N_1P_1 = PU + TSP, N_1P_2 = PU + DAP

N_2P_0= 80 kg N ha^{-1} as USG (Urea Super Granule), N_2P_1 = USG +TSP, N_2P_2 = USG + DAP

4.1.2 Yield and yield components parameters

4.1.2.1 Number of panicles hill^{-1}

Number of panicles hill^{-1} at harvest was presented in Table 4.9 and 4.10. Nitrogen application treatments were highly significant influenced at 1% level on number of panicles hill^{-1}. The number of panicles hill^{-1} was increased with the application of nitrogen fertilizer. In tested nitrogen sources, USG fertilizer application gave the higher number of panicles hill^{-1} (15.53) than PU fertilizer applications (14.40). Nitrogen omission treatments gave the lowest number of panicles. The slow release of nitrogen from USG ensured long time supply of N to the rice plants and helped to produce higher panicles and tillers. The results obtained for bearing tillers hill^{-1} are in conformity with the finding of Jee and Mahapatra (1989) who have mentioned that the deep placement of USG produced higher number of bearing tillers hill^{-1} than PU application.

The effects of phosphorus fertilizer were highly significant difference on number of panicles hill^{-1} at 5% level (Table 4.9). The maximum number of panicle hill^{-1} (14.87) was recorded from TSP fertilizer application statistically similar by DAP fertilizer (14.67) and the minimum number of panicle hill^{-1} (13.39) was resulted from no phosphorus fertilizer application. Zaman et al. (1995) also stated increments in the number of panicles m^{-2} of rice plant due to applied phosphorus by enhancing the production of effective tillers.

The number of panicle hill^{-1} ranged from 16.03 to 11.09 in table 4.10. Although there were not significant interaction on number of panicle hill^{-1} by combination of the different sources of nitrogen and phosphorus fertilizers, the maximum number of panicle hill^{-1} was recorded from N_2P_1 (USG + TSP) and the minimum was from N_0P_0 (control).

4.1.2.2 Panicle length (cm)

The panicle length as affected by different sources of nitrogen and phosphorus fertilizers, and their combined effects was presented in Table 4.9 and 4.10. Panicle length was significantly influenced by nitrogen treatments. Among them, nitrogen fertilizer treatments produced the greater panicle length than without nitrogen fertilizer. Bahmanyar and Mashaee, (2010) also found that panicle length was significantly influenced by nitrogen treatment. When PU and USG are compared, PU gave the higher panicle length that was statistically similar to USG fertilizer.

Panicle length was significantly different at 5% level among the phosphorus fertilizers treatments (Table 4.9). The maximum panicle length was resulted from TSP treatment (21.92 cm) which was statistically similar to that of DAP treatment (21.29 cm). The lowest was resulted from control (N_0P_0).

The interaction was not observed between nitrogen and phosphorus fertilizers in panicle length. Panicle length varied from 19.57 cm to 22.24 cm. The longest panicle length (22.24 cm) was obtained from the combined effect of N_2P_2 (PU + TSP) and the shortest panicle length (19.57 cm) was obtained from the combined effect of N_0P_0 (N & P omission).

4.1.2.3 Number of spikelets panicle^{-1}

Table 4.9 and 4.10 showed the results of number of spikelets panicle^{-1}. Statistical analysis showed significant difference at 1% level in number of spikelets panicle^{-1} between nitrogen treatments. Both USG and PU gave higher spikelets panicle^{-1} than control. It may be due the effect of nitrogen fertilizers. Dobermann and Fairhurst, 2000 reported that nitrogen promotes increased leaf size, spikelet number per panicle, percentage of filled spikelet in each panicle and grain protein content. The higher number of spikelets panicle^{-1} were obtained from USG (167.92) than PU (153.17) fertilizer. This may be due to the availability of more nitrogen from USG during grain formation and development that contributed to higher number of grains per panicle. Rama et al. (1989) also reported that the number of grains panicle^{-1} was higher due to deep placement of USG than PU application.

The application of phosphorus fertilizers were not significantly different (Pr = 0.6250) on number of spikelets panicle^{-1}. However, phosphorus application gave the greater spikeltes number than P omission. This finding was similar with Gebrekidan and Seyoum, 2006 that application of P increases the total number of spikelets per panicle in rice thereby contributing to increment in grain yield.

Combined effects of different sources of nitrogen and phosphorus fertilizer on spikelets panicle^{-1} ranged from 169.25 to 123.75 (Table 4.10). The highest number of spikelets panicle^{-1} (169.25) was occurred in N_2P_2 (USG + DAP) and the lowest number of spikelets panicle^{-1} was resulted from N_0P_0 (N & P omission).

Table 4.9 Mean effect of different sources nitrogen and phosphorus fertilizers on yield and yield components of rice during dry season, 2017

Treatments		No. of panicles hill^{-1}	No. of spikelets panicle^{-1}	1000 grain weight (g)	Filled grain %	Yield ton ha^{-1}	Panicle length (cm)	Harvest index (HI)
Nitrogen (N)								
N_0	N (omission)	12.96 c	127.25 c	20.21	74.16 b	4.68 c	20.65 b	0.47 b
N_1	PU	14.40 b	153.17 b	20.66	77.73 a	5.87 b	21.69 a	0.51 ab
N_2	USG	15.53 a	167.92 a	20.69	80.31 a	6.77 a	21.63 a	0.53 a
LSD $_{0.05}$		0.89	11.17	0.53	2.94	0.67	0.84	0.05
Phosphorus (P)								
P_0	P (omission)	13.39 b	146.42	20.28	76.32	5.17 b	20.76 b	0.49
P_1	TSP	14.83 a	150.58	20.57	77.67	5.86 a	21.92 a	0.50
P_2	DAP	14.67 a	151.33	20.71	78.23	6.27 a	21.29 ab	0.51
LSD $_{0.05}$		0.89	11.17	0.53	2.94	0.67	0.84	0.05
Pr>F								
Nitrogen (N)		0.0000	0.0000	0.1334	0.0009	0.0000	0.0285	0.0364
Phosphorus (P)		0.0047	0.6250	0.2595	0.4041	0.0101	0.0284	0.5764
N x P		0.1036	0.9974	0.6262	0.7547	0.9344	0.6271	0.8911
CV %		7.36	8.87	3.08	4.50	11.54	4.66	10.71

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

PU - Prilled Urea, USG - Urea Super Granule, TSP - Triple Super Phosphate, DAP - Diammonium Phosphate

Table 4.10 Combined effect of different sources nitrogen and phosphorus fertilizers on yield and yield components of rice during dry season, 2017

Treatments	No. of panicles hill^{-1}	No. of spikelts panicle^{-1}	1000 grain weight (g)	Filled grain %	Yield ton ha^{-1}	Panicle length (cm)	Harvest index (HI)
N_0P_0	11.09 d	123.75 d	19.64 b	73.49 c	3.92 e	19.57 b	0.45 b
N_0P_1	13.87 c	128.00 d	20.41 ab	74.49 c	4.92 de	21.53 a	0.47 ab
N_0P_2	13.92 c	130.00 cd	20.57 a	74.49 c	5.20 cd	20.84 ab	0.50 ab
N_1P_0	14.29 bc	149.25 bc	20.51 ab	75.17 bc	5.28 cd	21.25 a	0.51 ab
N_1P_1	14.59 abc	155.50 ab	20.62 a	78.33 abc	5.84 bcd	22.24 a	0.51 ab
N_1P_2	14.32 bc	154.75 ab	20.83 a	79.69 ab	6.48 ab	21.57 a	0.51 ab
N_2P_0	14.79 abc	166.25 ab	20.69 a	80.29 a	6.33 abc	21.46 a	0.52 ab
N_2P_1	16.03 a	168.25 ab	20.67 a	80.17 ab	6.83 ab	21.99 a	0.53 a
N_2P_2	15.78 ab	169.25 a	20.72 a	80.47 a	7.14 a	21.43 a	0.54 a
LSD $_{0.05}$	1.54	19.34	0.92	5.08	1.15	1.45	0.08
CV %	7.36	8.87	3.08	4.50	11.54	4.66	10.71

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

N_0P_0 = Control, N_0P_1 = 22 kg P ha^{-1} as TSP (Triple Super Phosphate), N_0P_2 = 22 kg P ha^{-1} as DAP (Diammonium phosphate),

N_1P_0 = 80 kg N ha^{-1} as Prilled Urea (PU), N_1P_1 = PU + TSP, N_1P_2 = PU + DAP

N_2P_0= 80 kg N ha^{-1} as USG (Urea Super Granule), N_2P_1 = USG +TSP, N_2P_2 = USG + DAP

4.1.2.4 Filled grain percent

The mean values of filled grain percent by the sources of nitrogen and phosphorus fertilizers was described in Table 4.9 and 4.10. The mean values of filled grain percent were highly significant difference in tested nitrogen fertilizers. Nitrogen fertilization provided the higher filled grain percent than nitrogen omission. In comparing N sources, USG gave the higher filled grain percent (80.13%) which was statistically similar to that of PU fertilizers application (77.73%). Yang et al., (2008) discussed that grain filling played an important role in grain weight, which is an essential determinant of grain yield in cereal crops.

The mean values of filled grain percent by phosphorus fertilizers application were not significant difference (Pr = 0.4041). Any source of P fertilizer gave the higher filled grain percent than P omission. The higher filled grain percent (78.23%) was resulted from DAP than TSP fertilizer treatments (77.67%).

The combined effects of the sources of nitrogen and phosphorus fertilizers were not significantly different on filled grain percent (Table 4.10). Filled grain percent was observed from 73.49 to 80.47% in this experiment. Maximum filled grain percent was found in treatment N_2P_2 (USG + DAP) and the lowest was resulted from control (N_0P_0).

4.1.2.5 1000 grain weight (g)

The different sources of nitrogen and phosphorus fertilizer and their combined effects on 1000 grain weight were shown in Table 4.9 and 4.10. There was no significant difference (Pr = 0.1334) on 1000 grain weight by nitrogen fertilizer treatments. Even though there was no significant difference, the higher 1000 grain weight was obtained from nitrogen application treatments than nitrogen omission treatments. In two types of nitrogen fertilizers, USG gave the higher value numerical value (20.69g) of 1000 grain weight than that of PU fertilizer (20.66g). Hasan (2007) and Alom (2002) stated that different nitrogen fertilizer did not have any significant effect on 1000 grain weight.

The mean effect of the phosphorus fertilizer treatments on thousand grain weight was not significantly different (Pr = 0.2595). The higher 1000 grain weight was obtained from phosphorus application than the recorded phosphorus omission. In comparing TSP and DAP fertilizers, the higher value was recorded from DAP than TSP treatment.

There was no significant interaction between the sources of nitrogen and phosphorus fertilizers in thousand grain weight in Table 4.10. Thousand grain weights ranged from 20.83g to 19.64g in the experiment. The maximum thousand grain weight was recorded from 20.83 N_1P_2 (PU+ DAP) and the minimum was resulted from control (N_0P_0). Thousand grains weight were not significantly influenced on nitrogen and phosphorus fertilizer application.

4.1.2.6 Harvest index (HI)

Harvest index of tested rice variety as affected by different sources of nitrogen and phosphorus fertilizer and their combined effects is presented in Table 4.9 and 4.10. Harvest index of rice was significant differences at 5% level among the nitrogen fertilizer treatments. Nitrogen application gave the higher harvest index than nitrogen omission treatments. The treatment with USG gave the higher harvest index (0.53) than PU treatment (0.51). Fageria (2007) reported that nitrogen fertilizer sources also improved grain harvest index which are positively associated with grain yield.

Harvest index (HI) had no significant different response to phosphorus fertilizer treatments in this experiment. According to findings of Alam et al. (2009), they also stated that no significant effect of phosphorus was found on the harvest index of rice.

No interaction effect was observed between different sources of nitrogen and phosphorus fertilizer on harvest index (HI). The maximum harvest index was recorded from N_2P_2 (USG + DAP) and the lowest was recorded from control (N_0P_0).

4.1.2.7 Grain yield (ton ha^{-1})

Grain yield of the different sources of nitrogen and phosphorus fertilizers and their combined effects was shown in Table 4.9 and 4.10. Grain yield of rice was highly significant differences among the nitrogen treatments. The nitrogen fertilizer treatment produced the greater grain yield while no nitrogen fertilizer treatment gave the lowest yield. It could be shown that grain yield of rice needed to use nitrogen fertilizers for getting higher yield. It may be due to the effect of nitrogen that can be increasingly affected to dry matter, panicle length and number of panicles per meter square which are correlated with grain yield (Bahmaniar and Ranjbar 2007). When compared the tested nitrogen sources, USG produced the higher yield (6.77 ton ha^{-1}) than PU fertilizer (5.87 ton ha^{-1}). This result could be explained by the fact that nitrogen supply with USG was synchronized with plant demand for N. Probably the continuous availability of N from USG played a vital role in cell division due to higher photosynthetic activities for the availability of N that helped in increasing the number of tillers. These results are in agreement with the findings of Hasanuzzaman et al. (2012) and Masum et al. (2008) who reported that USG produced the highest number of effective tillers hill^{-1}, filled grains panicle^{-1} which ultimately gave higher grain yield.

Table 4.9 showed that the grain yield was also significantly affected at 1% level by phosphorus fertilizer treatments. The greater grain yield was recorded from phosphorus application than no phosphorus fertilizer application. It showed that to produce higher rice yield, phosphorus fertilizers were needed. Within the tested phosphorus fertilizers, the higher numerically grain yield (6.27 ton ha^{-1}) was recorded from DAP treatment when compared to TSP treatment (5.86 ton ha^{-1}).

There was no interaction effect on number of grain yield by combination of the different sources of nitrogen and phosphorus fertilizers. The grain yield ranged from 7.14 ton ha^{-1} to 3.92 ton ha^{-1}. Although they were not significance different on number of grain yield, the maximum grain yield (7.14 ton ha^{-1}) was resulted from N_2P_2 (USG + DAP) and the minimum (3.92 ton ha^{-1}) from N_0P_0 (control).

4.1.2.8 Yield increase over control

The percent of grain yield increased over control were influenced by the application of the different sources of nitrogen and phosphorus fertilizers (Table 4.11). The increase in grain yield with USG and PU treatments over the control were 61% and 35% respectively. The grain yield of USG was 26% over PU fertilizer. It may be due to the effect of USG fertilizer that sufficiently supplied nitrogen for the entire rice growth stages and so increased grain yield than PU fertilizers. According to the results, USG fertilizer application was better than PU fertilizer. The increase in grain yield with TSP and DAP treatments over the control were 26% and 33%, respectively. Application of DAP gave the higher yield by 7% than application of TSP.

Any combined use of N and P fertilizers produced the higher yield than using N or P fertilizer alone. When PU combined with TSP or DAP, PU with DAP increased 16% than PU with TSP. When USG combined with any P fertilizer, USG + DAP produced more 8% yield than USG + TSP. According to my results, DAP fertilizer was better than TSP fertilizer. In all treatments, USG was produced the highest yield increase among other treatments when it applied alone or combined with any P fertilizers.

Table 4.11 Comparison of grain yield percent increase over control during dry season, 2017

Treatments	Yield increase (%)
PU	35
USG	61
TSP	26
DAP	33
PU + TSP	49
PU + DAP	65
USG + TSP	74
USG + DAP	82

4.1.3 Nutrient use efficiency

4.1.3.1 Nitrogen use efficiency (NUE)

Figure (4.5) showed the effect of N fertilizer on nitrogen use efficiency. Applying of nitrogen fertilizers were significantly difference in NUE at 5% level. Although they were not significant difference in NUE of PU and USG, USG gave higher NUE value than PU fertilizer. Siddika (2007) found that N-use efficiency was higher from USG in compared to prilled urea.

Nitrogen use efficiency was superior in combined application of any tested N and P fertilizers when compared with using N fertilizer alone. When PU fertilizer was applied with the tested phosphorus fertilizers, PU with DAP gave the higher NUE than with TSP. And also in USG combining with TSP and DAP, the higher NUE was resulted USG with DAP. The higher NUE was obtained from USG whatever it was applied alone or combined application of any tested P fertilizers than PU fertilizer in all treatments. Zaman et al. (1993) found that USG consistently produced significantly higher grain yield than PU. Also, nitrogen use efficiency was higher with USG than PU.

4.1.3.2 Phosphorus use efficiency (PUE)

The PUE as influenced by different sources of phosphorus fertilizers is presented in Figure 4.5. They were highly significance different in PUE as affected by the phosphorus fertilization. In the case of PUE, DAP fertilizer gave the value of PUE than that of TSP fertilizer because DAP fertilizer contains ammonium nitrogen 18% beyond P_2O_5 46%. When TSP or DAP are applied together with any tested nitrogen sources, the higher PUE was resulted from together DAP fertilizer.

The lowest NUE and PUE were obtained from the application of N and P fertilizers alone. It showed that application of N fertilizer without P fertilizer or application of P fertilizer without N fertilizer cannot get the better nutrient use efficiency. Sumner and Farina, 1986 reported that increased plant growth required both N and P that are mutually synergistic effects result in growth stimulation and enhanced uptake of both elements.

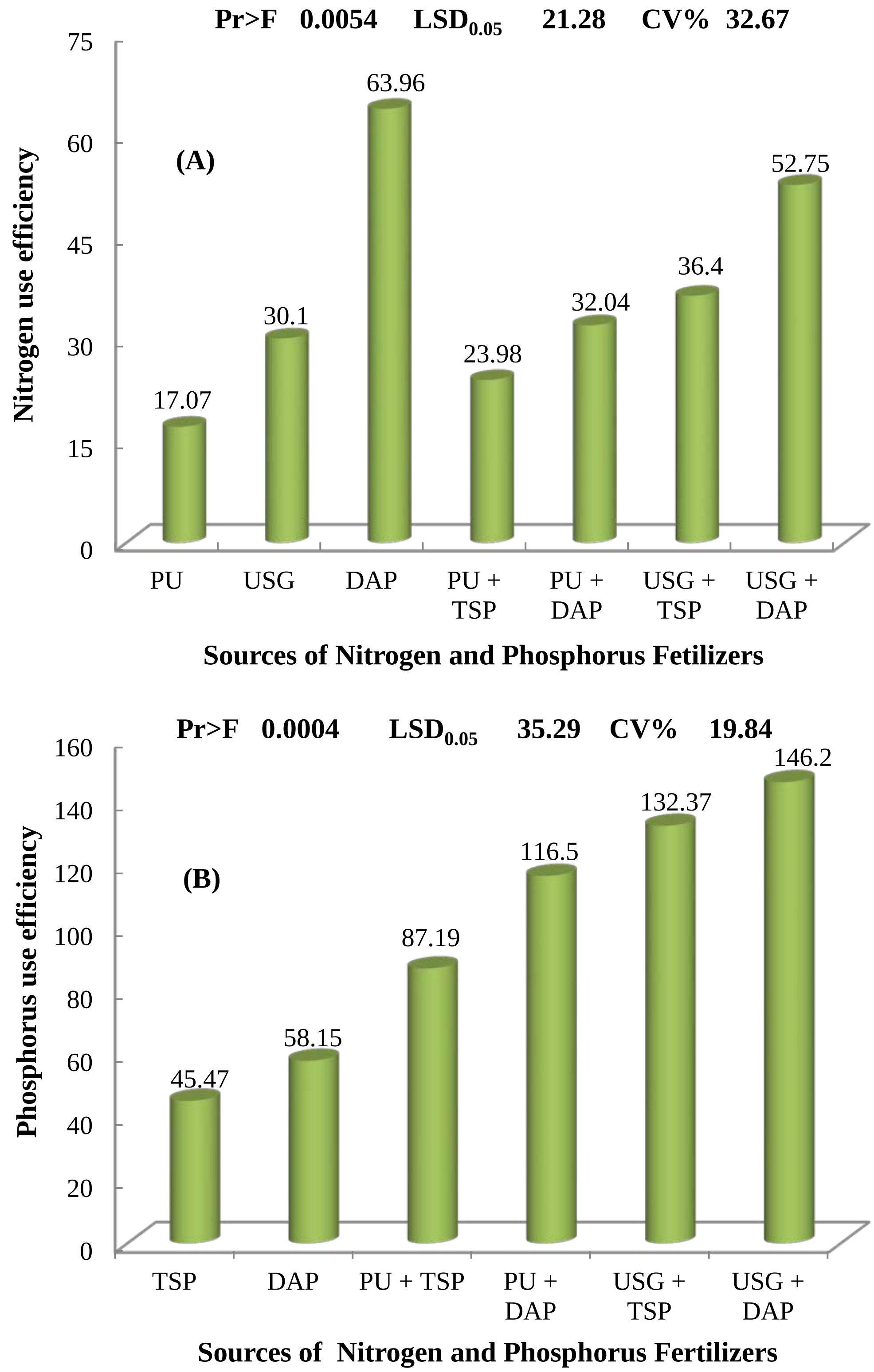


Figure 4.5 Mean values of nitrogen use efficiency (A) and phosphorus use efficiency (B) as affected by different sources of nitrogen and phosphorus fertilizers of rice during dry season, 2017

4.2 Field Experiment in Wet Season, 2017

The next experiment was conducted in the wet season during June to October. The experimental layout in this season was the same as previous dry season experiment to compare the response of rice yield and nutrient use efficiency of different sources of nitrogen and phosphorus fertilizers. Growth parameters, yield components and grain yield, and other growth parameters as affected by different sources of nitrogen and phosphorus fertilizers for wet season, 2017 are described and discussed in the following section.

4.2.1 Growth parameters

4.2.1.1 Plant height (cm)

Plant heights progressively increased from 14 to 84 day after transplanting (Figure 4.6). Plant heights were significantly different affected by nitrogen fertilizers application at all days after transplanting. The taller plant heights were recorded from nitrogen application plants than nitrogen omission. Furthermore, USG treatments gave the taller plant height than PU treatment at all collecting growth stages. This result was similar obtained by Singh and Singh (1980), Chakravorti (1989) and Alam (2002) who recorded a positive effect of USG on plant height.

In the resulted of application phosphorus fertilizers, plant heights were significantly different at 1% in 14 DAT and other collecting stages were not significantly different (Table 4.12). The taller plant heights were recorded from phosphorus application treatments than no phosphorus fertilizer application. It could be said that P can increase the plant height at initial stage of rice life cycle. De Datta (1981) has also been reported that after rice plants have attained the vegetative stage, and then the differences in P did not affect the plant height significantly. In the tested P sources, the higher plant height was obtained from DAP than TSP at 84 DAT.

Although there were no significant interaction of nitrogen and phosphorus on plant height, USG with DAP treatment gave the highest plant height among treatments in the analysis of variance (Table 4.13).

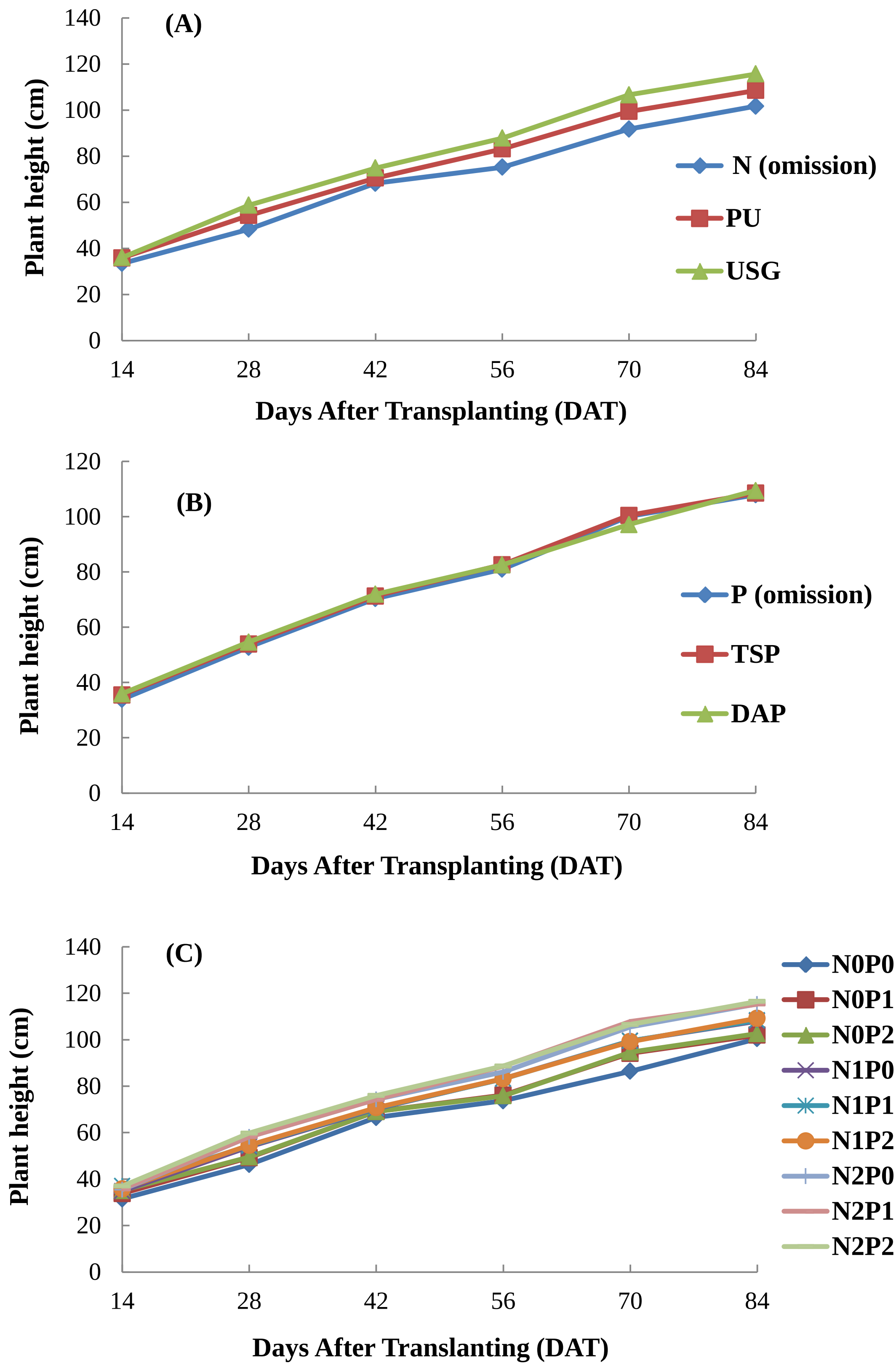


Figure 4.6 Mean value of plant height (cm) as affected by different sources of (A) nitrogen fertilizers, (B) phosphorus fertilizers and (C) their combination during wet season, 2017

Table 4.12 Mean effects of different sources of nitrogen and phosphorus fertilizers on plant height of rice during wet season, 2017

Treatments		Plant height (cm)					
		14 DAT	**28DAT**	**42 DAT**	**56 DAT**	**70 DAT**	**84 DAT**
Nitrogen (N)							
N_0	N (omission)	33.45 b	48.33 c	68.23 b	75.23 c	91.73 c	101.68 c
N_1	PU	35.88 a	54.30 b	70.52 b	83.19 b	99.42 b	108.53 b
N_2	USG	36.05 a	58.73 a	74.87 a	87.83 a	106.63 a	115.70 a
$LSD_{0.05}$		1.26	2.47	3.29	3.19	4.04	5.04
Phosphorus (P)							
P_0	P (omission)	33.92 b	52.78	70.37	81.02	100.14	107.93
P_1	TSP	35.52 a	53.97	71.32	82.63	100.50	108.54
P_2	DAP	35.93 a	54.62	71.93	82.60	97.15	109.44
$LSD_{0.05}$		1.26	2.47	3.29	3.19	4.04	5.04
Pr>F							
Nitrogen (N)		0.0004	0.0000	0.0013	0.0000	0.0000	0.0000
Phosphorus (P)		0.0074	0.3177	0.6190	0.5022	0.1928	0.8247
N x P		0.2252	0.8274	0.9525	0.9401	0.3776	0.99992
CV %		4.26	5.46	5.49	4.61	4.83	5.51

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

PU - Prilled Urea, USG - Urea Super Granule, TSP - Triple Super Phosphate, DAP - Diammonium Phosphate

Table 4.13 Combined effects of different sources of nitrogen and phosphorus fertilizers on plant height of rice during wet season, 2017

Treatments	Plant height (cm)					
	14 DAT	**28 DAT**	**42 DAT**	**56 DAT**	**70 DAT**	**84 DAT**
N_0P_0	31.50 c	46.25 d	66.55 c	73.70 c	86.40 d	100.45 c
N_0P_1	33.80 b	49.25 d	69.10 bc	76.14 c	94.15 c	101.97 bc
N_0P_2	35.05 ab	49.50 d	69.05 bc	75.85 c	94.65 c	102.62 bc
N_1P_0	34.85 ab	53.95 c	70.25 bc	83.22 ab	99.55 bc	107.99 abc
N_1P_1	37.00 a	54.40 bc	70.55 abc	83.10 b	99.50 bc	108.34 abc
N_1P_2	35.75 ab	54.55 bc	70.75 abc	83.25 ab	99.21 bc	109.25 ab
N_2P_0	35.40 ab	58.15 abc	74.30 ab	86.15 ab	105.50 ab	115.35 a
N_2P_1	35.75 ab	58.25 ab	74.30 ab	88.65 a	107.85 a	115.30 a
N_2P_2	37.00 a	59.80 a	76.00 a	88.70 a	106.55 a	116.45 a
$LSD_{0.05}$	2.19	4.28	5.70	5.52	6.99	8.73
CV %	4.26	5.46	5.49	4.61	4.83	5.51

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

N_0P_0 = Control, N_0P_1 = 22 kg P ha^{-1} as TSP (Triple Super Phosphate), N_0P_2 = 22 kg P ha^{-1} as DAP (Diammonium phosphate),

N_1P_0 = 80 kg N ha^{-1} as Prilled Urea (PU), N_1P_1 = PU+ TSP, N_1P_2 = PU + DAP

N_2P_0= 80 kg N ha^{-1} as USG (Urea Super Granule), N_2P_1 = USG +TSP, N_2P_2 = USG + DAP

4.2.1.2 Number of tillers hill^{-1}

Number of tillers hill^{-1} was recorded from 14 to 84 DAT and were shown in Table (4.14). Number of tillers hill^{-1} was significant difference by the nitrogen fertilization in 14 DAT and highly significant in 28, 42, 56, 70 and 84 DAT. The greater number of tillers hill^{-1} produced from nitrogen fertilizers application than N omission. According to the result of Irshad et al.(2000) they showed that number of tillers per hill was significantly increased by nitrogen application. Between the tested nitrogen fertilizers, USG produced the greater number of tillers hill^{-1} than PU fertilizer at 70 and 84 DAT. This finding was similar with Alam (2002) that total tillers hill-1 and effective tillers hill^{-1} increased significantly when USG was applied.
There was no significant effect on number of tillers hill^{-1} by application of phosphorus fertilizers (Table 4.14). Numerically, phosphorus fertilizers application produced more number of tillers hill^{-1} than P omission. These findings are in similar with Yoseftabar (2012) who recorded no significant differences in tiller numbers due to phosphorus fertilizers application. Number of tiller hill^{-1} were not significant different by the tested TSP and DAP fertilizers.

Number of tillers hill^{-1} as affected by the combination of different sources nitrogen and phosphorus fertilizers were not significant difference as presented in (Table 4.15). The highest number of tillers hill^{-1} was recorded from N_2P_2 (USG + DAP) and the lowest was resulted from N_0P_0.

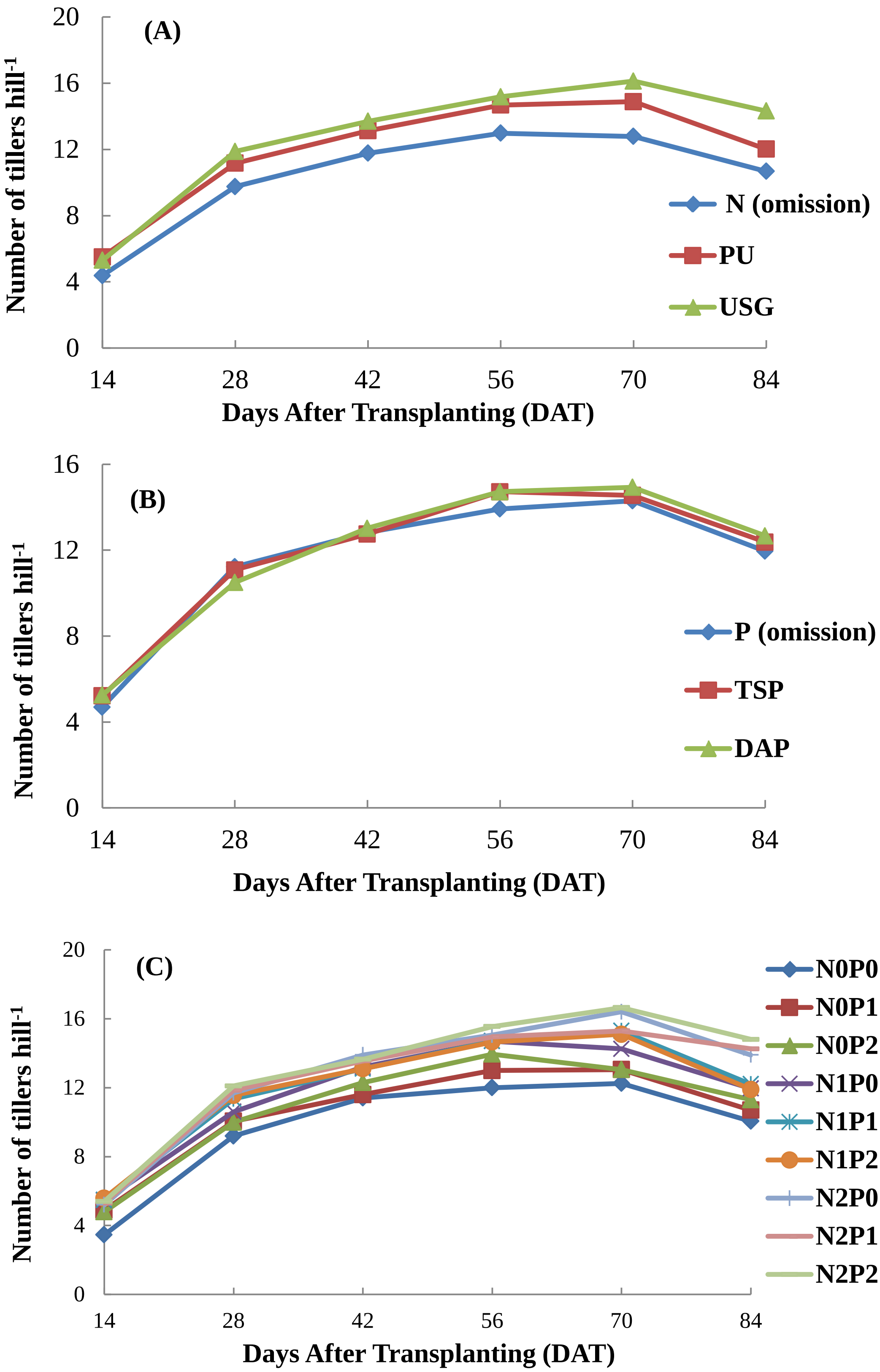


Figure 4.7 Mean value of number of tillers hill^{-1} as affected by different sources of (A) nitrogen fertilizers, (B) phosphorus fertilizers and (C) their combination during wet season, 2017

Table 4.14 Mean effects of different sources of nitrogen and phosphorus fertilizers on number of tillers hill^{-1} of rice during wet season, 2017

Treatments		Number of tillers hill^{-1}					
		14 DAT	28DAT	42 DAT	56 DAT	70 DAT	84 DAT
Nitrogen (N)							
N_0	N (omission)	4.38 b	9.75 b	11.77 b	12.98 b	12.78 c	10.68 c
N_1	PU	5.51 a	11.17 a	13.13 a	14.68 a	14.88 b	12.02 b
N_2	USG	5.30 a	11.88 a	13.70 a	15.18 a	16.12 a	14.32 a
$LSD_{0.05}$		0.86	0.85	0.98	0.977	1.08	1.26
Phosphorus (P)							
P_0	P(omission)	4.70	11.23	12.83	13.92	14.30	11.96
P_1	TSP	5.22	11.08	12.75	14.72	14.55	12.38
P_2	DAP	5.26	10.50	13.02	14.72	14.93	12.67
$LSD_{0.05}$		0.86	0.85	098	0.977	1.08	1.26
Pr>F							
Nitrogen Source (N)		0.0285	0.0001	0.0014	0.0003	0.0000	0.0000
Phosphorus Source		0.3460	0.1998	0.8493	0.2528	0.4883	0.5243
N x P		0.6107	0.9542	0.8754	0.5135	0.4856	0.9226
CV %		20.27	9.20	9.06	8.12	8.81	12.14

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

PU - Prilled Urea, USG - Urea Super Granule, TSP - Triple Super Phosphate, DAP - Diammonium Phosphate

Table 4.15 Combined effects of different sources of nitrogen and phosphorus fertilizers on number of tillers hill^{-1} of rice during wet season, 2017

Treatments	Number of tillers hill^{-1}					
	14 DAT	**28 DAT**	**42 DAT**	**56 DAT**	**70 DAT**	**84 DAT**
N_0P_0	3.46 b	9.20 d	11.40 c	12.00 c	12.25 d	10.05 d
N_0P_1	4.89 ab	10.05 cd	11.60 bc	13.00 bc	13.05 cd	10.70 d
N_0P_2	4.79 ab	10.00 cd	12.30 abc	13.95	13.05 cd	11.30 d
N_1P_0	5.45 a	10.60 bcd	13.20 ab	14.70 a	14.25 bc	11.95 cd
N_1P_1	5.49 a	11.35 abc	13.10 abc	14.70 a	15.30 ab	12.20 bcd
N_1P_2	5.59 a	11.55 ab	13.10 abc	14.65 ab	15.10 ab	11.90 cd
N_2P_0	5.20 ab	11.70 ab	13.90 a	15.05 a	16.40 a	13.90 abc
N_2P_1	5.30 a	11.85 ab	13.55 a	14.95 a	15.30 ab	14.25 ab
N_2P_2	5.40 a	12.10 a	13.65 a	15.55 a	16.65 a	14.80 a
LSD $_{0.05}$	1.49	1.47	17.0	1.69	1.87	2.19
CV %	20.27	9.20	9.06	8.12	8.81	12.14

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

N_0P_0 = Control, N_0P_1 = 22 kg P ha^{-1} as TSP (Triple Super Phosphate), N_0P_2 = 22 kg P ha^{-1} as DAP (Diammonium phosphate),

N_1P_0 = 80 kg N ha^{-1} as Prilled Urea (PU), N_1P_1 = PU+ TSP, N_1P_2 = PU+ DAP

N_2P_0= 80 kg N ha^{-1} as USG (Urea Super Granule), N_2P_1 = USG +TSP, N_2P_2 = USG + DAP

4.2.1.3 SPAD reading

The value of SPAD collected two weeks interval stating from 14 DAT to 84 DAT varied with the application of nitrogen fertilizers (Figure 4.8). There were highly significantly different in the tested nitrogen fertilizer in all collecting DAT except 14 DAT. The higher SPAD value was recorded from nitrogen application than nitrogen omission. This result agree with the finding of Rodriquez (2000) reported that SPAD-502 chlorophyll meter readings were affected by applications of N fertilizer sources. In comparing PU and USG fertilizers, the higher SPAD reading was recorded from USG than PU at all DAT. Nguyen quang co (2015) reported that deep fertilizer application had highest SPAD values than other type and fertilizer.

The means effect of SPAD value by phosphorus fertilizers were not significant different (Table 4.16). Numerically, phosphorus fertilizer application produced the greater SPAD than P omission. Shaobing Peng (1999) reported that higher SPAD values of zero-P plants at the same leaf N concentration was not associated with the differences in leaf thickness between zero-P and P-treated plants. When compared the two tested P fertilizers, DAP fertilizer gave higher SPAD value in numerical value than TSP fertilizer. It may be due the containing of nitrogen fertilizer in DAP beyond phosphorus content.

There were no significant interactions between different sources of nitrogen and phosphorus fertilizer on SPAD value.

4.2.1.4 Total dry matter (TDM)

Total dry matters were collected at active tillering, panicle initiation, heading and harvesting stages. The progressive improvements of total dry matter were recorded from active tillering to harvesting stages (Figure 4.9). Nitrogen fertilizations were highly significant difference on total dry matter in all collecting growth stages (Table 4.18). The higher total dry matter was resulted from nitrogen treatment than nitrogen omission. This finding was line with the results of Ju et al. 2009; Lin et al. 2009; Fukushima et al., 2011, they found the with nitrogen fertilizer application, the rice plant can absorb and produce more dry matter. In two types of nitrogen fertilizers, USG significantly provided the greater total dry matter than PU fertilizer at all collecting stages except active tillering stage. Masum et al. (2008) also revealed that USG applied plants gave higher TDM compared to prilled urea.

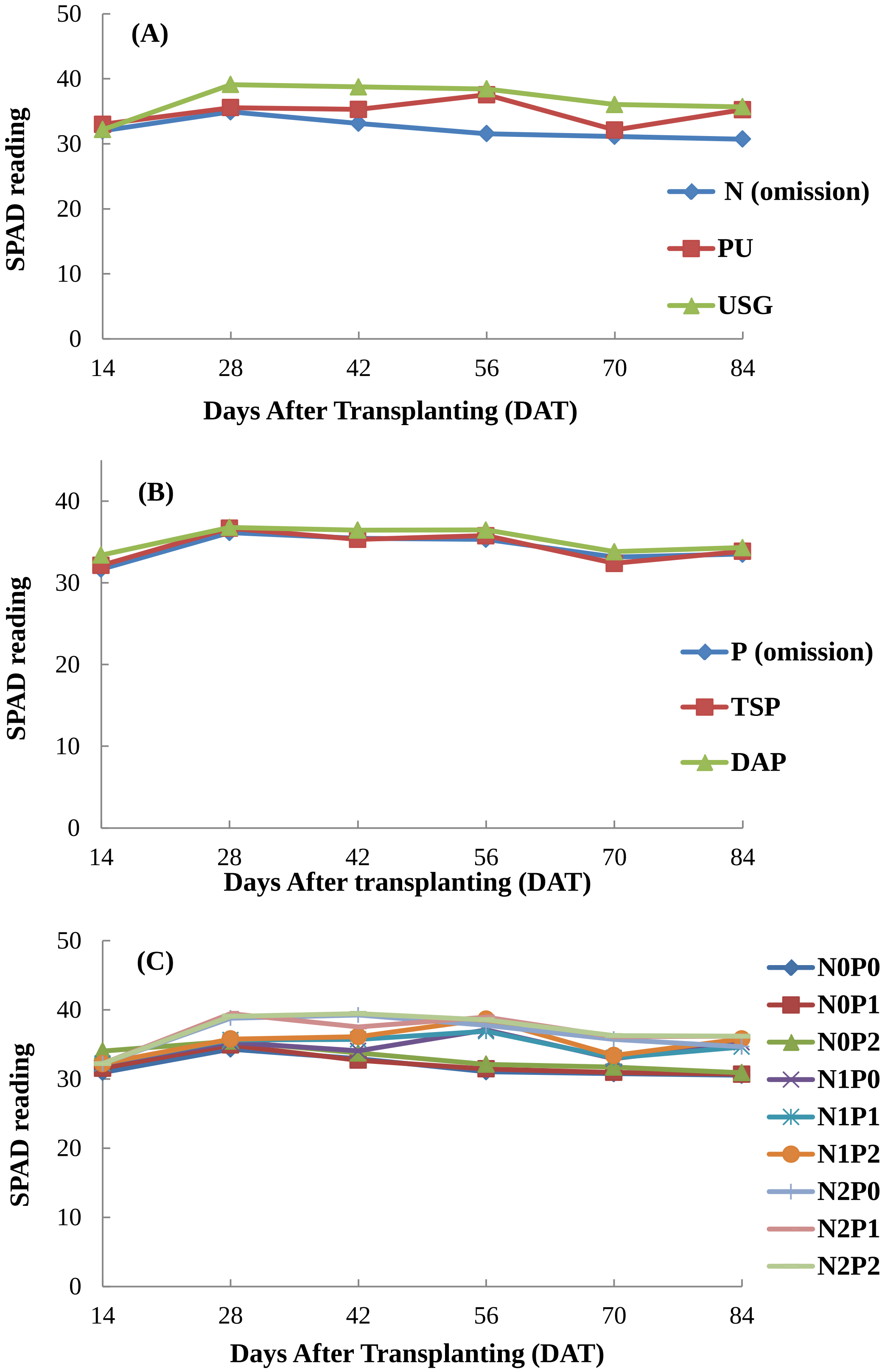


Figure 4.8 Mean value of SPAD reading as affected by different sources of (A) nitrogen fertilizers, (B) phosphorus fertilizers and (C) their combination during wet season, 2017

Table 4.16 Mean effects of different sources of nitrogen and phosphorus fertilizers on SPAD value of rice during wet season, 2017

Treatments		SPAD value					
		14 DAT	**28DAT**	**42 DAT**	**56 DAT**	**70 DAT**	**84 DAT**
Nitrogen (N)							
N_0	N (omission)	31.99	34.91 b	33.15 c	31.55 b	31.15 c	30.72 b
N_1	PU	33.00	35.57 b	35.30 b	37.55 a	32.12 b	35.25 a
N_2	USG	32.19	39.11 a	38.75 a	38.44 a	36.05 a	35.69 a
$LSD_{0.05}$		1.65	1.25	1.14	1.71	0.97	1.22
Phosphorus (P)							
P_0	P (omission)	31.67 b	36.14	35.43	35.31	33.15	33.50
P_1	TSP	32.13 ab	36.68	35.32	35.77	32.38	33.85
P_2	DAP	33.39 a	36.77	36.45	36.46	33.80	34.30
$LSD_{0.05}$		1.65	1.25	1.14	1.71	0.97	1.37
Pr>F							
Nitrogen Source (N)		0.4265	0.0000	0.0000	0.0000	0.0000	0.0000
Phosphorus Source		0.1032	0.5399	0.0968	0.3981	0.3914	0.4090
N x P		0.6698	0.9660	0.2065	0.8806	0.9835	0.6593
CV %		6.04	4.05	3.77	5.68	3.45	4.27

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

PU - Prilled Urea, USG - Urea Super Granule, TSP - Triple Super Phosphate, DAP - Diammonium Phosphate

Table 4.17 Combined effects of different sources of nitrogen and phosphorus fertilizers on SPAD value of rice during wet season, 2017.

Treatments	SPAD value					
	14 DAT	**28 DAT**	**42 DAT**	**56 DAT**	**70 DAT**	**84 DAT**
N_0P_0	30.95 b	34.33 b	32.96 d	31.06 b	30.79 d	30.54 b
N_0P_1	31.57 ab	34.93 b	32.73 d	31.46 b	30.95 d	30.71 b
N_0P_2	34.05 a	35.46 b	33.76 cd	32.14 b	31.72 cd	30.91 b
N_1P_0	32.24 ab	35.29 b	34.07 cd	37.09 a	32.94 bc	35.28 a
N_1P_1	33.35 ab	35.64 b	35.72 bc	36.90 a	33.05 bc	34.65 a
N_1P_2	33.41 ab	35.78 b	36.13 b	38.67 a	33.41 b	35.81 a
N_2P_0	31.81 ab	38.80 a	39.26 a	37.79 a	35.74 a	34.69 a
N_2P_1	31.47 ab	39.47 a	37.53 ab	38.97 a	36.14 a	36.19 a
N_2P_2	32.72 ab	39.07 a	39.47 a	38.57 a	36.28 a	36.19 a
$LSD_{0.05}$	2.86	3.16	1.97	3.29	2.27	2.38
CV %	6.04	4.05	3.77	5.68	3.45	4.27

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

N_0P_0 = Control, N_0P_1 = 22 kg P ha^{-1} as TSP (Triple Super Phosphate), N_0P_2 = 22 kg P ha^{-1} as DAP (Diammonium phosphate),

N_1P_0 = 80 kg N ha^{-1} as Prilled Urea (PU), N_1P_1 = PU + TSP, N_1P_2 = PU+ DAP

N_2P_0= 80 kg N ha^{-1} as USG (Urea Super Granule), N_2P_1 = USG +TSP, N_2P_2 = USG + DAP

The application of phosphorus fertilizers was not significant difference on total dry matter. However, phosphorus fertilizers application gave the higher numerical total dry matter value than P omission. In comparing TSP and DAP fertilizers, DAP gave the higher total dry matter in numerical value than TSP fertilizer.

Mean effect of the total dry matter between the combination of different sources of nitrogen and phosphorus fertilizer were presented in Table 4.19. Although no significant interaction was observed with the combination of nitrogen and phosphorus, USG + DAP was numerically the higher total dry matter than other combined treatments.

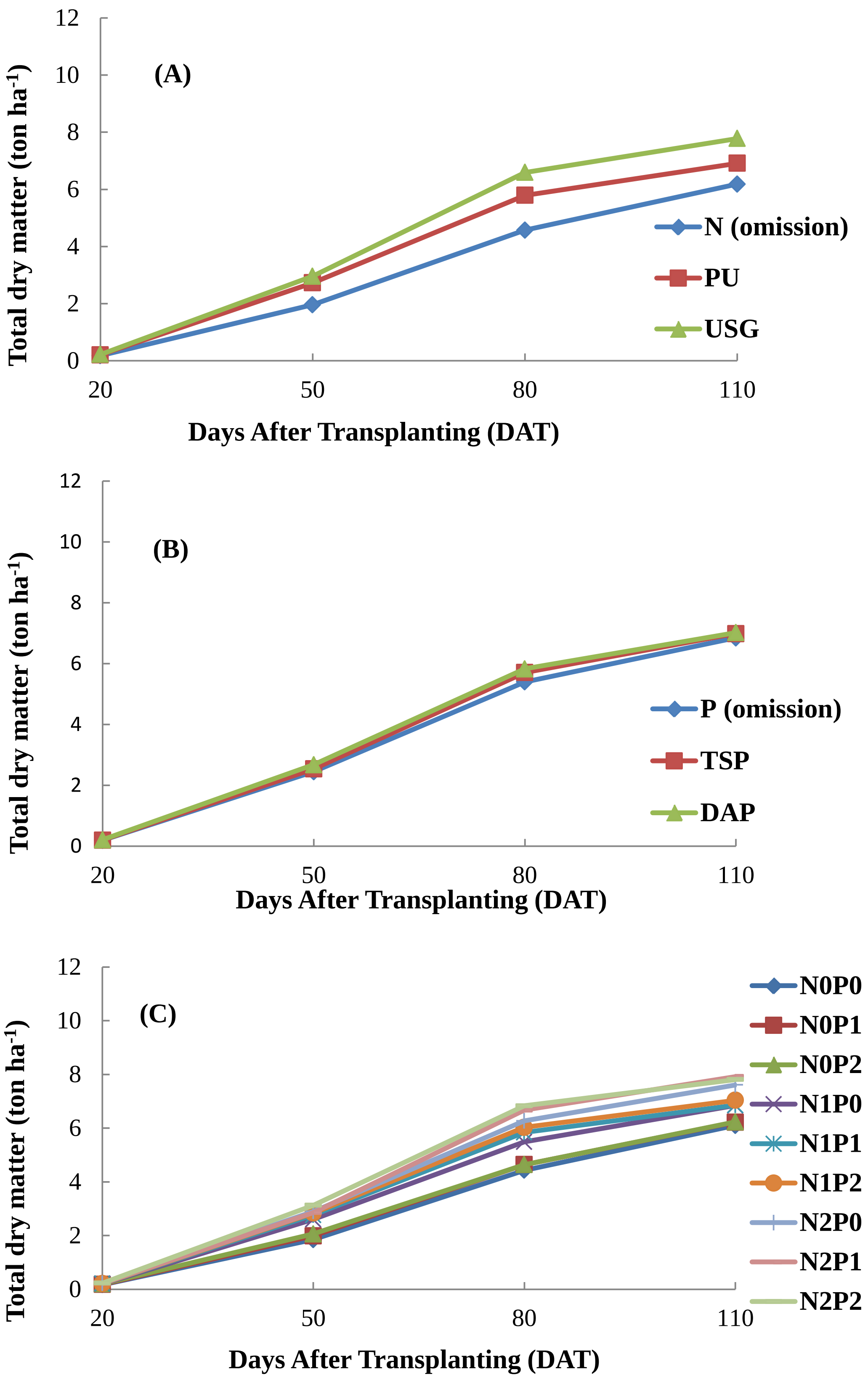


Figure 4.9 Mean value of total dry matter as affected by the source of (A) nitrogen fertilizers, (B) phosphorus fertilizers and (C) their combination during wet season, 2017

Table 4.18 Mean effects of different sources of nitrogen and phosphorus fertilizers on total dry matter of rice during wet season, 2017

Treatments		Total Dry Matter (ton ha^{-1})			
		Active tillering	Panicle Initiation	Heading Stage	Harvesting Stage
Nitrogen (N)					
N_0	N (omission)	0.18 b	1.96 c	4.57 c	6.18 c
N_1	PU	0.21 a	2.73 b	5.79 b	6.91 b
N_2	USG	0.22 a	2.96 a	6.59 a	7.78 a
$LSD_{0.05}$		0.02	0.20	0.38	0.33
Phosphorus (P)					
P_0	P (omission)	0.19	2.45	5.40	6.85
P_1	TSP	0.20	2.54	5.71	6.99
P_2	DAP	0.21	2.68	5.83	7.03
$LSD_{0.05}$		0.02	0.20	0.38	0.33
Pr>F					
Nitrogen (N)		0.0005	0.0000	0.0000	0.0000
Phosphorus (P)		0.1283	0.0944	0.0722	0.5049
N x P		0.7471	0.8843	0.9399	0.9326
CV %		9.99	9.49	7.97	5.62

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

PU - Prilled Urea, USG - Urea Super Granule, TSP - Triple Super Phosphate, DAP - Diammonium Phosphate

Table 4.19 Combined effects of different sources of nitrogen and phosphorus fertilizers on total dry matter of rice during wet season, 2017

Treatments	Total Dry Matter (ton ha $^{-1}$)			
	Active tillering	**Panicle Initiation**	**Heading stage**	**Harvesting stage**
N_0P_0	0.17 c	1.85 c	4.43 e	5.61 d
N_0P_1	0.18 bc	1.99 c	4.64 e	6.22 d
N_0P_2	0.20 ab	2.06 c	4.64 e	6.23 d
N_1P_0	0.20 ab	2.60 b	5.49 d	6.84 c
N_1P_1	0.21 a	2.76 b	5.84 cd	6.85 c
N_1P_2	0.21 a	2.84 ab	6.03 bcd	7.04 bc
N_2P_0	0.22 a	2.90 ab	6.27 abc	7.61 ab
N_2P_1	0.22 a	2.86 ab	6.67 ab	7.92 a
N_2P_2	0.23 a	3.13 a	6.83 a	7.81 a
$LSD_{0.05}$	0.03	0.35	0.66	0.57
CV %	9.99	9.49	7.97	5.62

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

N_0P_0 = Control, N_0P_1 = 22 kg P ha^{-1} as TSP (Triple Super Phosphate), N_0P_2 = 22 kg P ha^{-1} as DAP (Diammonium phosphate),

N_1P_0 = 80 kg N ha^{-1} as Prilled Urea (PU), N_1P_1 = PU+ TSP, N_1P_2 = PU+ DAP

N_2P_0= 80 kg N ha^{-1} as USG (Urea Super Granule), N_2P_1 = USG +TSP, N_2P_2 = USG + DAP

4.2.2 Yield and yield components parameters

4.2.2.1 Number of panicles hill^{-1}

Number of panicles hill^{-1} by the application of nitrogen fertilizer were highly significant different as shown in Table 4.20. It was increased with the application of nitrogen regardless of the sources over the nitrogen omission. Chopra and Chopra (2000) reported that effective tillers hill^{-1} increased with the application of nitrogen fertilizer. Urea super granule treatment gave the higher number of panicles hill^{-1} (12.97) than prilled urea fertilizer treatment (10.37). This result was agreement Chander and Pandey (1996) and Jee and Mahapatra (1989) mentioned that the deep placement of USG produced higher number of bearing tillers hill^{-1} than PU application.

There was no significant difference (Pr =0.5159) on number of panicles hill^{-1} by phosphorus fertilizer treatments (Table 4.20). Phosphorus fertilizer produced the greater panicle number than P omission. Alam et al. (2009) also founded that the application of phosphorus fertilizer increased tiller production.

The interaction effects between the source of nitrogen and phosphorus fertilizers were not found in number of panicle hill^{-1} (Table 4.21). Number of panicles hill^{-1} ranged from 8.55 to 13.80. The greater number of panicles hill^{-1} (13.80) was presented from USG + DAP than no nitrogen and phosphorus application.

4.2.2.2 Panicle length (cm)

Mean data recording the panicle length as affected by the different sources of nitrogen fertilizers were shown in Table 4.20. The panicle length was highly significant difference by the application of nitrogen fertilizers. The greater panicle length (21.55 and 21.13 cm) was resulted from the nitrogen fertilizers application treatments (PU and USG) than N omission (20.51cm). The higher panicle length (21.55cm) was resulted from USG that was statistically similar with PU (21.13cm). This result indicated that the panicle length showed non- significant variation due to the sources of forms of urea. These results were similar who have found that there were no significant difference in panicle length due to application of USG and PU (Sen and Pandey 1990).

Panicle length of the treatments with the different sources of phosphorus fertilizers were not significant (Pr = 0.7262). The higher panicle length was attained from TSP and DAP phosphorus fertilizers treatments (21.12 and 21.19 cm) in numerically than P omission (20.93 cm).

The interaction was not observed between the different source of the nitrogen and phosphorus fertilizers on panicle length (Table 4.21). Panicle length varied from 20.45 to 21.61 cm. The highest panicle length was recorded from USG + DAP. The minimum was resulted from N and P omission.

4.2.2.3 Number of spikelets panicle^{-1}

Number of spikelets panicle^{-1} were highly significant different in nitrogen fertilizer application (Table 4.20). The grater spikelets numbers were obtained from nitrogen application than no nitrogen treatments. The USG treatment produced the higher number of spikelets panicle^{-1} (152.18) statistically than PU fertilizer treatment (139.93). Sufficient supply of nitrogen as the form of USG contributed to grain formation which probably increased number of spikelets panicle^{-1}. Rama et al., (1989) reported that the number of grains panicle^{-1} was higher due to deep placement of USG than PU application. Moreover, Kumar et al. (1995) also stated that increased number of filled grains panicle^{-1} with the application of USG might be due to availability of nitrogen for seed formation and higher partitioning of dry matter to the grains.

Mean effect of the number of spikelets panicle^{-1} by the different sources of phosphorus fertilizers was presented in Table 4.20. Phosphorus fertilizers application was not significant different (Pr = 0.2259) on number of spikelets panicle^{-1}. The higher number of spikelets panicle^{-1} (141.39) recorded from DAP which was followed by TSP treatment (139.42) than P omission (132.79).

There was no significant interaction by the combination of the different sources of nitrogen and phosphorus fertilizers (Table 4.21). The highest number of spikelets panicle^{-1} (157.10) was recorded from N_2P_2 (USG + DAP) the minimum (118.60) was found from control N_0P_0 (N and P omission).

4.1.2.4 Filled grain percent

The mean values of filled grain percent by the sources of nitrogen and phosphorus fertilizers was described in Table 4.20. The nitrogen fertilizer application treatments were highly significant difference on filled grain percent. The higher filled grain percent was recorded from nitrogen fertilization when compared with no P fertilizer application. The application of USG (78.24%) gave superior filled grain percent than PU fertilizer treatments (75.96%). Filled grains percent was not affected by the form of urea. According to the finding of Castro and Sarker (2000), they stated that number of filled grain panicle increased with the application of nitrogen fertilizer.

Table 4.20 Mean effect of different sources nitrogen and phosphorus fertilizers on yield and yield components of rice during wet season, 2017

Treatments		No. of panicles hill^{-1}	No. of spikelets Panicle^{-1}	1000 grain weight (g)	Filled grain (%)	Yield ton ha^{-1}	Panicle length (cm)	Harvest index (HI)
Nitrogen (N)								
N_0	N (omission)	9.27 c	121.50 c	20.54	72.70 b	3.33 c	20.51 b	0.45 c
N_1	PU	10.37 b	139.93 b	20.65	75.96 a	4.16 b	21.13 a	0.48 b
N_2	USG	12.97 a	152.18 a	21.00	78.24 a	4.84 a	21.55 a	0.50 a
LSD $_{0.05}$		1.00	10.45	0.59	2.49	0.55	0.59	0.02
Phosphorus (P)								
P_0	P (omission)	10.58	132.79	20.52	74.99	3.86	20.93	0.47
P_1	TSP	10.87	139.42	20.84	75.77	4.18	21.12	0.48
P_2	DAP	11.15	141.39	20.84	76.13	4.29	21.19	0.49
LSD $_{0.05}$		1.00	10.45	0.59	2.49	0.55	0.59	0.02
Pr>F								
Nitrogen		0.0000	0.0000	0.2694	0.0005	0.0000	0.0053	0.0001
Phosphorus		0.5159	0.2259	0.4518	0.6332	0.2396	0.7262	0.0621
N x P		0.4001	0.5928	0.4214	0.8754	0.9838	0.9747	0.3388
CV %		10.95	8.99	3.41	3.90	15.75	3.36	4.80

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

PU - Prilled Urea, USG - Urea Super Granule, TSP - Triple Super Phosphate, DAP - Diammonium Phosphate

Table 4.21 Combined effect of different sources nitrogen and phosphorus fertilizers on yield and yield components of rice during wet season, 2017

Treatments	No. of panicles hill^{-1}	No. of spikelts Panicle^{-1}	1000 grain weight (g)	Filled grain %	Yield ton ha^{-1}	Panicle length (cm)	Harvest index (HI)
N_0P_0	8.55 c	118.60 c	19.89 b	72.67 c	2.96 d	20.45 b	0.43 d
N_0P_1	9.70 bc	120.84 c	20.81 ab	72.69 c	3.44 cd	20.46 b	0.46 c
N_0P_2	9.55 bc	125.04 bc	20.92 a	72.75 c	3.60 cd	20.62 ab	0.47 bc
N_1P_0	10.65 b	130.43 bc	20.79 ab	74.34 bc	3.92 bc	20.88 ab	0.47 bc
N_1P_1	10.35 b	140.33 ab	20.63 ab	76.79 abc	4.27 abc	21.34 ab	0.47 bc
N_1P_2	10.10 bc	149.03 a	20.52 ab	76.75 abc	4.30 abc	21.19 ab	0.49 abc
N_2P_0	12.55 a	149.34 a	20.87 ab	77.98 ab	4.68 ab	21.47 ab	0.50 ab
N_2P_1	12.55 a	150.10 a	21.06 a	77.83 ab	4.85 a	21.58 a	0.50 ab
N_2P_2	13.80 a	157.10 a	21.07 a	78.91 a	4.99 a	21.61	0.53 a
LSD $_{0.05}$	1.74	18.09	1.03	4.31	0.95	1.03	0.03
CV %	10.95	8.99	3.41	3.90	15.75	3.36	4.80

In each column, means followed by a same letters are not significantly different at LSD test 5% level.

N_0P_0 = Control, N_0P_1 = 22 kg P ha^{-1} as TSP (Triple Super Phosphate), N_0P_2 = 22 kg P ha^{-1} as DAP (Diammonium phosphate),

N_1P_0 = 80 kg N ha^{-1} as Prilled Urea (PU), N_1P_1 = PU + TSP, N_1P_2 = PU + DAP

N_2P_0= 80 kg N ha^{-1} as USG (Urea Super Granule), N_2P_1 = USG +TSP, N_2P_2 = USG + DAP

The mean values of filled grain percent were not significant different (Pr = 0.6332) by phosphorus treatments (Table 4.20). Phosphorus treatments (TSP and DAP) gave the numerically higher filled grain percent (75.77% and 76.13%) than P omission treatment (74.99%).

Mean effects of the combination of the different sources of nitrogen and phosphorus fertilizers were not significant difference (Pr = 0.8754) on filled grain percent. Filled grain percent ranged from 78.91 to 72.67%. The maximum filled grain percent (78.91) was found from USG + DAP and the minimum (72.67%) was recorded from N &P omission.

4.2.2.5 1000 grain weight (g)

1000 grain weight as affected by different sources of nitrogen and phosphorus fertilizer and their combined effects was shown in Table 4.20 and 4.21. The source of prilled urea and urea super granules exerted non-significant response on 1000-grain weight. Apparently the highest 1000-grain weight (21.00 g) was obtained with USG. The lowest 1000-grain weight (20.54 g) was observed at N_0 application. Sarder et al. (1988) and Mannan et al. (2010) found that no significant difference in 1000 grains weight due to the application of N.

The mean effect of the sources of phosphorus fertilizer treatments on thousand grain weight was not significantly different in table 4.20. Thousand grains weight was not significantly different (Pr = 0.4518) by the application of phosphorus fertilizer.

The interaction effect of the source of phosphorus and nitrogen with respect to 1000-grain weight was found to be statistically non-significant (Table 4.22). 1000 grain weight ranged from 19.89 to 21.07g. The maximum 1000 grain weight (21.07g) was found by USG + DAP, USG + TSP and the lowest (19.89g) was recorded from N and P omission.

4.2.2.6 Harvest index (HI)

Harvest index of tested rice variety as affected by different sources of nitrogen and phosphorus fertilizer and their combined effects is presented in Table 4.20 and 4.21. Harvest index of rice was highly significant differences in the nitrogen treatments. Nitrogen fertilizer treatments gave the greater harvest index when compared with nitrogen omission. The treatment with USG gave the higher harvest index (0.50) than the treatment PU (0.48).

Harvest index (HI) was not significant different by the sources of phosphorus fertilizer treatments in this experiment (Pr = 0.0621). Phosphorus fertilization gave the higher harvest index than P omission. In tested P sources, the greater numerically harvest index was resulted from DAP fertilizer than TSP fertilizer.

No interaction effect was observed between different sources of nitrogen and phosphorus fertilizer on harvest index (HI). The maximum harvest index (0.53) was recorded from USG + DAP and the lowest (0.43) was recorded from no N and P fertilizers treatment.

4.2.2.7 Grain yield (ton ha^{-1})

Grain yield of the different sources of nitrogen and phosphorus fertilizers and their combined effects was shown in Table 4.20 and 4.21. Grains yield was significantly influenced by the fertilization of nitrogen fertilizer. Both PU and USG gave higher grain yield than N omission. Therefore, nitrogen fertilizers were needed to produce more grain yield. When compared tested nitrogen fertilizers, USG produced significantly higher grain yield (4.84 ton ha^{-1}) than PU (4.16 ton ha^{-1}). The application of USG produced higher number of panicles hill^{-1}, number of spikelets panicle^{-1}, filled grain percent which ultimately gave high yield. This result was similar with the finding made by Miah et al. (2004) and Rahman (2003).

The analysis of variance presented in Table 20 showed that the source of phosphorus fertilizer had no significant effect on grain yield (Pr = 0.2396). The application of phosphorus fertilizer treatments (DAP and TSP) exhibited the higher grain yield (4.29 and 4.18 ton ha^{-1}) than P omission treatment. Although there were not significant, phosphorus fertilizers produced the higher yield. According to this result, phosphorus was essential for getting higher yield. In the tested P sources, yield of DAP (4.29 ton ha^{-1}) produced in numerical value than TSP (4.18 ton ha^{-1}).Our findings are confirmed by Keshwa and Singh (1988) and Venugopalan and Prasad (1989), who concluded that different P sources did not affect grain yield in cereals.

Mean effect of the combination of the different sources of nitrogen and phosphorus fertilizers were shown in Table 4.21. The interaction was not found on grain yield as affected by the combination of the different sources of nitrogen and phosphorus fertilizers. Grain yield ranged from 2.96 to 4.99 ton ha^{-1}. The maximum grain yield (4.99, 4.85 ton ha^{-1}) was resulted from USG + DAP, USG + TSP and the minimum grain yield (2.96 ton ha^{-1}) was recorded from N and P omission treatment.

4.1.2.8 Yield increase over control

The percent grain yield increased over control by the application of nitrogen and phosphorus fertilizers (Table 4.22). In the source of nitrogen fertilizers, the application of USG produced the higher yield by 25% than PU fertilizer. DAP fertilizer gave greater more yield by 6% on yields than TSP fertilizer. When PU combined with TSP and DAP, PU with DAP was not big difference with PU with TSP. However, PU + DAP can save (25%) rate of PU fertilizer than PU+ TSP. When compared PU and USG combination with any tested P sources, the higher yield was obtained by combination with USG than that of PU. When TSP and DAP were combined with any tested nitrogen sources, the combination with DAP gave the higher yield increase than TSP combination. In all treatments, the highest yield increase 69% over control were resulted by the combination of USG and DAP. According to the grain yield results, USG sufficiently supplied nitrogen for the entire rice growth stages and so increased grain yield than PU fertilizers.

Table 4.22 Comparison of grain yield percent increase over control during wet season, 2017

Treatments	Yield increase (%)
PU	33
USG	58
TSP	16
DAP	22
PU + TSP	44
PU+ DAP	45
USG + TSP	64
USG + DAP	69

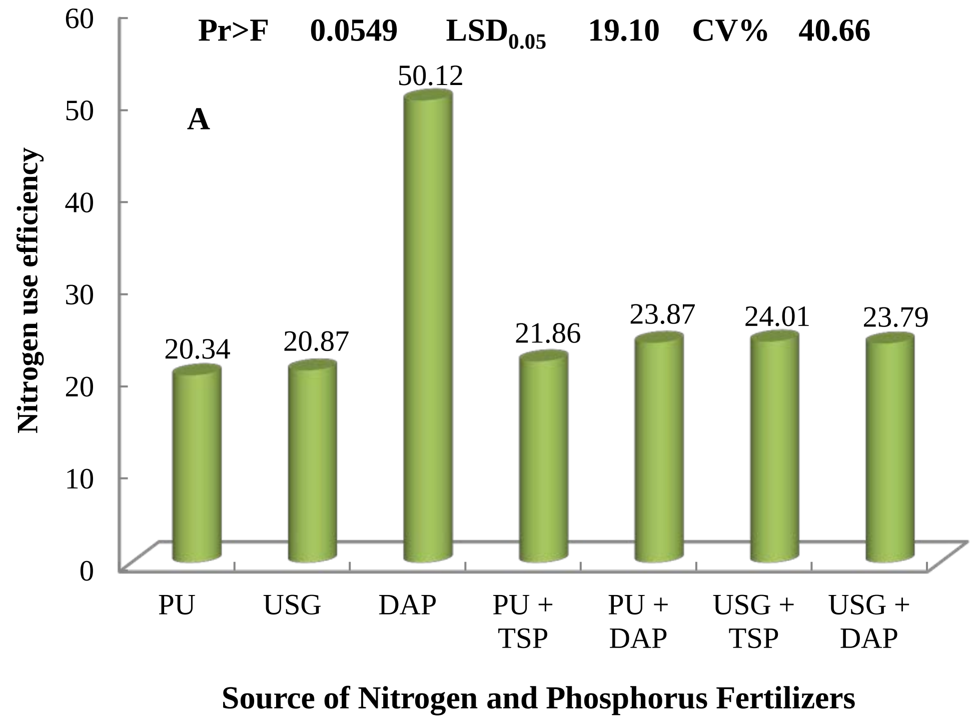
4.2.3 Nutrient use efficiency

4.2.3.1 Nitrogen use efficiency (NUE)

The NUE as influenced by different sources of nitrogen and phosphorus fertilizers is presented in Figure 4.10. There were no significant differences in NUE by the different sources of nitrogen fertilizers. In the two sources of nitrogen (Urea and USG), USG gave the higher NUE (20.87) than PU fertilizer (20.34). The application of USG significantly improved nitrogen use efficiency of rice than PU. Higher NUE of rice due to deep placement of N fertilizer was also reported by Jena et al. (2003) and Dash et al. (2003).The combined application of nitrogen fertilizers with phosphorus fertilizer produced higher NUE than application nitrogen fertilizer alone. It has been shown that for nitrogen efficiency to be particularly high the plant must access sufficient phosphorus.

4.2.3.2 Phosphorus use efficiency (PUE)

The PUE as influenced by different sources of nitrogen and phosphorus fertilizers is presented in Figure 4.10. Phosphorus use efficiency was not significant difference in the tested phosphorus fertilizers. In the two of sources phosphorus fertilizers, DAP gave the higher PUE than TSP. The combination P fertilizers with Urea and USG produced the higher value of PUE than phosphorus fertilizer application alone. When TSP and DAP are applied together with USG, USG combination resulted the higher PUE than that of PU fertilizers.



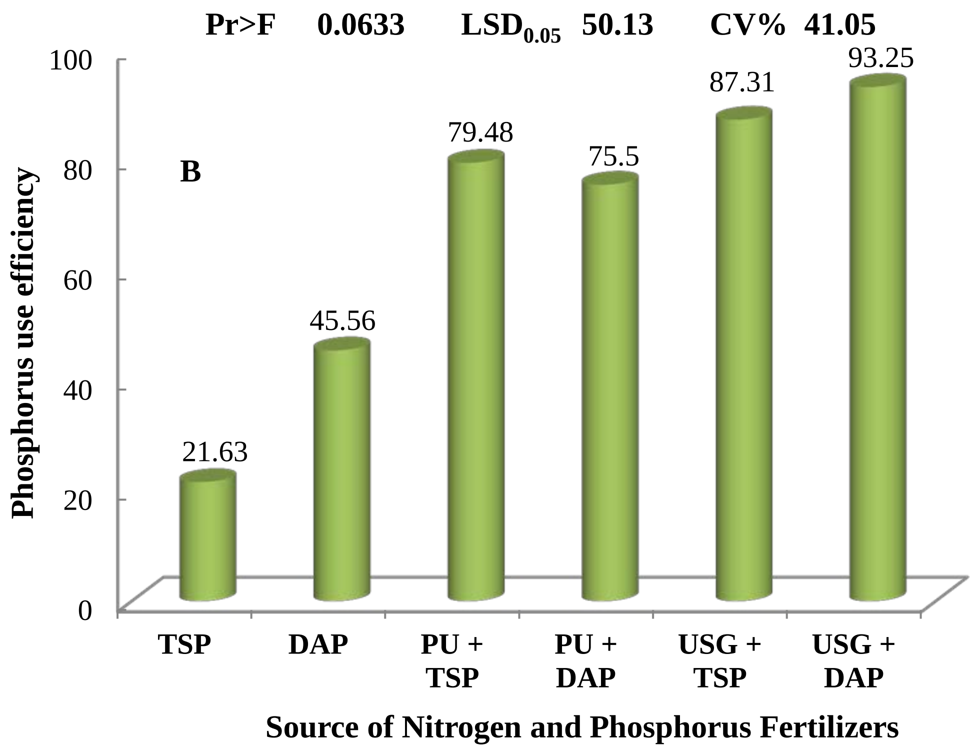


Figure 4.10 Mean values of nitrogen use efficiency (A) and phosphorus use efficiency (B) as affected by different sources of nitrogen and phosphorus fertilizers of rice during wet season, 2017

CHAPTER V
CONCLUSION

The present study emphasizes on the response of the different sources of nitrogen and phosphorus fertilizers on growth, grain yield, yield components and nutrient use efficiency of rice in dry and wet seasons, 2017. From the two strong investigations, the following could be concluded.

In both seasons, nitrogen and phosphorus fertilizers produced the higher yield components and yield than control treatment. Urea super granule significantly increased plant height, total dry matter, number of panicles hill^{-1}, number of spikelets panicle^{-1} leading to more yield as compared to prilled urea (PU). The application of USG increased yield by 26% and 25% over PU in dry and wet seasons respectively. It can be pointed out that USG was superior for increasing rice grain yield than PU. In the tested sources of phosphorus fertilizer, DAP fertilizer provided better yield 7% in dry season and 6% in wet season than TSP fertilizer.

When PU combined with two tested P sources, the combination of DAP resulted not only in higher grain yield by 16% in dry season but also in saving the dosage 25% PU fertilizer than the combination of TSP. In case of USG combining with two tested P sources, USG and DAP combination gave the greater yield by 8% and 5% than USG and TSP combination in dry and wet seasons respectively.

In both seasons, the best NUE was obtained by using DAP among treatments and the higher NUE value was obtained from USG than PU fertilizer. Moreover, application of USG with two tested P sources gave the higher NUE than that of PU in dry season. Even though non-significant difference, the higher PUE was obtained by using DAP alone or by combining with two tested nitrogen fertilizers than using TSP. Using the combination of two tested N and P fertilizers gave the greater NUE and PUE that leading to produce the better rice yield than using N or P fertilizer sources alone. The use of USG and DAP fertilizers resulted the best growth parameters, yield components, yield, NUE and PUE. It can be concluded that using the combination of USG and DAP fertilizers was efficient and effective for Sinthukha rice production.

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APPENDICES

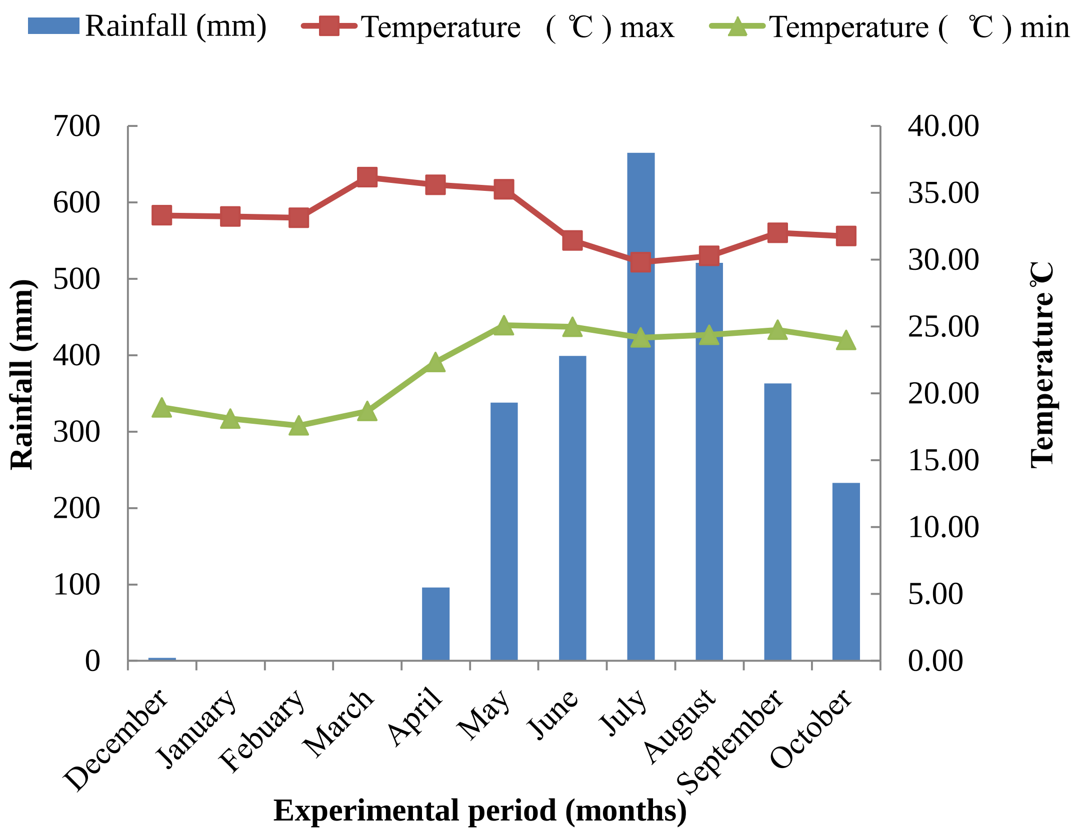
Appendix 1. Soil analysis methods

Parameter	Determination methods
Soil Texture	Pipette method
Soil pH	1:5 (Soil : Water) pH meter
Total N	Modified Kjeldahl Digestion method
Available N (ppm)	Semi-micro Kjeldahl distillation
Total P (ppm)	9C-Olsen’s P-Malachite green
Available P (ppm)	9C-Olsen’s P-Malachite green
Available K (ppm)	Atomic absorption spectrophotometer
Exchangeable Fe	Atomic absorption spectrophotometer
Organic carbon (%)	Walkley and Black method
Cation Exchange Capacity (CEC) (meq/100g)	Bascomd’s method

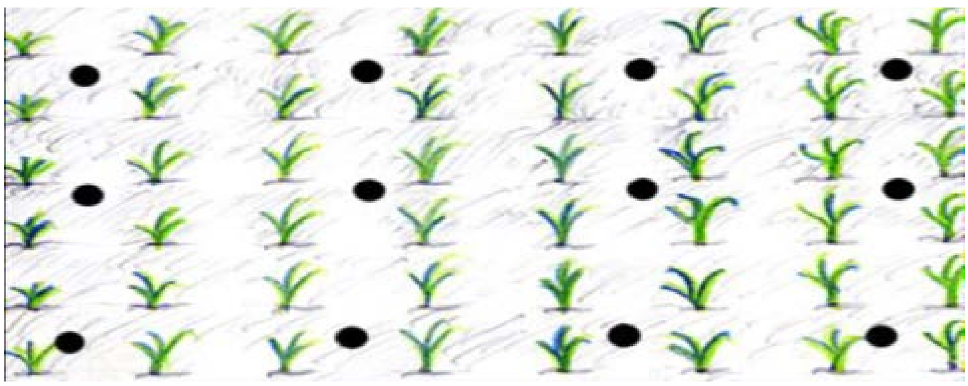
Appendix 2. Total rainfall and temperature data during experimental period (2017)

Month	Temperature (°C)		Rainfall (mm)
	Maximum	Minimum	
December	33.32	18.96	4
January	33.23	18.12	0
February	33.14	17.59	0
March	36.16	18.68	0
April	35.60	22.35	96
May	35.27	25.10	338
June	31.44	24.97	399
July	29.81	24.17	665
August	30.28	24.38	521
September	32.01	24.75	363
October	31.76	23.98	233

Source: Myanmar Rice Research center, Hmawbi township, Yangon Region



Appendix 3. Total rainfalls, minimum and maximum temperature at Hmawbi, MRRC, during experimental period (December, 2016 to October, 2017)



Appendix 4. layout for application of urea super granule in rice field

PLATES

Plate 1. Application of urea super granule in the corresponding treatment plots

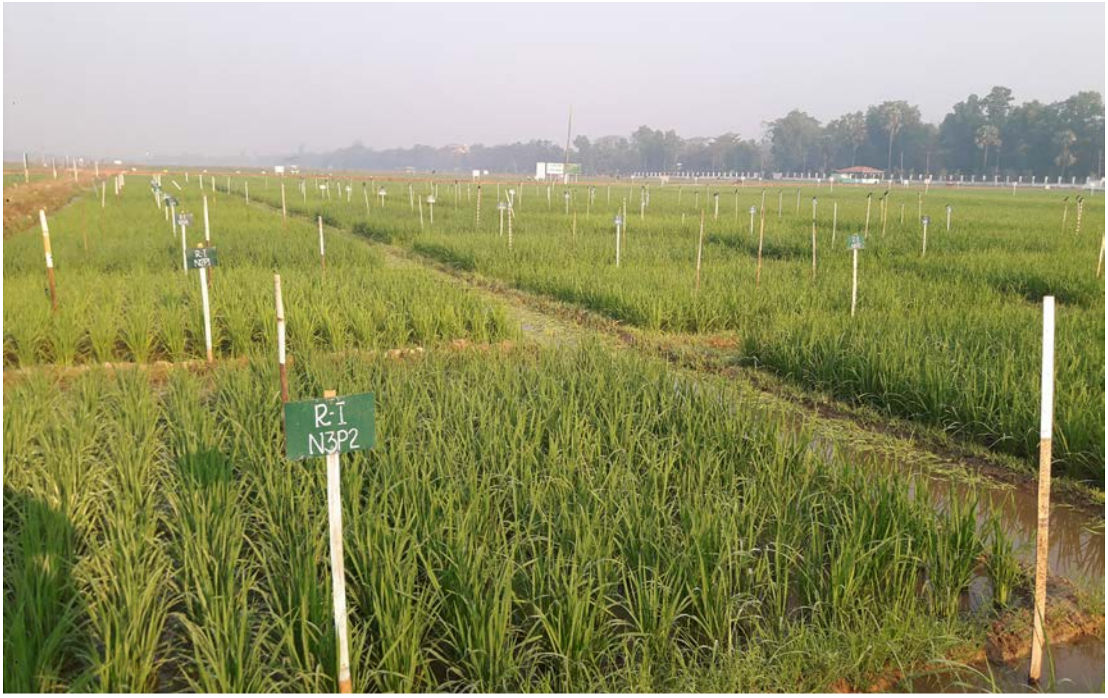


Plate 2. Experiment of different sources of nitrogen and phosphorus fertilizers on rice yield and nutrient use efficiency to in hmawbi

Plate 3. Experiment of different sources of nitrogen and phosphorus fertilizers on rice yield and nutrient use efficiency to in hmawbi

Plate 4. Experiment of different sources of nitrogen and phosphorus fertilizers on rice yield and nutrient use efficiency to in hmawbi