EFFECTS OF STRAIGHT AND COMPOUND FERTILIZERS ON THE GROWTH AND YIELD OF RICE

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EFFECTS OF STRAIGHT AND COMPOUND FERTILIZERS ON THE GROWTH AND YIELD OF RICE

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by

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The thesis attached hereto, entitled **"Effects of Straight and Compound Fertilizers on Growth and Yield of Rice"** was prepared under the direction of the chairman 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 Science).**

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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.

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DEDICATED TO MY BELOVED PARENTS,

U SOE MYINT AND DAW MYINT KYI

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ABSTRACT

Two seasons of rice experiment were tested to know the effects of recommended straight fertilizers application and compound fertilizers plus Urea fertilizer on growth and yield of rice in 2014. Shwe Thwe Yin rice variety was used and the experimental design was Randomized Complete Block Design (RCB) design with four replications. As straight fertilizers Urea, Triple super Phosphate (TSP) and Muriate of Potash (MOP) were applied with recommended rates of Department of Agricultural Research (DAR). The treatments were T1 (no fertilizers), T2 (three splits application of straight fertilizers), T3 (two splits application of straight fertilizers), T4 (15:15:15 compound fertilizer 125 kg ha-1 + 125 kg Urea ha^{-1}) and T5 (straight fertilizers the same as the nutrient ratio of T4), T6 (15:7:8 compound fertilizer 125 kg ha^{-1} +125 kg Urea ha^{-1}), and T7 (straight fertilizers the same as the nutrient ratio of T6). The plant growth data, yield components and yield data of both seasons were collected and analyzed. In both seasons, two splits application of recommended straight fertilizers treatment (T3) produced the highest plant height, maximum tiller numbers and maximum grain yield. The yield of T3 was 49 percent more yield than the control treatment T1 and 17 percent more than T4 treatment in dry season. In wet season, T3 produced 69 percent more grain yield than that of control treatment and 25 percent more grain yield than that of T4 treatment. The yield of 15:15:15 compound fertilizer plus Urea fertilizer was superior to that of 15:7:8 compound fertilizer plus Urea fertilizer.

Key words: straight fertilizers, compound fertilizers, Shwe Thwe Yin rice variet, yield and yield components

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CHAPTER I

INTRODUCTION

The global population is expected to exceed 9 billion people by 2050, and food security challenges are at the forefront of every discussion regarding agricultural production. In accordance with most estimates, food production will have to increase 50 to 70 percent to meet global demand (Phillips 2014). Meeting the food production challenges for a growing population is a daunting, but not impossible task. It will require focus, cooperation and a combining of technologies across several disciplines of agriculture and society.

The three leading food crops in the world are rice, wheat, and maize, which directly supply more than 50 percent of all calories consumed by the entire human population. Human consumption accounts for 85 percent of total productions for rice compare with 72 percent for wheat and 19 percent for maize (http://www.Knowledgebank.irri.org/ericeproduction/importanceofrice.html). So, as one of the most important crops used as main food and snacks for traditional culture, rice plays an important role in food security. Rice is the main food of over half of the world's population. Rice is a major source of energy and an important one of protein: 100 grams of raw white rice provide 361 kcal and 6 grams of protein. Rice also contains substantial amounts of zinc and niacin. On the other hand, it is low in calcium, iron, thiamine and riboflavin and has virtually no beta-carotene (Vitamin A) (Calpe 2006). It is the major dietary energy source for 17 countries in Asia and the Pacific, 9 countries in North and South America and 8 countries in Africa. Rice supply 20percentof the world’s dietary energy supply, while wheat supplies 19 percent and maize (corn) support 5 percent. Ranked as the most widely planted crop in Myanmar, the planting area of rice occupied 34 percent of the food crops in the country with nearly 8 million ha in 2012 (MOAI 2013).

The main challenge for rice research and development in the world which includes improvement of the small farmers’ welfare and rural employment on a sustainable and economic basis is to find ways and means to produce more food for the fast growing population with limited land, less labor, less water and even less chemical inputs as well as to improve (Tran 1997).

Implementing precision agriculture (PA) technologies within the context of 4R nutrient stewardship (the right nutrient source, applying nutrients at the right rate, at the right time, and in the right place) is an efficient and effective way that helps to meet the environmental, economic and social goals of sustainable agricultural systems (Phillips 2014).

The fertilizer industry will require to be a world leader in meeting this challenge as fertilizers are currently responsible for 50 percent of food production and will probably be even more important in the future (Phillips 2014).

Low soil levels of any nutrient may limit plant growth. Under natural conditions, nutrients are recycled from plants to soil to meet plant needs. This balance shifts when agricultural crops are grown because crops demand more nutrients than would be needed for natural vegetation. Significant amounts of nutrients are also removed in harvested crops. Anyone who has grown a production area, a garden, maintained a lawn, or kept house plants knows that it is necessary to apply a fertilizer to the soil to keep cultivated plants healthy and to produce the better quality crops. As they grow, plants mine nutrients they need from the soil. Unless these nutrients are refilled, plants will eventually cease to grow. In nature, the soil receives back the nutrients when plants die and decay. However, this does not happen with cultivated plants. Humans cultivate plants chiefly for food, either for themselves or for livestock. When cultivated plants are harvested, the nutrients that the plants mined from the soil are taken away. Because of these factors, supplemental nutrients may be necessary to ensure optimal crop growth and profitability. Supplemental nutrients may include fertilizers, animal manures, green manures, and legumes.

Plants contain more than 90 elements, but only 16 elements are recognized as essential. These elements are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, manganese, zinc, copper, molybdenum, boron and chlorine (Muslem et al. 2005).

Fertilizer supports nutrients and texture to soil that needs to provide nutrients to trees, vegetables, herbs, shrubs and flowers. The most basic types of fertilizers are organic and inorganic. Inorganic fertilizer is an artificial fertilizer and typically comes as a powder, pellets, granules or a liquid. Chemical, mineral, commercial and artificial fertilizers include one or more nutrients and are produced by chemical methods. These are fertilizers with nitrogen, phosphorus, potassium and calcium. Nitrous fertilizers are ammonium sulfate, ammonium nitrate, urea; phosphorous fertilizers are superphosphate, triple superphosphate; potassium fertilizers are potassium sulfate, potassium chloride and composite or compound fertilizers contain particular amount of nitrogen, phosphorous and potassium, which are fertilizers such as 20-20-0, 15-15-15, 18-46-0 and 26-13-0 (Ahmet 2011).

Among the plant nutrients, the macronutrients are nitrogen, phosphorus, and potassium. These three elements are most rapidly taken up from the soil by plants. Therefore, many commercial plant fertilizers supply these three essential elements. The general trend in fertilizer importation in most Asia and Pacific countries pointed out a general preference for Urea and very minimal for Potash. Senior scientists from India indicated that this is because Urea is the favored and main source of nitrogen because it is cheaper, easily available and supports rapid response. The widening gap between the withdrawal of soil nutrients to produce food and the provision of fertilizer supplements to prevent the total depletion of native soil nutrients is becoming an important common concern in Asia and the Pacific region (Mingsheng et al.2005). However, due to the variability in yield responses, grain prices and fertilizer costs, it is also critical to evaluate and compare the economics of fertilizer application in rice under different yield responses and price/cost scenarios.

Although the availability of high yielding plants and irrigation is good, the stagnation of yields and decline of soil fertility is brought about by unsound fertilizer use (Mingsheng et al.2005). Inadequate and unbalanced nutrient use is one of the major factors responsible for low crop productivity (Pattanayak et al. 2008). The long years of yield stagnation may be caused by excessive soil mining and by wide imbalance use of Urea with phosphorous and potassium fertilizers. Economic returns with nitrogen and phosphorous fertilization boosted with increase in yield responses and fertilizer prices, but those with potassium fertilization decreased with increase in potassium prices (He et al. 2014). Balanced nutrient management offers an opportunity to not only increase crop productivity, but also provides an option for rebuilding soil organic matter (Rusinamhodzi et al. 2014).

High agricultural commodity prices supply incentives for farmers in market-oriented economies to invest in fertilizers and other inputs for higher productivity. However, it is a disincentive for farmers to buy fertilizers, particularly phosphorous and potassium, having smallholdings and with the bulk of food production meant for family consumption (FAO 2012). The problem of high cost and unavailability of inorganic fertilizer has affected the growth of many crops and there is a requirement to look for alternative and locally available sources of fertilizer.

For fertilization, most of the farmers use their own experience and or that of fellow farmers, taking into account the expected profitability. Most of the farmers use both straight fertilizers and compound fertilizers in various growth stage of rice plant with various fertilizer rates. The advantage of the straight fertilizers is the low price compare to the other compound fertilizers. Straight fertilizer usually contributes one of the 3 main nutrients to the crops which are Nitrogen (N), Phosphorus (P) and Potassium (K).Compound fertilizers containing two or all of the three basic plant nutrients N, P_2O_5, and K_2O as well as microelements such as boron, manganese, copper, zinc, and molybdenum. Compound fertilizers have good physical properties, they do not cake. The nutrient ratios of compound fertilizers vary, depending on the method of production, the initial components, and the requirements of the plants fertilized.

Since poor fertilizer management practices lead to the waste of plant nutrients and subsequent the farmers more cost, it is need to know what type of fertilizers and fertilizer management practices is most effective for farmers and can get the highest grain yield of rice.

Therefore, this research was conducted with the following objective;

- to know the effects of recommended straight fertilizers application and compound fertilizers plus Urea fertilizer application on growth and yield of rice

CHAPTER II
LITERATURE REVIEW

2.1 Importance of rice

Rice (*Oryza sativa* L.) is fundamental food for more than half of the world's growing human population. It is important for the diets of millions of Asians, Sub Sahara Africa and Latin Americans living in the tropics and subtropics. Since world population is increasing, more rice demand is needed. Roughly 900 million of the world's poor rely on rice as producers or as consumers (Pandey et al. 2010). Farm yield of rice under irrigation ranges from 3 to 9 t ha^{-1} (Fischer 1998). Towards achieving food security, employment and income for the poor rural dwellers, rice is the main contributor.

Food security in Asia depends largely on intensive rice production and the productivity of rice. Rice crop is a main agricultural commodity for many less developed countries of Asia, where land is intensely cultivated, forests are disappearing, and water is becoming increasingly scarce (Dowling et al. 1998). In these areas rice is applied not only for their main food but also for their traditional snacks. In addition, by-products of rice are also used for feeding of animals. It also plays a central role in regional culture because of the idyllic agricultural villages that form around the beautiful paddies. Particularly for the people of Asia, rice has been the major source of calories and an important source of income and employment throughout most of their history.

In Myanmar, agriculture is the back-bone of the economy. Agricultural sector possess 39.99 percent of total production. Within the agricultural sector, crop production accounts for about 80 percent of total agricultural income. And within the crop sector, rice dominates land use. Annually, paddy accounts for roughly half of all planted area, with that share rising to about 60 percent during the monsoon season and falling to around 40 percent in the winter and summer seasons (Haggblade et al. 2013). Being the major staple food, rice is cultivated in every part of the country, irrespective of agro-ecological suitability contributing nearly 34 percent to the total food grain production (MOAI 2012). Myanmar was once the dominant world rice exporter, where an average of 10 million tons of rice is produced every year, from 500,000 tons to one million tons is exported today. (Tobias et al. 2012).

In a traditional Myanmar diet, the carbohydrates contained in rice are the main energy source. Since rice contains 6.1 g of protein per 100 g, and its protein is superior in quality to wheat protein, rice alone can support a person if that person eats enough of it (Toriyamaet al. 2005). In most rice-eating countries, Myanmar is contributing 76 percent of energy and 68 percent of protein (Juliano 1993).Rice at breakfast lessens the day’s food expense compared to popular Western style breakfasts. Morever, rice straw has been used to make coarse paper, as a cellulose source for ruminant livestock, composting and building materials, and as an ultra-pure source of silica (Beighley 2006). Rice straw contains about 1.5 percent potassium while contents of nitrogen and phosphorous are 0.6 percent and 0.1 percent receptively (Perera et al. 2010)

2.2 Agronomic characteristics of rice

The growth duration of the rice plant is 3-6 months, depending on the variety and the environment under which it is grown. During this time, rice completes two distinct growth phases: vegetative and reproductive. The vegetative phase is subdivided into germination, early seedling growth, and tillering; the reproductive phase is subdivided into the time before and after heading, i.e., panicle exertion. The time after heading is better known as the ripening period. Potential grain yield is primarily determined before heading. Ultimate yield, which is based on the amount of starch that fills the spikelet, is largely determined after heading. Hence, agronomically it is convenient to regard the life history of rice in terms of three growth phases: vegetative, reproductive, and ripening. A 120-day variety, when planted in a tropical environment, spends about 60 days in the vegetative phase, 30 days in the reproductive phase, and 30 days in the ripening phase (Yoshida 1981).

2.3 Rice growth stages

Rice plants belong to the grass family, Graminaceae. The growth of rice plant can be divided into three agronomic phases of development.

1. Vegetative phase (germination to panicle initiation (PI)
2. Reproductive phase (PI to heading) and

3. Grain filling and ripening or maturation phase (heading to maturity) (Mwangi et al. 2012).

The ability to identify growth stages is important for proper management of the rice crop. Because management practices are tied to the growth and development of the rice plant, an understanding of the growth of rice is essential for management of a healthy crop. Timing of agronomic practices associated with water management, fertility, pest control and plant growth regulation is the most important aspect of rice management. Understanding the growth and development of the rice plant enables the grower to properly time recommended practices.

When cells first begin actively dividing in the growing point or apical meristem, the process is called panicle initiation (PI) (Dunand and Saichuk 1999). Panicle initiation is the time when the panicle primordial initiates the production of a panicle in the uppermost node of the culms. At this point, the panicle is green ring or not visible to the naked eye. So, the panicle initiation is sometimes referred to as the green ring stage in rice.

2.4 Rice varieties based on rice plant duration

There are many rice varieties; some are named with respect to locality, some for their growth duration, some for the size and color of their grain, some for their aroma, and some for their appearance. Farmers classify rice in many different ways, some of which are widely accepted. The three best known classifications use time of sowing, water regime, and growth duration as criteria. With respect to classification based on time of sowing, four types have been denoted: pre-monsoon rice, monsoon rice, late monsoon rice, and winter rice. Classification based on water regime includes three situations; irrigated upland, and rain-fed. Classification according to growth duration consists of three groups; short- duration rice (140-145 days seed to seed) that matures in October is called “kauk-yin,” medium-duration rice (150-170 days) that ripens in November is known as “kauk-lat,” and late-duration rice (170-200 days) that ripens in December is called “kauk-kyi” (Win 1991). Farmer preferred rice varieties that gave high returns, fitted with local cropping patterns and that could enhance productivity.

Regularly the cultivated rice varieties vary 90-180 days of duration and rice plant reaches the flowering stage at 75 to 140 days after sowing (Mwangiet al. 2012).The prominent vegetative growths of rice are the plant height and the tillering.

In the rain-fed ecologies with short rainy seasons, early maturing plant types should be selected. Such short duration varieties will also be suitable in areas where farmers grow a second crop to take advantage of residual water after harvesting the early rice crop.

The farmer who want to grow rice crop rotation with other crops such as legume, used to grow short duration rice varieties. And then, they sow the legume crops when the moisture remains in the field. The tested rice variety of this study, Shwe Thwe Yin is a short duration rice variety. Short duration rice varieties are suitable to achieve higher yields and better soil quality under rice-legume crop rotation system. Cumulative grain yields of crops increased by 7-16 percent per rice-legume-rice crop rotation by using short duration rice variety (Thakuria et al. 2009)

2.5 Soil and climatic requirements for rice production

Rice occurs up well in different soil types. For normal growth, a suitable pH range is 5.5-6.5. Rice crop is primarily grown in the humid and sub humid, tropics and subtropics, but it can be grown in variety of climate. Myanmar is a sub-humid subtropics country. It is cultivated under favorable (irrigated with good water control) or unfavorable (rain-fed lowland, upland, deep water, and tidal wetlands) environments (http://www.agriculture and updates. blogspot.com/2011/10/climateandsoilforrice cultivation.html). The most important soil characteristic for lowland rice production is the presence of an impervious subsoil layer in the form of a fragi-pan, clay-pan or massive clay horizon that minimizes the percolation of irrigation water (Harrell and Saichuk 2009).

Although genetic factors are clearly important, numerous reports in the literature have shown that environmental variables imposed a strong impact on growth, development, and yield of crops. Rainfall is the most significant weather element for successful cultivation of rice. Temperature is another climatic factor which affects the development, growth and yield of rice. Since the rice plant is a tropical and sub-tropical plant, it needs a fairly high temperature, ranging from 20° to 40°C with the optimum temperature of 30°C during day time and 20°C during night time. The temperature requirement of rice plant varies with the growth phases. The critical mean temperatures for flowering and fertilization phase and ripening phase are the ranges of 16 -20ºC and 18-32ºC respectively. If the temperature is beyond 35ºC that affect grain filling of rice (http://www.agricultureandupdates. blogspot.com/2011 /10 /climateandsoilforricecultivation.html).

For most rice-growing environments of tropical South and Southeast Asia, the maximum yields of currently grown high yielding rice varieties are about 10 t ha^{-1} in the high-yielding season (HYS) and 7-8 t ha^{-1} in the low-yielding season (LYS) (Witt et al. 2007). Sunlight is very essential for photosynthesis of the plants. So, it is the source of energy for plant life. In the tropics, skilled rice farmers attain yields of 7-8 t ha^{-1} in the dry season, and 5-6 t ha^{-1} in the wet season (Dobermann and Fairhurst 2000).

2.6 Myanmar rice production

Overall the rice soils of Myanmar look relatively fertile. In the delta region, alluvial and swampy soils govern, and vertisols are more critical in the irrigated rice lands of the dry zone. Based on available surveys and farmer interviews, it shows that fertilizer use on rice is common, though farmers utilize at relatively low levels. The high cost of fertilizer and low rice price limit the use of fertilizer (Denning et al.2013). In 2012-13, total harvested area of paddy crop was 7208000 hectare and yield per hectare was 3.84 MT in Myanmar (MOAI 2013).

2.7 Fertilizer application for rice

Nowadays, more increases in rice productivity are necessitate for the growth in population and decreased availability of water and land. There is one of the most effective means, it is directing the issues in rice cultivation and raising the average yields at the farm level through research and subsequent dissemination of the resulting data (Nguyen and Ferrero 2006). Future yield increases will require improved crop care, integrated resource management approaches, and more knowledge intensive approaches for the efficient use of all inputs, including fertilizer nutrients.

Fertilizers nutrients play a major role in improving crop production. A yield target will be achieved only when the correct amount of nutrients is supplied at the right time to meet the crop's nutrient requirement during the crop growing season. Efficient and cost effective nutrient management approaches should aim to maximize crop uptake of nutrients from fertilizers. Poor input management and unbalanced nutrient use is one of the main agronomic problems encountered where intensive rice cultivation is practiced (Dobermann and Fairhurst 2000). Qichun and Huo (2005) found that unbalanced fertilization to rice crop had negative effect on the diversity of the microbial community and total microbial biomass in the soil.

Four right things, right product, right rate, right time and right place are the foundation of best management practices for fertilizer and balanced fertilization is one of the keys to increase nutrient use efficiency (Roberts 2007). So the application of appropriate fertilizer input will get high grain yield and also attain maximum profitability (Khuong et al. 2008).

Days to maturity, plant height, panicle m^{-2}, and grain yield of rice boosted with increasing fertilizer levels (Kanfany et al. 2014). If possible, nutrient inputs and nutrient removal should be the same. The applied nutrients generally leave the farm in harvested crop and animal feeds. When nutrient applied to the farm deeply exceed, the removal of nutrient from the farm, the risk of nutrient losses to ground water and surface water is greater (Farm Bureau of Louisiana 2000). It is important to apply the balance fertilizer application method to ensure the highest yield, minimum fertilizers inputs cost and environmental impacts.

In 2007, the worldwide rice area was 156 million hectare with the average yield of 4.2 t ha^{-1} using the total fertilizers of N, P_2O_5 and K_2O are 15.7, 4.8, 3.8 million tons respectively (Gregory et al. 2010). Application of fertilizers per unit area is the minimum in Myanmar among South East Asia (Miah et al. 2005).

2.8 Straight fertilizer

A qualification generally given to a nitrogenous, phosphatic, or potassic fertilizer having only one primary plant nutrient, i.e. nitrogen, phosphorous or potassium is called straight or single fertilizer (Miah et al. 2005). On the other hand, straight or single fertilizer term is used to describe the fertilizer containing only one of the elements nitrogen, phosphorous and potassium.

2.9 Compound fertilizer

A compound fertilizer is that consist at least two of the plant primary nutrients nitrogen, phosphorous and potassium attained chemically or by blending or both (Miah et al. 2005). The next definition of compound fertilizer is the any homogeneous product containing two or more of the following plant nutrient elements for fertilizing crops: nitrogen, phosphorous, potassium and magnesium (IFDC and UNIDO 1979). It may also include trace elements. The compound fertilizer is also known as composite fertilizer, complex fertilizer and multi-nutrient fertilizer. The shapes of compound fertilizer may be in the form of granules, pellets, prills, or crystals and may be free-flowing. Granular compound fertilizers are comfortable to handle and permit the uniform application of balanced quantities of nutrients in the field. In addition, granulation or pelletization of fertilizer mixtures does not allow the segregation in the bag of the individual constituents of a fertilizer mixture.

Compound fertilizers are technically more attractive than straight fertilizers particularly when placed in bands because of the mechanical application of two or more nutrients at once in combination with sowing or planting. Moreover, the mixing of straight fertilizers may not be well done in the distributor during the application because of the different size of the fertilizer particles.

An analysis that describes the concentrations of plant-available nutrients can be found on every bag of fertilizer. Generally, there are three numbers that describe, in order, the concentrations of N: P_2O_5: K_2O. The numbers in a fertilizer grade, such as 15:7:8 indicate the nitrogen, phosphate, and potash percentages. For example, a 15:7:8 fertilizer contains 15 percent N, 7 percent P_2O_5, and 8 percent K_2O by weight (Oldham 2000). Sometimes the fertilizer label provides additional numbers or additional analysis details if there are secondary or micronutrients such as sulfur, boron, or magnesium in the fertilizer.

2.10 Nitrogen for rice

2.10.1 Nitrogen sources

Nitrogen (N) is a part of all plant and animal proteins. Therefore, human survival depends on an abundant supply of nitrogen in nature. Approximately 80 percent of the atmosphere is nitrogen gas, but most plants cannot use this form of nitrogen. Decomposition of organic matter results in simple inorganic nitrogen forms such as ammonium (NH_4^+) and nitrate (NO_3^-). These are soluble in soil water and readily available for plant uptake (BMPs 2000). But supplemental nitrogen must be supplied through the soil to ensure the crop yield. A crop well supplied with nitrogen can produce substantially higher yields than one deficient in nitrogen.

The common chemical nitrogen fertilizers are anhydrous ammonia (82 percent N), nitrogen solutions (28 to 32 percent N) (a mixture of urea and ammonium nitrate in water), aqua ammonia (21 percent N), urea (46 percent N), ammonium nitrate (33 percent N), ammonium sulfate (21 percent N), calcium nitrate (16 percent

N), potassium nitrate (13 percent N) and sodium nitrate (16 percent N) (Vitosh et al. 1995, Vitosh 1996).

In submerged soils, ammonia is the major form of nitrogen available for rice. Although relatively low concentrations of ammonia are toxic to many upland crops, rice tolerates and uses ammonia efficiently at relatively high concentrations (Yoshida 1981).

2.10.2 Solubility of nitrogen fertilizer

Nitrogen is more mobile than P_2O_5 and K_2O in the soil and should be applied as closely as possible to the time of crop uptake. Response to nitrogen fertilizer is quick. After 2–3 days of nitrogen fertilizer application greening or improved vegetative growth appear although this depends on the rice variety, soil type, weather conditions, nitrogen fertilizer used, amount applied, and time and method of application of fertilizer (Dobermann and Fairhurst 2000). Nitrogen in the form of nitrate can be lost from soils via leaching and can be denitrified to nitrogen gas in reducing conditions, such as soils saturated with water (Maguire et al. 2009).

2.10.3 Effects of nitrogen on rice growth and yield

Nitrogen is the main contributor for the vegetative growth of the plant. The amount of 108 kg ha^{-1} of nitrogen is taken up in the 6 t ha^{-1} of rice products (Miah et al. 2005). Nitrogen plays a part of carbohydrate accumulation in culms and leaf sheaths during the pre-heading stage and in the grain during the ripening stage of rice (Swain et al, 2010). Being the agronomic parameters of rice, number of tillers hill^{-1}, days from sowing up to panicle initiation, heading dates, leaf area index, leaf area ratio, chlorophyll content,1000 grains weight, panicles length, agronomic efficiency, utilization efficiency and grain yield (t ha^{-1}) of rice crop were increased by increasing nitrogen levels up to 165 kg N ha^{-1} (Salem et al. 2011).

Nitrogen, a major essential plant nutrient is a key input for in increasing crop yield (Dastanetal. 2012). Rice yield and yield components increased notably with nitrogen fertilizer (Yoseftabar et al. 2012). The apparent nitrogen recovery efficiency range for rice is 43-71 percent and rice grain yield was controlled by nitrogen application time (Dillon et al. 2012). The average recovery rate of basally applied rapidly available fertilizer (RAF) nitrogen has been clarified to be about 30 percent in the tillage transplanting system using nitrogen-labeled fertilizer (Saigusa 2005).

The 1000 rice seeds weight had been significantly affected by applying Nitrogen fertilizer (Mohaddesi et al. 2011). Adequate amount of nitrogen supply during ripening stage of rice is necessary to delay leaf senescence, maintain photosynthesis during grain filling, and increase the protein content in the grain. Although nitrogen is required throughout the growing period of rice crop, the greatest requirement is between the early to mid-tillering and panicle initiation stages. Nitrogen fertilizer make the increment of panicle number, panicle length, primary branches, filled grain, 1000 garins weight, straw and grain yield increased significantly (Yoseftabar 2013a, Philrice 2010). In irrigated rice varieties, the removal of nitrogen with grain at harvest is 10.5 kg nutrient in grain t^{-1} grain yield (Witt et al. 2007).

By applying the dosage of 100-120 kg N ha^{-1}, the high rice grain yield and maximum profitability are recorded (Khuong et al. 2008). Yield and yield component characteristics of rice crop increased significantly with nitrogen fertilizer application (Yoseftabar et al. 2012). When transplanted rice followed a non-legume crop, grain yield of rice raised as nitrogen level increased up to 96 kg N ha^{-1}, this means rice yield is 61 percent larger than the control. At the same rates of nitrogen rice yield rose up to 25 percent when rice followed a legume crop. (Hamissa and Mahrous 1987).

Nitrogen nutrition influences leaf growth and leaf area duration and the number and size of vegetative and generative storage organs (Lawlor et al. 1989). Most non-legume crops need additional nitrogen to improve crop yield and quality and to optimize economic return to the grower. However, excess nitrogen can reduce yields and lower the quality of some crops. Excess nitrogen can also cut economic returns to producers, degrade water quality and cause other undesirable environmental effects (Carrie et al. 2012).

2.10.4 Functions and deficiency of nitrogen

Nitrogen is an essential component of amino acids, nucleic acids, nucleotides, and chlorophyll. It constitutes 2-4 percent of plant dry matter. Leaf nitrogen concentration is directly correlated to the rate of leaf photosynthesis and crop biomass production. It is responsible for the dark green color of stem and leaves, vigorous growth, branching/tillering, leaf production, size enlargement, and yield formation **(**Roy et al. 2006). Nitrogen has an effect on all parameters that contribute to yield. Nitrogen encourages rapid growth and increases leaf size and spikelet number per panicle. When adequate amount of nitrogen is applied to the crop, the demand of phosphorous and potassium nutrients increases.

Low soil nitrogen-supplying powers, inadequate application of mineral nitrogen fertilizer, low nitrogen fertilizer-use efficiency (losses from volatilization, denitrification, improper timing and placement, leaching, or run-off) are the causes of nitrogen deficiency. Nitrogen deficiency in plants results in a marked reduction in growth rate. Nitrogen deficient plants have a short and spindly appearance. Tillering is poor, and leaf area is small. As nitrogen is a constituent of chlorophyll, its deficiency appears as a yellowing or chlorosis of the leaves. This yellowness usually appears first on the lower leaves while upper leaves remain green as they receive some nitrogen from older leaves. In a case of severe deficiency, leaves turn brown and die. As a result, crop yield and protein content are reduced. When nitrogen is deficient, the plants are stunted, yellowish (older leaves or whole plants are yellowish green in color) (Fairhurst et al. 2007), since nitrogen is mobile within the plant, it is translocated from old senescent leaves to younger leaves (Dobermann and Fairhurst 2000). At tillering and panicle initiation stages, the demand for nitrogen is large, so it is critical to supply the sufficient amount of nitrogen at these growth stages (Dobermann and Fairhurst 2000).

2.10.5 Nitrogen losses

Ammonium (NH_4^+) forms of nitrogen are subject to losses through volatilization, especially when surface applied, but because NH_4^+ has a positive charge, it is retained by soil particles especially when injected below the soil surface. But the ammonium form is attracted to and held by soil particles, so it does not readily leach through the soil with rainfall or irrigation water. Substantial amounts of ammonium can also be lost from surface applications of urea, especially during the warm summer months; applications of fertilizer salts, such as ammonium sulfate, at these times, will reduce these losses. If leaching and/or denitrification are known to be concerns, then ammonium forms of nitrogen can perform better. One of the main causes of soil acidity is the oxidation of ammonium forms of nitrogen to nitrate-nitrogen, the main plant available form, but in most situations there is little practical difference between nitrogen forms in fertilizers. Nitrate (NO_3^-) are not attached to soil particles and do move downward with soil water and can be leached into groundwater or run off into surface waters (BMPs 2000). Fertilizer applications can be split to improve nitrogen use efficiency by crops. For example, part of the crop nitrogen requirement can be applied as starter fertilizer that can be placed in bands beside seed rows when planting row crops. This helps the first stages of crop growth without applying large rates of nitrogen that could be lost before the crop requires it. The rest of the crop nitrogen requirement can be applied immediately prior to the time of maximum crop uptake (Maguire et al. 2009). Over 50 percent of the applied nitrogen can be lost from agricultural systems as N_2, trace gases, or leached nitrate (Vitousek et al. 1997; Tilman 1998)

2.11 Phosphorous for rice

2.11.1 Phosphorous sources

The immediate source of phosphorus for plants is dissolved in the soil solution. A soil solution containing only a few parts per million of phosphate is usually considered that it is adequate for plant growth. Only 0.1 percent of total P is available to plant (Zou et al. 1992). Naturally occurring phosphorous exists in a phosphate form either as soluble inorganic phosphate, soluble phosphate, particulate phosphate or mineral phosphate. The mineral forms of phosphorus (calcium, iron and aluminum phosphates) are low in solubility. The amount of these elements (calcium, iron and aluminum) present in reactive forms varies with different soils and soil conditions. They determine the amount of phosphorus that can be fixed in the soil.

Rock phosphate, normal; superphosphate (20 percent P_2O_5) (also referred to as ordinary superphosphate), concentrated superphosphate (46 percent P_2O_5), di-ammonium phosphate (18-46-0), monoammonium phosphate (11-48-0) and poly-phosphates are some inorganic phosphorous fertilizers (Vitosh1996).

2.11.2 Solubility of phosphorous

Phosphate is absorbed from the soil solution and used by plants. It is replaced in the soil solution by soil minerals, soil organic matter decomposition or applied fertilizers. Phosphate is not readily soluble. Most of the ions are either used by living plants or adsorbed to sediment, so the potential of their leaching to groundwater is low. That portion of phosphate bound to sediment particles is virtually unavailable to living organisms, but becomes available as it detaches from sediment. Only a small part of the phosphate moved with sediment into surface water is immediately available to aquatic organisms. Additional phosphate can slowly become available through biochemical reactions, however. The slow release of large amounts of phosphate from sediment layers in lakes and streams could cause excessive algae blooms and excessive growth of plants, thereby affecting water quality (BMPs 2000). An increase in the availability of phosphate is an obvious benefit of soil submergence. Thus, the application of phosphate is less vital to lowland rice than to upland rice and other upland crops (Yoshida 1981).

Soil phosphorous is present in both the organic and inorganic forms. As with all nutrients required by rice, organic forms are not immediately plant available. Since organic phosphorous is slowly converted to the inorganic form, phosphorous fertilizer applications are very important on soils deficient in this nutrient. Flooding a rice soil increases the availability of soil phosphorous to plants. However, alternating flooding and draining cycles has a significant impact on phosphorous availability. When the soil is drained and aerated, phosphorous availability to plants is often decreased. Reflooding on the other hand will enhance phosphorous release (Harrell and Saichuk 2009).

Phosphate rocks (PRs) are suitable for direct application as a possible alternative to more expensive soluble phosphate fertilizers in agricultural fields. But the ability of the PRs to release phosphates in the plant available forms depends on the particle size and chemical and mineralogical characteristics of the PRs as well as the properties of the soil in which they are applied. According to the result of Ghosal and Chakraborty (2012) triple super phosphate fertilizer (TSP) released maximum phosphorous (3.05 percent to 3.27 percent with soil, 2.11 percent to 2.22 percent without soil) by the 7th day of incubation. The partially acidulated source was found to release P, higher than rock phosphates but lower than TSP. Solubility measurement cannot be used to predict specific yield response but they can serve as a useful means of predicting relative performance of one source to another and this assist in selection of the most appropriate source. Panhwar et al. (2012) proved that inoculation of TSP fertilizer along with the Phosphate-solubilizing bacteria (PSB) improved the association, phosphorous uptake, available soil phosphorous and growth of aerobic rice. The amount of phosphorous solubilized, phosphorous need of the bacteria, root exudation of the specific plant, and soil conditions (including soil phosphorous status, phosphorous sorption capacity, and pH) are among many possible factors that could affect whether the phosphorous is taken up by plants or not (Adesmoye and Kloepper 2009).

2.11.3 Effects of phosphorous on rice growth and yield

Although the rice requirement for phosphorous is much less than that for nitrogen, the continuous removal of phosphorous exploits the soil phosphorous reserve if the soil is not replenished through fertilizer or manure application. Chemical phosphorous fertilizer is a costly agricultural input for rice farmers of the developing world, and sometimes the material is not available in the local market. Plant height, total tiller number, bearing tiller and yield increased significantly with phosphorus fertilizer application (Yoseftabar 2013b). During vegetative growth, phosphorous supply is sufficient when phosphorous leaf concentration is >0.4 percent. To get yields greater than 7 t ha^{-1}, phosphorous concentration in the straw at harvest and in the flag leaf at flowering should be >0.06 percent >0.18 percent phosphorous respectively (Dobermann and Fairhurst 2000). When the rice field can produce 6 $tonha^{-1}$ of rice, the removal of phosphorous in rice product is 18 kg ha^{-1} (Miah et al. 2005)

When rice crop is transplanted as a subsequent crop of a non-legume crop, application of 16 kg P ha^{-1} (36 kg P_2O_5) increased yield by 14 percent (Hamissa and Mahrous 1987). The dosage of 30-50 kg P_2O_5 ha^{-1}can gives the high rice grain yield and maximum profitability (Khuonget al. 2008). Phosphorous fertilizer application grants a residual effect that can keep on for several years (Dobermann and Fairhurst 2000). The grain can remove the 2.0 kg nutrient of phosphorous in grain t^{-1}. Phosphorous promotes tillering, root development, early flowering, and ripening (especially when temperature is low). It is particularly important in early growth stages (Philrice 2010).

Different levels of phosphorous are recognized to enhance many changes in plant metabolism such as total respiration rate (Wanke et al. 1998), amino acids concentration and enzyme activities (Almeida et al. 2000).

2.11.4 Functions and deficiency of phosphorous in rice plant

Phosphorous is essential for growth, cell division, root lengthening, seed and fruit development, and early ripening. It is a part of several compounds including oils and amino acids. A primary nutrient, phosphorus is important for energy storage and transfer in plants, since phosphorus is a fundamental constituent of adenosine triphosphate (ATP), nucleotides, nucleic acids, and phospholipids that are energy carriers within the plants **(**Roy et al. 2006, Shenoyand Kalagudi 2005, Khan et al. 2012, 2014). Phosphorus fertilizer is not only a major essential plant nutrient but also a key input for in increasing crop yield (Dastanet al. 2012). Phosphorous is much less abundant in plants (as compared with nitrogen and K) having a concentration of about one-fifth to one-tenth that of nitrogen in plant dry matter **(**Roy et al. 2006). Phosphorous is absorbed as the orthophosphate ion (either as $H_2PO_4^-$ or HPO_4^{2-}) depending on soil pH. As the soil pH increases, the relative proportion of $H_2PO_4^-$ decreases and that of HPO_4^{2-} increases.

It also performs major function to maintain the membrane integrity. It is mobile within the plant and enhances growth and development of rice crop including root development. So, it is principally critical in early growth stages and the addition of mineral phosphorous fertilizer is needed when the rice plant's root system is not yet completely developed and the native soil phosphorous supply is small.

When the plant faces phosphorous shortage (stress), phosphorous from the old leaves is readily translocated to young tissue. With such a mobile element, the pattern of redistribution seems to be determined by the properties of the source (old leaves, and stems) and the sink (shoot tip, root tip, expanding leaves and later into the developing seed).

Plant growth is markedly restricted under phosphorous deficiency, which retards growth, tillering and root development and delays ripening. The deficiency symptoms usually start on older leaves. A bluish-green to reddish color develops, which can lead to bronze tints and red color. A shortage of inorganic phosphate in the chloroplast reduces photosynthesis. Because ribonucleic acid (RNA) synthesis is reduced, protein synthesis is also reduced (Roy et al. 2006). A decreased shoot/root ratio is a feature of phosphorous deficiency, as is the overall lower growth of tops.

When the plant show stunted dark green with erect leaves and reduced tillering, it means that phosphorous is deficient in that plant. There are some factors that cause phosphorus deficiency such as low indigenous soil phosphorous-supplying power, inadequate application of mineral phosphorous fertilizer, low efficiency of applied phosphorous fertilizer as a result of high phosphorous fixation capacity in soil or erosion losses (in upland rice fields only), excessive use of nitrogen fertilizer with insufficient phosphorous application, cultivar differences in susceptibility to phosphorous deficiency and response to phosphorous fertilizer, crop establishment method.

2.11.5 Phosphorous losses

Of the major plant nutrients, world resources of phosphorous are the smallest and, thus, on a global scale, phosphorous should be used as efficiently as possible in order to conserve the resource base and to maintain and increase, where necessary, agricultural productivity. Applying phosphorous to a soil where there is sufficient readily plant available phosphorous, such that there is no increase in yield or benefit to crop quality, is an inefficient use of fertilizer or manure and bio-solids. When phosphorous is required, both the amount applied and the timing of the application is important for improving the efficiency with which the phosphorous is used. Total phosphorous content of the cultivated soil was 29 percent lower than that of the adjacent permanent pasture (Hedley et al. 1982). When P, another growth limiting nutrient, is applied in high percentage, sometimes up to 90 percent, is precipitated by metal complexes in the soil and can later lead to phosphorous pollution (Rodriguez and Fraga 1999).

2.12 Potassium for rice

2.12.1 Potassium sources

Potassium (K) is considered next to nitrogen (N) as regards its role in rice production (Bao 1985). Soils commonly contain over 20000 parts per million (ppm) of total potassium (K). Nearly all of this is a structural component of soil minerals and is unavailable to plants. Plants can use only the exchangeable potassium on the surface of soil particles and potassium dissolved in the soil water. This often amounts to less than 100 ppm.

The three forms of soil potassium are unavailable, slowly available or fixed, and readily available or exchangeable potassium. Micas, feldspars and clay minerals, minerals containing unavailable potassium, weather or break down and release their potassium as the available potassium ion (K^+). This process is too slow to supply the full potassium needs of field crops. The supply of slowly available or fixed potassium also largely determines the soil’s ability to supply potassium over extended periods of time. Readily available potassium is that which is dissolved in soil water or held on the surface of clay particles. Dissolved potassium levels in the soil water are usually

5-10 ppm. Plants absorb dissolved potassium readily, and as soon as the concentration of potassium in the soil solution drops, more is released into the solution from the exchangeable forms.

Therefore, potassium fertilization should be made to ensure the yield of crops. The most common potassium fertilizer for use on field crops is potassium chloride, or muriate of potash (MOP). And the other potassium fertilizers are Potassium chloride (60 to 62 percent K_2O), Potassium sulfate (50 percent K_2O), Potassium magnesium sulfate (22 percent K_2O), Potassium hydroxide, Potassium nitrate (44 percent K_20) (Vitosh 1996).

2.12.2 Solubility of potassium

Soil potassium is affected less by flooding than nitrogen or phosphorous. Availability of potassium changes very little with draining and flooding (Harrell and Saichuk 2009). Surendran (2005) showed that split application of potassium was found to be better than entire basal application. Application of 50 percent K_2O each at tillering and panicle initiation stages increased the growth and yield attributes of rice and nitrogen, phosphorous, potassium and sulphur uptake. Similarly it has a positive impact on available potassium and sulphur. Application of muriate of potash (MOP) was superior to sulphate of potash (SOP) on rice. Potassium application 50 percent at transplanting and 50 percent at panicle initiation along with nitrogen is recommended in Malanad where light textured soils and high rainfall conditions are prevalent. Thus, potassium can be applied in 1-3 split applications and depends on soil potassium buffering characteristics, crop establishment method used and the local importance of potassium for reducing pest and diseases incidence (Ravichandran and sriramachand-rasekharan 2011).

2.12.3 Effects of potassium on rice growth and yield

Potassium is often the most limiting nutrient after nitrogen (N) in high yielding rice systems (Balasubramanian et al. 2003). Plants accumulate high amounts of potassium (K). On average, potassium constitutes 2 percent of the total dry weight of plants. In fresh tissues, its concentration ranges from 20 to 100 mM. Potassium is generally said to be “the cation for all anions.” (Bucker et al. 2006).The dosage of 30-70 kg K_2O ha^{-1} could give the high rice grain yield and maximum profitability (Khuonget al. 2008). Maximum grain yield of rice was recorded with 30 kg K_2O ha^{-1}

(Bahmanyarand Mashaee2010). It also increases the rice plant's tolerance of adverse climatic conditions, lodging, insect pests, and diseases (Dobermann and Fairhurst 2000). Average potassium removal in the harvested portion of rice crops is 8 lb potassium (K) ton^{-1} (Mikkelsen 2008).

Potash nutrient is taken up 102 kg ha^{-1} with the rice yield of 6 t ha^{-1} (Miah et al. 2005).The dosages of 40 kg K_2O ha^{-1}supported the highest number of total tillers and effective tillers, maximum number of total spikelet and grains panicle^{-1} result the highest grain yield (Uddin et al. 2013). At flowering stage, potassium content of stems was higher than leaves (Bahmanyarand Mashaee2010). At harvest, the potassium removal of rice grain is 2.5 kg nutrient in grain t^{-1} grain yield (Fairhurstet al. 2007). Potassium can delay leaf senescence, and therefore contributes to greater canopy photosynthesis and crop growth. Potassium improves root growth and plant vigor and helps prevent lodging. It also enhances crop resistance to pests and increases number of spikelet per panicle, percentage filled grains, and 1000 grains weight. Potassium fertilization increased grain yield by 8 to 11 percent above rice receiving no potassium (Elliot et al. 2010).

Within the plant the complex formation of protein from nitrate and its distribution around the plant are highly dependent upon adequate potassium supply. If 'normal optimum' rates of nitrogen are applied in the absence of sufficient K, full response to nitrogen will not be obtained and residues of nitrogen may remain and be leached at the end of the season (PDA 2006).

2.12.4 Functions and deficiency of potassium in rice plant

Although potassium is an essential nutrient for plant growth, it often accepts less attention than nitrogen and phosphorous in many crop production systems. It carries out essential functions in plant cells and helps for the transport of the products of photosynthesis. It also provides strength to plant cell walls since it is involved in the lignification of sclerenchyma tissues and play a role for greater canopy photosynthesis and crop growth. Although it does not have a distinct effect on tillering, potassium increases the number of spikelet per panicle, percentage of filled grains, and 1,000-grain weight (Dobermann and Fairhurst 2000). On the entire plant level, potassium improves leaf area and leaf chlorophyll content, delays leaf senescence. The following factors are the causes of potassium deficiency:

-low soil K-supplying capacity,

-insufficient application of mineral potassium fertilizer,

-complete removal of straw from the farm after harvesting of the crop,

-small inputs of potassium in irrigation water,

-low recovery efficiency of applied potassium fertilizer as high soil K-fixation capacity or leaching losses,

-presence of excessive amounts of reduced substances in poorly drained soils (e.g., H_2S, organic acids, Fe^{2+}) that result in retarded root growth and potassium uptake,

-wide Na:K, Mg:K, or Ca:K ratios in soil, and

-sodic /saline soil conditions.

When potassium is deficient, the visual symptoms are dark green plants with yellowish brown leaf margins or dark brown necrotic spots which first appear on the tips of older leaves in plant (Fairhurst et al. 2007).

2.12.5 Potassium losses

Fertilizer potassium should be applied in rice crops in such a way that minimum is lost through leaching and maximum is utilized for plant growth and grain production. In order to increase the use efficiency and reduce loss of K, it should be applied in split at various phases of plant growth and development (Uddinet al. 2012a). Potassium can be lost in the soil by the following ways.

(1) Crop removal

(2) Fixation and

(3) Leaching (Sparks and Carski 1985).

CHAPTER III

MATERIALS AND METHODS

The pot experiments were conducted during the summer season (February-June) and rainy season (June - October) of 2014. The Shwe Thwe Yin rice variety (IR 50) was taken to test in this experiment from Rice Division of Department of Agricultural Research (DAR).

3.1 Experimental site

The experiments were conducted at screen house of Department of Soil and Water Science, Yezin Agricultural University (YAU), Nay Pyi Taw. The area is located at 19˚ 10' N latitude, 96˚ 07' E longitude with the elevation of 102 meters above sea level.

3.2 Experimental design and treatments

In both growing seasons, the experiments were laid out in randomized complete block (RCB) design with four replicates. The tested variety was Shwe Thwe Yin (IR 50). Straight and compound fertilizers were used as treatments. For straight fertilizers treatments, Nitrogen was applied as urea, phosphorous as triple super phosphate (TSP), and potash as Muriate of Potash (MOP). As compound fertilizers, 15:15:15 (Armo) and 15:7:8 (Golden Lion) compound fertilizers were used. The rate of straight fertilizers was used as the recommended rate of Department of Agricultural Research (DAR) and as follow.

Recommended rate of straight fertilizers for one hectare of rice cultivation

Nitrogen = 85 kg N (Urea 185 kg)
Phosphorous = 30 kg P_2O_5 (Triple super phosphate (TSP) 62kg)
Potash = 37 kg K_2O (Muriate of Potash (MOP) 62 kg)

Among the different compound fertilizers in the market, 15:15:15 (Armo) and 15:7:8 (Golden Lion) compound fertilizers were selected for test. The 15:15:15

compound fertilizer contains 15 percent N, 15 percent P_2O_5 and 15 percent K_2O and the 15:7:8 compound fertilizers contain 15 percent N, 7 percent $P_2O_5$and 8 percent K_2O. So, 15:15:15 compound fertilizer is more cost than 15:7:8 compound fertilizer. For one acre of rice cultivation, farmers used to apply one bag of compound fertilizer at basal plus 0.5 bag of urea at 10 Day After Transplanting (DAT) and 0.5 bag of urea at Panicle Initiation stage (PI). So, in this experiment, above two kinds of compound fertilizers plus Urea were used as treatments. Compound fertilizers are more cost compare with straight fertilizers, therefore all nitrogen, phosphorous, potassium straight fertilizers were used as the nutrient content of each compound fertilizer plus Urea treatment to compare the rice yield between the different fertilizers input cost.

So, the treatments are as follow and the detail explanation of all treatments are in Appendix (6).

T1	no fertilizer
T2	three splits application of straight fertilizers
T3	two splits application of straight fertilizers
T4	15:15:15 compound fertilizer 125 kg ha^{-1} + 125 kg Urea ha^{-1}
T5	straight fertilizers the same as the nutrient ratio of T4
T6	15:7:8 compound fertilizer 125 kg ha-1 +125 kg Urea ha^{-1}
T7	straight fertilizers the same as the nutrient ratio of T6

In straight fertilizers treatments, T2 and T3, Urea, Triple Super Phosphate (TSP) and Muriate of Potash (MOP) were used as straight fertilizers with recommended rate. In compound fertilizers treatments, the rate of nutrients was used as farmer practice. In T5 and T7, the straight fertilizers that will be adjusted to compound plus Urea were Urea, TSP and MOP.

3.3 Experimental soil

A composite soil sample of 0-15 cm depth from Yezin Agricultural University farm was collected. Some physicochemical properties of initial soil were analyzed at the Soil Analysis laboratory, Land Use Division, Department of Agriculture, Yangon before growing the plant.

Table 3.1 Physicochemical properties of experimental soil

Property	**Content**	**Rating**
Texture		Sandy loam
Bulk density (g cm^{-3})	1.23	
pH	5.92	Moderately acid
Nitrogen (Total N percent)	0.23	Medium
Phosphorous (ppm)	23.48	Very High
Potassium (mg 100 g^{-1})	26.22	High
Potassium (meq 100 g^{-1})	0.57	High
CEC (meq 100 g^{-1})	12.89	Low
Organic matter (percent)	1.7	Low
EC (ms cm^{-1})	0.14	Very Low

3.4 Number, size and arrangement of pots

A total of 28 plastic pots were used in this experiment. The pots were laid out in the screen house with randomized complete block (RCB) design by four replications. The size of the pots was 26 cm in height, 30 cm diameter at the top and 21.3 cm at the bottom. The collected soil was well pulverized and dried in the shade and then passed with 2 mm sieve. The 13.0 kg of soil was filled into plastic pot of 28 cm diameter to a depth of 20 cm. Under puddle condition, 25 day old seedlings were transplanted in each pot. Two hills were planted in one pot with one seedling per hill.

3.5 Measurement parameters for growth

Growth parameter such as plant height and number of tillers hill^{-1} was recorded one week interval. Plant height was measured from the surface of the soil to the tip of the topmost leaf. The number of tillers hill^{-1}, was recorded until the heading stage. After harvesting, plant samples were taken and air dried until the dry weight was stable. After that, the dry weight was used to compute the harvest index.

3.6 Data collection and calculation

Before starting the first season experiment, the soil sample was taken to analyze. The data of tiller numbers and plant heights of all treatments were measured in two weeks interval from 14 day after transplanting (DAT) to 56 (DAT) heading stage of rice plant. According to the IRRI and WARDA (2007) the plant height was measured from the base of the shoot to the tip of the tallest leaf blade, to nearest centimeter.

Crops were harvested when most of the panicles turned yellow. All of the panicles per pot were collected to record yield and yield components. Rice plant was cut just above the soil surface in each pot for dry mater yield. The number of seeds per panicle and panicle number were directly counted, while the grain yield (GY) (g) was estimated using electronic weighing balance. All measurements were taken in triplicates. Straw was air- dried until the constant weight. Straw yield (SY) was used to calculate the rice harvest index (HI) and the formula of HI is as follows:
Harvest index (H.I.) =

$$\text{HI} = \frac{\text{economic yield}}{\text{biological yield}}$$

(Yoshida 1981)

The number of panicles hill^{-1} (effective tillers hill^{-1}), un-effective tillers hill^{-1}, spikelet number panicle^{-1}, filled grain percent and 1000 grains weight were also measured at harvest. All soil samples of each pot were taken to analyze the nitrogen, phosphorous and K_2O concentration whenever each experiment growing season was harvested.

3.7 Crop management

Since, the sheath rot disease was found at ripening stage in the dry season, Mencozeb 80 WP was used. In wet season, there was no insect pest and disease.

3.8 Weather data

Temperature, solar radiation, and rainfall influenced rice yield by directly affecting the physiological processes involved in grain production, and indirectly through diseases and insects. From a crop physiologist’s point of view, crop period, productivity, and stability are important aspects of rice cultivation. Climatic factors affect each of them in different ways. All weather data for both seasons were obtained from meteorological station at Department of Agricultural Research in Yezin (Appendix 1). The monthly average values of temperature and monthly rainfall of two experiment growing periods (from February to October 2014) on Yezin area were shown in Figure (3.1). In the first experiment season (Feb-June, 2014), the maximum temperature was 38.8 ºC (April) and the minimum temperature was 15.2 ºC (Feb). The maximum temperature of second experiment season (June – October, 2014) was 34.4 ºC (June) and the minimum was 22 ºC (October). The range of temperature of the flowering time of first season (May) was (23.8-37.9) and that of second season (September) was (23.9 – 33.5). Extreme temperatures are destructive to plant growth and, hence, define the environment under which the life cycle of the rice plant can be completed (Yoshida 1981).

3.10 Statistical analysis

All data were analyzed by the Analysis of Variance (ANOVA) procedure using statistix software (8th edition). Where significant differences were detected, the means were separated by the least significant difference (LSD) at 5 percent probability level. Pearson correlation analysis among yield and yield components was also computed.

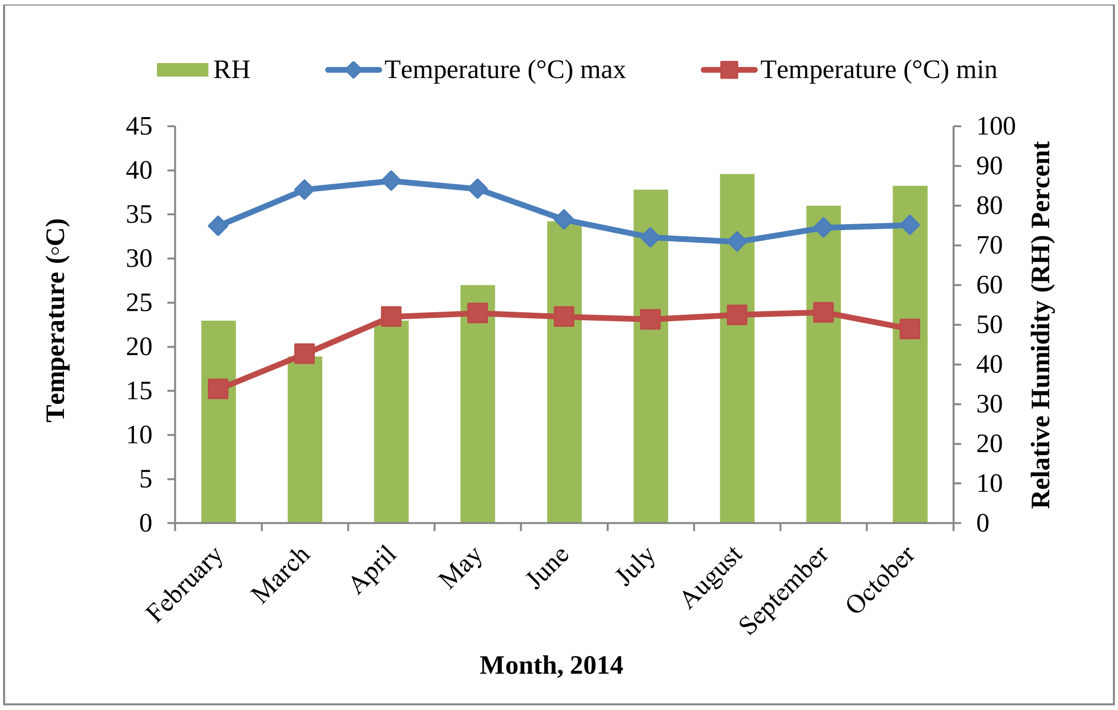

Figure 3.1 Monthly average temperatures and average relative humidity of two experiment growing periods (from February to October 2014) on Yezin area

CHAPTER IV

RESULTS AND DISCUSSION

4.1 First experiment (dry season, 2014)

This experiment was conducted to compare the effects of straight and compound fertilizers on yield and yield components of rice (Shwe Thwe Yin).

4.1.1 Yield and yield components as affected by straight and compound fertilizers on Shwe Thwe Yin rice variety during the dry season, 2014

4.1.1.1 Plant height (cm)

The plant heights of all treatments tested was measured at 7 days interval from 14 to 56 days after transplanting (DAT) and the trend of these data was presented in Figure 4.1. The plant heights in all treatments increased continuously up to 56 DAT (heading). AT 14 DAT and 21 DAT, the plant heights were significant difference at 5 percent level. The highly significantly difference in plant height among the treatments was occurred at 35, 42, 49 and 56 DAT at 1 percent level.

At 14 DAT, the highest value of plant height (37.90 cm) was measured in T4 (15:15:15 compound fertilizer 125 kg ha^{-1} + 125 kg Urea ha^{-1}) treatment and the T6 (15:7:8 compound fertilizer 125 kg ha^{-1} + 125 kg Urea ha^{-1}) treatment caused the highest value 47.35 cm at 21 DAT. There was found that the result of no statistically and mathematically difference among the T2 (three splits application of straight fertilizers), T3 (two splits application of straight fertilizers) and T5 (straight fertilizers same as the nutrient ratio of T4) treatments at 35 DAT while the maximum value (65.30 cm) was produced by T5. The highest values of 42, 49 and 56 DAT were 74.60 cm, 84.80 cm, and 99.58 cm respectively and these values were produced by T3 treatment only. Plant height was significantly increased only with the application of urea (Fageria et al. 2011).The plant height increased significantly with nitrogen and phosphorus fertilizer (Yoseftabar 2013b). Almost all of the lowest plant height data was possessed by control treatment, T1 (no fertilizers). The plant height, number of productive tillers, filled grains per panicle, panicle length, grain and straw yield of rice were higher in the plots which receive potassium in two splits (50 per cent at tillering and 50 percent at panicle initiation T4 (15:15:15 compound fertilizer 125 kg ha^{-1} + 125 kg Urea ha^{-1}) (Surendran 2005).

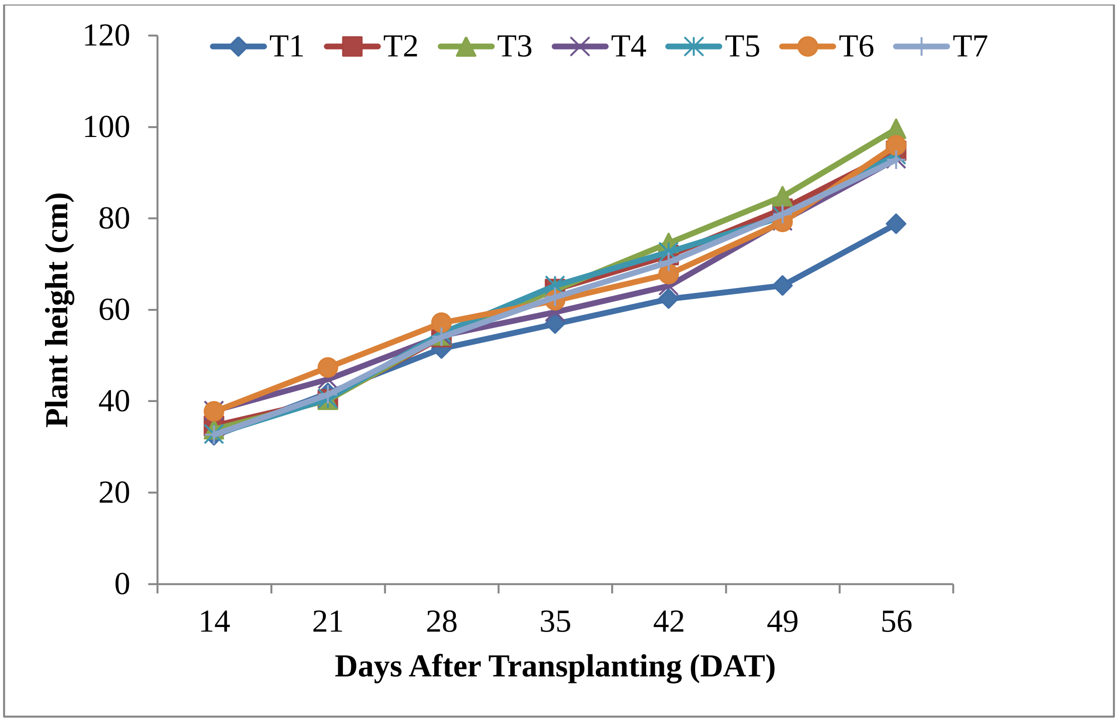

Figure 4.1 Mean values of plant heights as affected by straight and compound fertilizers on Shwe Thwe Yin rice variety during the dry season, 2014

Treatments

T1 = no fertilizer

T2 = three splits application of straight fertilizers

T3 = two splits application of straight fertilizers

T4 = 15:15:15 compound fertilizer 125 kg ha^{-1} + 125 kg Urea ha^{-1}

T5 = straight fertilizers the same as the nutrient ratio of T4

T6 = 15:7:8 compound fertilizer 125 kg ha^{-1} +125 kg Urea ha^{-1}

T7 = straight fertilizers the same as the nutrient ratio of T6

4.1.1.2 Number of tillers hill^{-1}

The tiller numbers were also counted at 7 days interval and Figure (4.2) showed how the tillers of all treatments tested increased from 14 DAT to 56 DAT. There were highly significant differences in tiller numbers at 14, 21, 35, 49 and 56 DAT at 1 percent level while the 28 and 42 DAT caused the significant differences in that growth parameter at 5 percent level.

Although treatment T4 (15:15:15 compound fertilizer 125 kg ha^{-1} + 125 kg Urea ha^{-1}) and T6 (15:7:8 compound fertilizer 125 kg ha^{-1} +125 kg Urea ha^{-1}) produced the maximum tiller numbers in the early growth stages of plant (14, 21 and 28 DAT), only T3 (two splits application of straight fertilizers) treatment produced the maximum tiller numbers in the later growth stages (from 35 to 56 DAT). The maximum tiller numbers of 3.9, 10.5, 13.9, 18.3, 28.0, 31.8 and 31.6 were produced by T4, T4, T6, T3, T3, T3 and T3 treatments receptively at each data collection times of 14, 21, 28, 35, 42, 49 and 56 DAT. Yoseftabar (2013b) reported that the total tiller increased significantly with nitrogen and phosphorus fertilizer. Similarly in plant height, nearly all of the least tiller number was caused by T1 (no fertilizers). Application of potassium significantly increased tiller number (40-140 percent), plant height (<30 percent), shoot (120-140 percent) and root (80-300 percent) dry matter production and stem diameter (30-80 percent) in all varieties, although differences between varieties were observed. Lodging occurred primarily from the base, due to poor root growth in the absence of potassium (Bhiah et al. 2010).

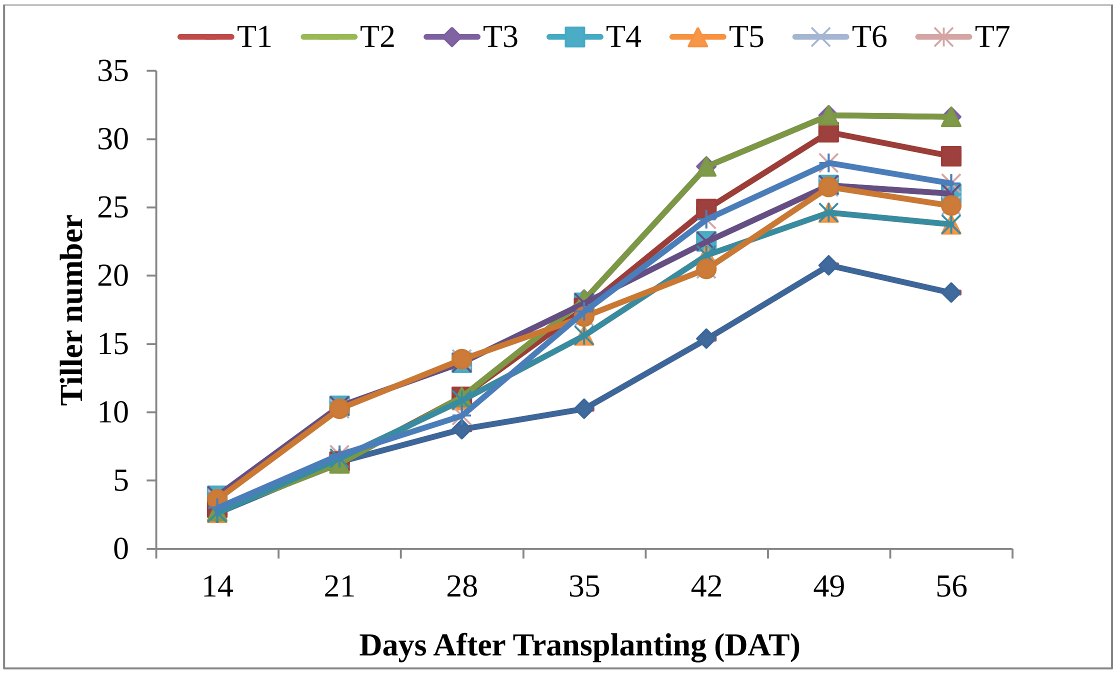

Figure 4.2 Mean values of tiller numbers as affected by straight and compound fertilizers on Shwe Thwe Yin rice variety during the dry season, 2014

Treatments

T1 = no fertilizer

T2 = three splits application of straight fertilizers

T3 = two splits application of straight fertilizers

T4 = 15:15:15 compound fertilizer 125 kg ha^{-1} + 125 kg Urea ha^{-1}

T5 = straight fertilizers the same as the nutrient ratio of T4

T6 = 15:7:8 compound fertilizer 125 kg ha-1 +125 kg Urea ha^{-1}

T7 = straight fertilizers the same as the nutrient ratio of T6

4.1.1.3 Number of panicle hill^{-1}

The number of panicle hill^{-1} at harvest was indicated in (Table 4.1). It was highly significant difference at 1 percent level. The range of panicle number hill^{-1} caused by all treatments was from 16.63 to 27.13. The T2 (three splits application of straight fertilizers), treatment applied with straight fertilizers according to the recommendations of the Department of Agricultural Research (DAR), (all phosphorous at basal, nitrogen and potassium was used 1/3 at basal, 1/3 at 10 day after transplanting (DAT) and 1/3 at panicle initiation (PI) gave the maximum number of panicle hill^{-1} (27.13). Yoseftabar et al. (2012) reported that split application of nitrogen fertilizer increased the yield and yield components of rice. The control treatment T1 (no fertilizers) produced the minimum number of panicle hill^{-1} (16.63).

In this parameter, although the values of compound fertilizer treatments T4 (15:15:15 compound fertilizer 125 kg ha^{-1} + 125 kg Urea ha^{-1}), T6 (15:7:8 compound fertilizer 125 kg ha^{-1} +125 kg Urea ha^{-1}) and the equal nutrient value with straight fertilizers to compound fertilizers treatments T5 (straight fertilizers same as the nutrient ratio of T4), T7 (straight fertilizers same as the nutrient ratio of T6) was not as good as the value of straight fertilizers treatments T2 (three splits application of straight fertilizers), T3 (two splits application of straight fertilizers), there was no significant difference among T4, T5, T6 and T7. These four treatments supplied less nitrogen at early plant stages than T2 and T3 treatments. Also, the larger amount of phosphorous and potassium was supplied in straight fertilizers treatments of T2 and T3 than other treatments. Sufficient amount of phosphorous promote the growth of plant root and hence consequent increase in nutrient absorption by larger root number. The addition of mineral phosphorous fertilizer is needed when the rice plant’s root system is not yet fully developed and the native soil phosphorous supply is small. Phosphorous can remobilize within the plant during later growth stages if sufficient phosphorous has been absorbed during early growth (Dobermann and Fairhurst 2000).

4.1.1.4 Number of spikelet panicle^{-1}

A significant difference was found in the statistical result of number of spikelet panicle^{-1} at 5 percent level (Table 4.1). There was a range of 109.25 - 141.00 in this yield component parameter. The maximum spikelet number (141.00) was counted from T3 (two splits application of straight fertilizers), application of recommended straight fertilizers (all phosphorous at basal, 1/2 of nitrogen and potassium fertilizers at 10 DAT and another 1/2 at PI). The minimum spikelet number (109.25) was produced by control treatment, T1 (no fertilizers). Although T3 treatment was treated with the least amount of nitrogen at PI stage, it had already gotten the sufficient amount of nitrogen at early stage of plant. So it can produce the larger number of spikelet panicle^{-1} at later panicle forming stage of plant. Using 80 kg N ha^{-1} produced (163.97) spikelet panicle^{-1} (Uddin 2012b). Except T3 and T1, among the rest of treatments, there was no mathematically significant different of this parameter. Sufficient potassium supply increases the number of spikelet panicle^{-1} (Dobermann and Fairhurst 2000). Means of paddy yield and yield components of rice showed that maximum value of tillers hill^{-1} (26.81), grains panicle^{-1} (68.81), 1000 grains weight (22.00 g), paddy yield (4.73 tha^{-1}) and minimum percentage of sterile grains (6.39%) were observed in treatment receiving split use of Potash (Awan 2007).

4.1.1.5 1000 grains weight (g)

Although the nutrient amount treated by different straight and compound fertilizers application habits at different plant growth stages were not equal, there was no significant difference in 1000 grains weight (g) (Table 4.1). The maximum number of 1000 grains weight (18.15 g) and the minimum number (17.58 g) were produced by T6 (15:7:8 compound fertilizer 125 kg ha^{-1} +125 kg Urea ha^{-1}) and T3 (two splits application of straight fertilizers) treatments respectively while the rest of other treatments gave the statistically similar values. The one of yield component parameters, 1000 grains weight is usually a stable varietal character and it was less affected by management practices (Dobermann and Fairhurst 2000). Yoshida (1981) also reported that since the grain size is rigidly controlled by the size of the hull, the 1000 grains weight is a stable varietal character. Hence, grain cannot grow to a size greater than that permitted by the hull no matter how favorable weather conditions and nutrient supply are.

4.1.1.6 Filled grain percent

The statistical result of filled grain percent was presented in (Table 4.1). There was a highly significant difference among the filled grain percent data of all tested treatments at 1 percent level with the range of 72.00 - 82.75. The highest value (82.75 percent) was produced by T3 (two splits application of straight fertilizers) while T2 (three splits application of straight fertilizers) and T4 (15:15:15 compound fertilizer

125 kg ha^{-1} + 125 kg Urea ha^{-1}) produced the 80.50 percent and 80 percent respectively. These three treatments were not statistically different. The lowest value (72.00 percent) was created by T1 (no fertilizers). The more amount of potassium fertilizer compared to other treatments was applied at panicle initiation (PI) stage of plant in T3 treatment. Adequate amount of potassium application increased leaf area and leaf chlorophyll content, delayed leaf senescence, and therefore contributed to greater canopy photosynthesis, crop growth and filled grain percent of rice (Dobermann and Fairhurst 2000).

4.1.1.7 Grain yield

Grain yield data of all treatments was shown in (Table 4.1). There was highly significantly difference on grain yield data among the treatments tested. Grain yield was highly significantly increased in treatments with the more of nitrogen nutrient contents. This result was agreed with the Fageria et al. (2011). The highest grain yield (51.03 g hill^{-1}) was observed in T3 (two splits application of straight fertilizers) treatment and the lowest value (25.90 g hill^{-1}) was produced by T1 (no fertilizers) treatment. Among all treatments, straight fertilizer treatments, T2 (three splits application of straight fertilizers) and T3 gave the highest grain yield and these treatments get more nutrient content for the whole plant life compared to other treatments.

Grain yield can be analyzed as yield obtained without fertilizer and yield increase obtained by fertilizer application. All the grain yield data was superior to the control treatment T1. The values that superior to the control treatment produced by T3, T2, T4 (15:15:15 compound fertilizer 125 kg ha^{-1} + 125 kg Urea ha^{-1}), T6 (15:7:8 compound fertilizer 125 kg ha^{-1} +125 kg Urea ha^{-1}), T7 (straight fertilizers same as the nutrient ratio of T6) and T5 (straight fertilizers same as the nutrient ratio of T4) treatments were 49 percent, 46 percent, 39 percent, 35 percent, 34 percent and 29 percent respectively (Appendix 9).

According to the cost of fertilizer inputs for one acre of rice cultivation, the fertilizer cost of T3 treatments was lesser than that of T4, while the yield of T3 was 17 percent more than T4. Although another compound fertilizer treatment, T6, was lesser input fertilizer cost than T3 treatment, it was reduced 22 percent in yield compared to T3. Yield increased significantly with phosphorous fertilization (Lee et al. 2008). Fertilizer application can cause a 30-100 percent increase in yield compared with no fertilizer application (Win 1991). Manzoor et al. (2008) reported that the increased grain yield of rice with split applying of potash may be due to continuous supply of potassium to crop during crop growth stages. The efficient potassium uptake by rice plant produces in better growth and development when it is applied at maximum tillering stage and at panicle initiation stage of rice plant. Grain yield in maize and sorghum also showed positive relationship with increase in potash levels and increase in its number of split applications (Saleem et al. 2011). In the last few decades the rate of nitrogen, phosphorous and potassium fertilizer application has tremendously increased in crop production (Adesmoye and Kloepper 2009).

4.1.1.8 Harvest index

Table (4.1) also showed the harvest index (HI) data of all treatment tested. There was no significant difference in harvest index. The highest value (0.48) was produced by T4 (15:15:15 compound fertilizer 125 kg ha^{-1} + 125 kg Urea ha^{-1}) and the lowest value (0.42) was generated by T3 (two splits application of straight fertilizers) treatment. Although T3 treatment applied more amounts of nitrogen, phosphorous and potassium, the HI of this treatment was lesser than other treatment. This result was agreed with the finding of Uddin (2012). The harvest index is about 0.3 for traditional tall varieties and 0.5 for improved, short varieties (Yoshida 1981).

4.1.1.9 Correlation relationship among yield and yield components under straight and compound fertilizers application

The correlation relationship among yield and yield components characters presented in the Table (4.2). In this study, plant yield was positively and significantly correlated with number of panicle hill^{-1} (r = 0.815*) and filled grain percent (r = 0.906*). Agahi et al. (2007) reported that number of productive tillers and number of grains panicle^{-1} were positively and significantly correlated with the grain yield while another yield components characters were not correlated.

Table 4.1 Yield and yield components as affected by straight and compound fertilizers on rice (ShweThwe Yin) during the dry season, 2014.

Treatments	No. of panicle hill^{-1}	No. of spikelet panicle^{-1}	1000 grains weight (g)	Filled grain percent	Grain yield (g hill^{-1})	Harvest Index (HI)
T1	16.63 d	109.25 d	17.60	72.00 c	25.90 f	0.47
T2	27.13 a	117.50 bcd	17.63	82.50 a	47.80 b	0.43
T3	24.63 ab	141.00 a	17.58	82.75 a	51.03 a	0.42
T4	23.50 bc	121.00 bc	18.00	80.00 a	42.35 c	0.48
T5	21.38 c	114.25 cd	17.83	76.00 b	36.55 e	0.45
T6	23.38 bc	123.50 bc	18.15	74.75 bc	39.78 d	0.45
T7	22.38 bc	125.25 b	17.60	74.50 bc	39.05 de	0.44
LSD$_{0.05}$	2.99	9.58	0.59	3.73	2.50	0.05
Pr>F	**	**	ns	**	**	ns
CV%	8.85	5.30	2.22	3.24	4.17	8.07

Mean followed by the similar letter in each column are not significantly different at 5 percent LSD

** significant at 1 percent level, ns = non-significant

T1 (no fertilizers), **T2** (three splits application of straight fertilizers), **T3** (two splits application of straight fertilizers), **T4** (15:15:15 compound fertilizer 125 kg ha^{-1} + 125 kg Urea ha^{-1}), **T5** (straight fertilizers the same as the nutrient ratio of T4),**T6** (15:7:8 compound fertilizer 125 kg ha^{-1} +125 kg Urea ha^{-1}), **T7** (straight fertilizers the same as the nutrient ratio of T6)

Table 4.2 Correlation relationship among yield and yield components under straight and compound fertilizers application (dry season, 2014)

	Total dry matter	**No. of panicle hill^{-1}**	**No. of spikelet panicle^{-1}**	**1000 grains weight (g)**	**Filled grain percent**	**Grain yield (g hill^{-1})**	**Harvest Index**
No. of panicle hill^{-1}	0.449	1					
No. of spikelet panicle^{-1}	0.463	0.164	1				
1000 grains weight (g)	0.184	-0.315	-0.357	1			
Filled grain percent	0.059	0.780	0.353	-0.421	1		
Grain yield (g hill^{-1})	0.015	0.815*	0.639	-0.491	0.906*	1	
Harvest Index	0.438	-0.427	-0.505	0.730	-0.316	-0.561	1

*Significant at 5 percent level

4.2 Second experiment (wet season, 2014)

The second experiment was done to compare the effects of straight and compound fertilizers on yield and yield components of rice (Shwe Thwe Yin).

4.2.1 Yield and yield components as affected by straight and compound fertilizers on Shwe Thwe Yin rice variety during the wet season, 2014

4.2.1.1 Plant height (cm)

The plant heights were measured at 7 days interval from 14 to 56 days after transplanting (DAT) and these data was presented in Figure 4.3. AT 21 DAT to 56 DAT, the plant heights were highly significant difference at 1 percent level while the plant height was significant different at 5 percent level on 14 DAT.

The highest plant height data were 36.38 cm at 14 DAT, 45.25 cm at 21 DAT, 54.18 cm at 28 DAT, 62.08 cm at 35 DAT, 71.53 cm at 42 DAT, 82.88 cm at 49 DAT and 98.88 cm at 56 DAT and these data were caused by T6 (15:7:8 compound fertilizer 125 kg ha^{-1} +125 kg Urea ha^{-1}), T3 (two splits application of straight fertilizers), T3, T7 (straight fertilizers the same as the nutrient ratio of T6), T2 (three splits application of straight fertilizers), T3 and T2 receptively at each data collection time. From 28 DAT to 56 DAT, the plant height data of T2, T3 and T7 were statistically and mathematically not significant different. At all the time of data collection, although the highest plant heights were occupied by T2, T3, T4 (15:15:15 compound fertilizer 125 kg ha^{-1} + 125 kg Urea ha^{-1}), T6 and T7 treatments alternately, the lowest plant heights were always occupied by T1 (no fertilizers), control treatment.

Bahmanyar and Mashaee (2010) reported that plant height, number of tiller, number of grain panicle^{-1}; hollow grain percentage, grain and biological yield were significantly affected by nitrogen and potassium fertilization.

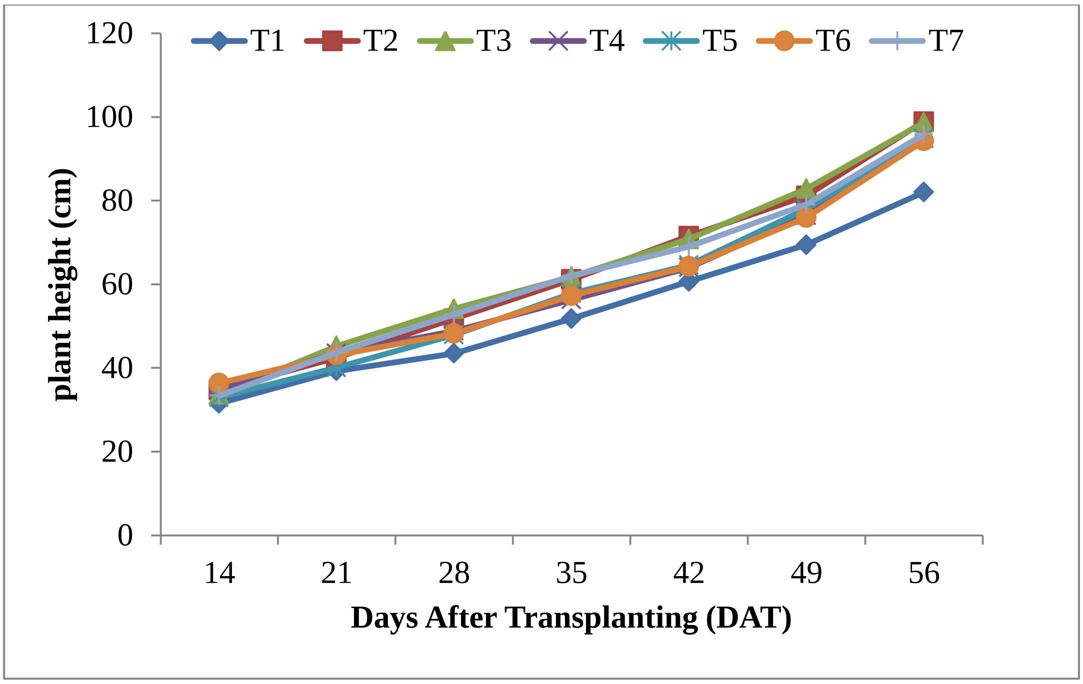

Figure 4.3 Mean values of plant heights as affected by straight and compound fertilizers on Shwe Thwe Yin rice variety during the wet season, 2014

Treatments

T1 = no fertilizer

T2 = three splits application of straight fertilizers

T3 = two splits application of straight fertilizers

T4 = 15:15:15 compound fertilizer 125 kg ha^{-1} + 125 kg Urea ha^{-1}

T5 = straight fertilizers the same as the nutrient ratio of T4

T6 = 15:7:8 compound fertilizer 125 kg ha^{-1} +125 kg Urea ha^{-1}

T7 = straight fertilizers the same as the nutrient ratio of T6

4.2.1.2 Number of tillers hill^{-1}

The tiller numbers counted at 7 days interval were shown in Figure (4.4). Except 14 DAT, all of the rest data collection times (21 DAT to 56 DAT) were highly significant different on tillers number hill^{-1}. The significant different at 5 percent level was found in 14 DAT only. The maximum plant height data were possessed by T2 (three splits application of straight fertilizers), T3 (two splits application of straight fertilizers) and T6 (15:7:8 compound fertilizer 125 kg ha^{-1} +125 kg Urea ha^{-1}) treatments alternatively. These data were 4.5 at 14 DAT (T3), 9.5 at 21 DAT (T6), 12.88 at 28 DAT (T3), 17.38 at 35 DAT (T3), 24.5 at 42 DAT (T3), 27.75 at 49 DAT (T3) and 25.38 at 56 DAT (T2) and the next 25.38 at 56 DAT (T3). Therefore, the most of above data was possessed by T3 treatment. Like plant height data, the minimum tiller numbers hill^{-1} data were possessed by T1 (no fertilizers) treatment at all data collection times. At 28 and 35 DAT, there was found that tiller numbers hill^{-1} of all treatments were not statistically different except T1 (no fertilizers).

The number of tillers plant^{-1} across the rice cultivars increased with increase rate of NPK (Ndaeyo et al. 2008). From 14 DAT to 28 DAT, tiller numbers of T2, T3, T4 (15:15:15 compound fertilizer 125 kg ha^{-1} + 125 kg Urea ha^{-1}) and T5 (straight fertilizers the same as the nutrient ratio of T4) treatments are not mathematically different. Among all of the treatments, these above four treatments got the more amount of phosphorous compared to other treatments. Phosphorous is important to rice plants because it promotes tillering, root development, early flowering, and ripening. The phosphorous deficient rice plants are stunted and dirty-dark green, and they have erect leaves, relatively few tillers, and decreased root mass (Dobermann and Fairhurst 2000). No application of potassium ranked the lowest growth parameters (Awan et al. 2007). Tillering is highly impaired by nitrogen or phosphorus deficiency. Tillering stops when nitrogen content in the blade becomes 2.0 percent phosphorus 0.03 percent and potassium 0.5 percent. The tillering rate increases linearly with an increasing nitrogen content of up to 5 percent. With phosphorus, the tillering rate increases up to about 0.2 percent, above which an increase in phosphorus has no effect on tillering. Similarly, potassium content as high as 1.5 percent increases the tillering rate (Yoshida 1981).

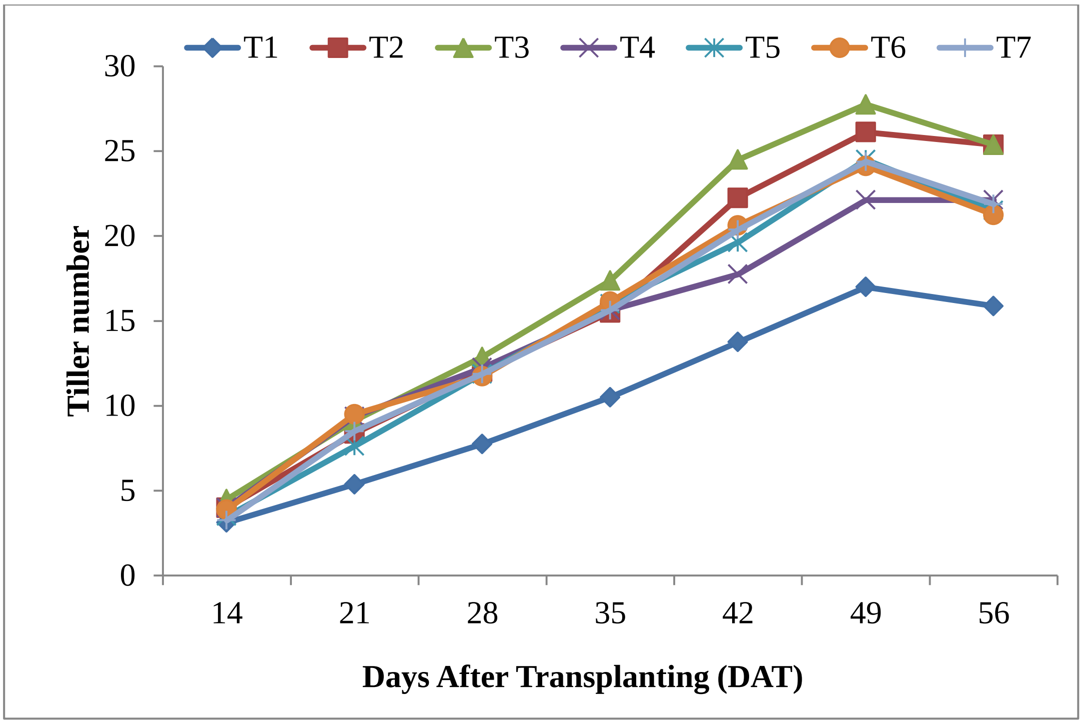

Figure 4.4 Mean values of tiller numbers as affected by straight and compound fertilizers on Shwe Thwe Yin rice variety during the wet season, 2014

Treatments

T1 = no fertilizer

T2 = three splits application of straight fertilizers

T3 = two splits application of straight fertilizers

T4 = 15:15:15 compound fertilizer 125 kg ha^{-1} + 125 kg Urea ha^{-1}

T5 = straight fertilizers the same as the nutrient ratio of T4

T6 = 15:7:8 compound fertilizer 125 kg ha^{-1} +125 kg Urea ha^{-1}

T7 = straight fertilizers the same as the nutrient ratio of T6

4.2.1.3 Number of panicle hill^{-1}

The number of panicle hill^{-1} data at harvest were highly significant different at 1 percent level. This data was indicated in (Table 4.3). The maximum value of panicle number hill^{-1} was observed from the treatments T2 (three splits application of straight fertilizers) and T3 (two splits application of straight fertilizers) and the values were 23.13 and 23.00 receptively. The minimum panicle number hill^{-1} (14.25) was caused by T1 (no fertilizers), control treatment. The number of panicles plant^{-1} was significantly influenced by increase in NPK fertilizer rates (Ndaeyo et al. 2008).

There was found that the panicle number hill^{-1} at harvest of straight fertilizers treatments T2 and T3 were larger than the compound fertilizers plus urea treatments T4 (15:15:15 compound fertilizer 125 kg ha^{-1} + 125 kg Urea ha^{-1}) and T6 (15:7:8 compound fertilizer 125 kg ha^{-1} +125 kg Urea ha^{-1}) and the equal nutrient value with straight fertilizers to compound fertilizers treatments T5 (straight fertilizers the same as the nutrient ratio of T4) and T7 (straight fertilizers the same as the nutrient ratio of T6). These four treatments T4, T5, T6 and T7 were treated with less nitrogen, phosphorous and potassium for their growth and development compared with only straight fertilizer treatments T2 and T3. But the cost for fertilizer inputs of T4 treatment was higher than that of T2 and T3 and the T6 treatment was nearly as cost as T2, and T3 treatments.

4.2.1.4 Number of spikelet panicle^{-1}

The maximum spikelet numbers panicle^{-1} (128.75) was found in T3 (two splits application of straight fertilizers) treatments while there was found highly significant different at 1 percent level in that parameter. The control treatment, T1 (no fertilizers) gave the minimum spikelet number panicle^{-1} (96.25) (Table 4.3). Treatment T3 and T2 (three splits application of straight fertilizers) was treated by more amount of nutrient compared to other treatments and the nitrogen fertilizer of these treatments was applied by split application.

Plant height, panicle number, leaf size, spikelet number, and number of filled spikelet were increased by nitrogen application (Dobermann and Fairhurst 2000).

4.2.1.5 1000 grains weight (g)

A stable varietal character, thousand grain weight was not significant different among the treatments tested (Table 4.3). The maximum thousand grain weight (17.88

g) was produced by T6 (15:7:8 compound fertilizer 125 kg ha^{-1} +125 kg Urea ha^{-}) and the minimum thousand grain weight (17.55 g) was given by T1 (no fertilizers) treatment. The thousand grain weight data of all treatments were not statistically and mathematically different.

4.2.1.6 Filled grain percent

Table 4.2 showed the statistical result of filled grain percent and it is highly significantly difference among the tested treatments at 1 percent level. The highest value (82.25 percent) was produced by T2 (three splits application of straight fertilizers) while T2 and T3 (two splits application of straight fertilizers) were not statistically different. The control treatment, T1 (no fertilizers) gave the lowest value (70.75 percent).

4.2.1.7 Grain yield

Grain yield data (g hill^{-1}) of the wet season experiment was shown in (Table 4.3). The grain yield data of the treatments was highly significant difference at 1 percent level. The maximum grain yield (49.75 g hill^{-1}) was observed in T3 (two splits application of straight fertilizers) treatment and the minimum value (15.63 g hill^{-1}) was produced by T1 (no fertilizers) treatment. Straight fertilizer treatments, T2 (three splits application of straight fertilizers) and T3 gave the highest grain yield and these treatments get more nitrogen, phosphorous and potassium content for the whole plant life compared to other treatments.

Among all of the treatments, T1 (no fertilizers) treatment produced the lowest grain yield. The values that superior to the control treatment created by T3, T2, T4 (15:15:15 compound fertilizer 125 kg ha^{-1} + 125 kg Urea ha^{-1}), T6 (15:7:8 compound fertilizer 125 kg ha^{-1} +125 kg Urea ha^{-1}), T5 (straight fertilizers the same as the nutrient ratio of T4) and T7 (straight fertilizers the same as the nutrient ratio of T6) treatments were 69 percent, 63 percent, 58 percent, 54 percent, 53 percent and 51 percent respectively.

Although the cost of fertilizer inputs of T2 and T3 for one acre of rice cultivation was lesser than that of T4, while the yield of T3 and T2 was 25 percent and 12 percent more than that of T4 receptively. Another compound fertilizer plus urea fertilizer treatment, T6, was lesser input fertilizer cost than T2 and T3 treatment, but it was reduced 31 percent and 19 percent in yield compared to T3 and T2 receptively.

Except T2 and T3 treatment, the rest treatments are not treated with sufficient potassium. Potassium is an essential plant nutrient and it improves root growth and plant vigor. It is often the most limiting nutrient after nitrogen in high yielding rice systems. Most irrigated rice field needs to be applied in adequate amounts of Potassium fertilizer. Other nutrients need to be applied in balanced amounts to make sure a good crop response to fertilizer potassium application and to achieve a healthy and productive crop (Balasubramanian et al. 2003). The surplus amounts of nitrogen decreased with increasing potassium fertilizer application (Liao et al. 2010). Application of Nitrogen increased yield components like panicle number and number of grains per panicle (Adigbo et al. 2003). The increase in applied nitrogen rate can significantly increase rice seed yield because of increasing leaf area and duration and hence, increasing photosynthesis potential (Moosavi and Mohamadi 2014). Yield and yield components increased with nitrogen fertilizer application (Yoseftabar et al. 2012). Pande et al. (1993) reported that there was significant increase in grain yield when nitrogen was applied in combination with phosphorous and potassium fertilizer. Nutrient uptake increased with the increase in fertilizer application and also with the progress of crop growth.

4.2.1.8 Harvest index

Harvest index (HI) data was also shown in Table (4.3). There was highly significant difference in harvest index. The highest value (0.48) was produced by T3 (two splits application of straight fertilizers) and the lowest value (0.40) was generated by T1 (no fertilizers) treatment. In all treatments, straights fertilizer treatments T2 (three splits application of straight fertilizers) and T3 was treated with the highest potassium level. Shoot dry weight and grain yield were significantly influenced by potassium level (Fageria 2010). It is reported that basal skipping of potassium and applying potassium in two equal splits recorded the highest nitrogen and potassium uptake in grain and straw yields in soils with medium potassium status (Ravichandran and sriramachandrasekharan 2011). Grain and straw yields of rice as influenced by split application of potassium over entire basal application. Under transplanted conditions of rice, requirement of potassium at early stages are met by the indigenously available soil potassium and then the requirement of potassium at tillering and panicle initiation stage was best satisfied by the application (top dressing) of water soluble potassium fertilizer receiving 50 percent at the respective stages (Surendran 2005). Time of fertilizer application may considerably influence crop response to fertilizer. Application of potassium in proper time (split doses) enhanced the enzymatic activities, probably caused higher mobilization of nutrients in soil and plant and translocation of photosynthetic in plant system, which ultimately resulted in higher grain and straw yields (Pal et al. 2000).

4.2.1.9 Correlation relationship among yield and yield components under straight and compound fertilizers application

Grain yield was positively and highly significantly correlated with biological yield, number of panicle number hill^{-1}, number of spikelet panicle^{-1} and filled grain percent (Table 4.4), indicating the importance of these components in rice yield. Correlation analysis also show that the harvest index positively and significantly correlated with the grain yield. These finding was agreed with that of Osman et al. (2012).

Table 4.3 Yield and yield components as affected by straight and compound fertilizers on rice (ShweThwe Yin) during the wet season, 2014.

Treatments	No. of panicles hill^{-1}	No. of spikelet panicle^{-1}	1000 grains weight (g)	Filled grain percent	Grain yield (g hill^{-1})	Harvest Index (HI)
T1	14.25 e	96.25 g	17.55	70.75 d	15.63 f	0.40 d
T2	23.13 a	119.25 b	17.65	82.25 a	42.13 b	0.46 ab
T3	23.00 a	128.75 a	17.55	81.75 a	49.75 a	0.48 a
T4	19.88 b	114.50 c	17.85	79.75 ab	37.55 c	0.46 b
T5	18.38 bc	111.00 d	17.80	77.25 bc	33.625 de	0.45 b
T6	17.13 cd	106.00 e	17.88	76.25 c	34.23 d	0.42 c
T7	16.63 d	102.25 f	17.65	74.75 c	31.95 e	0.40 d
LSD$_{0.05}$	1.52	3.27	0.48	2.99	2.16	0.02
Pr>F	**	**	ns	**	**	**
CV%	5.43	1.98	1.83	2.59	4.15	3.01

Mean followed by the similar letter in each column are not significantly different at 5% LSD

**significant at 1 percent level, ns = non-significant

T1 (no fertilizers), **T2** (three splits application of straight fertilizers), **T3** (two splits application of straight fertilizers), **T4** (15:15:15 compound fertilizer 125 kg ha^{-1} + 125 kg Urea ha^{-1}), **T5** (straight fertilizers the same as the nutrient ratio of T4), **T6** (15:7:8 compound fertilizer 125 kg ha^{-1} +125 kg Urea ha^{-1}), **T7** (straight fertilizers the same as the nutrient ratio of T6)

Table 4.4 Correlation relationship among yield and yield components under straight and compound fertilizers application (wet season, 2014)

	Total dry matter	No. of panicles hill^{-1}	No. of spikelet panicle^{-1}	1000 grains weight (g)	Filled grain percent	Grain yield (g hill^{-1})	Harvest Index
No. of panicle hill^{-1}	0.8644*	**1**					
No. of spikelet panicle^{-1}	0.8715 *	0.9609**	1				
1000 grains weight (g)	0.1154	-0.0871	-0.0888	1			
Filled grain percent	0.8988**	0.9800**	0.9421**	0.1065	1		
Grain yield (g hill^{-1})	0.9865 **	0.9207**	0.9392**	0.0684	0.9415**	1	
Harvest Index	0.7445	0.9089**	0.9527**	0.0546	0.9118**	0.8380*	1

*Significant at 5 percent level, ** significant at 1 percent level

CHAPTER V
CONCLUSION

The effects of straight fertilizers and compound plus Urea fertilizer application on Shwe Thwe Yin rice variety were investigated in the dry and the wet season of 2014.

According to the outcomes of these two season pot experiment, it was clearly found that the yield and yield components were significantly increased with the increased amount of nutrients. In fact, the nutrient contents of recommended straight fertilizers treatments are more than that of compound plus Urea fertilizer treatments and the treatments that adjusted nutrients to compound treatments.

In both seasons, the two split application of recommended straight fertilizers produced the highest value of plant height and tiller number of rice plant. All of the fertilizer treatments produced more grain yield and yield component parameters than control treatment. The highest grain yield was produced by two splits application of recommended straight fertilizers.

The yield of three splits application of recommended straight fertilizers was lower than that of two splits recommended straight fertilizers application. But its yield was more than that of other treatments. Application of straight fertilizers in two splits at 10 DAT and panicle initiation stages of rice plant can give the highest grain yield. It is less nutrient loss comparing with the basal application of straight fertilizers. And then it can reduce the labor cost over the three splits of fertilizer application.

In compound fertilizer treatments, the yield of 15:15:15 compound fertilizer plus Urea fertilizer was more than that of 15:7:8 compound fertilizer plus Urea fertilizer. The yield of straight fertilizer adjusted to compound fertilizer produced the mathematically similar yield and yield component parameters with readymade compound plus Urea fertilizer.

So the application of recommended straight fertilizer produced more grain yield than compound fertilizer plus Urea fertilizer. It is required to know the knowledge of fertilizers and to get the fertilizers in the market for application of straight fertilizers. However, further investigation is needed to confirm the effects at the field level.

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Appendix1. Monthly rainfall, monthly average values of maximum and minimum temperature and relative humidity at Yezin during two experiment growing periods (from February to October 2014)

Month	**Temperature (ºC)**		**Rainall (mm)**	**Relative Humidity (percent)**
	Maximum	**Minimum**		
February	33.7	15.2	0	51
March	37.8	19.2	0	42
April	38.8	23.4	0.27	51
May	37.9	23.8	2.29	60
June	34.4	23.4	7.2	76
July	32.4	23.1	4.8	84
August	31.9	23.6	11.9	88
September	33.5	23.9	5.33	80
October	33.8	22	3.68	85

Appendix2. Effects of straight and compound fertilizers application on plant height of Shwe Thwe Yin rice variety, the dry season, 2014

Treatments	Plant height (cm)						
	14 DAT	**21 DAT**	**28 DAT**	**35 DAT**	**42 DAT**	**49 DAT**	**56 DAT**
T1	32.48 c	41.75 b	51.50 b	56.93 c	62.38 d	65.30 c	78.78 c
T2	34.63 abc	40.38 b	53.98 ab	64.48 a	71.90 ab	82.05 ab	94.73 b
T3	33.85 bc	40.25 b	54.33 ab	64.38 a	74.60 a	84.80 a	99.58 a
T4	37.90 a	44.80 ab	54.35 ab	59.50 bc	65.28 cd	79.43 b	93.00 b
T5	32.78 c	40.55 b	54.90 ab	65.30 a	72.65 ab	80.40 ab	93.95 b
T6	37.75 ab	47.35 a	57.15 b	62.05 ab	67.83 bcd	79.20 b	95.98 ab
T7	32.65 c	41.45 b	54.05 ab	62.80 ab	70.43 abc	80.93 ab	92.83 b
$LSD_{0.05}$	4.020	4.839	3.523	3.483	5.459	5.182	4.821
Pr>F	*	*	ns	**	**	**	**
CV%	7.83	7.69	4.37	3.77	5.30	4.42	3.50

Mean followed by the similar letter in each column are not significantly different at 5% LSD

*Significant at 5 % level, ** significant at 1% level, ns=non-significant

Appendix3. Effects of straight and compound fertilizers application on tiller numbers of Shwe Thwe Yin rice variety, the dry season, 2014

Treatments	Tiller numbers						
	14 DAT	**21 DAT**	**28 DAT**	**35 DAT**	**42 DAT**	**49 DAT**	**56 DAT**
T1	2.63 c	6.38 b	8.75 b	10.25 b	15.38 c	20.75 d	18.75 d
T2	3.00 bc	6.38 b	11.13 ab	17.63 a	24.88 ab	30.50 ab	28.75 ab
T3	2.75 c	6.25 b	11.13 ab	18.25 a	28.00 a	31.75 a	31.63 a
T4	3.88 a	10.45 a	13.63 a	18.00 a	22.50 ab	26.63 bc	26.00 bc
T5	2.63 c	6.63 b	10.88 ab	15.63 a	21.50 bc	24.63 cd	23.75 c
T6	3.63 ab	10.25 a	13.88 a	17.00 a	20.50 bc	26.50 bc	25.13 bc
T7	3.00 bc	6.88 b	9.75 b	17.38 a	24.13 ab	28.25 abc	26.75 bc
$LSD_{0.05}$	0.713	2.336	3.136	3.983	6.233	4.668	4.049
Pr>F	**	**	*	**	*	**	**
CV%	15.62	20.69	18.67	16.45	18.72	11.64	10.55

Mean followed by the similar letter in each column are not significantly different at 5% LSD

*Significant at 5 % level, ** significant at 1% level

Appendix4. Effects of straight and compound fertilizers application on plant height of Shwe Thwe Yin rice variety, the wet season, 2014

Treatments	**Plant height (cm)**						
	14 DAT	**21 DAT**	**28 DAT**	**35 DAT**	**42 DAT**	**49 DAT**	**56 DAT**
T1	31.55 c	39.30d	43.50 d	51.80 c	60.68 c	69.45 d	82.03 d
T2	34.73 ab	42.45 bc	51.80 b	61.15 a	71.53 a	81.15 ab	98.88 a
T3	33.65 abc	45.25 a	54.18 a	61.85 a	70.83 a	82.88 a	98.68 ab
T4	34.98 ab	43.53 ab	48.85 c	56.33 b	63.98 b	76.50 bc	94.80 bc
T5	33.00 bc	40.10 cd	47.93 c	57.85 b	64.60 b	78.00 bc	94.93 bc
T6	36.38 a	43.13 ab	48.23 c	57.30 b	64.30 b	75.95 c	94.30 c
T7	33.40 bc	43.73 ab	52.78 ab	62.08 a	69.03 a	79.08 abc	95.85 abc
$LSD_{0.05}$	2.806	2.543	2.172	2.593	3.275	4.845	3.880
Pr>F	*	**	**	**	**	**	**
CV%	5.57	4.03	2.95	2.99	3.32	4.20	2.77

Mean followed by the similar letter in each column are not significantly different at 5% LSD

*Significant at 5 % level, ** significant at 1% level

Appendix5. Effects of straight and compound fertilizers application on tiller numbers of Shwe Thwe Yin rice variety, the wet season, 2014

Treatments	Tiller numbers						
	14 DAT	**21 DAT**	**28 DAT**	**35 DAT**	**42 DAT**	**49 DAT**	**56 DAT**
T1	3.13 d	5.38 c	7.75 b	10.50 b	13.75 d	17.00 d	15.88 b
T2	4.00 ab	8.38 ab	12.00 a	15.50 a	22.25 ab	26.13 ab	25.38 a
T3	4.50 a	9.13 ab	12.88 a	17.38 a	24.50 a	27.75 a	25.38 a
T4	4.00 ab	9.38 ab	12.25 a	15.63 a	17.75 c	22.13 c	22.13 b
T5	3.50 bcd	7.63 b	11.88 a	16.00 a	19.63 bc	24.50 bc	21.50 b
T6	3.88 abc	9.50 a	11.75 a	16.13 a	20.63 bc	24.13 bc	21.25 b
T7	3.25 cd	8.50 ab	11.88 a	15.63 a	20.38 bc	24.38 bc	21.88 b
$LSD_{0.05}$	0.744	1.836	2.249	2.107	2.903	2.667	1.801
Pr>F	*	**	**	**	**	**	**
CV%	13.36	14.95	13.19	9.30	9.85	7.57	5.53

Mean followed by the similar letter in each column are not significantly different at 5% LSD

*Significant at 5 % level, ** significant at 1% level

Appendix6. Fertilizer application of all treatments

T1	**Control** (no fertilizers)
T2	**Three splits application of straight fertilizers** (all TSP at basal, three equal splits application of Urea and MOP at basal, 10 DAT and PI)
T3	**Two splits application of straight fertilizers** (all TSP at basal, two equal splits application of Urea and MOP at 10 DAT and PI)
T4	**15:15:15 compound fertilizer 125 kg ha^{-1} + 125 kg Urea ha^{-1}** (all compound at basal, two equal splits of Urea at 10 DAT and PI)
T5	**Straight fertilizers the same as the nutrient ratio of T4** (two equal splits of 125 kg Urea at 10 DAT and PI, all of the rest Urea , TSP and MOP at basal)
T6	**15:7:8 compound fertilizer 125 kg ha^{-1} +125 kg Urea ha^{-1}** (all compound at basal, two equal split of Urea at 10 DAT and PI)
T7	**Straight fertilizers the same as the nutrient ratio of T6** (two equal splits of 125 kg Urea at 10 DAT and PI, all of the rest Urea , TSP and MOP at basal)

Appendix7. Nutrient rates for one hectare of rice field according to the straight fertilizers application and compound plus Urea fertilizers application

Fertilizers	N	P_2O_5	K_2O
		Kg ha^{-1}	
Recommended straight fertilizers	85	30	37
Compound (15:15:15) + Urea	75.75	18.75	18.75
Compound (15:7:80 + Urea	75.75	9.61	14.95

Appendix8. Cost of fertilizer inputs for each treatment of straight and compound fertilizers application

Treatments	Cost of fertilizer (kyats) ha^{-1}	Remark
T1	0	
T2	127256	
T3	127256	
T4	135905	T2 and T3 less cost than T4 (6.36 percent)
T5	98543	
T6	103782	T2 and T3 more cost than T6 (18.45 percent)
T7	65407	

Appendix9. Superior yield percent of all fertilizer treatments over the control (no fertilizer) treatments, the dry season, 2014

Treatments	Yield (g hill^{-1})	Superior yield percent over control T1 (no fertilizers) treatment
T1	25.90	-
T2	47.80	46
T3	51.03	49
T4	42.35	39
T5	36.55	29
T6	39.78	35
T7	39.05	34

Appendix10. Superior yield percent of all fertilizer treatments over the control (no fertilizer) treatments, the wet season, 2014

Treatments	Yield (g hill^{-1})	Superior yield percent over control T1 (no fertilizers) treatment
T1	15.63	-
T2	42.13	63
T3	49.75	69
T4	37.55	58
T5	33.63	53
T6	34.23	54
T7	31.95	51