POTASSIUM FERTILIZER MANAGEMENT ON RICE CULTIVATION

KHIN PYONE NWE

SEPTEMBER 2015

POTASSIUM FERTILIZER MANAGEMENT ON RICE CULTIVATION

A thesis presented by

KHIN PYONE NWE

to

The post-graduate committee of the Yezin Agricultural
University in partial fulfillment of the requirements for
the Degree of Master of Agricultural Science
(Soil Science)

Department of Soil and Water Science

Yezin Agricultural University

SEPTEMBER 2015

The thesis attached hereto, entitled **"Potassium Fertilizer Management on Rice Cultivation"** 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).**

………………………………
Dr. Kyaw Ngwe
Chairperson of Supervisory Committee
Professor and Head
Department of Soil and Water Science
Yezin Agricultural University

………………………………
Daw San San Myint
External Examiner
Deputy Director
Land Use Division
Department of Agriculture

………………………………
Dr. Swe Swe Mar
Member of Supervisory Committee
Assistant Lecturer
Department of Soil and Water Science
Yezin Agricultural University

………………………………
Dr. Myint Thu Zar
Member of Supervisory Committee
Lecturer
Department of Plant Breeding,
Physiology and Ecology
Yezin Agricultural University

………………………………
Dr. Kyaw Ngwe
Professor and Head
Department of Soil and Water Science
Yezin Agricultural University

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

…………………….

Dr. Myo Kywe

Rector

Yezin Agricultural University

Nay Pyi Taw

Date ………………………

DECLARATION OF ORIGINALITY

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

………………………………

Khin Pyone Nwe

Date …………………………..

DEDICATED TO MY BELOVED PARENTS

U TIN MYINT AND DAW EIN KHIN

ACKNOWLEDGEMENTS

First and foremost, I wish to express my heartfelt gratitude to Dr. Myo Kywe, Rector, Yezin Agricultural University (YAU) and Dr. Ye Tint Tun, Director General, Department of Agricultural Research (DAR) for their kind permission and encouragement to conduct this study. I would like to acknowledge the advice, guidance and helpful assistance of Pro rectors Dr. Soe Soe Thein (Academic) and Dr. Nang Hseng Hom (Administrative).

It gives me immeasurable pleasure to express my sincere appreciation and profound gratitude to my thesis advisor Dr. Kyaw Ngwe, Professor and Head, Department of Soil and Water Science, YAU, for sharing his wise knowledge, skillful guidance, careful supervision, unflinching interest, encouragement and thought provoking discussion towards the successful completion of my research study and completely writing of thesis.

I would like to extend my thanks to the external examiner Daw San San Myint, Deputy Director, Land Use Division, Department of Agriculture, for her professional guidance and comments, and critical reading of this manuscript.

I deeply acknowledge to my supervisory committee members, Dr. Myint Thu Zar, Lecturer, Department of Plant Breeding, Physiology and Ecology, YAU, and Dr. Swe Swe Mar, Assistant Lecturer, Department of Soil and Water Science, YAU, for their constructive comment, valuable suggestions, productive advice and critical reading in this manuscript.

I would like to express special thanks and gratitude to all of my teachers, colleagues, and laboratory staff from the Department of Soil and Water Science, YAU, for giving their valuable time in my research activities in time of need.

My heartfelt thanks also go to my lovely senior Ma Khin Thuzar Nwe, junior Ma May Zin Aung and all of my friends for their sympathetic support, suggestions and sharing my stress in time of need and throughout the study period of master course.

My sincere thanks go to Managing Director, Myanmar Awba Group Co.Ltd., Yangon, for granting me the “Myanmar Awba Scholarship Award” as a part of financial support for conducting my research work.

Last but not least, words fail me to extend heartiest thanks to my ever-loving parents U Tin Myint and Daw Ein Khin, my elder sister Ma Lon May Tin and my younger brother Dr. Htet Wai Moe for their heartfelt love, patience, eternal support, kindly encouragements, painstaking and prayers provided during my study period since my childhood. Without the efforts and encouragement of my family members, I would have never come to this stage of success.

ABSTRACT

Potassium (K) is an essential element for crop production. Proper potassium nutrition is critical for maximizing rice grain yields. Timing of K fertilizer application is an important management tool in maximizing K use efficiency. Maximum efficiency is acquired when K^+ is applied so as to be available for uptake by the plants as needed. Unbalanced potassium fertilization has negative effects on crop quality and on crop resistance to pests and diseases. The purpose of the present study was to evaluate the effect of potassium on growth and yield of rice and to find out the best suited scheme / timing of potassium fertilizer application for rice crop. With this regard, pot experiments were conducted at the screen house of Department of Soil and Water Science, Yezin Agricultural University during the dry and wet season of 2014. In this investigation, a recommended dose of potassium fertilizer (37 kg ha^{-1}) was used and eight treatments i.e. T1 (all potash applied as basal), T2 (all potash applied at 25 DAT), T3 (all potash applied at 45 DAT), T4 (½ potash applied as basal and remaining ½ at 25 DAT), T5 (½ potash applied as basal and remaining ½ at 45 DAT), T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT), T7 (1/3 potash applied as basal, 1/3 at 25 DAT and remaining 1/3 at 45 DAT) and T8 (Control - no K applied) were performed.

Base on the two season results, yield and yield components with potassium use efficiency were responded to different time of potassium fertilizer application. T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT) and T2 (all potash applied at 25 DAT) produced more grain yield in both seasons. Lower grain yield was achieved at control and only basal application treatments. The greater potassium use efficiency was obtained by the application of potash at 25 DAT and two splits at 25 DAT and 45 DAT treatments. According to the results of this study, basal application of potash (traditional method) can be replaced by a late application of potash at 25 DAT and two equal split applications of potash at 25 DAT and 45 DAT can be promoted for getting maximum benefit. However, further investigations should be conducted to confirm the effect of potassium at field level.

Key words: *Potassium, fertilizer management, split application, rice yield*

CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure **Page**

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important food crop of the world and the staple food of more than 3 billion people or more than half of the world's population. Rice is grown in more than a hundred countries with a total harvested area of about 160 million hectares, producing more than 700 million tons every year (IRRI 2010). About 1 billion households depend on rice cultivation for employment and their main source of livelihood (Shimamura 2005).

The world population is expanding rapidly and will pass from its current number of 7.0 billion to 9.4 billion by the year 2050 (United States Census Bureau 2012). To provide enough food for an expanding world population, a massive increase in crop production is required to meet the food demands of future generations, while preserving the ecological and energy-related resources of our planet (Wang et al. 2013).

Rice is the most extensively cultivated cereal crop in Myanmar, which covers about 37.23% of total cropped area. The area and production of rice in the country were 7.7 million hectares, comprising 6.6 million hectares under monsoon rice and 1.1 million hectares under summer rice and 29.01 million metric tons, respectively with an average yield of 3.83 MT/ha in 2011-2012 (MOAI 2012). Although the soil and climatic conditions of Myanmar are favorable for rice cultivation throughout the year, the average yield is lower than the other rice growing countries of the world. Therefore, emphasis should be given to increase the yield of rice through the adoption of proper variety and fertilizer management along with other improved technology and management practices.

Many factors are responsible for increasing yield and quality of crops. Among these, proper and balanced application of fertilizers is one of the most important factors contributing towards higher productivity (Ahmad et al. 1994). Judicious and proper use of fertilizers can noticeably increase the yield and improve the quality of rice. The practice of correct dosage and timely application of fertilizer nutrients plays an important role in efficient use of fertilizers (Awan et al. 2007).

The imbalanced and inadequate application of fertilizers has serious repercussions for efficacy of the applied fertilizers. Balanced, integrated and efficient use of fertilizers, among other inputs, has tremendous potential to increase crop productivity. Development of practices to improve the efficiency of nutrients requires an understanding of the fate of the applied nutrient and their effect on crop production. Greater opportunities exist for increased crop production by increasing rate, timing and improving management of mineral fertilizers (Ravichandran and Sriramachandrasekharan 2011).

Potassium (K) is one of the three pillars of balanced fertilizer use, along with N and P. It is necessary to continually emphasize the role and importance of K in crop production as a balanced fertilizer use to produce ever increasing requirement of food, fiber and other farm based commodities. Most crops take up as much or more K than N (Ravichandran and Sriramachandrasekharan 2011). Potassium is required in high amounts to maintain adequate crop growth (Mengel and Kirkby, 2001); (Singh and Wanjari 2014). As the global population and food production has grown, so the total amount of potassium removed from farmland has also increased, and this has to be replaced to maintain the fertility and productive capacity of the soil. This replenishment plays a vital role in supporting sustainable global food security (IPI 2014).

Potassium has essential functions in osmoregulation, enzyme activation, regulation of cellular pH, cellular cation-anion balance, regulation of transpiration by stomata, and the transport of assimilates (Dobermann and Fairhurst 2000). Potassium plays a major role in the ability of plants to tolerate externally induced stress, such as drought, frost, high light levels and attack from pests and disease (IPI 2014). K increases the number of spikelets per panicle, percentage of filled grains, and 1,000-grain weight (Dobermann and Fairhurst 2000).

Proper K nutrition in rice encourages tillering, panicle development, spikelet fertility, leaf area and leaf longevity and promotes plant uptake of N and P, disease resistance, root elongation and thickness, culm (stem) thickness and strength and resistance to lodging (Haifa 2008).

Sound soil fertility management involves the use of potassium in proper relationship to inputs of the other macronutrients such as nitrogen (N), phosphorous (P) and sulphur (S). The concept of integrated plant nutrient management integrates all other production factors in order to maintain soil fertility and productivity, to prevent land degradation and desertification, to alleviate soil nutrient mining and prevent erosion. Without adequate potassium, the full potential benefits of investments in the other major fertilizer nutrients and the other essential crop production inputs such as water are at risk. Potassium encourages more efficient nutrient utilization by plants, which in turn contributes to economic viability, improved ecological conditions and sustainable agriculture (MMSD 2002).

The amount of K fixed increases with added K, whereas the present K fixed relative to total added K decreases (Bouabid et al. 1991); (Awan 2007). Fixation of K fertilizers may affect its recovery to crops. About 23 to 86 % of the applied K can be fixed and its fixation increases with increasing clay contents, lime and amount of K applied (Mehdi and Ranjha 1995); (Manzoor et al. 2008).

One of the reasons of low efficiency of fertilizer for enhancing crop productivity is imbalance use of applied nutrients. Problem of K fixation can be reduced to some extent and efficiency may be improved by different K application methods. Also sources of K and their time of application may affect the K recovery (Manzoor et al. 2008). At times, the indiscriminate and improper application with unfavorable conditions may not provide adequate nutrients supply because of its poor absorption and translocation in plant system.

Unbalanced potassium fertilization has negative effects on crop quality and on crop resistance to pests and diseases. Insufficient potash application results in a significant depletion of soil potash reserves, yield loss and a higher economic risk for farmers (MMSD 2002). Application time of K-fertilizers is important to ensure that adequate amounts of K^+ are present in the soil solution when crop uptake rates are at maxima, and also to avoid losses of K by leaching. Split applications have resulted in higher yields in Japan, China, and India (Cooke 1986).

Generally splitting the total dressing into three gave the best results in both the dry and wet season; the times were: one-third basal before transplanting, one-third 20 days after transplanting, and the remaining third at panicle initiation (Cooke 1986). Applying K in three splits at transplanting, active tillering, and panicle initiation; or two splits at transplanting, and active tillering stages, gave the best yields. These gains were related to the maintenance of high concentrations of K in the plants. It appeared that the soil had sufficient K to support the initial growth of the rice but later applications were essential to maintain the concentrations (Cooke 1986); (Ram and Parasad 1985).

Significantly higher yield of rice have been reported due to split application rather than single application (Das et al. 1975); (Singh and Singh 1978). Split application of K gave 20% more yield than that of full dose applied at transplanting (Ismunadji 1976). Fertilizer K 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 (Uddin et al. 2012a). A little information is available on the effectiveness of split application of K fertilizer in rice cultivation in Myanmar.

Therefore, keeping in mind the importance and significance of K in rice production, this research was initiated with the following objectives;

i. To evaluate the effect of potassium on growth and yield of rice,
ii. To find out the best suited scheme / timing of potassium fertilizer application for rice crop.

CHAPTER II

LITERATURE REVIEW

2.1 Potassium

Potassium (K) is an essential element for all life. It is considered the major nutrient element for plants because its use as fertilizers is more widespread and in greater amounts than other elements. Potassium is abundant in nature and occurs in considerable total amounts in most soils (Fageria 2009). In lowland and upland rice, uptake of K^+ is higher than N uptake (Fageria 2001); (Fageria and Baligar 2001); (Fageria et al. 2003). Crop yields have significantly increased in the last few decades in developed as well as developing countries through the introduction of modern production technologies; as a result, supplies of K^+ in the soils are rapidly exhausted (Fageria 2009). Many soils of the tropical and temperate regions are unable to supply sufficient K^+ to field crops (Fageria 1989). Moreover, in many crops, maximum amount of K^+ is retained in the straw (Fageria et al. 1990b). Supply of adequate K^+ rate for field crop production is essential not only to increase productivity but also to reduce the cost of crop production, reduce environmental pollution, and maximize efficiency of K^+ use.

2.1.1 Forms of Potassium in Soil

Among the major plant nutrients, potassium is the most abundant plant nutrient in soils. It constitutes an average of 1.9% of the earth's crust. Potassium is known to exist in four different forms, namely; structural (mineral) 5000 to 25,000 mg kg^{-1}, non-exchangeable (fixed or difficultly available) 50-750 mg kg^{-1}, exchangeable 40-600 mg kg^{-1} and water-soluble forms 1-10 mg kg^{-1} (Tisdale et al. 1985).

Amount of K present in all the forms was lowest in kaolinite dominant red and lateritic soils due to predominance of kaolinitic clay minerals which cannot fix K and also have low cation exchange capacity (CEC). Water soluble and exchangeable K were highest in smectite dominant black soils which was due to presence of minerals with less K fixing power and these soils showed considerable variation in the status of different forms of K though the soils have same family of mineralogy (montmorillonite). Whereas, non-exchangeable and exchangeable K and total K were highest in illite and mica dominant alluvial soils (Ravichandra and Sriramachandrasekharan 2011). Generally, there is essentially no organic form of K in soils. Potassium contained in manures and crop residues returned to soils is rapidly leached out of the organic material and is dissolved in the soil solution, where it can react with the clay minerals (Parasad and Power 1997).

In soils with low levels of both exchangeable and non-exchangeable K, K application must be done to achieve full yield potential of crops (Srinivasa Rao et al., 2010). Due to larger contribution of non-exchangeable K to plant K needs, lack of crop responses to applied K have been reported even in soils with low exchangeable K. The major sources of non-exchangeable K in soils are K rich 2:1 clay minerals such as micas and vermiculite. Continuous and adequate K nutrition of plants depends not only on the amount of plant available K in soils but also on its rate of release to the soil solution (Ravichandran and Sriramachandrasekharan 2011).

The amount of potassium present in the soil solution is often smaller than the crop requirement for potassium. Hence continuous renewal of potassium in the soil solution for adequate nutrition of high yielding varieties of rice is obvious (Bijay-Singh et al. 2004). K concentration of soil solution directly controls the K-supply to the plant.

2.1.2 Potassium Functions in Plants

Potassium is abundant in the soil/plant system and is unique among the basic plant nutrients in its multi-functional contribution to plant metabolic processes. The interaction of K with plant systems and constituents is varied and extensive (Bailey et al. 1993). Potassium plays many vital roles in crop plants such as K^+ increases root growth and improves water and nutrient uptake, aids in photosynthesis and food formation, helps translocation of sugars and starch, produces grain rich in starch and increases the protein content of plants (Fageria and Gheyi 1999). K^+ is intimately involved in the opening and closing of stomata. K not only can increase the resistance of plant tissues, but it also reduces fungal populations in the soil, reduce their pathogenicity, and promote more rapid healing of injuries (Huber and Arny 1985). K^+ builds cellulose and reduces lodging. Plants well supplied with potassium lose less water since K maintains turgor and has a positive influence on stomata closure as well.

Potassium is required to activate at least 60 different enzymes involved in plant growth and metabolism (Anon 1987). K is also essential to the performance of multiple plant enzyme functions, and it regulates the metabolite pattern of higher plants, ultimately changing metabolite concentrations (Marschner 2012); (Mengel 2001). K is also essential for the translocation of photoassimilates in root growth (Romheld and Kirkby 2010). Translocation of sugars uses energy from ATP that requires K for its synthesis. Sugar translocation is greatly reduced in K-deficient plants (Havlin et al. 2014). K addition had a positive effect on plant size and canopy cover (Davis 1994).

K provides strength to plant cells walls and is involved in the lignification of sclerenchyma tissues. On the whole-plant level, K increases leaf area and leaf chlorophyll content, delay leaf senescence, and therefore contributes to greater canopy photosynthesis and crop growth (Dobermann and Fairhurst 2000). Potassium plays several roles in plant metabolism, and to perform these roles positively, it should interact positively with other essential nutrients (Dibb and Thomson 1985). Increased K allowed for rapid assimilation of absorbed NH_4^+ ions in the plant, maintaining a low, nontoxic level of NH_3 (Dibb and Welch 1976). Increased yield of crops with the addition of N and P requires higher level of K in the soil (Dibb and Thomson 1985); (Fageria et al., 1997a, 1997b). Furthermore, Fe_2^+ toxicity in flooded rice reduced with the addition of adequate rate of K^+ in the soil (Fageria 1984).

The maintenance of adequate K nutrition is critical for mitigating or preventing damage by drought stress and controlling the water balance (Abdel Wahab and Abd-Alla 1995). An adequate K status may facilitate osmotic adjustment, which maintains higher turgor pressure, relative water content and lower osmotic potential, thus improving the ability of plants to tolerate drought stress (Egilla et. al. 2005); (Kant and Kafkafi 2002). K deficient plants are less able to withstand water stress, mostly because of their inability to fully utilize available water (Havlin et al. 2014). Fine K nutrition not only increased plant total dry mass and leaf area, but also improved the water retention in plant tissues under drought stress (Lindhauer 1985).

2.1.3 Soil Potassium Cycle

The earth's crust has an average potassium content of 2.6 percent. Parent materials and youthful soils could easily contain in a plow layer 40,000 to 50,000 pounds per acre, or kilograms per hectare. The potassium content below the plow layer could be similar (Foth 1990). The soil mineralogy has a profound influence on the potassium cycle in soil - plant systems (Fageria 2009). Micas, especially biotite, weather faster and release their potassium much more readily than do feldspars. The feldspars tend to exist as larger particles than micas, with the feldspars largely in the sand and silt and the micas in silt and clay fractions. Weathering of feldspar results in the dissolution of the feldspar crystal and release of K^+ to the soil solution. The potassium in micas is interlayer potassium. Weathering of micas results in the migration of K^+ out of the interlayer space along the edge of weathering mica particles. The K^+ appears in the soil solution or is adsorbed onto a cation exchange site (Foth 1990).

Potassium, like N, is not easily lost from soil-plant systems and unlike P, is not immobilized in the soil. The main K^+ addition sources for plant growth are chemical fertilizers, crop residues, organic manures and K^+ - bearing minerals (Fageria 2009). The majority of K^+ moves to plant roots by diffusion (Bertsch and Thomas 1985). Hence, nonexchangeable K^+ and mineral K^+ are the major K^+ forms in the soil – plant system. Potassium ions move from one category to another whenever the removal or addition of K^+ disturbs the equilibrium within this soil K^+ pool (Fageria et al. 2003). The ability of a soil to replenish solution K^+ is dependent on the transformations between the various labile K^+ forms and the nature of their respective equilibrium with the soil solution (Bertsch and Thomas 1985).

Potassium fixation is affected by the equilibrium conditions in the soil and soil drying and wetting. The application of potassium fertilizer greatly increases the amount of solution potassium. Drying the soil at this time results in increased concentration of K^+ in the soil solution at the edges of clay particles and the movement of potassium into the interlayer spaces, where it becomes entrapped or fixed. By contrast, soon after the harvest of a crop, the concentration of K^+ in the soil solution is low (Foth 1990).

2.2 Importance of Rice

Rice is one of the world’s most important food grains. Globally, no food grain is more important than rice from a nutritional perspective, a food security perspective, or an economic perspective (Coats 2003). As a cereal grain, rice is the predominant staple food for 17 countries in Asia and the Pacific, 9 countries in North and South America and 8 countries in Africa. It is the grain with the second-highest worldwide production, after maize (FAO 2004). Rice is normally grown as an annual plant, although in tropical areas it can survive as a perennial and can produce a ratoon crop for up to 30 years. Rice is rich in nutrients and contains a number of vitamins and minerals. It is an excellent source of complex carbohydrates, the best source of energy (Table 2.1).

Throughout Southeast Asia today, rice is more than just food: it is the central subject of economic policy, a determinant of national objectives, and an important anchor in the maintenance of political stability (Redfern et al. 2012). Its values lie in food grain in the diets of millions of Asians, Sub Sahara Africa and Latin Americans living in the tropics and subtropics. It is likely that rice will continue to remain a major source of their daily food since population growth in these areas is increasing at a high rate (Sasaki 2002). Rice contributes towards achieving food security, employment and income for the poor rural dwellers (Mwangi et al. 2013).

Myanmar is the world’s sixth-largest rice-producing country. Rice is the principal agricultural crop and is the staple food of the entire population. A rice-surplus country, Myanmar has one of the highest levels of per capita rice consumption in the world. Rice has been cultivated in Myanmar for domestic consumption since prehistoric times. Rice is life for the Myanmar people, being interwoven with the social and economic fabric of the people’s lives (Win 1991).

In 2012-13, it was estimated that rice was grown in about 7.24 million hectares with a production of 27.70 million MT in Myanmar. Current average yield was estimated at 3.84 tons ha^{-1} (MOAI 2013). The major rice producing regions of Myanmar are in the delta. Ayeyawady, Bago and Sagaing regions make up more than half of the country’s harvested rice area (MOAI 2012). Myanmar’s major rice ecosystems include rainfed lowland rice, irrigated lowland rice, deepwater rice and upland rice. There are two growing seasons for rice: monsoon season and summer season. In Myanmar, approximately 18-20 % of the rice production comes from the summer crop season, while the majority portion comes from the monsoon rice season (FAO 2009).

Table 2.1 Nutritional values of rice

Item	**Nutritional value per 100 g of rice**	
Energy	1527 kJ	365 kcal
Carbohydrates	80.00 g	
Sugar	0.12 g	
Dietary fiber	1.30 g	
Fat	0.66 g	
Protein	7.13 g	
Vitamins		
Thiamine (Vitamin B1)	0.0701 mg	6 %
Riboflavin (Vitamin B2)	0.0149 mg	1%
Niacin (Vitamin B3)	1.62 mg	11%
Pantothenic acid (B5)	1.1014 mg	20%
Vitamin B6	0.164 mg	13%
Trace metals		
Calcium	28 mg	3%
Iron	0.80 mg	6%
Magnesium	25 mg	7%
Manganese	1.088 mg	52%
Phosphorus	115 mg	16%
Potassium	115 mg	2%
Zinc	1.09 mg	11%
Water	11.61 g	

Percentages are relative to US recommendations for adults.

Source: Adapted from USDA Nutrient data base 2012 (USDA 2012)

2.2.1 Impacts of Rice Production

The crop is grown primarily in the humid and subhumid tropics and subtropics (Fischer 1998). Rice production systems of the region have over recent years become increasingly threatened by the effects of climate change (Masutomi et al. 2009), as a large portion of the rice-growing areas are located in especially vulnerable regions.

Rice cultivation is well-suited to countries and regions with low labor costs and high rainfall, as it is labor-intensive to cultivate and requires ample water. However, rice can be grown practically anywhere, even on a steep hill or mountain area with the use of water-controlling terrace systems. Although its parent species are native to Asia and certain parts of Africa, centuries of trade and exportation have made it commonplace in many cultures worldwide (www.wikipedia.en-Rice.htm).

The greatest levels of productivity are found for irrigated rice, which is the most intensified production system, where more than one crop is grown per year and yields are high - 12.5 tonnes/ha/year compared with 2.5 tonnes/ha/year for rainfed rice (Mutert and Fairhurst 2002). About 80 million ha of rice - more than half the harvested area - is grown under irrigated conditions worldwide. Farm yield under irrigation ranges from 3 to 9 t ha^{-1}. The irrigated rice ecosystem contributes 75% of global rice production and provides the predominant source of marketable surpluses for growing populations. Irrigated rice is grown in bunded, puddled fields with assured irrigation, with one crop a year (in the subtropics and temperate zones) or more than one crop annually (in the humid and subhumid tropics) (Fischer 1998).

Nearly 24 million ha are intensively cultivated and double-cropped in southern China, Indonesia, the Philippines, Vietnam, Bangladesh, and southern India. The water needs of the dry-season crop are large because of high evapotranspiration and low rainfall. About 25% of the world’s rice land, nearly 40 million ha, is rainfed. This ecosystem contributes 18% of the global rice supply. Average yields are low because farmers grow mainly traditional varieties. The potential for increasing production is great for this ecosystem. Nearly 12 million ha of rainfed lowland rice are in Thailand and Myanmar, where traditional low yielding varieties are grown because their high grain quality is valuable in the export market (Fischer 1998).

Rice production is central to the economy and food security of Myanmar. Between 1900 and 1940, Myanmar exported 2 to 3 million MT rice annually, up to 70% of national production (Win 1991). In recent years, exports have dropped below 1 million MT per annum (USDA 2012), as a population growth has outpaced productivity improvement. Myanmar’s role in international trade has now diminished to that of a relatively minor player. With growing world demand, a large area favorable for rice growing, and opportunities for productivity improvement across the whole value chain, Myanmar has the potential to regain its status as a leading rice exporter (Denning et al. 2013).

2.2.2 Agronomic Characteristics of Rice

Rice plant growth can be divided into three agronomic stages of development: (1) vegetative (germination to panicle initiation); (2) reproductive (panicle initiation (PI) to heading); and (3) grain filling and ripening or maturation (heading to maturity) (Yoshida 1981). These stages influence the three yield components: number of panicles per unit land area, the average number of grain produced per panicle and the average weight of the individual grains. These three components determine grain yield (Moldenhauer et al. 2000).

The vegetative growth stage is characterized by active tillering, a gradual increase in plant height and leaf emergence at regular intervals. The duration of the vegetative phase (germination to panicle initiation) is generally considered the most variable of all the growth phases (Yoshida 1981); (Vergara, 1991); (Moldenhauer and Gibbons 2003). Culm elongation, a decline in tiller number, booting, emergence of the flag leaf, heading and flowering characterize the reproductive stage (Moldenhauer et al. 2000). Ripening is characterized by leaf senescence and grain growth – increases in grain size and weight and changes in grain colors (Yoshida 1981). Tillering characteristics are important to yield because they affect the number of culms per square meter, the uniformity of ripening in the field, and grain yields per panicle (Wells and Faw 1978); (Jennings et al. 1979). Yield per hectare is the most important consideration in rice. Rice yield is a product of number of panicles per unit area, number of spikelets per panicle, percentage of filled grains and weight of 1000 grains (Yoshida 1981).

2.2.3 Soil Requirement for Rice

Rice is a crop of tropical climate. Rice is cultivated in almost all types of soils with varying productivity like light to heavy soil, except very sandy. Clay or clay loam soil is the best for rice cultivation due to its high water holding capacity (www.sikkimagrisnet.org). The major soil groups where rice is grown are riverine alluvium, red-yellow, red loamy, hill and sub-montane, Terai, laterite, costal alluvium, red sandy, mixed red and black and medium and shallow black soils (www.agropedia.iitk.ac.in.htm.com). Rice will grow well over a relatively wide pH range of 5 to 7.5, although the best soils are slightly acidic (pH 5.5 to 6.6) (Martin et al. 1976).

2.2.4 Climate Requirements for Rice

Rice crop is best suited to tropical and sub-tropical humid climate but it is grown in variety of climate except extreme cold temperate. The climatic factors such as temperature, solar radiation, and humidity influence rice yield by directly affecting the physiological processes involved in grain production, and indirectly through diseases and insects (Yoshida 1981).

2.2.4.1 Temperature

The atmospheric temperature has considerable effect on growth and development of rice plant. Rice needs relatively high temperature for their optimum growth and development. Temperature requirement of rice is different for different growth stages (Table 2.2) according to variety, duration of critical temperature, diurnal changes, and physiological status of the plant (Yoshida 1981).

The critical mean temperature for flowering and fertilization ranges from 16 to 20°C. For vegetative growth a temperature range of 25 to 30°C and for grain filling and ripening 20 to 25°C temperature was reported best. For higher grain yield a day temperature of 25 to 32°C and night temperature of 15 to 20°C is desirable (Yoshida 1978). Temperature beyond 35°C affects not only pollen shedding but also grain filling. A higher mean temperature ranging between 25 to 32°C per day would reduce the growth duration and accelerate flowering whereas a mean temperature of less than 15°C would slow during vegetative growth and plants fail to flowers. Therefore, for vigorous vegetative growth moderately high temperature is required. It is well known that mild temperature of night and clear sunny weather during day time is better for high yield of rice, but temperature less than 15°C is not advantageous for panicle initiation as well as for crop growth (www.sikkimagrisnet. org). Within the critical low and high temperatures, temperature affects grain yield by affecting tillering, spikelet formation, and ripening. There is usually an optimum temperature for different physiological processes and these vary to some degree with variety (Yoshida 1981).

Table 2.2 Response of the rice plant to various temperatures at different growth stages

Growth stage	Critical temperature * (°C)		
	Low	Medium	Optimum
Germination	16 -19	45	18 - 40
Seedling emergence and establishment	12-35	35	25 - 30
Rooting	16	35	25 - 28
Leaf elongation	7 - 12	45	31
Tillering	9 - 16	33	25-31
Initiation of panicle primodia	15	-	-
Panicle differentiation	15-20	30	-
Anthesis	22	35 - 36	30-33
Ripening	12-18	> 30	20-29

*Refers to daily mean temperature except for germination

Adapted and modified from Yoshida (1978; 1981)

2.2.4.2 Solar Radiation

The yield of rice is influenced by the solar radiation particularly during the last 35 to 45 days of its ripening period. The effect of solar radiation is more profound where water, temperature and nitrogenous nutrients are not limiting factors. Bright sunshine with low temperature during ripening period of the crop helps in the development of carbohydrates in the grains (www.agricultureandupdates.blogspot. com.). Shading during the vegetative stage only slightly affects yield and yield components and during the reproductive stage has a pronounced effect on spikelet number. During ripening it reduces grain yield considerably because of a decrease in the percentage of filled spikelets (Yoshida 1981). Clear sunny weather during ripening and moist-humid during vegetative phase is desirable for rice crop. Low solar radiation would hamper ripening of grains and would increase chaff production enormously (www. sikkimagrisnet.org). Solar radiation at the reproductive stage has the greatest effect on grain yield; that at the ripening stage, the next highest effect; and that at the vegetative stage, an extremely small overall effect (Yoshida 1981).

2.2.4.3 Relative Humidity

Too little or too much rainfall at any stage of rice growth can cause partial or total crop failure. Moist humid weather during vegetative growth and dry-sunny weather during ripening is most desirable. A relative humidity of 60-80 % is said to be optimum (www.vasat.icrisat.org).

2.3 Potassium Nutrition in Rice

Potassium is taken up by rice and other plants as the K^+ ion. The rice plant's concentration of K is highest during the seedling stage and gradually declines with plant development or increasing dry matter accumulation (Sims and Place 1968); (Norman et al. 2003). K increases the number of spikelets per panicle, percentage of filled grains, and 1,000-grain weight. K improves the rice plant's tolerance of adverse climatic conditions, lodging, insect pests, and diseases. During vegetative growth up to flowering, the K supply is usually sufficient, and a response to additional K is unlikely when the leaf concentration is between 1.8% and 2.6%. To produce the maximum number of spikelets per panicle, the K content of mature leaves should be >2% at the booting stage (Dobermann and Fairhurst 2000).

Rice grain yield increases of 10% due to K fertilization are common and may approach 50% on some soils (Dobermann et al. 1996); (Slaton et al. 2009). At agronomic level, the demand for K largely varies with plant species and productivity. Seventy five per cent of the total K uptake even before booting stage and most of the remaining K^+ even before grain formation begins. The potassium content is highest (about 70-75%) in leaves and culms, with relatively little K accumulated in the milled grain (Ravichandran and Sriramachandrasekharan 2011).

2.3.1 Effects of Potassium on Yield and Yield Components of Rice

Plant height increased significantly with increasing the doses of potassium fertilizer. Number of non-effective tillers was significantly influenced by potassium level. The highest number of non-effective tillers was found in low dose of potassium level and the lowest number in medium dose of potassium level (Hasan 2007).

Proper potassium (K) nutrition is critical for maximizing rice grain yields. K is very mobile within the rice plant. Proper potassium (K) nutrition in rice promotes tillering, panicle development, spikelet fertility, nutrient uptake of nitrogen and phosphorus, leaf area and leaf longevity, disease resistance, root elongation and thickness, culm (stem) thickness and strength, rice plant tolerance to diseases and pests, rice plant resistance to lodging (Haifa 2008).

Mukherjee and Sen (2005) conducted one experiment during the Kharif season of 1999 to study the effects of rice husk and fertilizer levels of potassium on the growth and yield of rice. The application of potassium significantly improved plant height, number of tillers hill^{-1}, dry matter accumulation, and chlorophyll content and leaf area index. Rice husk and fertilizer level had significant and positive effects on grain and straw yield. Trials on sandy clay loam soil with four K rates applied the whole basally at transplanting or in 2 equal split dressings at transplanting and panicle initiation or 3 split dressings of 50% at transplanting, 25% at tillering and 25% at panicle initiation were conducted (Krishnappa et al. 2006). K applied in split dressings were more effective than at transplanting. Applied K increased number of effective tillers.

Increasing K rates increased paddy yields. K applied in split dressings were more effective than when applied at transplanting alone. Applied K increased soil K availability, K contents hill^{-1} and increased the number of chaffy grains panicle^{-1} (Krishnappa et al. 2006). Narang et al. (1997) showed that split application of K to rice (33% at sowing, 33% as foliar spray at flag leaf stage and 33% as foliar spray at grain development) gave higher yields over soil application of whole K sowing.

2.3.2 Potassium Fertilizer Management in Rice

In rice cultivation, the farmers are giving much attention only to N fertilization and very often P and K applications are carried out at minimal level, mostly missing K fertilization. This practice of imbalance and inadequate fertilizer application affects the soil productivity in general and particularly depletes the essential nutrients (Cassman et al. 1996).

Timing of fertilizer K^+ application is an important management tool in maximizing K use efficiency. Maximum efficiency is obtained when K^+ is applied so that it is available for uptake by the plants as needed. Generally, K^+ fertilizer is applied as a basal application at the time of sowing because of its relative immobility in clay soils. However, the large losses of potassium are attributable to leaching and runoff (Fageria 2009). Extractable K increased with K application rate and decreased with soil depth (Fageria et al. 1990a). Applied K increased extractable K in both the surface and the subsoil. Leaching of K^+ to lower depths was especially noticeable at the higher K rates. In this situation, split application of K^+ may be an appropriate management practice to reduce K^+ losses by leaching and improving K^+ utilization efficiency by crop plants (Fageria 2009).

There were significant differences in yields upon differential application of K. The key components of potassium management should include: (1) an estimate of crop potassium demand, potential indigenous potassium supply and recovery of potassium from applied inorganic and organic sources to predict the potassium inputs required to maintain a targeted yield level, (2) a schedule for timing potassium applications depending on soil potassium buffering characteristics and an understanding of the relationship between potassium nutrition and pest incidence and (3) knowledge on the relationship between the potassium budget, residual effects of potassium fertilizers, and changes in soil supply over time (Ravichandran and Sriramachandrasekharan 2011).

Time of fertilizer application may considerably influence crop response to fertilizer. Nutrient requirements of a crop differ considerably during different growth periods. Potassium uptake is more or less continuous throughout the different stages of growth (Ravichandran and Sriramachandrasekharan 2011). The uptake of K essentially occurs during the vegetative stage in general and can reach maximum values of 10 kg ha $^{-1}$ day $^{-1}$ and above in crop (Rameshkumar et al. 2003).

In general, basal application of fertilizer K is recommended in rice. However, the requirement for continued supply of the nutrients and possibility of leaching loss of applied K and luxury consumption justify its top dressing. The topdressing may be advantages with the following situations, (1) when the natural supply of K from the soil and irrigation water decreases in the latter growth phase, (2) the soil becomes highly reduced with time and hydrogen sulphide, organic acids, ferrous iron and carbonates accumulate inhibiting K uptake by the crop, (3) for medium to low tillering and late maturing genotypes, (4) for varieties sensitive to P deficiency and iron toxicity, and (5) in wet season (Ravichandran and Sriramachandrasekharan 2011).

Potassium can be applied in 1-3 split applications. The number of splits required depends on soil K buffering characteristics, crop establishment method used and the local importance of K for reducing pest and diseases incidence (Ravichandran and Sriramachandrasekharan 2011). K applied in split dressings were more effective than when applied at transplanting alone (Krishnappa et al. 2006). Split application of K (part at planting and part at side-dressed later) is recommended to avoid salinity effects and leaching losses both in annual and perennial crops. The beneficial effects of split application of K have been reported in a number of crops and countries: lowland rice in India, Japan, Bangladesh, and Indonesia (Parasad and Power 1997).

2.3.3 Potassium Deficiency Symptoms

Leaf tips are yellowish brown when K deficiency is severe. Since K is mobile in the plant, visual deficiency symptoms typically appear first in the lower leaves, progressing toward upper leaves (new growth) (Havlin et al. 2014). Symptoms appear first on older leaves, then along the leaf edge, and finally on the leaf base. Upper leaves are short, droopy, and ‘dirty’ dark green. Older leaves change from yellow to brown and, if the deficiency is not corrected, discoloration gradually develops on younger leaves. Leaf tips and margins may dry up. Yellow stripes may appear along leaf interveins, and lower leaves become droopy. Leaf symptoms of K deficiency (particularly the appearance of yellowish brown leaf margins) are similar to those of tungro virus disease. When K deficiency is severe, rusty brown spots appear on the tips of older leaves and later spread over the whole leaf, which then turns brown and becomes dessicated. Irregular necrotic spots may also occur on panicles (Dobermann and Fairhurst 2000). Potassium deficient plants grow slowly and have poorly developed root systems. Stalks are weak, and lodging is common (Fageria 2009).

K deficiency is often not detected because its symptoms are not as easy to recognize as those of P and N deficiency, and symptoms tend to appear during later growth stages. Leaf symptoms are usually more apparent in hybrid rice varieties than in inbred modern varieties, because of their greater K demand and narrower optimal N: K ratio (Dobermann and Fairhurst 2000). K stress increases crop damage by bacterial and fungal diseases, insect and mite infestation, and nematode and virus infection (Havlin et al. 2014).

CHAPTER III

MATERIALS AND METHODS

3.1. Potassium Fertilizer Management on Rice Cultivation

This research contained both dry season and wet season experiments. Dry season and wet season experiments were conducted from February 2014 to June 2014 and from June 2014 to October 2014 respectively.

3.2. Experimental Site

Pot experiments were conducted at the screen house of Department of Soil and Water Science, Yezin Agricultural University, located at 19° 10′ N latitude and 96° 07′ E longitude with the altitude of 213 meters above sea level.

3.3. Weather Data of the Experimental Area

The relative humidity, maximum and minimum temperatures during the experimental period were obtained from the meteorological station at Department of Agricultural Research.

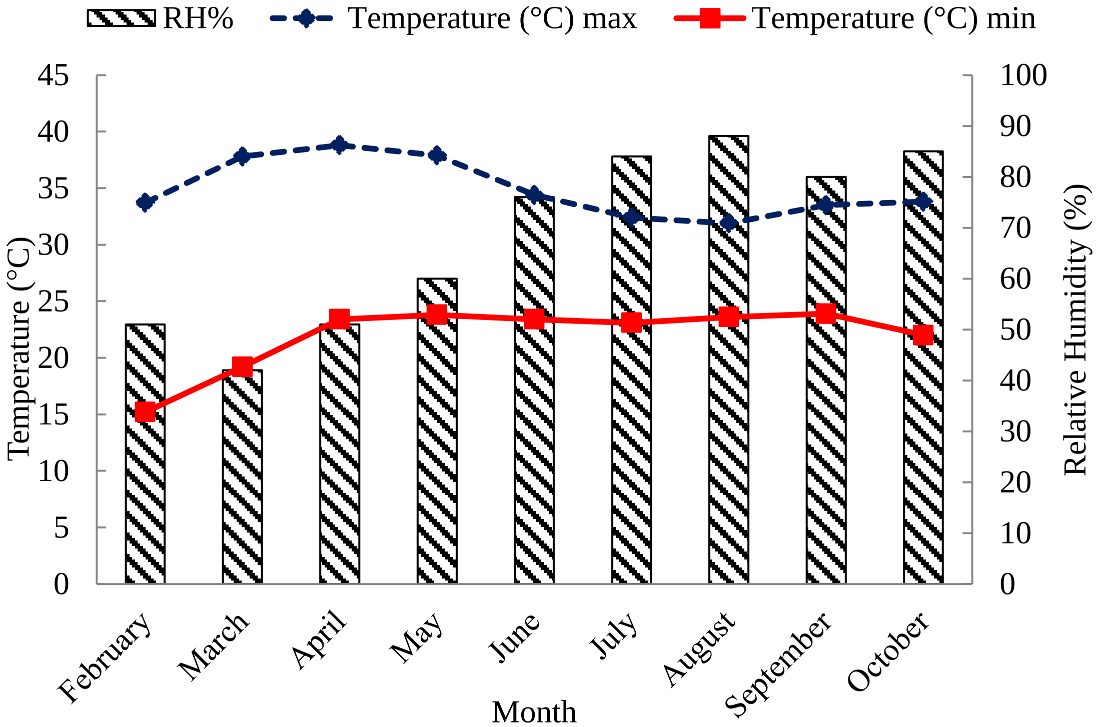

Figure 3.1 Relative humidity, minimum and maximum temperature during experimental period in Yezin (February – October 2014)

3.4. Soil Sampling and Analysis

Before conducting the experiment, a composite soil sample in the depth of 0 – 15 cm from Yezin Agricultural University Field was collected, air-dried, crushed and passed through 2 mm sieve for analysis. Some physicochemical properties of the soil were analyzed at Soil Analytical Laboratory, Land Use Division, Department of Agriculture, Yangon.

Table 3.1 Physico-chemical properties of experimental soil before sowing

Properties	Rating (content)
Soil Texture	Sandy Loam
Soil pH	5.92
Bulk density (g cm^{-3})	1.23
Nitrogen (Total N%)	0.23 (Medium)
Available P (ppm)	23.48 (High)
Available K (meq/100g)	0.57 (Medium)
Cation Exchange capacity (meq/ 100g)	12.89 (Low)
Organic matter (%)	1.7 (Low)

3.5. Establishment of Experiment

The pot experiment was laid out in Randomized Complete Block Design with four replications in which nutrient management was used as the treatments. Shwe Thwe Yin variety was used as a tested cultivar. The treatments tested in this experiment are as follow.

T1 - all potash applied as basal

T2 - all potash applied at 25 DAT

T3 - all potash applied at 45 DAT

T4 - ½ potash applied as basal and remaining ½ at 25 DAT

T5 - ½ potash applied as basal and remaining ½ at 45 DAT

T6 - ½ potash applied at 25 DAT and remaining ½ at 45 DAT

T7 - 1/3 potash applied as basal, 1/3 at 25 DAT and remaining 1/3 at 45 DAT

T8 – Control (no K applied)

3.6. Preparation of Pots

A total of 32 plastic pots, each with a diameter of 30 cm at the top and 21.3 cm at the bottom and a height of 26 cm, were used in this experiment. The collected soils were pulverized and dried in the shade and after that passed with 2 mm sieve. 13 kg soil was filled into to the plastic pot of 28 cm diameter to a depth of 20 cm to give a bulk density of 1.23 g cm^{-3}. Then the pots were allowed to submerge about one week. Under puddle condition, 25 days old seedlings were transplanted in each pot.

3.7. Fertilizer Application

Nitrogen fertilizer at the rate of 85 kg N ha^{-1} was added to each pot in two equal splits at 10 days after transplanting and panicle initiation stage. Phosphorous fertilizer at the rate of 13 kg P ha^{-1} was applied as basal application to every plastic pot. Potassium fertilizer in the form of muriate of potash at the rate of 30 kg K ha^{-1} was used according to the treatments.

3.8. Data Collection

3.8.1. Measurement Parameters for Growth

(a) Plant height

The plant height was recorded at one week interval starting from 14 days after transplanting. Plant height was measured in centimeter (cm) from the base of the plant to the tip of uppermost leaf.

(b) Number of tillers per hill

The number of tiller per hill was also recorded weekly interval starting from 14 days after transplanting. It was recorded until the heading stage.

3.8.2. Measurement Parameters for Yield and Yield Components

(a) Number of panicles per hill

The tillers having panicle with at least one grain were considered as effective tillers (panicles) and were recorded.

(b) Panicle length

Panicle length was measured from the basal node of the rachis to the apex of each panicle. Each observation was an average of 5 panicles.

(c) Number of spikelets per panicle

Total number of spikelets present on each panicle were counted from 10 panicles and averaged. The spikelet number included filled, partial filled and unfertilized spikelets.

(d) Number of grains per panicle

Presence of any food material in the spikelets was considered as grain and number of grains present on each panicle was counted.

(e) Number of unfilled spikelets per panicle

Spikelets that lacked any food materials inside was considered as unfilled spikelets and such spikelets present on each panicle were counted.

(f) 1000 grain weight (g)

A random sample of thousand well developed, whole grains was taken from each pot and their weights were recorded after sun drying with an electrical balance.

(g) Filled grain %

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

(h) Straw yield

Straw obtained from the harvest area of each unit plot including sample plants were dried in the sun. Then the straw yield was expressed in dry weight basis.

(i) Grain yield

The grains from the pot area were harvested, hand threshed and sun dried and grain yield per hill was calculated.

(j) Biological yield

Grain and straw yields are altogether regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield (t ha^{-1}) = Grain yield + Straw yield

(k) Grain harvest index

The harvest index was calculated by dividing the economic yield (grain yield) by biological yield and was expressed as percentage.

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

(Fageria 2009)

3.9. Effect of Potassium on Rice Grain Yield

The following formula was used for the measurement of potassium used efficiency.

$$\text{Potassium Use Efficiency (KUE)} = \frac{GY_{+K} - GY_{0\,K}}{FK}$$

(Dobermann and Fairhurst 2000)

Where, GY_{+K} = grain yield in a treatment with K application (kg ha^{-1})

$GY_{0\,K}$ = grain yield in a treatment without K application (kg ha^{-1})

FK = the amount of fertilizer K applied (kg ha^{-1})

3.10. Crop Management

Pots were kept free of weeds by hand weeding. Water was applied with alternate wetting and drying system. Although there was no insect damage during the dry season, the incidence of little brown plant hopper was occurred in the wet season. Therefore Dimethoate was used to control brown plant hopper. During the dry season, the crop was found to be infested with sheath rot disease which was successfully controlled by applying Mancozeb.

3.11. Statistical Analysis

Experimental data were analyzed by using Statistix (Version 8). Treatment means were compared using Least Significant Difference (LSD) test at 5% probability level.

CHAPTER IV

RESULTS AND DISCUSSION

4.1. Dry season experiment (February to June 2014)

The "Potassium fertilizer management on rice cultivation" experiment was conducted at Yezin Agricultural University during the dry season, 2014. The results obtained from this study have been presented and discussed in this chapter.

4.1.1 Effect of potassium fertilizer management on growth parameters

4.1.1.1 Plant height (cm)

The data on plant height recorded at various growth stages after transplanting are presented in Figure 4.1. Plant height in all treatments increased progressively from 14 day after transplanting (DAT) to 56 DAT.

It was observed that there was the highly significant difference at 5% level on plant height as influenced by different methods of potassium fertilizer application at 21 DAT and 1% level at 49 DAT and 56 DAT respectively.

At 21 DAT, the plant height ranged from 41.88 cm to 46.86 cm. The maximum plant height (46.86 cm) was achieved by T1 (all potash applied as basal) which was statistically indistinguishable from that of T5 (½ potash applied as basal and remaining ½ at 45 DAT) (46.11 cm). T8 (Control) produced the minimum plant height (41.88 cm).

At 49 DAT, the tallest plant height (89.76 cm) was recorded from T3 (all potash applied at 45 DAT), whereas the shortest plant height (81.63 cm) was perceived by T8 (Control).

The plant height as affected by different potassium fertilizer management varied from 96.84 cm to 104.38 cm at 56 DAT. The highest plant height (104.38 cm) was obtained from T3 (all potash applied at 45 DAT), although T8 (Control) performed the lowest plant height (96.84 cm).

Apart from 21 DAT, 49 DAT and 56 DAT, plant height was not influenced by different methods of potassium fertilizer application in this experiment. Bhiah et al. (2009) reported that potassium increased plant height and K deficiency enhanced lodging (Mahbub et al. 2006); (William and Smith 2001).

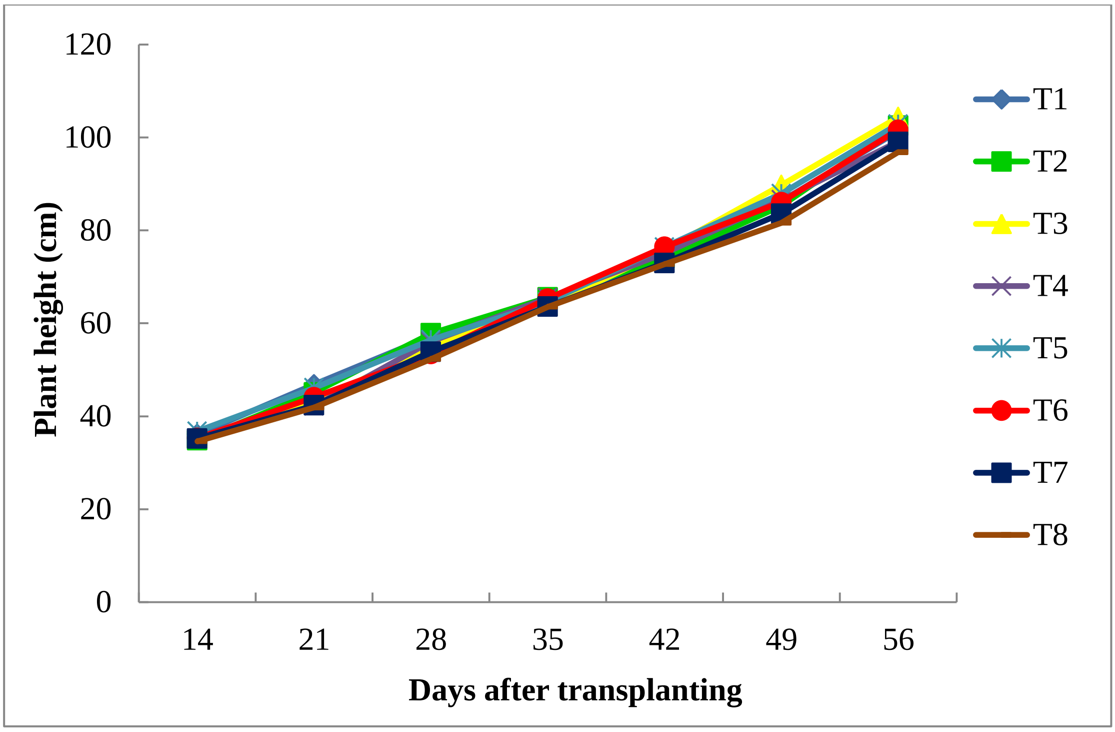

Figure 4.1 Mean value of plant height as affected by potassium fertilizer management during the dry season, 2014

T1 – (all potash applied as basal), **T2** – (all potash applied at 25 DAT), **T3** – (all potash applied at 45 DAT), **T4** – (½ potash applied as basal and remaining ½ at 25 DAT), **T5** – (½ potash applied as basal and remaining ½ at 45 DAT), **T6** – (½ potash applied at 25 DAT and remaining ½ at 45 DAT), **T7** – (1/3 potash applied as basal, 1/3 at 25 DAT and remaining 1/3 at 45 DAT), **T8** – (Control)

4.1.1.2 Number of tillers hill^{-1}

Figure 4.2 describes the effect of potassium fertilizer management on the number of tillers hill^{-1} during the dry season of 2014. The tiller number was recorded at 7 days interval starting from 14 DAT to 56 DAT. According to the results, the highly significant difference was observed on the number of tillers hill^{-1} as affected by different methods of potassium fertilizer application at 35 DAT, 42 DAT, 49 DAT and 56 DAT although the tiller numbers at the beginning days were not different at 5% level.

At 35 DAT, the number of tillers hill^{-1} was highly significantly different at 1% level and the highest tiller number (16.38) was obtained from T2 (all potash applied at 25 DAT). The minimum number of tillers hill^{-1} (13.75) was found in T8 (Control) which was remarkably similar to T1 (all potash applied as basal).

The number of tillers hill^{-1} ranged from 20.00 to 27.25 at 42 DAT. The maximum number of tillers hill^{-1} (27.25) was acquired by T2 (all potash applied at 25 DAT) which was statistically comparable with that of T5 (½ potash applied as basal and remaining ½ at 45 DAT) and T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT) and the values were (27.13) and (27.00) respectively. T8 (Control) produced the minimum number of tillers hill^{-1} (20.00). Thakur et al. (1993) and Haque et al. (1997) stated that application of potassium increased the number of tillers.

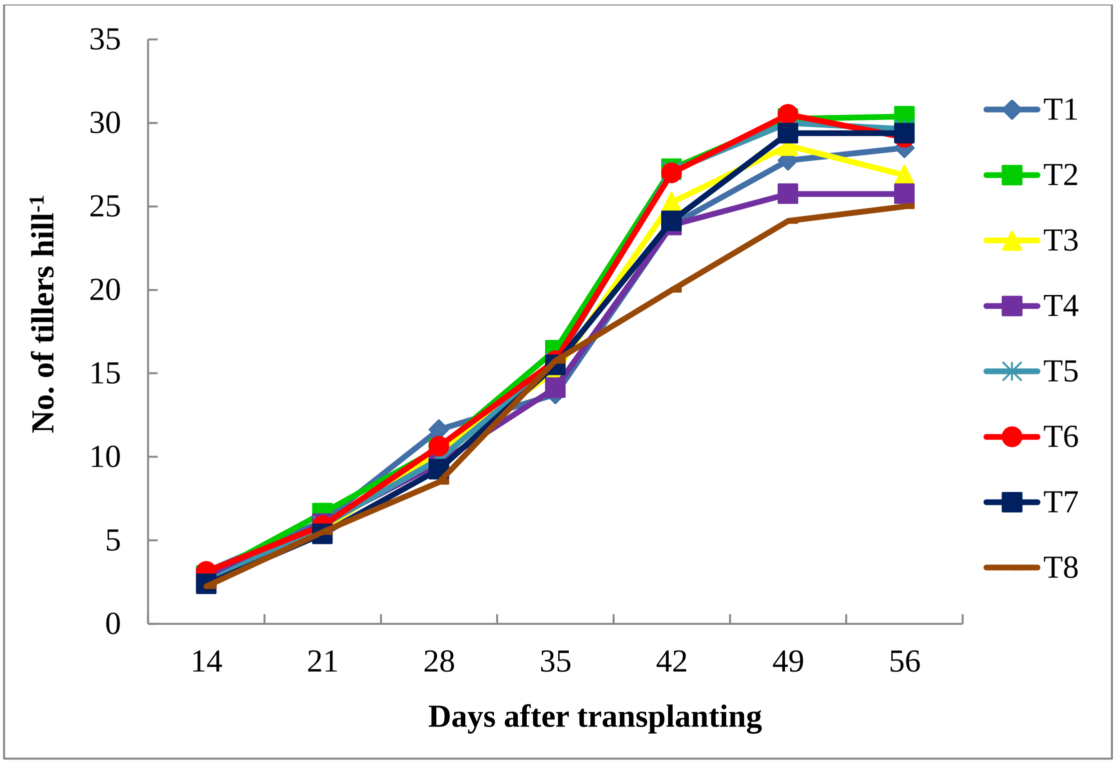

Figure 4.2 Mean value of number of tillers hill^{-1} as affected by potassium fertilizer management during the dry season, 2014

T1 – (all potash applied as basal), **T2** – (all potash applied at 25 DAT), **T3** – (all potash applied at 45 DAT), **T4** – (½ potash applied as basal and remaining ½ at 25 DAT), **T5** – (½ potash applied as basal and remaining ½ at 45 DAT), **T6** – (½ potash applied at 25 DAT and remaining ½ at 45 DAT), **T7** – (1/3 potash applied as basal, 1/3 at 25 DAT and remaining 1/3 at 45 DAT), **T8** – (Control)

4.1.2 Effect of potassium fertilizer management on yield and yield components parameters

4.1.2.1 Number of panicles hill^{-1}

Number of panicles hill^{-1} at harvest is presented at Table 4.1. Effect of different application time of potassium on the number of panicles hill^{-1} was significantly different at 1% level. Among the treatments, the maximum number of panicles hill^{-1} (23.67) was observed from T2 (all potash applied at 25 DAT) which was statistically identical with T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT) (23.33). The minimum number (17.67) was noticed in T8 (Control). Similar result has also been reported by Ali et al. (2005) that maximum number of productive tillers was observed with broadcasting of potassium at 25 DAT. Thakur (1993) noted that number of panicles is the most important factor that causes variation in the grain yield of rice.

4.1.2.2 Panicle length (cm)

The panicle length as affected by the different methods of potassium fertilizer application is described in Table 4.1. The panicle length was significantly different at 1% level. The longest panicle (25.34cm) was observed from T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT) and the shortest panicle length (22.56cm) was recorded from T8 (Control). The increase in panicle length may be due to continuous supply of potassium to the crop during crop growth stages. The efficient potash uptake by rice plant results in better growth and development when applied at maximum tillering stage (25 DAT) and at panicle initiation stage (45 DAT). This result was in agreement with Manzoor et. al. (2008) who reported that the longest panicle was obtained from the treatment where potash was applied in two equal splits ½ at 25 DAT and ½ at 45 DAT which was statistically at par with the treatment where whole potash was applied at 25 DAT.

4.1.2.3 Number of spikelets panicle^{-1}

Mean effect of potassium fertilizer management on the number of spikelets panicle^{-1} is shown in Table 4.1. There was a significant difference in number of spikelets panicle^{-1} at 5% level. The maximum number of spikelets panicle^{-1} (144.49) was collected from T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT) which was statistically akin to T2 (all potash applied at 25 DAT) (144.23). T7 (1/3 potash applied as basal, 1/3 at 25 DAT and remaining 1/3 at 45 DAT) produced the minimum number of spikelets panicle^{-1}, which was found statistically similar to that of T8 (Control) and the spikelets number were 124.28 and 123.20 respectively. Potassium fertilizer management significantly affected the number of total spikelets panicle^{-1}. It is generally recognized that the number of spikelets panicle^{-1} or number of panicles per unit area determines rice yield depending on the cultivar. Grain yield increased in most cultivars with increased number of spikelets panicle^{-1}. Kato et al. (2008) and Hasegawa et al. (1994) made similar report that spikelets number per unit area contributes immensely to yield.

4.1.2.4 Number of grains panicle^{-1}

The statistical results of number of grain panicle^{-1} as influenced by different methods of potassium fertilizer application are presented in Table 4.1. There was a highly significant difference in number of grains panicle^{-1} at 1% level. It was recorded the highest number of grains panicle^{-1} (127.57) in T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT) which was significantly different from other treatments. The lowest number (94.77) was found in T8 (Control).

The finding is similar to the results obtained by Manzoor et al. (2008). Split application of potassium at active growth stages brings about adequate potash supply which increased plant photosynthesis rate because it is required in the activation of starch synthesis and also conversion of soluble sugars into starch is a vital step in the grain filling process (Sharma et al. 1980); (Ramos et al. 1999).

4.1.2.5 Number of unfilled spikelets panicle^{-1}

The mean values of number of unfilled spikelets panicle^{-1} are exhibited in Table 4.1. Although there were no significant differences among the treatments tested, the maximum number of unfilled spikelets panicle^{-1} (28.44) was achieved by T8 (Control). The minimum number of unfilled spikelets panicle^{-1} (16.93) was obtained from T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT) which was statistically similar to that of T5 (½ potash applied as basal and remaining ½ at 45 DAT) (18.30) and T3 (all potash applied at 45 DAT) (18.34). The results showed that the higher number of unfilled spikelets panicle^{-1} was occurred when no K fertilizer was added. Hasan (2007) also reported that K fertilizer decreased the number of unfilled spikelets.

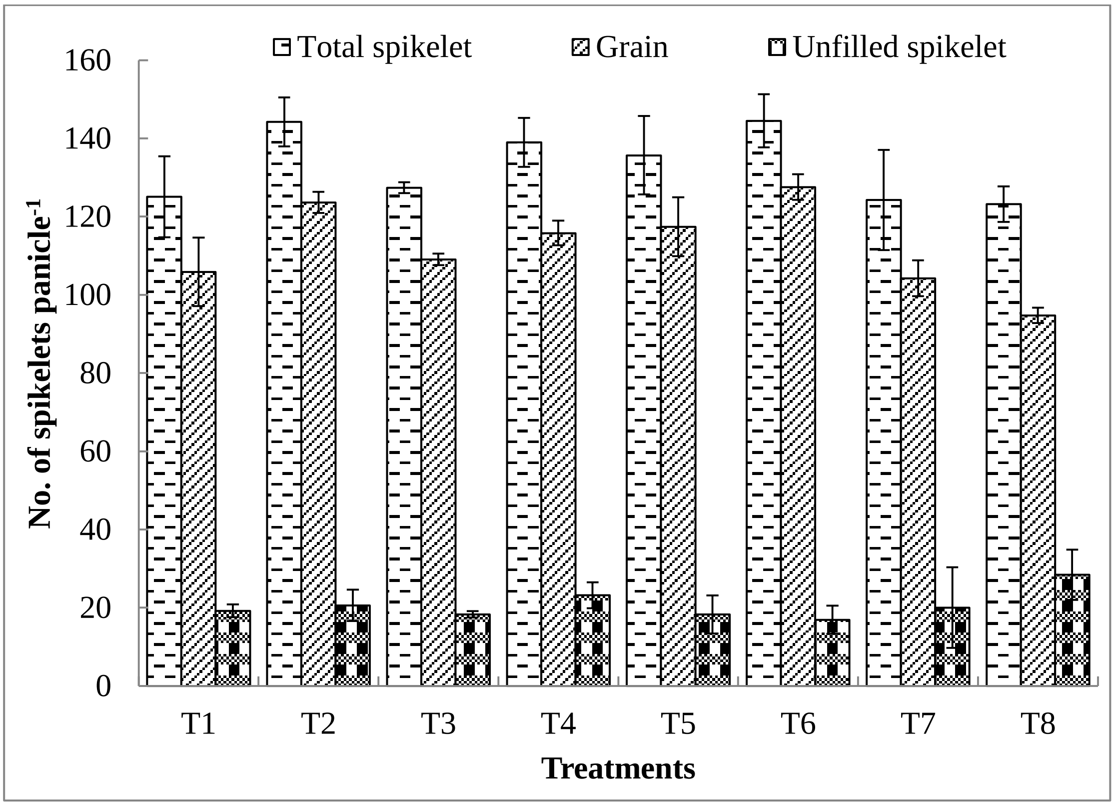

Figure 4.3 Effect of potassium fertilizer management on number of spikelets, grains and unfilled spikelets panicle^{-1} of rice during the dry season, 2014

4.1.2.6 1000 grain weight (g)

Effect of potassium fertilizer application methods on 1000 grain weight of rice is performed in Table 4.1. No significant difference was observed in 1000 grain weight among the treatments tested. The maximum 1000 grain weight (17.81 g) was exhibited by T3 (all potash applied at 45 DAT) which was not remarkably different from that of T2 (all potash applied at 25 DAT), and T1 (all potash applied as basal). The minimum 1000 grain weight (16.67 g) was obtained from T7 (1/3 potash applied as basal, 1/3 at 25 DAT and remaining 1/3 at 45 DAT) and T8 (Control). Among the

Table 4.1 Yield and yield components of rice as affected by potassium fertilizer management during dry season, 2014

Treatment	Number of panicles hill^{-1}	Panicle length (cm)	Number of spikelets panicle^{-1}	Number of grains panicle^{-1}	Number of unfilled spikelets panicle^{-1}	1000 grain weight (g)
T1	19.67 cd	23.28 bc	125.08 bc	105.87 d	19.22 ab	17.59
T2	23.67 a	24.30 ab	144.23 a	123.63 ab	20.60 ab	17.60
T3	22.00 ab	24.54 ab	127.40 bc	109.07 cd	18.34 b	17.81
T4	21.00 bc	24.18 ab	138.99 ab	115.80 bc	23.19 ab	17.17
T5	22.67 ab	24.22 ab	135.70 abc	117.40 bc	18.30 b	17.33
T6	23.33 a	25.34 a	144.49 a	127.57 a	16.93 b	17.27
T7	21.00 bc	23.73 bc	124.28 c	104.23 d	20.05 ab	16.67
T8	17.67 d	22.56 c	123.20 c	94.77 e	28.44 a	16.67
LSD$_{0.05}$	2.31	1.29	14.09	8.75	8.44	0.83
Pr>F	**	**	*	**	ns	ns
CV%	6.16	3.64	6.05	4.45	23.37	2.7

Means followed by different letters in the same column are significantly different by LSD test at 5% level.

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

T1 – (all potash applied as basal), **T2** – (all potash applied at 25 DAT), **T3** – (all potash applied at 45 DAT), **T4** – (½ potash applied as basal and remaining ½ at 25 DAT), **T5** – (½ potash applied as basal and remaining ½ at 45 DAT), **T6** – (½ potash applied at 25 DAT and remaining ½ at 45 DAT), **T7** – (1/3 potash applied as basal, 1/3 at 25 DAT and remaining 1/3 at 45 DAT), **T8** – (Control)

yield components, 1000 grain weight was less influenced by the treatment combinations because it is more or less genetically controlled characteristics. It is usually a stable varietal character and the management practice has less effect on its variation (Yoshida 1981).

4.1.2.7 Filled grain %

The significant difference in filled grain% was observed among the different methods of potassium fertilizer application (Table 4.2). The filled grain % ranged from 77.03 to 88.35. T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT) produced the maximum percentage of filled grain (88.35). This was followed by T5 (½ potash applied as basal and remaining ½ at 45 DAT) and it was not noticeably different from T1, T2, T3, T4, and T7. The lowest filled grain % (77.03) was found in T8 (Control). Yoshida (1981) expressed that factors such as weather, soil, fertilizer application, and incidence of diseases and insects affect filled-spikelet or sterility percentages.

4.1.2.8 Straw yield (g hill^{-1})

According to the dry season results, straw yield as influenced by different potassium fertilizer management is exhibited in Table 4.2. It can be clearly seen that there was a highly significant difference on straw yield of rice at 1 % level. Among the treatments tested in this experiment, the highest straw yield (50.17 g) was procured by T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT) which was statistically indistinguishable from that of T2 (all potash applied at 25 DAT) (49.85 g). The lowest straw yield (36.19 g) was recorded from T8 (Control). Awan et al. (2007) also claimed that straw yield of rice crop was increased significantly due to potash application in two equal splits.

4.1.2.9 Grain yield (g hill^{-1})

Effect of potassium fertilizer management on grain yield of rice is demonstrated in Table 4.2. The highly significant difference among the treatments was noticed at 1% level of significance. The grain yield of rice ranged from 31.84 g hill^{-1} to 51.33 g hill^{-1}. All treatments produced significantly higher yield than control. The highest grain yield (51.33 g hill^{-1}) was recorded from T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT) which was remarkably similar to that of T2 (all potash applied at 25 DAT) (51.11 g hill^{-1}) whereas the lowest yield (31.84 g hill^{-1}) was perceived by T8 (Control). The result found in T5 (½ potash applied as basal and remaining ½ at 45 DAT) was the second highest and the value was 46.37 g hill^{-1}. The grain yield of T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT) was 29% greater than T1, 0.4% greater than T2, 17% greater than T3, 19% greater than T4, 10% greater than T5, 28% greater than T7 and 38% greater than T8.

This result was consistent with the findings of Ravi and Rao (1992) and Dwivedi et al. (2000) who stated that significant increase in paddy yield was recorded when potash was applied in splits at different growth stages over a single application as basal. Application of K in two splits at active tillering and panicle initiation recorded the highest grain yield of rice. Split application of potassium helps in efficient absorption and translocation of nutrients from soil and foliage, thereby increasing the yield by reducing the sterility percentage (Annadurai et al. 2000).

4.1.2.10 Biological yield (g hill^{-1})

Biological yield varied significantly due to the different methods of potassium fertilizer application as shown in Table 4.2. It was observed that there was a highly significant difference on the biological yield of rice at 1% level. It ranged from 68.03 g to 101.50 g. The maximum value of biological yield (101.50 g) was obtained by T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT) and the effect was statistically similar to that of T2 (all potash applied at 25 DAT) (100.96 g). T8 (Control) produced the minimum biological yield (68.03 g).

Table 4.2 Yield and yield components of rice as affected by potassium fertilizer management during dry season, 2014

Treatment	Filled grain %	Straw yield (g hill^{-1})	Biological yield (g hill^{-1})	Grain yield (g hill^{-1})	Increase over control (%)
T1	84.64 a	39.35 d	75.77 d	36.42 d	12.58
T2	85.78 a	49.85 a	100.96 a	51.11 a	37.70
T3	85.61 a	44.60 bc	87.06 c	42.46 c	25.01
T4	83.36 a	43.05 c	84.86 c	41.82 c	23.86
T5	86.58 a	47.46 ab	93.83 b	46.37 b	31.33
T6	88.35 a	50.17 a	101.50 a	51.33 a	37.97
T7	84.31 a	39.20 d	75.93 d	36.73 d	13.31
T8	77.03 b	36.19 e	68.03 e	31.84 e	-
$LSD_{0.05}$	5.42	2.94	3.86	1.69	
Pr>F	*	**	**	**	
CV%	3.67	3.84	2.56	2.30	

Means followed by different letters in the same column are significantly different by LSD test at 5% level.

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

T1 – (all potash applied as basal), **T2** – (all potash applied at 25 DAT), **T3** – (all potash applied at 45 DAT), **T4** – (½ potash applied as basal and remaining ½ at 25 DAT), **T5** – (½ potash applied as basal and remaining ½ at 45 DAT), **T6** – (½ potash applied at 25 DAT and remaining ½ at 45 DAT), **T7** – (1/3 potash applied as basal, 1/3 at 25 DAT and remaining 1/3 at 45 DAT), **T8** – (Control)

4.1.2.11 Grain harvest index (GHI)

The variation of grain harvest index of rice due to different application time of potassium fertilizer is described in Table 4.3. Harvest index as affected by potassium fertilizer management was significantly different at 1% level. T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT) and T2 (all potash applied at 25 DAT) produced the maximum number of harvest index and the value were 0.51 each respectively. The minimum harvest index (0.47) was calculated at T8 (Control). Sinclair (1998) and Hay (1995) have expressed that GHI is an important trait associated with the dramatic increase in crop yields during the 20th century.

4.1.3 Potassium Use Efficiency (KUE)

Table 4.3 describes the potassium use efficiency (KUE) as affected by different potassium fertilizer management on rice during the dry season, 2014. The response of potassium fertilizer management on KUE was found to be statistically significant at 1% level. The greatest value of KUE (41.47) was observed from T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT) which was followed by T2 (all potash applied at 25 DAT) (41.00). The minimum KUE was calculated at T1 (all potash applied as basal) (9.74). Potassium use efficiency is positively associated with grain yield in crop plants (Fageria 2009). Improving potassium use efficiency in crop plants can improve their yields.

Table 4.3 Mean effect of potassium fertilizer management on grain harvest index (GHI) and potassium use efficiency (KUE) during the dry season, 2014

Treatment	GHI	KUE
T1	0.48 bc	9.74 d
T2	0.51 a	41.00 a
T3	0.49 b	22.60 c
T4	0.49 ab	21.23 c
T5	0.49 ab	30.91 b
T6	0.51 a	41.47 a
T7	0.48 b	10.40 d
T8	0.47 c	-
$LSD_{0.05}$	0.02	3.60
Pr>F	**	**
CV%	1.79	9.27

Means followed by different letters in the same column are significantly different by LSD test at 5% level.

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

T1 – (all potash applied as basal), **T2** – (all potash applied at 25 DAT), **T3** – (all potash applied at 45 DAT), **T4** – (½ potash applied as basal and remaining ½ at 25 DAT), **T5** – (½ potash applied as basal and remaining ½ at 45 DAT), **T6** – (½ potash applied at 25 DAT and remaining ½ at 45 DAT), **T7** – (1/3 potash applied as basal, 1/3 at 25 DAT and remaining 1/3 at 45 DAT), **T8** – (Control)

4.1.4 Correlation between yield and yield components of rice

The correlation between grain yield and yield components of rice during the dry season, 2014 is shown in Table 4.4. It was observed that the grain yield was significant and positively correlated with number of panicles hill^{-1}, number of spikelets panicle^{-1}, grain harvest index, panicle length, and filled grain %. The result was in line with the findings of Snyder and Carlson (1984) who reported that GHI was correlated positively with grain yield. The number of panicles hill^{-1} was significant and positively correlated with the number of spikelets panicle^{-1}, harvest index, panicle length and filled grain %. In this investigation, there was a significant and positive correlation between the number of spikelets panicle^{-1} and panicle length at 5% level. Harvest index and filled grain % were significant and positively correlated with panicle length at 1% level.

Table 4.4 Correlation between yield and yield components of rice as affected by different potassium fertilizer management during the dry season, 2014

	No. of panicles hill^{-1}	No. of spikelets panicle^{-1}	Grain Harvest index	Panicle length	1000 grain weight	Filled grain %	Yield
No. of panicle hill^{-1}	1						
No. of spikelets panicle^{-1}	0.7850*	1					
Grain Harvest index	0.9075**	0.9164**	1				
Panicle length	0.8957**	0.7494*	0.8615**	1			
1000 grain weight	0.5284	0.3330	0.5144	0.4794	1		
Filled grain %	0.8865**	0.5894	0.7585*	0.8669**	0.5963	1	
Yield	0.95**	0.9132**	0.9708**	0.8770**	0.5291	0.8015*	1

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

4.2 Wet season experiment (June - October 2014)

Wet season experiment was conducted as the same layout of dry season experiment to compare the effect of potassium fertilizer management on the performance of rice (Shwe Thwe Yin). Grain yield, yield components and other growth parameters as affected by potassium fertilizer management for wet season, 2014 are described and discussed in the following sections.

4.2.1 Effect of potassium fertilizer management on the growth parameters

4.2.1.1 Plant height (cm)

Plant height as influenced by different potassium fertilizer management at 14, 21, 28, 35, 42, 49 and 56 days after transplanting (DAT) are presented in Figure 4.4. The plant height in all treatments increased continuously from 14 DAT to 56 DAT.

Significant difference was observed among the different potassium fertilizer management in 21 DAT at 1% level and 35, 49 and 56 DAT at 5% level of significance.

Plant height at 21 DAT varied from 37.51 cm to 43.56 cm. T1 (all potash applied as basal) gave the maximum plant height (43.56 cm) and followed by that of T5 (½ potash applied as basal and remaining ½ at 45 DAT) (42.81 cm). The second highest plant height was observed from T2 (all potash applied at 25 DAT) (40.11 cm). T3 (all potash applied at 45 DAT) produced the minimum plant height (37.51 cm).

At 35 DAT, the maximum plant height (62.34 cm) was recorded from T4 (½ potash applied as basal and remaining ½ at 25 DAT) which was statistically similar to that of T2 (all potash applied at 25 DAT) (61.98 cm). The minimum plant height (57.99 cm) was obtained by T3 (all potash applied at 45 DAT).

The highest plant height (83.56 cm) was occurred in T3 (all potash applied at 45 DAT) at 49 DAT although the lowest plant height (77.33 cm) was perceived by T8 (Control).

At 56 DAT, the maximum value of plant height (99.51 cm) was got by T5 (½ potash applied as basal and remaining ½ at 45 DAT) which was statistically identical with that of T3 (all potash applied at 45 DAT) and T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT) and the values were 99.07 cm and 98.94 cm respectively. The minimum value (92.64 cm) was recorded from T8 (Control).

Surendran (2005) reported that plant height was higher in the plots which receive potassium in two splits (50% at tillering and 50% at panicle initiation).

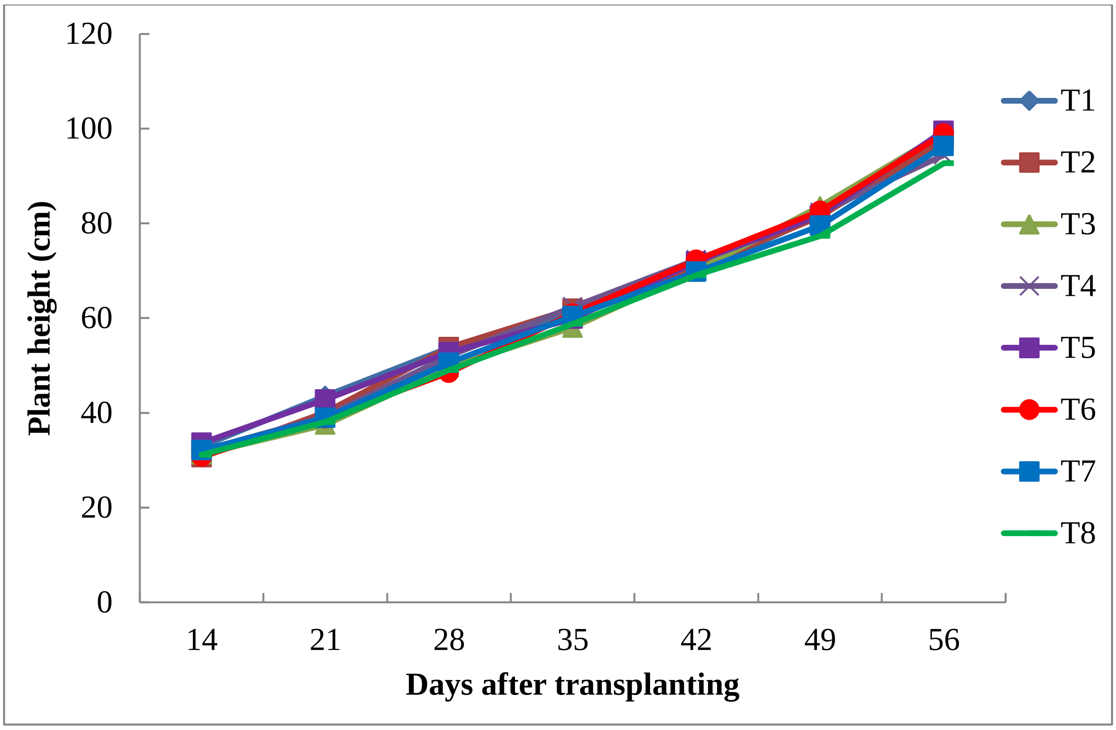

Figure 4.4 Mean value of plant height as affected by potassium fertilizer management during the wet season, 2014

T1 – (all potash applied as basal), **T2** – (all potash applied at 25 DAT), **T3** – (all potash applied at 45 DAT), **T4** – (½ potash applied as basal and remaining ½ at 25 DAT), **T5** – (½ potash applied as basal and remaining ½ at 45 DAT), **T6** – (½ potash applied at 25 DAT and remaining ½ at 45 DAT), **T7** – (1/3 potash applied as basal, 1/3 at 25 DAT and remaining 1/3 at 45 DAT), **T8** – (Control)

4.2.1.2 Number of tillers hill^{-1}

Effect of potassium fertilizer management on the number of tillers hill^{-1} during the wet season, 2014 is demonstrated in Figure 4.5. Significant differences were observed among the treatments at 28, 35, 42, 49 and 56 DAT at 5% and 1% level of significance respectively.

At 28 DAT, the highest number of tillers hill^{-1} (11.11) was acquired by T1 (all potash applied as basal) whereas the lowest number (8.44) was achieved by T8 (Control). Application of potassium significantly increases number of tillers hill^{-1} in rice (Sarkar et al. 2001).

T2 (all potash applied at 25 DAT) produced the maximum number of tillers hill^{-1} at 35, 42, 49 and 56 DAT and the values were (15.86, 25.75, 25.75 and 26.16) respectively. Minimum number was observed from T8 (Control) at 35, 42, 49 and 56 DAT.

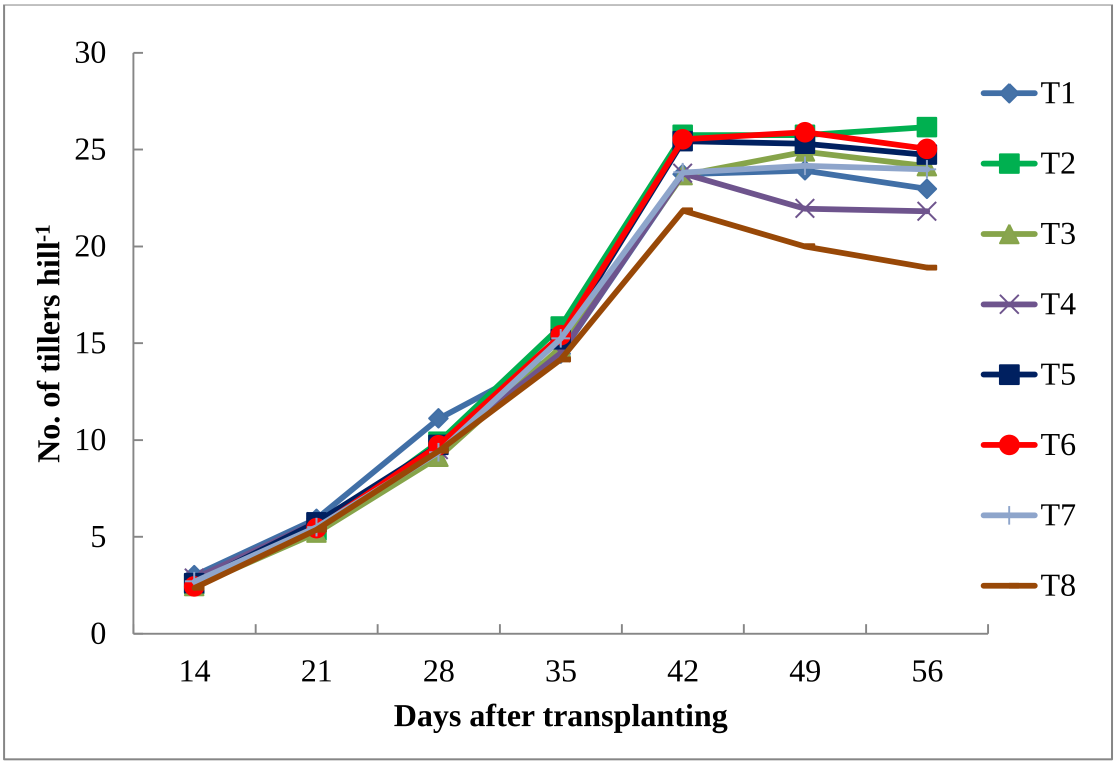

Figure 4.5 Mean value of number of tillers hill^{-1} as affected by potassium fertilizer management during the wet season, 2014

T1 – (all potash applied as basal), **T2** – (all potash applied at 25 DAT), **T3** – (all potash applied at 45 DAT), **T4** – (½ potash applied as basal and remaining ½ at 25 DAT), **T5** – (½ potash applied as basal and remaining ½ at 45 DAT), **T6** – (½ potash applied at 25 DAT and remaining ½ at 45 DAT), **T7** – (1/3 potash applied as basal, 1/3 at 25 DAT and remaining 1/3 at 45 DAT), **T8** – (Control)

4.2.2 Effect of potassium fertilizer management on yield and yield components parameters

4.2.2.1 Number of panicles hill^{-1}

Number of panicles hill^{-1} as affected by potassium fertilizer management during the wet season is portrayed in Table 4.5. There was a significant difference in the number of panicles hill^{-1} at 5% level. The number of panicles hill^{-1} ranged from 14.60 to 21.07. The maximum number of panicles (21.07) was recorded from T2 (all potash applied at 25 DAT) which was found statistically indistinguishable from that of T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT) and T5 (½ potash applied as basal and remaining ½ at 45 DAT) and the values were (20.89 and 20.26) respectively. The minimum number (14.60) was achieved by T8 (Control). The highest number of panicles hill^{-1} was observed from the application of 50% potassium each at tillering and panicle initiation (Surendran 2005).

4.2.2.2 Panicle length (cm)

Mean effects of different potassium fertilizer management on panicle length is exhibited in Table 4.5. The panicle length was statistically different at 5% level of significance. The length was found to be varied from 20.38 cm to 23.38 cm. The longest panicle length (23.38 cm) was observed from T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT) and the value was remarkably identical with T2 (all potash applied at 25 DAT) (23.20 cm). The shortest length of panicle (20.38 cm) was collected from the treatment T8 (Control). Similar results were reported by Sarkar et al. (1995) and Raju et al. (1999). Surendran (2005) also stated that potassium applied in two equal splits at tillering and panicle initiation produced the greatest length of panicle.

4.2.2.3 Number of spikelets panicle^{-1}

The number of spikelets panicle^{-1} varied significantly in different treatments due to different potassium fertilizer management at 1% level of significance and the results have been presented in Table 4.5. The maximum number of spikelets panicle^{-1} (141.99) was perceived by T6 (½ potash applied at 25 DAT and remaining ½ at 45

DAT) which was followed by that of T2 (all potash applied at 25 DAT) and T4 (½ potash applied as basal and remaining ½ at 25 DAT) and the values were (141.73 and 136.49) respectively. T8 (Control) produced the minimum number of spikelets (120.70) and the values were noticeably similar to that of T7 (1/3 potash applied as basal, 1/3 at 25 DAT and remaining 1/3 at 45 DAT) (121.78) and T1 (all potash applied as basal) (122.58). Spikelets number per square meter was the most important component limiting yield in some location (Yoshida 1981).

4.2.2.4 Number of grains panicle^{-1}

Results in Table 4.5 show the mean values of the number of grains panicle^{-1} during the wet season of 2014. The number of grains panicle^{-1} varied from 91.76 to 124.29. T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT) produced the highest number of grains panicle^{-1} (124.29) and it was statistically indistinguishable from that T2 (all potash applied at 25 DAT) (120.50) whereas T8 (Control) gave the lowest number of grains panicle^{-1} (91.76). The increase in number of grains panicle^{-1} might be due to increased potash uptake efficiency when applied at maximum tillering and at panicle initiation stages. The positive response of potassium application on number of grains panicle^{-1} in rice crop has also been conveyed by Lauchli and Pfluger (1979) and Malik et al. (1988). Potassium helped in proper filling of seeds which resulted higher number of plump seeds and thus increased the number of grains panicle^{-1} (Uddin et al., 2012b).

4.2.2.5 Number of unfilled spikelets panicle^{-1}

The statistical results of number of unfilled spikelets panicle^{-1} as influenced by different potassium fertilizer management are presented in Table 4.5. No significant difference was observed in the number of unfilled spikelets panicle^{-1} among the treatments tested in this experiment. The maximum number of unfilled spikelets panicle^{-1} (28.95) was occurred in T8 (Control) although the minimum number (17.70) was recorded from T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT). Uddin et al. (2012b) reported that the higher number of unfilled spikelets panicle^{-1} was observed when no potassium fertilizer was applied.

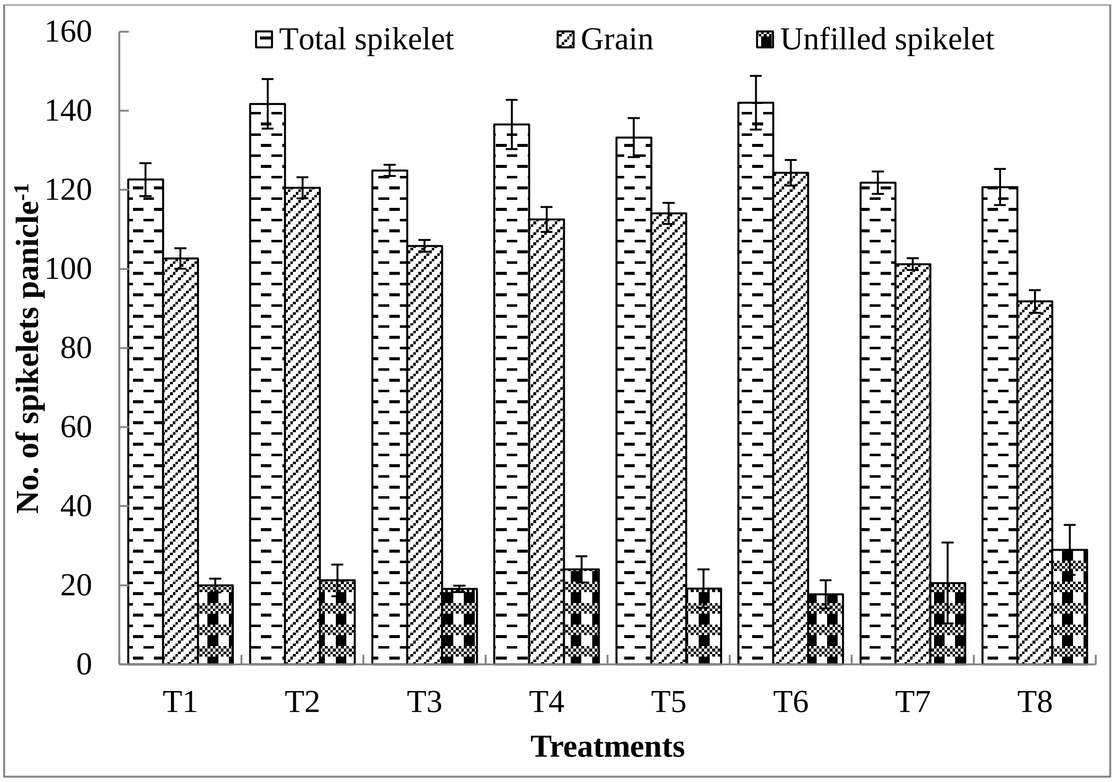

Figure 4.6 Effect of potassium fertilizer management on number of spikelets, grains and unfilled spikelets panicle^{-1} of rice during the wet season, 2014

4.2.2.6 1000 grain weight (g)

In wet season experiment, 1000 grain weight was not significantly affected by different potassium fertilizer management under the study (Table 4.5). 1000 grain weight ranged from 16.52 g to 17.66 g. Matsushima (1980) stated that the weight of 1000 grains always exhibits the least variation under any cultural seasons and practices, compared with other components.

Table 4.5 Mean effect of potassium fertilizer management on yield and yield components of rice during wet season, 2014

Treatment	Number of panicles hill^{-1}	Panicle length (cm)	Number of spikelets panicle^{-1}	Number of grains panicle^{-1}	Number of unfilled spikelets panicle^{-1}	1000 grain weight (g)
T1	16.23 bc	20.47 bc	122.58 c	102.65 cd	19.94	17.34
T2	21.07 a	23.20 a	141.73 a	120.50 a	21.23	17.45
T3	18.80 ab	22.37 ab	124.90 bc	105.80 c	19.10	17.66
T4	17.88 abc	22.06 abc	136.49 a	112.49 b	24.00	17.02
T5	20.26 a	21.16 bc	133.20 ab	114.04 b	19.17	17.18
T6	20.89 a	23.38 a	141.99 a	124.29 a	17.70	17.13
T7	18.37 ab	21.83 abc	121.78 c	101.21 d	20.57	16.57
T8	14.60 c	20.38 c	120.70 c	91.76 e	28.95	16.52
LSD$_{0.05}$	3.50	1.91	9.18	4.20	8.40	0.90
Pr>F	*	*	**	**	ns	ns
CV%	10.81	5.93	4.02	2.20	22.49	3.00

Means followed by different letters in the same column are significantly different by LSD test at 5% level.

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

T1 – (all potash applied as basal), **T2** – (all potash applied at 25 DAT), **T3** – (all potash applied at 45 DAT), **T4** – (½ potash applied as basal and remaining ½ at 25 DAT), **T5** – (½ potash applied as basal and remaining ½ at 45 DAT), **T6** – (½ potash applied at 25 DAT and remaining ½ at 45 DAT), **T7** – (1/3 potash applied as basal, 1/3 at 25 DAT and remaining 1/3 at 45 DAT), **T8** – (Control)

4.2.2.7 Filled grain %

Effect of different potassium fertilizer management on filled grain % is shown in Table 4.6. In this experiment, significant differences of filled grain % were observed among the treatment at 5% level of significance. The maximum filled grain percentage (87.60) was acquired by T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT) although it was not remarkably diverse from other treatments except T8. T8 (Control) produced the lowest filled grain percent (76.13). Yoshida et al. (1972) reported that weather conditions, cultural management and nutrient supply greatly influence each yield component of rice. Use of potassium, especially at the later growth stage of crop growth is believed to reduce the sterility percentage of rice (Uddin et al. 2012a).

4.2.2.8 Straw yield (g hill^{-1})

Mean values of straw yield as influenced by potassium fertilizer management is presented in Table 4.6. In wet season experiment, significant differences were not found among the treatments. However, maximum straw yield (46.93 g hill^{-1}) and (44.96 g hill^{-1}) was provided by T2 (all potash applied at 25 DAT) and T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT) whereas T8 (Control) produced the minimum straw yield (32.53 g). Kamalanathan and Arivazhagan (2003) concluded that basal skipping of potash and application of entire quantity of potash into two equal splits viz. 50% potash each at tillering and panicle initiation stages resulted in higher growth and grain and straw yield of rice in Kharif and Rabi seasons, respectively.

4.2.2.9 Grain yield (g hill^{-1})

Grain yield of rice as affected by different potassium fertilizer management is demonstrated in Table 4.6. It can be clearly seen that there was a highly significant difference on grain yield among the treatments tested in this experiment at 1% level. Grain yield ranged from 26.26 g hill^{-1} to 44.80 g hill^{-1}. The highest grain yield (44.80 g hill^{-1}) was procured by T2 (all potash applied at 25 DAT) which was statistically similar to that of T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT) (43.50

g hill^{-1}). The lowest grain yield (26.26 g hill^{-1}) was obtained from T8 (Control). T1 (all potash applied as basal) produced the second lowest grain yield (30.81 g hill^{-1}).

This result is similar to that of Ali et al. (2005) who noted that among the different time of potash application treatments, maximum increase in paddy yield was obtained with potassium broadcasting 25 days after transplanting. Manzoor et al. (2008) also reported that maximum paddy yield was recorded in the treatment where potash was applied in two equal splits ½ at 25 DAT and ½ at 45 DAT, which was at par with the treatment where whole of potash was applied at 25 DAT. Samrathlal et al. (2003) and Awan et al. (2007) also claimed that significantly increased grain yield of rice crop was obtained when potash was applied in two equal splits. Ghosh et al. (1995) reported that grain yield was increased by split application of K as compared with 100% basal application. Similarly, Haque et al. (1982) and Ismumadji et al. (1982) also reported yield increases in lowland rice with the split application of K^+. Increase in yield of rice might be due to prolonged availability of K in soil, significant decrease in number of chaff grain, increased tillering and concentration of K in straw and grain (Ravichandran and Sriramachandrasekharan 2011).

4.2.2.10 Biological yield (g hill^{-1})

Different methods of potassium fertilizer application showed the highly significant difference on the biological yield of rice at 1% level of significance during the wet season, 2014 (Table 4.6). The maximum values of biological yield (91.73 g hill^{-1}) was perceived by T2 (all potash applied at 25 DAT) and it was followed by T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT) (88.45 g hill^{-1}). The minimum biological yield (58.79 g hill^{-1}) was recorded from T8 (Control).

Table 4.6 Yield and yield components of rice as affected by potassium fertilizer management during wet season, 2014

Treatment	Filled grain %	Straw yield (g hill^{-1})	Biological yield (g hill^{-1})	Grain yield (g hill^{-1})	Increase over control
T1	83.74 ab	35.78	66.58 de	30.81 e	14.77
T2	85.08 ab	46.93	91.73 a	44.80 a	41.38
T3	84.71 ab	41.26	77.94 bc	36.68 c	28.41
T4	82.46 b	38.97	74.34 cd	35.38 c	25.78
T5	85.68 ab	43.94	84.20 ab	40.26 b	34.77
T6	87.60 a	44.96	88.45 a	43.50 a	39.63
T7	83.56 ab	37.01	69.37 d	32.36 d	18.85
T8	76.13 c	32.53	58.79 e	26.26 f	-
$LSD_{0.05}$	5.04	9.12	8.51	1.32	
Pr>F	*	ns	**	**	
CV%	3.44	12.96	6.36	2.08	

Means followed by different letters in the same column are significantly different by LSD test at 5% level.

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

T1 – (all potash applied as basal), **T2** – (all potash applied at 25 DAT), **T3** – (all potash applied at 45 DAT), **T4** – (½ potash applied as basal and remaining ½ at 25 DAT), **T5** – (½ potash applied as basal and remaining ½ at 45 DAT), **T6** – (½ potash applied at 25 DAT and remaining ½ at 45 DAT), **T7** – (1/3 potash applied as basal, 1/3 at 25 DAT and remaining 1/3 at 45 DAT), **T8** – (Control)

4.2.2.11 Grain harvest index (GHI)

Effect of different potassium fertilizer management on grain harvest index is exhibited in Table 4.7. In wet season experiment, no significant response was observed among the treatments. However, the maximum value of harvest index (0.49) was achieved by T2 (all potash applied at 25 DAT) and T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT) whereas the minimum harvest index (0.45) was obtained from T8 (Control).

4.2.3 Potassium Use Efficiency (KUE)

In the wet season experiment, potassium use efficiency (KUE) as influenced by different methods of potassium fertilizer application is described in Table 4.8. The values ranged from 65.55 to 95.33. The highest values of KUE (39.45) was calculated from T2 (all potash applied at 25 DAT) and it was followed by that of T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT) (36.67). T1 (all potash applied as basal) provided the lowest value of KUE (9.67). KUE is an important index in determining crop yield (Fageria 1992).

Table 4.7 Mean effect of potassium fertilizer management on grain harvest index (GHI) and potassium use efficiency (KUE) during the wet season, 2014

Treatment	GHI	KUE
T1	0.46	9.67 e
T2	0.49	39.45 a
T3	0.47	22.17 c
T4	0.48	19.39 c
T5	0.48	29.79 b
T6	0.49	36.67 a
T7	0.47	12.98 d
T8	0.45	-
$LSD_{0.05}$	0.04	2.91
Pr>F	ns	**
CV%	4.95	7.83

Means followed by different letters in the same column are significantly different by LSD test at 5% level.

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

T1 – (all potash applied as basal), **T2** – (all potash applied at 25 DAT), **T3** – (all potash applied at 45 DAT), **T4** – (½ potash applied as basal and remaining ½ at 25 DAT), **T5** – (½ potash applied as basal and remaining ½ at 45 DAT), **T6** – (½ potash applied at 25 DAT and remaining ½ at 45 DAT), **T7** – (1/3 potash applied as basal, 1/3 at 25 DAT and remaining 1/3 at 45 DAT), **T8** – (Control)

4.2.4 Correlation between yield and yield components of rice

The relationship between the yield and yield components of rice as affected by different potassium fertilizer management during the wet season, 2014 is presented in Table 4.8. In wet season experiment, grain yield was highly significant and positively correlated with number of panicles hill^{-1}, number of spikelets panicle^{-1} and grain harvest index at 1% level and panicle length and filled grain % at 5% level. Number of spikelets panicle^{-1} was significant and positively correlated with harvest index and panicle length at 1% and 5% level respectively. Grain harvest index was highly and positively correlated with number of panicles hill^{-1} and panicle length at 1% level of significance. It was also found that there was a strong correlation between the number of panicles hill^{-1} and filled grain %. Number of panicles hill^{-1} was significant and positively correlated with number of spikelets panicle^{-1} and panicle length at 5% level.

4.3 Pooled analysis of yield and yield components of rice (dry and wet seasons, 2014)

The data regarding the yield and yield components of rice during the two seasons were nearly similar and therefore these were pooled. The mean data of two seasons are presented in Table 4.9. Yield and yield related traits were highly significantly different among the treatments tested in this experiment whereas no significant difference was observed in the number of spikelets panicle^{-1}, 1000 grain weight and filled grain % between the two seasons. In both seasons, T2 (all potash applied at 25 DAT) and T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT) produced the maximum grain yield and T8 (Control) showed the minimum grain yield of rice.

Table 4.8 Correlation between yield and yield components of rice as affected by different potassium fertilizer management during the wet season, 2014

	No. of panicles hill^{-1}	No. of spikelets panicle^{-1}	Grain Harvest index	Panicle length	1000 grain weight	Filled grain %	Yield
No. of panicle hill^{-1}	1						
No. of spikelets panicle^{-1}	0.7879*	1					
Grain Harvest index	0.9403**	0.9229**	1				
Panicle length	0.8186*	0.7651*	0.8565**	1			
1000 grain weight	0.4878	0.3677	0.4187	0.3986	1		
Filled grain %	0.8657**	0.5957	0.7953*	0.6594	0.6192	1	
Yield	0.9685**	0.8854**	0.9527**	0.8287*	0.5783	0.8234*	1

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

Table 4.9 Pooled analysis of yield and yield components of rice as affected by potassium fertilizer management from the dry and wet seasons, 2014

Treatment	Number of panicles hill^{-1}	Number of spikelets panicle^{-1}	1000 grain weight (g)	Filled grain %	Grain yield (g hill^{-1})
T1	18.12 cd	123.83 bc	17.47	84.19 ab	33.62 d
T2	22.37 a	142.98 a	17.53	85.43 ab	47.96 a
T3	20.40 abc	126.15 bc	17.74	85.16 ab	39.57 c
T4	19.44 bc	137.74 a	17.09	82.91 b	38.60 c
T5	21.47 ab	134.45 ab	17.26	86.13 ab	43.32 b
T6	22.11 a	143.24 a	17.20	87.97 a	47.42 a
T7	19.68 abc	123.03 c	16.62	83.94 ab	34.55 d
T8	16.13 d	121.95 c	16.60	76.58 c	29.05 e
LSD$_{0.05}$	1.69	7.04	0.50	3.07	1.08
Pr>F	**	**	**	**	**
Season x Treatments	**	ns	ns	ns	**
CV%	7.2	4.6	2.5	3.1	2.3

Means followed by different letters in the same column are significantly different by LSD test at 5% level.

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

T1 – (all potash applied as basal), **T2** – (all potash applied at 25 DAT), **T3** – (all potash applied at 45 DAT), **T4** – (½ potash applied as basal and remaining ½ at 25 DAT), **T5** – (½ potash applied as basal and remaining ½ at 45 DAT), **T6** – (½ potash applied at 25 DAT and remaining ½ at 45 DAT), **T7** – (1/3 potash applied as basal, 1/3 at 25 DAT and remaining 1/3 at 45 DAT), **T8** – (Control)

CHAPTER V

CONCLUSION

The present study emphasized the effect of different time of potassium fertilizer application on the yield and yield components of rice during the dry and wet season of 2014.

Base on the two strong investigations, yield and yield components with nutrient use efficiency were responded to different application time of potassium fertilizer. T6 (½ potash applied at 25 DAT and remaining ½ at 45 DAT) and T2 (all potash applied at 25 DAT) produced more grain yield in both seasons. Lower grain yield was achieved at control and only basal application treatments. The greater potassium use efficiency was obtained by the application of potash at 25 DAT and two splits at 25 DAT and 45 DAT treatments.

The increased grain yield of rice as a result of potassium fertilizer application at recommended rate having two equal splits (½ potash applied at 25 DAT and remaining ½ at 45 DAT) was accredited directly to continuous supply of potassium to the crop during crop growth period. The rice plant ultimately proved more beneficial and increased in panicle length, number of effective tillers hill^{-1} and number of grains panicle^{-1} while decreased percentage of sterile grain by enhancing grain filling. Furthermore, this practice may prove helpful in case when full quantity of potash is not available at transplanting or the financial status of the farmer may not allow him to purchase the total quantity of potash at one time.

According to the results of this study, basal application of potash (traditional method) can be replaced by a late application of potash at 25 DAT (maximum tillering stage) and split application of potash in two splits ½ at 25 DAT and remaining ½ at 45 DAT can be promoted for getting maximum benefit. Since this study was tested with Shwethweyin variety under irrigated lowland conditions in the pots, field studies of the treatments used in this experiment should be carried out to further ascertain their effects on the KUE and yield of popular rice varieties under different rice agroecosystems.

REFERENCES

Abdel Wahab, A.M. and M.H. Abd-Alla. 1995. The role of potassium fertilizer in nodulation and nitrogen fixation of faba bean (*Vicia faba* L.) plants under drought stress. Biol. Fert. Soils. pp. 147–150.

Ahmad, S., A. M. Ranjha and T. Waheed. 1994. Long term effect of ammonium chloride application in comparison with conventional nitrogen sources for rice production. JAPS. 4 (1-2): 1-3.

Ali A., M.S. Zia, F. Hussain, M. Salim, LA. Mahmood and A. Shahzad. 2005. Efficacy of different methods of potassium fertilizer application on paddy yield, K uptake and agronomic efficiency. Pak. J. Agri. Sci. 42 (1-2): 27-32.

Annadurai, K., S.P. Palaniappan, P. Masilamani and R. Kavimani. 2000. Split application of potassium on rice – A review. Agric. Rev., 21(1): 36-44.

Anon. 1987. Functions of potassium in plants. In: Potassium for Agriculture, Armstrong D.L. (Ed.).

Awan, T.H., Z. Manzoor, M.E. Safdar and M. Ahmad. 2007. Yield response of rice to dynamic use of potassium in traditional rice growing area of Punjab. Pakistan J. Agri. Sci.., 44 (1): 130-135.

Bailey, LD, CA. Grant and M. Choudary. 1993. The Environmental Enhancing Nutrient. Fertilizer International 327: 25-30.

Bertsch, P. M. and G. W. Thomas. 1985. Potassium status of temperate region soils. In: Potassium in agriculture, R. D. Munson, Ed., 131 - 162. Madison, WI: ASA, CSSA, and SSSA.

Bhiah, K. M., C. Guppy, P. Lockwood, and R. Jessop. 2009. Effect of potassium on rice lodging under high nitrogen nutrition. 19th World Congress of Soil Science, Soil Solutions for a Changing World held on 1-6 August 2010, Brisbane, Australia.

Bijay-Singh, Yadvinder-Singh, Patricia Imas, and Xie Jian-chang. 2004. Potassium Nutrition of the Rice – Wheat Cropping System. Advances in Agronomy, Volume 81. pp. 203-259.

Bouabid, R., M. Badraoui and P.R. Bloom. 1991. Potassium fixation and charge characteristics of soil clays. Soil Sci. Soc. Am. J. 55: 1493-1498.

Cassman, K.G., Dobermann, P.C. Sta Cruz, G.C. Gines, M.1. Samson, J.P. Descalsota, J.M. Alcantara, MA Dizon and D.C. Olk. 1996. Soil organic matter and the indigenous nitrogen supply of intensive irrigated rice systems in the tropics. Plant and Soil, 182: 267-287.

Coats, B. 2003. Global Rice Production. In Rice: Origin, History, Technology, and Production, C. Wayne Smith. Ed. ISBN 0-471-34516-4. pp. 247-270.

Cooke, G.W. 1986. The Role and Importance of Potassium in the Agricultural Systems of the Humid Tropics: the Way Forward: Proc. 19th Coll. Int. Potash Institute, Bern/Switzerland.

Das, K.C., A. Mishra and J. Pandey. 1975. Split application of potassium for rice. Indian J. Potassium Res. 1(1):13-16.

Davis, JG. 1994. Managing plant nutrients for optimum water use efficiency and water conservation Advances in Agronomy. 53: 85-119.

Denning, G., K. Baroang, T. M. Sandar, and other MDRI and MSU colleagues. 2013. Rice Productivity Improvement in Myanmar. Background Paper No.2. pp. 4-4.

Dibb, D. W. and L. F. Welch. 1976. Corn growth as affected by ammonium vs. nitrate absorbed from soil. Agron. J. 68:89–94.

Dibb, D. W. and W. R. Thompson, Jr. 1985. Interaction of potassium with other nutrients. In: Potassium in agriculture, R. D. Munson, Ed., 515–533. Madison, WI: ASA, CSSA, and SSSA.

Dobermann, A. and T. H. Fairhurst. 2000. Rice: Nutrient Disorders and Nutrient Management. Handbook Series. ISBN 981-04-2742-5. pp. 72-83.

Dobermann, A., P.C. Sta. Cruz, and K.G. Cassman. 1996. Fertilizer inputs, nutrient balance, and soil nutrient-supplying power in intensive, irrigated rice systems. I. Potassium uptake and K balance. Nutr. Cycling Agroecosyst. 46:1–10.

Dwivedi, A. P., R. S. Dixit, S. P. Sing and I. I. Kumar. 2000. Response of hybrid rice to N, P and K levels, (in) Extended Summaries of National Symposium on Agronomy: Challenges and Strategies for the New Millenium, held during

15-18 November 2000 at' Gujarat Agricultural University Campus, Junagarh. pp. 38.

Egilla, J.N., F.T. Davies, and T.W. Boutton. 2005. Drought stress influences leaf water content, photosynthesis, and water-use efficiency of hibiscus rosa-sinensis at three potassium concentrations. Photosynthetica. pp. 135–140.

Fageria, N. K. 1984. Fertilization and mineral nutrition of rice. Campus, Rio de Janeiro/CNPAF, Goiania, Brazil.

Fageria, N. K. 1989. Tropical soils and physiological aspects of crops. Brasilia, Goiânia, Brazil: EMBRAPA/CNPAF.

Fageria, N. K. 1992. Maximizing crop yields. New York: Marcel Dekker.

Fageria, N. K. 2001. Response of upland rice, dry bean, corn and soybean to base saturation in cerrado soil. Rev. Bras. Eng. Agric. Ambien. 5:416–424.

Fageria, N. K. 2009. The use of nutrients in crop plants. ISBN 978-1-4200-7510-6. pp. 131-158.

Fageria, N. K. and H. R. Gheyi. 1999. Effcient crop production. Campina Grande, Brazil: Federal University of Paraiba.

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

Fageria, N. K., A. B. Santos, and V. C. Baligar. 1997b. Phosphorus soil test calibration for lowland rice on an Inceptisol. Agron. J. 89:737–742.

Fageria, N. K., N. A. Slaton, and V. C. Baligar. 2003. Nutrient management for improving lowland rice productivity and sustainability. Adv. Agron. 80:63–152.

Fageria, N. K., R. J. Wright, V. C. Baligar, and J. R. P. Carvalho. 1990a. Upland rice response to potassium fertilization on an Oxisol. Fert. Res. 21:141–147.

Fageria, N. K., V. C. Baligar, and C. A. Jones. 1997a. Growth and mineral nutrition of eld crops, 2nd edition. New York: Marcel Dekker.

Fageria, N. K., V. C. Baligar, and D. G. Edward. 1990b. Soil-plant nutrient relationships at low pH stress. In: Crops as enhancers of nutrient use, V. C. Baligar and R. R. Duncan, Eds., 475–507. New York: Academic Press.

FAO (Food and Agriculture Organization). 2004. Rice and human nutrition [online]. International year of rice 2004. FAO. Rome, Italy. Available from: http://www.fao.org/rice2004/en/f-sheet/factsheet3.pdf.

FAO (Food and Agriculture Organization). 2009. FAO/WFP crop and food security assessment mission to Myanmar [online]. Special report 22 January 2009. FAO. Rome, Italy. Available from: http://foodsecuritylink.net/ myanmar/index.php?

Fischer, K. S. 1998. Challenges for rice research in Asia: Sustainability of rice in the global food system. Dowling, NG, SM. Greenfield, and KS. Fischer, editors. Davis, Calif. (USA): Pacific Basin Study Center, and Manila (Philippines): International Rice Research Institute. pp. 95-98.

Foth, H. D. 1990. Plant-Soil Macronutrient Relations. In: Fundamentals of soil science - 8th ed. Michigan State University. ISBN 0-471-52279-1. pp. 202-205.

Ghosh, S.K., S. Pal and A.K. Mukhapadhay.1995. Split application of potassium to maximize its efficiency on yield of high yielding rice. Indian J. Agron. 39(4):259-264.

Haifa. 2008. Nutritional recommendations for: RICE. pp 28-34.

Haque, M. A., M. A. Hashem, M. A. Islam and M. Jahiruddin. 1997. Effect of N, P, S and Zn on indigenous cyanobacteria and yield of BR2 rice. Prog. Agril. 8(1& 2): pp. 43-47.

Haque, S. A., Z. H. Bhuya, A. K. M. Idris Ali, F. A. Choudhury, M. Jahiruddin, and M. M. Rahman. 1982. Response of HYV paddy to potash fertilization in different regions of Bangladesh. In: Phosphorus and potassium in the tropics, E. Pushparajah and E. H. A. Hamid, Eds., 425–430. Proceedings of International Conference on Phosphorus and Potassium in the Tropics, Kuala Lumpur, Malaysia, August 1981, Malaysian Society of Soil Science, Kula Lumpur.

Hasan, M. M. 2007. Effect of different levels of potassium on the growth, yield and seed quality of modern transplant *aman* cultivar. M. S. Thesis, Dept. Agron., Bangladesh Agril. Univ., Mymensingh. pp. 40-55.

Hasegawa T., Y. Koroda, N. G. Seligman and T. Horie. 1994. Response of spikelet number to plant nitrogen concentration and dry weight in paddy rice. Agron. J., 86: 673-676.

Havlin, J.L., S. L. Tisdale, W. L. Nelson and J. D. Beaton. 2014. Soil fertility and fertilizers: An introduction to nutrient management. 8th Edition. pp 223-238.

Hay, R. K. M. 1995. Harvest index: A review of its use in plant breeding and crop physiology. Ann. Appl. Biol. 126:197–216.

Huber, D. M. and D. C. Arny. 1985. Interactions of potassium with plant diseases. In: Potassium in agriculture, R. D. Munson, Ed., 467–488. Madison, WI: ASA, CSSA, and SSA.

IPI (International Potash Institute). 2014. Potassium: a Nutrient Essential for Life. ISBN 978-3-905887-11-2. DOI 10.3235/978-3-905887-11-2. 22p.

IRRI. 2010. IRRI (International Rice Research Institute). http:// www.irri.org/about rice/ rice facts/what is rice?.

Ismunadji, M. 1976. Fertilizer Use and Plant Health. proc. 12 the Colloq. Inster. Potash Inst., Berne. pp. 47-60.

Ismunadji, M., I. Nasution, and S. Parthohardjono. 1982. Potassium nutrition of lowland rice. In: Phosphorus and potassium in the tropics, E. Pushparajah and E. H. A. Hamid, Eds., 315–321. Proceedings of International Conference on Phosphorus and Potassium in the Tropics, Kuala Lumpur, Malaysia, August 1981, Malaysian Society of Soil Science, Kula Lumpur.

Jennings, P. R., W. R. Coffman, and H. E. Kauffman. 1979. Rice Improvement. International Rice Research Institute, Manila, The Philippines.

Kamalanathan, J, and Arivazhagan K., 2003. Effect of timing of potassium application on the performance of rice genotypes. *M.Sc. (Agri),* Annamalai Univ., Annamalainagar, (India).

Kant, S. and U. Kafkafi. 2002. Potassium and Abiotic Stresses in Plants. In Potassium for Sustainable Crop Production; Pasricha, N.S., Bansal, S.K., Eds.; Potash Institute of India: Gurgaon, India. pp. 233–251.

Kato, Y., A. Kamoshita, and J. Yamagishi. 2008. Preflowering abortion reduces spikelet number in upland rice (*Oryza sativa* L.) under water stress. Crop Sci., 48: 2389-2395.

Krishnappa, M., K. N. Gowda, V. Shankarayan, Maharudrappa, and M. M. Khan, 2006. Effect of graded levels and split application of potassium on its availability and yield of rice. J. Potassium Res. 6(4): 156-161.

Lauchli, A. and R. Pfluger. 1979. In: Potassium Research Review and Trends. Intl. Potash Inst., Bern, Switzerland. pp 111-163.

Lindhauer, M.G. 1985. Influence of K nutrition and drought on water relations and growth of sunflower (*Helianthus-annuus* L.). J. Plant Nutr. Soil Sci. pp. 654–669.

Mahbub, M. A., M. Khanam, M. S. Rahman, M. A. Hossain and A. R. Gomosta. 2006. Determination of lodging characters of some BRRI recommended rice varieties at three nitrogen levels during wet season in Bangladesh. Bangladesh J. Bot. 35: 117-124.

Malik, M.N.A., S.U. Din and M.I. Makhdum. 1988. Effect of muriate and sulphate of potash on the growth and yield components of late sown wheat. Sarhad J. Agri., 4(5): 565-569.

Manzoor, Z., T. H. Awan, M. Ahmad, M. Akhter and F. A. Faiz. 2008. Effect of Split Application of Potash on Yield and Yield Related Traits of Basmati Rice. Rice Research Institute Kala Shah Kaku, Lahore, Pakistan. J. Anim. Pl. Sci. 18(4): pp. 120-124.

Marschner, P. 2012. Marschner’s Mineral Nutrition of Higher Plants, 3rd ed.; Academic Press: London, UK. pp. 178–189.

Martin, J. H., W. H. Leonard, and D. L. Stamp. 1976. Rice. In Principles of Field Crop Production. Macmillan, New York, pp. 539–562.

Masutomi, Y., K. Takahashi, H. Harasawa, and Y. Matsuoka. 2009. Impact assessment of climate change on rice production in Asia in comprehensive consideration of process/parameter uncertainty in general circulation models. Agric. Ecosyst. Environ. 131(3–4):281–291.

Matsushima, S. 1980. Rice Cultivation for the Million: Diagnosis of rice cultivation and techniques of yield increase. Japan scientific societies press Tokyo.

Mehdi, SM. and A.M. Ranjha. 1995. Effect of texture, lime and temperature on fixation of applied Potassium. PJAS. 32(2-3): 153-159.

Mengel, K. 2001. Principles of Plant Nutrition, 5th ed.; Kluwer Academic Publishers: Dordrecht, the Netherlands. pp. 481–509.

Mengel, K. and E.A. Kirkby. 2001. Principles of Plant Nutrition. 849p.

MMSD. 2002. Potash Case Study. Information supplied by the International Fertilizer Industry Association. Mining, Minerals and Sustainable Development. No. 65. 9p.

MOAI. 2012. Talking figures: some statistics in agriculture of Myanmar and Asia-Pacific Region. Ministry of Agriculture and Irrigation, Myanmar. November, 2012.

MOAI. 2013. Myanmar Agriculture at a Glance. pp. 42 - 42.

Moldenhauer, K. A. K. and J. H. Gibbons. 2003. Rice Morphology and Development. In Rice : origin, history, technology, and production; C. Wayne Smith and R. H. Dilday., ed.; pp. 103-128.

Moldenhauer, K., C. E. Wilson, Jr., P. Counce and J. Hardke. 2000. Rice growth and development. In: Rice Production Handbook. Eds: Dr. Jarrod T. Hardke. Division of Agriculture, Cooperative Extension Services, University of Arkansas. United States Department of Agriculture and Country Governments Cooperating.: pp. 9-20.

Mukherjee, D. and A. Sen. 2005. Influence of rice husk and fertility levels on the nutrient content of rice (*Oryza sativa*). Dept. Agron. Inst. Agril. Sci. Varanasi, India Agric. Sci. Digest. 25(2):151-152.

Mutert, E. and T. H. Fairhurst. 2002. Developments in rice production in Southeast Asia. Better Crops International, 15.

Mwangi J. K., H. Murage, E. M. Ateka and A. B. Nyende. 2013. Agronomic Diversity Among Rice (*Oryza Sativa* L.) Lines in a Germplasm Collection from Kenya. pp. 730-743.

Narang, R. S., S. S. Mahal, R. S. Seemabedi, and K. S. Gosal. 1997. Response of rice and wheat fertilization under maximum yield research strategies. Environ. Ecol. 15(2): 474-477. [Rice Abs. 20(4): 308].

Norman R. J., C. E. Wilson, Jr., and N. A. Slaton. 2003. Soil Fertilization and Mineral Nutrition in U.S. Mechanized Rice Culture. In Rice : origin, history, technology, and production; C. Wayne Smith and R. H. Dilday., ed.; pp. 331-412.

Prasad, R., and J.F. Power. 1997. Soil fertility management for sustainable agriculture. ISBN 1-56670-254-2. pp. 211-228.

Raju, R. A., K. S. Reddy and M. N. Reddy. 1999. Potassium fertilization in rice (*Oryza Saliva* L.) on vertisols of Godavari flood plains. Indian J. of Agron. 44(1): 99-101.

Ram, P. and R. N. Parasad. 1985. Efficacy of time of potassium application in wetland rice on Haplaquent of Meghalaya. Indian J. Agric. Sci. 55: pp. 338-341.

Rameshkumar,S.C., R.S. Reddy, C.R. Shivaprasad, S. Harindranath, L.K.G. Naidu, L. Budihal, S. Srinivas, P. Krishnan, and K.S. Gajabhiye. 2003. In: Reconciling Environment and Economic Executive Summaries of EERC Projects. Eds Jyoti, Parikh, K. and Raghu Ram,T. L.

Ramos, D.G., J.P. Descalsota and G.O. Sen Valentin. 1999. Efficiency of foliar applications of mono potassium, phosphate. Terminal Report submitted to the Funding Agency, ROTEM AMFERT NEGEV. By Phil Rice Philippines.

Ravi, K. and K. Rama Rao. 1992. Studies on levels and times of application of Potassium for kharif rice (*Oryza sativa* L). The Andhra Agri. J. 30 (1-2): 74-76.

Ravichandran, M. and M.V. Sriramachandrasekharan. 2011. Optimizing timing of potassium application in productivity enhancement of crops. Annamalai University, Annamalainagar-608002, Tamil Nadu, India. Karnataka J. Agric. Sci., 24 (1): pp. 75-80.

Redfern, S. K., N. Azzu and J. S. Binamira. 2012. Rice in Southeast Asia: facing risks and vulnerabilities to respond to climate change. Plant Production and Protection Division, FAO, Rome National IPM Program, Philippines. pp. 295-314.

Romheld, V. and E.A. Kirkby. 2010. Research on potassium in agriculture: Needs and prospects. Plant Soil. pp. 155–180.

Samrathlal, M., S. Surendra and Y.S. Shivay. 2003. Response of hybrid rice (Oryza Sativa) to nitrogen and potassium application in sandy clay–loam soils. Indian J. of Agri. Sci. 73(1): 8-11.

Sarkar, R. K., B. Bhattacharya, A. M. Chakraborty, S. Rana and C. Satpathy. 1995. Response of rice to N and K application in Gangetic alluvial soils of West Bengal. J. Potassium Res. 11(3): 297-301.

Sarker, M. A. H., M. A. Samad, M. R. Amin, D. B. Pandit, and M. A. H. S. Jahan. 2001. Effect of nitrogen levels on the ear size, grain development and yield of rice. Bangladesh J. Agril. Sci. 28(2): pp. 303-310.

Sasaki, T. 2002. Rice genomics to understand rice plant as an assembly of genetic codes. Curr. Sci. 83: pp. 834-839. .

Sharma, R.C., M. Singh and K.C. Sud. 1980. Relative response of the potato to three sources of potassium. Indian J. Agron. 21 (4): 241-248.

Shimamura, Y. 2005. A greeting. In Rice is life: scientific perspectives for the 21st century. Proceedings of the World Rice Research Conference held in Tokyo and Tsukuba, Japan, 4-7 November 2004. Toriyama K, KL. Heong, B. Hardy, eds. Los Baños (Philippines): International Rice Research Institute, and Tsukuba (Japan): Japan International Research Center for Agricultural Sciences. CD-ROM. 590 p.

Sims, J. L., and G. A. Place. 1968. Growth and nutrient uptake of rice at different growth stages and nutrient levels. Agron. J. 60:692–696.

Sinclair, T. R. 1998. Historical changes in harvest index and crop nitrogen accumulation. Crop Sci. 38:638–643.

Singh, D. and R. Singh. 1978. Potassium status of soils and response of rice to applied potassium. J. Potassium Res. 15(1-4):83-87.

Singh, M. and R.H. Wanjari. 2014. Potassium Response in Vertisols in Long-Term Fertilizer Experiment in India. Research Findings. International Potash Institute.

Slaton, N.A., B.R. Golden, R.J. Norman, C.E. Wilson, Jr., and R.E. DeLong. 2009. Correlation and calibration of soil potassium availability with rice yield and nutritional status. Soil Sci. Soc. Am. J. 73:1192–1201.

Snyder, F. W. and G. E. Carlson. 1984. Selecting for partitioning of photosynthetic products in crops. Adv. Agron. 37:47–72.

Srinivasa Rao, Ch., A. Subba Rao, K.V. Rao, B. Venkataeswarlu, and A.K. Singh. 2010. Categorisation of districts based on non exchangeable potassium. Implications in efficient K fertility management in Indian Agriculture. Indian J.Fert., 6: 40-54.

Surendran, U. 2005. Split Application of Muriate of Potash and Sulphate of Potash on Growth, Yield Attributes, Uptake and Availability of Nutrients in Lowland Rice CV. PY-5. The Journal of Agricultural Science, 2005, vol. 1, no.2. pp. 42-48.

Thakur, R. B. 1993. Effect of sowing method and nitrogen rate on the performance of high yielding varieties of rice (*Oryza sativa*). Indian J. Agron. 38(4): 547-550.

Thakur, R. B., A. K. Jhan and R. P. R. Sharma. 1993. Effect of levels and times of K application of potash on wetland rice. Proc. Intl. Symp. On A decade of potassium research. Nov. 18-20. New Delhi, India. pp. 138.

Tisdale, S.L., W.L. Nelson, and J.D. Beaton. 1985. Soil Fertility and Fertilizers, 4th ed.,Macmillan, New York, pp. 754.

Uddin, M. S., M. J. Abedin Mian and M. A. Saleque. 2012a. Response of Rice (*Oryza sativa* L.) to Split Application of Potassium in Old Brahmaputra Flood Plain Soil. ISSN 0258-7122. Bangladesh J. Agril. Res. 37(1): 179-184.

Uddin, S., M.A.R. Sarkar and M.M. Rahman. 2012b. Effect of Nitrogen and Potassium on Yield Performance of Dry Direct Seeded Rice cv. NERICA 1 in AUS season. *(M.S. Thesis)* Bangladesh Agricultural University, Mymensingh. pp. 66.

United States Census Bureau. 2012. International Data Base - Total Midyear Population for the World: 1950–2050. Available online: http://www.census.gov/population/international/data/idb/ worldpoptotal.php.

USDA (United State Development of Agriculture). 2012. Composition of foods raw, processed, prepared USDA National Nutrient Database for standard reference, Release 24 [online]. Available from: http://www.ars.usda.gov/SP2UserFiles/Place/12354500/Data/SR24/sr24_doc.pdf.

Vergara, B. S. 1991. Rice plant growth and development. In Rice Production, Vol. I. B. S. Luh, ed. Van Nostrand Reinhold, New York. pp. 13–22.

Wang, M., Q. Zheng, Q. Shen and S. Guo. 2013. The Critical Role of Potassium in Plant Stress Response. International Journal of Molecular Sciences. ISSN 1422-0067. www.mdpi.com/journal/ijms. pp. 7370-7371.

Wells, B. R., and W. F. Faw. 1978. Short-statured rice response to seeding and N rates. Agron. J. 70:477–480.

William, J. and S.G. Smith. 2001. Correcting potassium deficiency can reduce rice stem diseases. Better Crops. 85: 7-9.

Win, U. K. 1991. A century of rice improvement in Burma. IRRI. P.O. Box 933, 1099 Manila Philippines. ISBN 971-22-0024-8. 157p.

Yoshida, S. 1978. Tropical Climate and its Influence on Rice. IRRI Res. Pap. Ser. 20.

Yoshida, S. 1981. Fundamentals of Rice Crop Science. International Rice Research Institute, Los Banos, Laguna, Philippines. 269p.

Yoshida, S., J. H. Cock and F.T. Parao. 1972. Physiological aspects of high yields. In: International Rice Research Institute. Los Banos, Philippines. Rice Breeding pp. 455-569.

APPENDICES

Appendix 1 Total rainfall, temperature and relative humidity data at Yezin during experimental period (2014)

Month	Temperature (°C)		Rainfall (mm)	Relative Humidity (%)
	Maximum	Minimum		
February	33.7	15.2	0	51
March	37.8	19.2	0	42
April	38.8	23.4	8	51
May	37.9	23.8	71	60
June	34.4	23.4	217	76
July	32.4	23.1	148	84
August	31.9	23.6	369	88
September	33.5	23.9	160	80
October	33.8	22	114	85

Appendix 2 Effect of different methods of potassium fertilizer management on plant height of rice at different growth stages during the dry season, 2014

Treatment	Plant height (cm)						
	14 DAT	21 DAT	28 DAT	35 DAT	42 DAT	49 DAT	56 DAT
T1	36.13	46.86 a	57.25	64.94	73.78	86.30 bc	101.31 bc
T2	34.83	45.11 ab	57.85	65.58	73.98	85.24 bc	102.55 ab
T3	35.36	42.91 bc	55.20	63.79	75.75	89.76 a	104.38 a
T4	35.19	42.21 bc	56.10	65.51	75.09	86.60 b	99.10 cd
T5	36.78	46.11 a	56.48	64.63	76.41	87.89 ab	102.91 ab
T6	35.29	44.10 abc	53.38	65.31	76.46	86.09 bc	101.64 abc
T7	35.21	42.35 bc	53.89	63.59	72.97	83.58 cd	99.04 cd
T8	34.61	41.88 c	52.34	63.58	72.75	81.63 d	96.84 d
$LSD_{0.05}$	2.36	2.95	4.17	3.48	3.39	2.93	2.77
Pr>F	ns	*	ns	ns	ns	**	**
CV%	4.5	4.6	5.1	3.7	3.1	2.3	1.9

Means followed by different letters in the same column are significantly different by LSD test at 5% level.

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

T1 – (all potash applied as basal), **T2** – (all potash applied at 25 DAT), **T3** – (all potash applied at 45 DAT), **T4** – (½ potash applied as basal and remaining ½ at 25 DAT), **T5** – (½ potash applied as basal and remaining ½ at 45 DAT), **T6** – (½ potash applied at 25 DAT and remaining ½ at 45 DAT), **T7** – (1/3 potash applied as basal, 1/3 at 25 DAT and remaining 1/3 at 45 DAT), **T8** – (Control)

Appendix 3 Effect of different methods of potassium fertilizer management on number of tillers hill^{-1} at different growth stages during the dry season, 2014

Treatment	Number of tillers hill^{-1}						
	14 DAT	21 DAT	28 DAT	35 DAT	42 DAT	49 DAT	56 DAT
T1	3.13	6.13	11.63	13.75 d	23.88 b	27.75 abc	28.50 ab
T2	2.88	6.63	10.50	16.38 a	27.25 a	30.25 a	30.38 a
T3	2.88	5.63	10.37	15.13 bc	25.25 ab	28.63 ab	26.88 bc
T4	2.75	6.00	9.63	14.13 cd	23.88 b	25.75 bc	25.75 c
T5	2.50	5.88	9.88	15.63 ab	27.13 a	30.00 a	29.63 a
T6	3.13	5.88	10.63	15.75 ab	27.00 a	30.50 a	29.13 ab
T7	2.38	5.38	9.25	15.50 ab	24.13 b	29.38 ab	29.38 a
T8	2.25	5.50	8.50	13.75 d	20.00 c	24.13 c	25.00 c
LSD$_{0.05}$	0.72	1.10	1.83	1.20	2.63	3.67	2.46
Pr>F	ns	ns	ns	**	**	*	**
CV%	18.0	12.7	12.4	5.5	7.2	8.8	6.0

Means followed by different letters in the same column are significantly different by LSD test at 5% level.

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

T1 – (all potash applied as basal), **T2** – (all potash applied at 25 DAT), **T3** – (all potash applied at 45 DAT), **T4** – (½ potash applied as basal and remaining ½ at 25 DAT), **T5** – (½ potash applied as basal and remaining ½ at 45 DAT), **T6** – (½ potash applied at 25 DAT and remaining ½ at 45 DAT), **T7** – (1/3 potash applied as basal, 1/3 at 25 DAT and remaining 1/3 at 45 DAT), **T8** – (Control)

Appendix 4 Effect of different methods of potassium fertilizer management on plant height of rice at different growth stages during the wet season, 2014

Treatment	Plant height (cm)						
	14DAT	21 DAT	28 DAT	35 DAT	42 DAT	49 DAT	56 DAT
T1	32.88	43.56 a	53.78	60.94 ab	69.73	81.70 ab	96.16 abc
T2	30.63	40.11 b	53.85	61.98 a	70.58	81.44 ab	97.65 ab
T3	31.25	37.51 c	49.60	57.99 c	70.05	83.56 a	99.07 a
T4	32.04	39.21 bc	52.00	62.34 a	72.29	82.30 ab	94.40 bc
T5	33.67	42.81 a	52.78	59.83 abc	71.91	81.69 ab	99.51 a
T6	30.79	38.90 bc	48.48	60.91 ab	72.26	82.59 ab	98.94 a
T7	32.11	38.95 bc	50.57	60.39 abc	69.77	79.48 bc	96.34 abc
T8	31.11	38.08 bc	49.04	58.78 bc	69.05	77.33 c	92.64 c
$LSD_{0.05}$	2.10	2.27	4.21	2.71	3.38	3.61	3.77
Pr>F	ns	**	ns	*	ns	*	*
CV%	4.48	3.87	5.58	3.05	3.25	3.02	2.65

Means followed by different letters in the same column are significantly different by LSD test at 5% level.

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

T1 – (all potash applied as basal), **T2** – (all potash applied at 25 DAT), **T3** – (all potash applied at 45 DAT), **T4** – (½ potash applied as basal and remaining ½ at 25 DAT), **T5** – (½ potash applied as basal and remaining ½ at 45 DAT), **T6** – (½ potash applied at 25 DAT and remaining ½ at 45 DAT), **T7** – (1/3 potash applied as basal, 1/3 at 25 DAT and remaining 1/3 at 45 DAT), **T8** – (Control)

Appendix 5 Effect of different methods of potassium fertilizer management on number of tillers hill^{-1} at different growth stages during the wet season, 2014

Treatment	Number of tillers hill^{-1}						
	14DAT	21 DAT	28 DAT	35 DAT	42 DAT	49 DAT	56 DAT
T1	3.01	5.93	11.11 a	14.16 c	23.73 bc	23.92 ab	22.97 bc
T2	2.56	5.33	9.90 ab	15.86 a	25.75 a	25.75 a	26.16 a
T3	2.45	5.21	9.13 bc	14.79 bc	23.68 bc	24.89 ab	24.14 abc
T4	2.86	5.77	9.50 bc	14.50 bc	23.77 b	21.95 bc	21.83 c
T5	2.61	5.75	9.74 abc	15.20 ab	25.43 ab	25.30 ab	24.73 ab
T6	2.43	5.44	9.73 bc	15.41 ab	25.53 ab	25.89 a	25.03 ab
T7	2.70	5.50	9.37 bc	15.24 ab	23.82 b	24.16 ab	23.98 abc
T8	2.37	5.37	8.44 c	14.16 c	21.85 c	20.00 c	18.90 d
LSD$_{0.05}$	0.71	0.75	1.38	0.95	1.91	3.39	2.75
Pr>F	Ns	Ns	*	*	**	*	**
CV%	18.52	9.25	9.76	4.34	5.36	9.61	7.99

Means followed by different letters in the same column are significantly different by LSD test at 5% level.

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

T1 – (all potash applied as basal), **T2** – (all potash applied at 25 DAT), **T3** – (all potash applied at 45 DAT), **T4** – (½ potash applied as basal and remaining ½ at 25 DAT), **T5** – (½ potash applied as basal and remaining ½ at 45 DAT), **T6** – (½ potash applied at 25 DAT and remaining ½ at 45 DAT), **T7** – (1/3 potash applied as basal, 1/3 at 25 DAT and remaining 1/3 at 45 DAT), **T8** – (Control)

Appendix 6 Effect of potassium fertilizer management on grain yield of rice during the dry season, 2014

Treatment	Yield	
	Basket / acre	Ton/ ha
T1	228.39 c	11.80 c
T2	320.39 a	16.55 a
T3	266.08 bc	13.75 bc
T4	259.91 bc	13.43 bc
T5	287.80 ab	14.87 ab
T6	320.00 a	16.53 a
T7	226.84 c	11.72 c
T8	173.70 d	8.98 d
$LSD_{0.05}$	41.11	2.12
Pr>F	**	**
CV%	9.01	9.01

Means followed by different letters in the same column are significantly different by LSD test at 5% level.

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

T1 – (all potash applied as basal), **T2** – (all potash applied at 25 DAT), **T3** – (all potash applied at 45 DAT), **T4** – (½ potash applied as basal and remaining ½ at 25 DAT), **T5** – (½ potash applied as basal and remaining ½ at 45 DAT), **T6** – (½ potash applied at 25 DAT and remaining ½ at 45 DAT), **T7** – (1/3 potash applied as basal, 1/3 at 25 DAT and remaining 1/3 at 45 DAT), **T8** – (Control)

Appendix 7 Effect of potassium fertilizer management on grain yield of rice during the wet season, 2014

Treatment	Yield	
	Basket/acre	Ton/ha
T1	185.05 d	9.56 d
T2	276.89 a	14.31 a
T3	221.04 bc	11.42 bc
T4	214.49 c	11.08 c
T5	240.61 b	12.43 b
T6	276.28 a	14.27 a
T7	192.83 d	9.96 d
T8	138.37 e	7.15 e
$LSD_{0.05}$	20.07	1.04
Pr>F	**	**
CV%	5.25	5.25

Means followed by different letters in the same column are significantly different by LSD test at 5% level.

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

T1 – (all potash applied as basal), **T2** – (all potash applied at 25 DAT), **T3** – (all potash applied at 45 DAT), **T4** – (½ potash applied as basal and remaining ½ at 25 DAT), **T5** – (½ potash applied as basal and remaining ½ at 45 DAT), **T6** – (½ potash applied at 25 DAT and remaining ½ at 45 DAT), **T7** – (1/3 potash applied as basal, 1/3 at 25 DAT and remaining 1/3 at 45 DAT), **T8** – (Control)