EFFECTS OF DIFFERENT RATES OF POTASSIUM FERTILIZER ON RICE PRODUCTIVITY WITH OR WITHOUT RICE HUSK ASH IN MINBYA SOIL

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

Department of Soil and Water Science
Yezin Agricultural University
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The thesis attached hereto, entitled **“Effects of Different Rates of Potassium Fertilizer on Rice Productivity with or without Rice Husk Ash in Minbya Soil”** 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 and Water Science).**

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DECLARATION OF ORIGINALITY

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

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DEDICATED TO MY BELOVED PARENTS

U KYAW KHIN AND DAW NWE

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ABSTRACT

Two consecutive pot experiments were conducted at the screen house, Department of Soil and Water Science, Yezin Agricultural University, during the period from March to December 2015 to study the effect of potassium fertilizer and rice husk ash (RHA) on yield and yield components and some physicochemical properties of Minbya soil. The two factor factorial experiment comprised of two levels of rice husk ash i.e. with 5 ton ha^{-1} RHA and without RHA and four levels of potassium fertilizer i.e. K omission, 16 kg K ha^{-1}, 24 kg K ha^{-1} and 32 kg K ha^{-1}. The experiment was laid out in randomized complete block design with four replications. The highest grain yield was resulted from 32 kg K ha^{-1} due to production of higher number of tillers $hill^{-1}$, filled grain percent, number of panicles $hill^{-1}$ and higher harvest index. In contrast, K omission produced lower yield due to inferior number of tillers $hill^{-1}$ and yield component parameters. For rice husk ash effect, results indicated that application of 5 ton ha^{-1} RHA amended treatment produced the highest values of plant growth and yield component parameters whereas the minimum values of these parameters were obtained from without RHA. After dry and wet seasons experiments, some physical properties of soil such as bulk density values decreased accompanying increased total porosity at all RHA amended treatments. Some chemical properties of soil such as pH, cation exchange capacity (CEC), organic carbon, available K and available P were also noticeably increased due to the RHA application. The results indicated that the application of 32 kg K ha^{-1} and 5 ton ha^{-1} RHA was found to be the most effective treatment for increasing the yield of rice and maintained some of the physicochemical properties of soil.

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CHAPTER I
INTRODUCTION

Rice (*Oryza sativa* L) is a critical staple food for almost half the world's population, for whom rice cultivation is the primary source of food. In Asia, 95 percent of the world's rice is grown and consumed. The requirement for rice is increasing with the increasing world population and it is estimated, that in order to meet the rice demand of the future, the world's annual rice production must increase from 520 million tons today to 880 million tons by the year 2025 through improvement in agronomic practices and introduction of high yielding cultivars (Shrestha and Ladha 1998).

In Myanmar, rice is the staple food of about 51.7 million people. Agricultural sector is a major source of income, employment, foreign exchange earnings, and an important contributor to the economic growth of the country. To obtain high yields and to maintain system productivity, considerable fertilizer applications are necessary. Fertilizer has been the key input in augmenting food grain production in Myanmar as well as in the world. The major nutrients for plants are nitrogen, phosphorous and potassium. Among them, potassium (K) is an essential nutrient that affects most of the biochemical and physiological processes that influence plant growth and metabolism (Wang et al. 2013). Potassium performs important roles in enzyme activation, photosynthesis, photosynthate translocation, protein synthesis and plant water relations and is known to play an important role in the plant's ability to resist disease (Slaton et al. 2010).

Potassium has received much less attention in rice research than nitrogen, despite the fact that total K uptake can be greater than N uptake. Yield response of rice to K fertilization becomes more evident after years of intensive cropping, particularly when both N and P are applied or when the K supplying capacity of the soil is low (Dobermann et al. 1996). Among the three essential macro-nutrients, nitrogen response can be easily observed so that farmers are mainly concerned about the application of N fertilizer and tend to neglect P and K fertilizers for rice cultivation. Potassium application alleviated the stress condition and significantly improved dry matter yield and yield components in rice. Consequently, soil K deficiency in paddy fields is becoming one of the key limiting factors for sustainable agricultural production (Reyhaneh 2012).

The harvesting of plant materials, such as grains, fruits or foliage, removes potassium they have taken up from the soil. 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 is often the most limiting nutrient after nitrogen (N) in high yielding rice systems. Agricultural activities produce billions of tons of other materials long regarded as waste. The main types of agricultural wastes are crop residues and farm animal wastes (Bruttini 1923). With appropriate techniques, agricultural wastes can be recycled to produce an important source of energy and natural fertilizer for crops. Recycling agricultural wastes can help a developing country to reduce its dependence on foreign energy supplies and raise the standard of living in its rural areas (Pequegnat 1975).

In general, rice husks are residue from the rice processing industry. For rice-based cropping systems, the use of rice straw and rice husk has been practiced for a long time (Eagle et al. 2001). Rice husk is a major byproduct obtained from paddy. For every four tons of paddy one ton of husk is produced. Burning of husk generates about 15–20 % of its weight as ash (Muthadhi et al. 2007). When burned, rice husks help to build up of soil structure and aeration as they hold shape for a long time (Aspinall 2003). Rice husk ash (RHA), which is believed to contain various nutrients that enable it to serve as a source of fertilizer. Using rice husk ash cause to producing more grain and straw in paddy and the yield increase too (Talashiker and Chavan 1995). RHA can improve not only moisture but also better aeration between soil and plant and also improves plant growth and yield (Thuzar 2011). RHA is a complementary potential fertilizer source that is suitable for rice plant and it is broadly used in agricultural production. RHA is a good source of potassium and it can be used as a potassium source for crop production (AICOAF 2001).

The substitution of RHA can be more effective for organic farming and low external input for sustainable agriculture (LEISA 1996). Farmers are showing an inclination to revert back to traditional farming with the least usage of synthetic chemicals. In addition, unbalanced uses of synthetic fertilizers and chemicals result in many problems in the present decade (Chaitra 2006). He and Li (2004) indicated that combined application of organic and inorganic fertilizers can increase the activities of soil quality and available nutrient content. Furthermore, the application of organic manure mixed up with chemical fertilizer can prove to be an excellent procedure in maintaining and improving the soil fertility, and increasing fertilizer use efficiency.

The present study was undertaken with the following objectives.

1) to evaluate the effect of rice husk ash (RHA) and potassium fertilizer application on yield of rice in Minbya soil.
2) to determine the appropriate amount of potassium fertilizer for rice production in Minbya soil.
3) to investigate the response of rice husk ash and different rates of potassium fertilizer on some physicochemical properties of Minbya soil.

CHAPTER II
LITERATURE REVIEW

2.1 Potassium

Potassium is an essential element for all living organism, for human, animal and plant growth. Along with nitrogen (N) and phosphorous (P), it is regarded as a macro element for plant nutrition (IPI 2014). Potassium (K) is required for normal growth and development of plant (Bakhash et al. 2008). Potassium is absorbed by plants in larger amounts than any other nutrient except N. Plants deficient in potassium are less resistant to drought, excess water, and high and low temperatures. They are also less resistant to pests, diseases and nematode attacks. Because potassium improves the overall health of growing plants and helps them fight against disease, it is known as the "quality" nutrient. Potassium is easy to apply, and it increase yields and quality of crops on deficient soils. It has an essential role in the plant and increases the value of the crop to which it is applied (Jones 1979).

Although the total K content of soil is usually many times greater than the amount taken up by a crop during a growing season, in most cases only a small fraction of it is available to plants (Fageria 1989). Potassium is present in relatively large quantities in most soils. In tropical soils, total K content can be quite low because of the origin of the soils, high rainfall, and continued high temperatures. Unlike N and P, which are deficient in most tropical soils due to leaching and/or fixation, the need for K frequently arises only after a few years of cropping a virgin soil (Havlin et al. 1999).

2.2 Potassium in Soil

Soil K can be divided into three groups, based on availability to plants: the unavailable form, the slowly available or fixed form, and the readily available or exchangeable form (Table 1). Generally, 90 to 98 percent of the total potassium in soils is in the relatively unavailable form, 1 to 10 percent in the slowly available form, and 0.1 to 2 percent in the readily available form (Brady and Well 2002).

Table 2.1 Occurrence and availability of major forms of soil potassium

Portion of total K (%)	Form of potassium	Availability
90 to 98	Potassium containing minerals (Micas, Feldspars, etc.)	Relatively unavailable
1 to 10	Clay minerals (Illitic types)	Slowly available “ Trapped K^+ ” or “ Non-exchangeable K^+ ”
0.1 to 2	Exchangeable K^+ and soil solution K^+	Readily available

Unavailable potassium. Depending on soil type, approximately 90-98% of total soil K is in the unavailable form as a part of soil minerals (feldspars and micas). Plants cannot use the K in this crystalline-insoluble form. This form of potassium is converted to either the slowly available or the readily available form by the process of weathering.

Slowly available potassium. This form of K is trapped between layers of clay minerals (vermiculite, smectite, and other 2:1 type minerals) and is frequently referred to as “fixed potassium”. Growing plants cannot use much of the slowly available K during a single growing season. Slowly available K can also serve as a reservoir for readily available K. While some slowly available K can also be fixed between clay layers and thus be converted into slowly available K.

Readily available potassium. Potassium that is dissolved in soil water and that is held on the exchange site of clay particles (exchangeable K) is considered readily available for plant nutrition. Plants readily absorb the K dissolved in the soil solution. As soon as the K concentration in the soil solution drops, more K is released from the exchangeable K. The K attached to the exchange sites on the outer surface of clay minerals is more readily available for plant growth than the K bound to the inner surface (between the layers) of the clay minerals.

2.3 Factors Affecting the Potassium Availability to the Plants

Plants differ in their ability to take up K depending on several factors. Many soil, plant, and environmental factors influence potassium availability to plants but the most important factors that affect availability of K in the soil and resulting plant uptake are –

(a) Clay minerals: The greater the proportion of clay minerals high in K, the greater the potential K availability in a soil. Plants can obtain more available K in soils with a high clay content as compared with a soil of low clay content (Tisdale et al. 1985). Soil containing vermiculite, montmorillonite, or illite have more K than soils containing predominantly kaolinitic clays, which are more highly weathered and very low in K. The different are due to their much higher cation exchange capacity (CEC). The ability of a soil to retain applied K is very dependent on the CEC of the soil. Soils with higher CEC have a greater ability to retain added K (Havlin et al. 1999). The capacity of a soil to supply potassium to crops over an extended period of time is fundamentally dependent upon:

1. The K content of the primary minerals.
2. The rate of release of K by the primary minerals.
3. The quantity of clay (secondary) minerals present.
4. The type of clay minerals (IPI 2014).

(b) Organic matter: Organic matter has well known indirect effects on the availability of soil K, in that it promotes aggregate formation and stability and thus water-holding capacity and aeration which favour root extension. Humification of plant residues and soil organisms can produce a type of organic matter with high cation exchange capacity (IPI 2014).It is possible that organic matter is important in holding soil K in exchangeable form. Unlike for nitrogen and phosphorus, the organic matter in soils contains very little potassium but provides a temporary storage for soil K. The application of organic materials to the soil often increases the plant K uptake while uptake of Ca and Mg were decreased (Malik et al. 2013).

(c) Soil temperature: The effect of temperature on K uptake is due to changes in both availability of soil K and root activity. Root activity, plant functions, and physiological processes all increase as soil temperature increases. This increase in physiological activity leads to increased K uptake. Reduced temperature slows down plant processes, plant growth, and rate of K uptake. Cooler soil temperature reduces the rate and extent of root growth and limits K uptake. The supplemental K needed to increase K uptake at low temperatures overcomes some of the adverse effect that low temperature has on rate of diffusion. Providing high levels of K is a practical way of overcoming some of the problems of low temperature (Havlin et al. 1999).

(d) Soil aeration: Respiration and the normal functioning of roots are strongly dependent on an adequate O_2 supply. Under high moisture levels or in compact soils, root growth is restricted, O_2 supply is lowered, and absorption of K and other nutrients is slowed. The inhibitory action of poor aeration on nutrient uptake is most pronounced with K (Havlin et al. 1999).

(e) Soil moisture: At low soil moisture, water films around soil particles are thinner and discontinuous, resulting in a more tortuous path for K^+ movement. This affects the movement of potassium to roots by diffusion strongly. With increased potassium levels or higher moisture contents in the soil, potassium diffusion is accelerated (Tisdale et al. 1985). Alternate wetting/drying and freezing/thawing enhance both the fixation of potassium in nonexchangeable forms and the release of previously fixed potassium to the soil solution (Brady and Well 2002).

2.4 Potassium Fixation

Potassium fixation and release in soil are important issues in long-term sustainability of a cropping system. Potassium fixation influences the effectiveness of fertilization in soil–plant systems. Fixation of added K is an important reaction in the dynamics of soil K and it affects the availability of K to plants. In general, K fixation is a chemical process that is governed by the equilibrium between K located in interlayer positions of K-bearing minerals and K held at planar sites and in the soil solution. Continuous intensive cropping without potassium enhances the potassium fixation capacity. Soils differ widely in their K fixation and release capacity owing to differences in quantity and the nature of clay, composition of associated minerals, cation-exchange capacity, soil reaction, free lime, organic carbon, and amount of added K fertilizers (Sharma and Mishra 1991).

With the application of potassium fertilizer, potassium first goes into the soil solution and soon after most of it goes into the exchangeable and some to the nonexchangeable forms. As crops remove the readily available potassium, the reactions are reversed and exchangeable potassium goes into solution. As a result, there is constant fixation and release of potassium in the soil (Follett et al. 1981).

Most experimental results have reported that soils having greater proportions of expanding 2:1 type clay minerals such as illite, vermiculite and smectite in their clay fraction may show stronger K fixation. To obtain satisfactory yields on such soils high fertilizer rates are required to overcome the fixation of K by the clay minerals. Fixation of K is the result of reentrapment of K^+ ions between the layers of the 2:1 clays (Havlin et al. 2014). In fact, K fixation in the clay interlayer may occur when the electrostatic attraction forces between the negatively charged silicate layers and the positively charged interlayer ions exceed the interlayer expanding forces resulting from ion hydration. The 1:1 minerals such as kaolinite do not fix K (Kittrick 1966). As NH_4^+ and H^+ are very similar to K in ionic radius, both ions can compete with K for fixing sites in the clay minerals (Rich and Black 1964, Berllett and Simpson 1967). Potassium fixation by various soils after saturation with different cation revealed that lower values for K fixation in H^+ and NH_4^+ soil and higher value in Ca^{2+}, Mg^{2+} and Na^+ soil. Thus, K fixation is usually less important in acid soils than in neutral or alkaline soils (Grewall and Kanwar 1973).

Martin (1964) noted that there was a marked increase in K fixation in soils where pH was elevated to about 9 or 10 with sodium carbonate. At pH values up to 2.5, there was essentially no fixation; between pH 2.5 and 5.5, the amount of K fixation increase very rapidly. Above pH 5.5, the amount of fixation increased slowly. Liming to a very acid soil to pH of 6 would increase K uptake by plants. The increase in K fixation between pH 5.5 and 7.0 can be ascribed to the decreased numbers of $Al(OH)_x$ species which decrease K fixation. At low pH, the lack of K fixation is probably due to large numbers of H_3O^+ and their ability to replace K as well (Rich and Obenshain 1955; Rich and Black 1964). Wetting and drying and freezing and thawing can significantly affect K fixation (Hanway and Scott 1957; Cook and Hutcheson 1960). The degree of K fixation or release on wetting or drying is dependent on the type of colloid present and the level of K^+ ions in the soil solution. Potassium fixation by 2:1 clay minerals may be strongly influenced by the kind of adsorbed cations or the anions within the system.

The K fixation and its retention in slowly available form will be beneficial in coarse-textured soils under rice or in high rainfall regions. Several researchers have reported that a significant portion of K (70–90%) required by plants comes from the nonexchangeable pool in the absence of easily supplied K, thus indicating the beneficial role of the fixed K (Chen, Zhou and Wang 2003). K fixation results in conservation of K, which can become available over a long period of time and thus is not entirely lost to plants, although plants vary in their ability to utilize slowly available K.

2.5 Potassium in Plant Nutrition

Potassium is found in cell and plant fluids. It is only weakly bound and not thought to be a part of fixed organic compounds in the plant. Potassium is very readily absorbed by the plants. A major part of the absorbed potassium exists in the cell sap in soluble form. It is very mobile in the plant and moves readily from older tissues to the growing points of roots and shoots. Potassium is usually taken up earlier than nitrogen and phosphorus and uptake increases faster than dry matter production. This means that potassium accumulates early in the growing period and then is translocated to other plant parts (Follet et al. 1981).

2.5.1 Potassium in rice

Potassium is an essential plant nutrient for plant growth and reproduction. It is a very important cation in photosynthesis, enzyme activation, organic acids, fats and nitrogenous compounds. It has also an important role in the formation and transport of carbohydrates and proteins, water economy, cell elongation, resistance to drought, frost, lodging, pests, diseases and physiological disorders (Barber 1985: Singh and Wanjari 2014).

Various rice research studies have shown that potassium stimulates early growth, increases protein production, improves the efficiency of water use and improve resistance to diseases and insects due to its important role in plant adaptation to environmental stresses. Small grain crops deficient in potassium also lodge because their straw are weakened (Troeh and Thompson 2005).

Potassium fertilizer application can increasingly effect on grains per panicle, number of filled grains and 1000 grain weight (Bansal et al. 1993, Kalita et al. 1995, Bahmaniar and Ranjbar 2007, Ojha and Talukdar 2002). The average rice yield increased 17% due to potash application (IPPI 1986). Carbohydrate metabolism of rice is affected by the level of potassium supply, and increasing the levels of potassium helps in building up starch (Mishra 1985). Optimum K nutrition results in higher concentration of starch in the plant (Mengel and Kirkby 1987). Potassium applied at any stage of growth in rice increased the starch and soluble carbohydrate content in the grains (Vijayan and Reedharan 1972). Protein synthesis is especially dependent on potassium. When plants are deficient in K, proteins are not synthesized despite an abundance of available N. Potassium increased the rate of translocation of amino acids to the grain and the rate of protein formation (Mengel and Kirkby 1987).

Source of potassium and time of application affect the potassium recovery in plant. Timing of fertilizer K^+ application is an important management tool to maximize economic return to the grower. Maximum efficiency is obtained when K is available for uptake by plants as needed. In Myanmar, basal application of potash was adopted in previous years. Therefore, the large losses of potassium are attributable to leaching and runoff. Maximum efficiency is obtained when K^+ is applied so that it is available for uptake by the plants as needed. The increase grain yield of rice was obtained when continuous supply of potassium to the crop during crop growth period in the form of split application (Ravi and Rao 1992, Singh and Singh 2000, Malavolta 1985, Su 1976). Rice yield increased as much as 4% through the split application of potash over basal application (Lwin et al. 2004). Ravichandran and Sriramachandrasekharan (2011) showed that split application of K to rice in three splits (at early tillering, active tillering and panicle initiation stages) gave higher grain and straw yields. Combined application of K and N had a remarkable positive reciprocal effect on crops, and was an important approach in improving K use efficiency (Li et al. 2009).

2.5.2 Functions of potassium

Potassium increases yields and improves the quality of agricultural produce, and enhances the ability of plants to resist diseases, insect attacks, cold and drought stresses and other adverse conditions. It helps in the development of a strong and healthy root system and increases the efficiency of the uptake and use of nitrogen and other nutrients. Potassium helps in the photosynthesis process, through which the sugars and energy that the plant needs for its development are formed and converted. It improves the nutritive value of grains, tubers and fruits by increasing the contents of protein and oil in seeds, of starch in tubers and seeds, and of vitamin C and sugar in the fruits. With an adequate supply of potassium, cereals produce plump grains and strong stalks (IPI 2014).

Potassium is absorbed by plants in the ionic form (K^+). Unlike nitrogen and phosphorus, potassium does not form organic compounds in the plants. Its primary function seems to be tied to plant metabolism (Gupta 1999). K^+ is required to activate at least 60 different enzymes involved in plant growth. Potassium activates several enzymes especially in the metabolization of carbohydrate (Fageria and Gheyi 1999).

Potassium is an essential element for plant growth and reproduction. Some plant tissues accumulate relatively large concentration of potassium from the growth medium. It plays many important regulatory roles in biochemical and physiological functions of plant growth, although it does not become a part of the chemical structure of plants. Potassium is vital in photosynthesis (Gupta 1999). Potassium applied at any stage of growth in rice increased the starch and soluble carbohydrate content in the grains. Plants well supplied with potassium contain more carbohydrates than plants deficient in this element. Potassium increased the rate of translocation of amino acids to the grain and the rate of protein formation (Mengel and Kirkby 1987). Another key role of potassium is in the transport of water and essential nutrient thought the plant in the xylem (Alam and Naqvi 2004).

Potassium aids in the uptake of other nutrients and in their movement within the plant. For example, K^+ and NO_3 may move together (Troeh and Thompson 2005). Plants also depend upon potassium to regulate the opening and closing of stomata, through which carbon dioxide enters and oxygen leaves the plant. If potassium supply is inadequate, the stomata become slow to respond and water vapour is lost. Potassium, thus is involved in regulating stomata and thereby gas exchange. Plants receiving adequate potassium tend to have a slower transpiration rate than potassium deficient plants (Beringer and Nothdurft 1985).

Potassium is necessary for normal lignin and cellulose development, which gives strength and stiffness to plants, enabling them to stand upright with reduced lodging. When exposed to hot dry winds the plants with adequate potassium apparently close their stomata much more quickly than potassium deficient plants (Follett et al. 1981). Potassium influences the absorption or transpiration of water so that crops respond best to potassium fertilizers in dry seasons. K deficient plants are less able to withstand water stress, mostly because of their inability to fully utilize available water (Havlin et al. 2014). Not only can K^+ increase the resistance of plant tissues, but it may also reduce fungal populations in the soil, reduce their pathogenicity, and promote more rapid healing of injuries. Potassium application alleviated the stress condition and significantly improved dry matter yield and yield components in rice (Ebrahimi 2012).

2.5.3 Potassium deficiency symptoms

Potassium deficiency of rice is recognized as a common yield limitation in many rice-growing areas of the world due to intensive production, high yielding cultivars, and increased use of N fertilizer (Dobermann et al. 1996). Potassium, like N and P, is highly mobile in plant tissues. Hence, K^+ deficiency symptoms first appear in the older leaves (Follett et al. 1981). Deficiency of potassium may lead to lodging, increased water stress, reduced photosynthetic rates, and decline in quality of economic products of crops. K deficiency is often not detected because it symptoms are not as easy to recognize as those of P and N deficiency, and symptoms tend to appear during later growth stages. Potassium deficiency symptoms show up as scorching along leaf margins of older leaves. Potassium-deficient plants grow slowly. They have poorly developed root systems, early leaf senescence, leaf wilting, and leaf rolling. Shoots may show short, bushy, zigzag growth, with dieback late in season. Stalks are weak, and lodging is common. Seed and fruit are small and shriveled, and plants possess low resistance to disease. Plants under stress from short K^+ supplies are very susceptible to unfavorable weather (Fageria 2009).

Potassium deficiency in rice is more common under the following crop management practices:

1) Excessive use of N or N plus P fertilizer with insufficient K application.
2) In direct sown rice during early growth stage, when the plant population is large and root system is shallow.
3) Cultivars differ in susceptibility to K deficiency and response to K fertilizer (Dobermann and Fairhurst 2000).

In contrast to nitrogen and phosphorus, typical symptoms of potassium deficiency rarely show up during early growth stages. Lack of potassium therefore remains often unnoticed. Following symptoms indicate potassium deficiency (Von Uexkull 1977).

(a) Leaves: Leaves of K deficient plants are dark green with many rusty spots, giving them a dirty appearance. The spots appear first on the upper parts of older leaves. Leaf tips and margins become necrotic, having a reddish-brown or yellow brown color. A rapid leaf senescence after heading is often observed. Older leaves, especially during mid-day, are droopy and younger leaves may roll up and show symptoms resembling moisture stress.

(b) Stems: Stems are short and thin, resulting in stunted plants. Many varieties deficient in potash are more susceptible to lodging.

(c) Tillering: Except for cases of extreme deficiency, tillering is not much affected by potassium deficiency.

(d) Panicle: Panicles of potassium deficient plants are small and generally have a high percentage of empty grains.

(e) Grains: Number of filled grains per ear is small. They become small in size and irregular in shape and the quality and the weight of 1000 grains decreases. When the husk is removed potassium deficient grains lack the luster of healthy ones. The percentage of unripe and undeveloped grains increase.

(f) Straw: A potassium content in the straw at harvest of below 1% K is considered to indicate potassium deficiency.

(g) Roots: Roots of K deficient plants are usually very poorly developed. Tap roots are thin and short, and the branches and hair roots very thin. The color of roots often tends to turn dark brown to black, indicating root rot.

2.6 Effects of Organic Residues and Unbalanced Fertilization

The use of organic matters such as animal manures, human waste, food wastes, sewage sludge and plant residues have long been established in agriculture as beneficial for plant growth and yield and the maintenance of soil fertility. Organic matters are excellent source of plant available nutrients and their addition to soil can improve soil structure, soil fertility and crop yields (Norman and Clive 2005). The application of chemical fertilizers is costly and may gradually lead to environmental problems. Nowadays, interest in agriculture production based on organic-manure application is growing, and the demands for the resulting products are increasing. Therefore, the effective use of organic materials in rice farming is also likely to be promoted. Many researches have shown that combination of organic amendment and chemical fertilizer significantly contributed to the growth and yield of rice (Buri et al. 2004, Rao et al. 1976, Oh 1979, Nyalemegbe et al. 2009).

Application of organic residues can improve the soil quality and is more profitable in environment protection when compared with application of chemical fertilizer alone (Reganold 1995). Plant residues are very important for regeneration and maintenance of soil structure in the transplanted rice ecosystem (Verma and Bhagat 1992). Utilization of plant residue to the soil is known to have beneficial effects on soil nutrients, soil physical condition, soil biological activity, and crop performance (Wade and Sanchez 1983, Hulugalle et al. 1986, Sharma and Prasad 2003). Recycling of crop residues is an integral part of integrated plant nutrition which is now being increasingly recognized as the strategy for sustaining high crop yield level with minimal depletion of soil fertility (Bhardwaj 1995). Mamaril et al. (1999) concluded that the combined use of organic and inorganic fertilizers in crop production has been widely recognized as a way of increasing yield and improving productivity of the soil.

Most of the farmers in Rakhine state are mainly concerned about the application of N fertilizer and tend to neglect P and K fertilizers for rice cultivation because their application often does not produce the yield advantages of the past. Such imbalanced nutrient management practices may impair productivity of the soils. Uniform application of fertilizer is usually essential for high K utilization efficiency. Integrated nutrient management - the combined use of chemical fertilizers and organic amendments - can be a measure to maintain sustainable soil productivity in tropical countries. Proper application of organic and inorganic fertilizers can increase the activities of soil microorganisms and enzymes and soil available nutrient contents (He and Li 2004). With increasing cropping intensity and production in rice-based systems, the often unbalanced nutrient management practices with low potassium inputs, and the decreasing recycling of K-rich rice residues, low K availability and growth limitation by K deficiency are becoming a growing problem in many Asian rice-based systems. Because K deficiency reduces grain yield, grain quality, and the efficiency of other nutrients applied, proper K nutrition of rice crops is critical to sustain or even enhance the productivity and profitability of rice cultivation (Yi Yi Cho 2010).

2.7 Rice Husk Ash

Agricultural activities produce billions of tons of other materials long regarded as waste. The main types of agricultural wastes are crop residues and farm animal wastes (Bruttini 1923). With appropriate techniques, agricultural wastes can be recycled to produce an important source of energy and natural fertilizer for crops. Reutilizing agricultural wastes can help a developing country to reduce its dependence on foreign energy supplies and raise the standard of living in its rural areas (Pequegnat 1975).

Rice residues are important natural resources, and recycling of these residues improves the soil physical, chemical and biological properties. Complete removal of residues from the field leads to a soil organic matter and soil quality decrease in agricultural systems. For rice-based cropping systems, the use of rice straw and rice husk has been practiced for a long time (Eagle et al. 2001). Rice husk is one of the most widely available agricultural wastes in many rice producing countries around the world. Rice husk is a complementary potential fertilizer source that is suitable for rice plant (Natarajan et al. 1998).

Rice husk is being produced in more than 75 countries around the world and the annual world output is about 116 million tons (FAO 2002). For every four tons of paddy one ton of husk is produced. If it is properly processed, rice husk may become a potentially environmentally friendly source of soil amendment. Use of organic amendments is generally seen as a key issue for soil health and sustainability in intensive rice-based systems, both in terms of maintaining the amount and quality of soil organic matter (SOM) and in terms of supplying important micronutrients (Gill and Meelu 1982, Ponnamperuma 1984, Mahapatra et al. 1991).

In Rakhine state, rice husk is used as fuel for rice mill boilers. Rice husks are also a good source of fuel to produce power. Small scale applications between 10-200 kW usually use a rice husk gasifyer coupled with a modified internal combustion engine that drives a generator. These are common in Rakhine state and produce rice husk ash as a waste. Small-scale resource-poor farmers in Rakhine state cannot afford expensive agrochemical such as potassic fertilizer. Rice husk ashes are therefore easily available, cheap and can be effectively used in agriculture for soil enrichment and amendment. Rice husk ash contains higher percentage of potassium and phosphorous than nitrogen. Potassium and phosphorus contents of paddy husk were 0.1 – 2.54 % K_2O and 0.01 – 2.69 % P_2O_5 respectively (Bronzeoak Ltd. 2003).

Rich husk ash contains nutrient materials which makes it able to use as the fertilizer. Using rice husk ash cause to producing more grain and straw in paddy and the yield increase too (Talashiker and Chavan 1995, Savant et al. 1997). Rice husk ash has variously been used both as an amendment to improve crop yield and can be effectively used as fertilizer incorporation with other organic materials. Rice husk ash can be substituted instead of utilizing inorganic K because rice husk ash could be easily available and profitable in small scale growers leading to organic farming and low cost.

CHAPTER III

MATERIALS AND METHODS

Two consecutive pot experiments were carried out. Experiment I was conducted from February to August 2015 (dry season) and experiment II was performed from July to December 2015 (rainy season). The details of materials used, methods and experiment techniques adopted during the course of experiment are described in this chapter.

3.1 Experimental Site

The study was conducted at the screen house of Department of Soil and Water Science, Yezin Agricultural University, Zeyarthiri Township, Nay Pyi Taw. It is situated at 19° 10′ N latitude and 96° 07′ E longitude with the altitude of 213 meters above sea level.

3.2 Soil Sampling, Analysis and Determination of the Chemical Composition of Rice Husk Ash

A composite surface soil sample (0-15 cm depth) was collected from different locations in rice growing fields of Minbya Township, Rakhine State. The sample was air-dried, crushed and sieved through a 8 mm sieve. Some physicochemical properties of soil such as soil texture, bulk density, porosity, soil pH, available N, available P, available K, soil organic carbon, organic matter % and cation exchange capacity (CEC) of soil sample were analyzed at the Department of Agricultural Research before growing the plant. Composite samples of RHA were collected from different rice mills factories and ice-making factories located in Minbya Township. Chemical composition of RHA such as carbon percent, available K, available P, silicon percent, pH and cation exchange capacity (CEC) were determined at the Department of Agricultural Research.

Table 3.1 Some physicochemical properties of experimental soil

Characteristics	Rating
% sand (0.2 – 0.02 mm)	19
% silt (0.02 – 0.002 mm)	68
% clay (< 0.002 mm)	13
Texture class	Silt loam
Bulk density (g cm^{-3})	1.21
Particle density (g cm^{-3})	2.39
Porosity (%)	41.55
pH	5.5 (moderately acidic)
CEC ($cmol_c$ kg^{-1})	6.2 (low)
EC (ds m^{-1})	0.091 (non-saline)
O.M (%)	1.57 (very low)
Organic carbon (%)	0.91
Available N (mg kg^{-1})	60 (medium)
Available P (mg kg^{-1})	17.6 (medium)
Available K (mg kg^{-1})	56.7(low)

Table 3.2 Chemical composition of rice husk ash using in this experiment

Parameters	Amount
Carbon (% by mass)	8.90
Available K (% by mass)	2.11
Available P (% by mass)	1.17
Si (% by mass)	60.05
pH	8.40
CEC ($cmol_c$ kg^{-1})	6.70

3.3 Experimental Details

3.3.1 Design

The experiment was laid out in two factor factorial randomized complete block design with four replications. Thirty-two pots were used comprising 8 treatments and 4 replications. Pots were arranged in rows that were 45 cm apart and the pots within each row were 30 cm apart.

3.3.2 Treatment

The treatment details are as follows.

Factor A	**-**	**Rice Husk Ash (RHA) application**
$\mathbf{H_0}$	-	without RHA
$\mathbf{H_1}$	-	with RHA (5 ton ha^{-1})

Factor B	**-**	**Rates of Potassium Fertilizer**
$\mathbf{K_0}$	-	control (K omission)
$\mathbf{K_1}$	-	16 kg K ha^{-1}
$\mathbf{K_2}$	-	24 kg K ha^{-1}
$\mathbf{K_3}$	-	32 kg K ha^{-1}

3.3.3 Pot preparation

Plastic pots with a diameter of 30 cm at the top, 21.3 cm at the bottom and 26 cm in height were used. The soil was filled from the bottom of the pot up to 21 cm and 20 kg of soil was put in each pot. Twenty days old seedlings of Sin Thwe Latt variety were transplanted with two plants per pot. Then the pots were uniformly irrigated.

3.3.4 Fertilizer and rice husk ash (RHA) application

Rice husk ash (5 ton ha^{-1}) was used in basal at two days after pot preparation. Before experiment, all fertilizers that used in this experiment were analyzed at Department of Agricultural Research. According to analytical results, urea (46% of N), triple superphosphate (19% of P) and muriate of potash (49% of K) were used in this experiment. For all the treatments, nitrogen and phosphorous nutrients were supplied. The usual doses of 87 kg N ha^{-1} and 13 kg P ha^{-1} were applied in the form of urea and triple superphosphate, respectively. The triple superphosphate fertilizer was applied as basal application but urea and potassium were applied at three equal splits: at recovery stage (7-10 DAT), active tillering and panicle initiation stage.

3.3.5 Test cultivar

Sin Thwe Latt, a high yielding rice cultivar, most cultivated rice variety in Minbya Township, was used as tested cultivar in this experiment.

3.4 Data Collection

3.4.1 Measurement parameters for growth

Growth parameter such as plant height and number of tillers hill^{-1} were collected at one week interval.

(a) Plant height

Plant height was recorded in centimeter (cm) by measuring the distance from ground level to the tip of the tallest leaf starting from 14 days after transplanting (DAT).

(b) Number of tillers hill^{-1}

Numbers of tillers were also collected at weekly interval from each pot from 14 DAT to heading stage.

3.4.2 Measurement parameters for yield and yield components

Number of panicles hill^{-1}, panicle length, number of spikelets panicle^{-1}, filled grain percentage and 1000 grain weight were measured at harvest.

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

The number of panicles hill^{-1} was counted from each pot at harvest time and the collected data was averaged.

(b) Panicle length

Panicle length was measured from each pot as a linear distance from the neck-node of the panicle to the tip of the panicle. Each measurement was an average of 5 panicles.

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

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) Filled grain percentage

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

(e) 1000 grain weight (g)

Fully developed grains were randomly selected from each pot and their weights were recorded.

(f) Grain yield

The grains were harvested from the pot area and hand threshed, winnowed and sum dried. The dried grains from each treatment were weight and computed to gram per plant.

3.4.3 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)

3.4.4 Cultural management and pest and disease control

Hand weeding was done whenever necessary in both seasons. The pots were subjected with alternate wetting and drying system. Rats and birds damage were occurred in both wet and dry seasons. This problem was successful eliminated by sheltering the experimental plot with plastic sheets and covering with fishing net. In both dry and wet season, the crop was found neither insect damage nor infection of bacterial diseases.

3.4.5 Determination of some physical and chemical properties of soil

After dry and wet seasons, some physical properties of experimental soils such as bulk density, particle density and porosity values were determined in Department of Soil and Water Science, YAU by using the following formulas. Some chemical properties of soil such as pH, CEC, organic carbon, available K and available P were analyzed at the Department of Agricultural Research.

$$\text{Bulk Density (g cm}^{-3}\text{)} = \frac{(W1-W2)}{V}$$

W1 = weight of the weighing bottle (g)

W2 = weight of soil sample + weighing bottle (g)

V = volume of water which replaced the soil sample (cm^3)

$$\text{Particle density (g cm}^{-3}) = \frac{(W2\text{-}W1)}{[(W2\text{-}W1)+W4]\text{-}W3}$$

W1 = weight of pycnometer (g)

W2 = weight of pycnometer + soil (g)

W3 = weight of pycnometer + soil + water (g)

W4 = weight of pycnometer + water (g)

$$\text{Porosity (\%)} = \left(1 - \frac{\text{bulk density}}{\text{particle density}}\right) \times 100$$

(Blake and Hartge 1986)

3.4.6 Statistical analysis

The data were analyzed by using statistical software Statistix (Version 8). All the data were subjected to analysis of variance and mean separation among treatments were done by Least Significant Difference (LSD) test at 5% probability level.

3.4.7 Weather data

All weather data for both seasons were obtained from meteorological station at Department of Agricultural Research, Yezin.

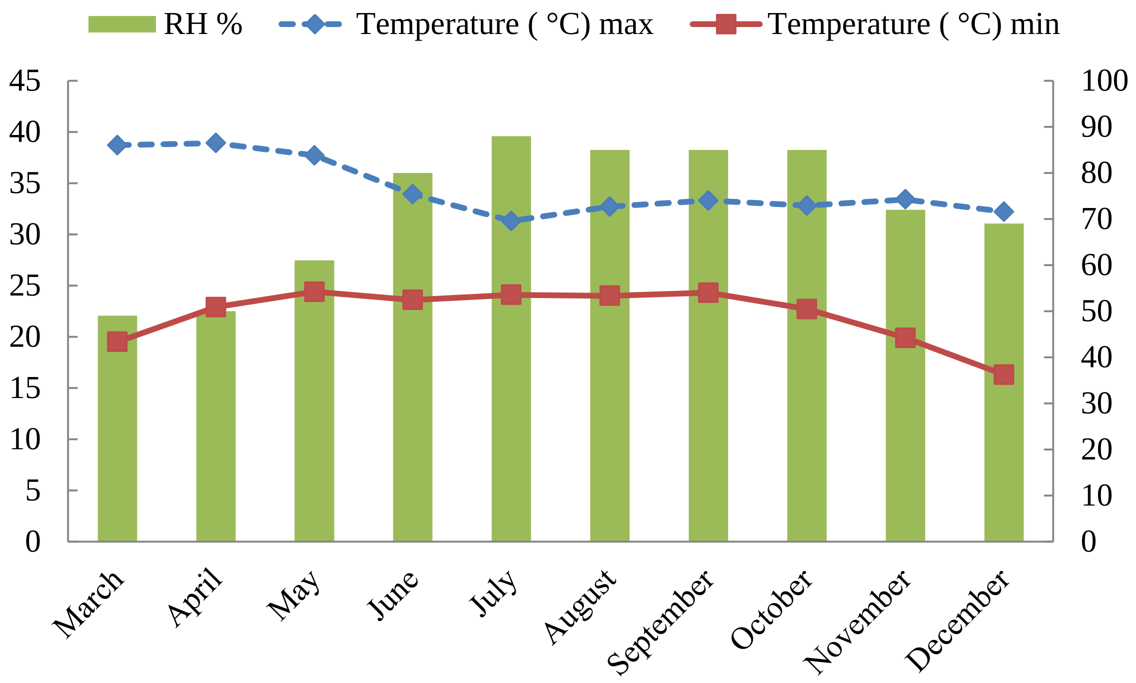

Figure 3.1 Relative humidity, minimum and maximum temperature during experimental period in Yezin (February - August 2015).

CHAPTER IV
RESULTS AND DISCUSSION

4.1 Dry Season Experiment (February to August, 2015)

Response of rice husk ash (RHA) and different rates of potassium fertilizer on grain yield and yield components and other parameters for dry season experiment is presented in the following sections.

4.1.1 Effect of rice husk ash and different rates of potassium fertilizer on growth parameters

4.1.1.1 Plant height (cm)

Plant height as affected by rice husk ash, different rates of potassium fertilizer and their combined effects is presented in Table 4.1 and 4.2. Plant heights were highly significant different among RHA treatments. At all DAT, plant heights were highly significant difference at 14 DAT, 21 DAT, 42 DAT, 49 DAT and 56 DAT and significant at 35 DAT, 70 DAT and 77 DAT. Daftadar and Savant (1995) reported that plants treated with rice hull ash are healthier than untreated ones, and their use can increase plant height. Although plant height was not significantly affected by potassium fertilizer, 32 kg K ha^{-1} produced tallest plant height than any other potassium treatments. K omission produced the minimum plant height. Increasing potassium rate significantly encouraged cell division and elongation resulted in tallest plant (Zayed et al. 2007).

Plant height in all treatments increased continuously from 14 DAT to 77 DAT (Figure 4.1).The combined effect of potassium fertilizer and rice husk ash were highly significant at 14 DAT, 21 DAT, and significant at 35 DAT, 42 DAT and 49 DAT. The remaining combined effects were not significantly effect on plant height. At 77 DAT, the highest plant height was found in the H_1K_3 treatment (108.31 cm), whereas the shortest plant height was obtained from H_1K_0 (102.13 cm).

4.1.1.2 Number of tillers $hill^{-1}$

Mean effect of rice husk ash and potassium fertilizer managements on number of tiller $hill^{-1}$ was shown in Table 4.2. Number of tillers $hill^{-1}$ was significantly affected by the application of rice husk ash. The highest number of tillers $hill^{-1}$ (8.83) was obtained from with RHA 5 ton ha^{-1}. Seyedeh et al. (2012) reported that rice husk ash contains over 60% silica and application of RHA significantly increased the number of reproductive tillers.

Number of tillers $hill^{-1}$ were highly significant difference among potassium fertilizer managements and significant at $P<0.05$ in rice husk ash application. All potassium fertilizer managements resulted higher number of tillers $hill^{-1}$ than potassium omission treatments in both with or without rice husk ash application. Among different rates of potassium fertilizer managements, application of 32 kg K ha^{-1} gave the highest number of tillers $hill^{-1}$ (9.76) followed by that of 24 kg K ha^{-1} (8.53). The lowest number of tillers $hill^{-1}$ (7.03) was obtained from K omission. These findings was similar to that of Reyhaneh et al. (2012) who found that the number of tillers increased significantly ($P<0.01$) by the application of potassium over control. Thakur et al. (1993) stated that application of potassium increased the number of tillers. The effect of rice husk ash was significant at 5% level of significance.

There was no interaction between different rates of potassium fertilizer and rice husk ash. This result indicated that rice husk ash effect was not influenced on number of tillers $hill^{-1}$ responded to potassium fertilizer managements. Number of tillers $hill^{-1}$ recorded from 14 DAT to 77 DAT at one week interval was described in Table 4.4. The combined effect of potassium fertilizer and rice husk ash was not significantly different. At 77 DAT, the maximum number of tillers $hill^{-1}$ (15.25) was obtained from the combined effect of H_1K_3 (32 kg K ha^{-1} with 5 ton ha^{-1} RHA) and the minimum number of tillers $hill^{-1}$ (8.75) was obtained from the combined effect of H_0K_0 (K omission and without RHA).

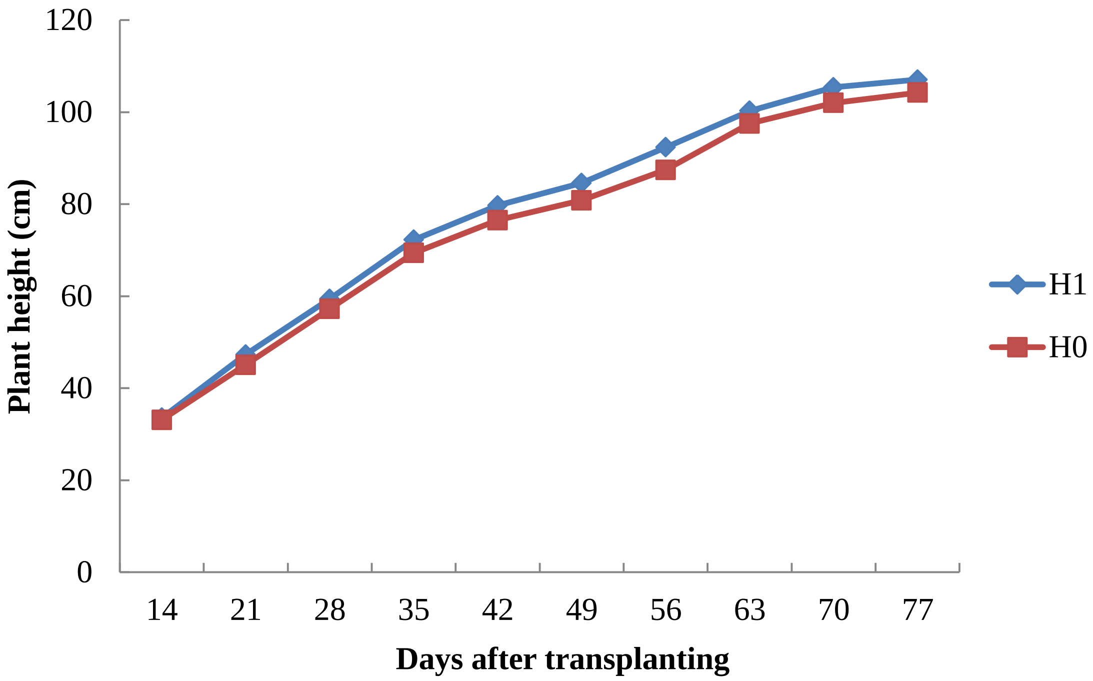

Figure 4.1 Mean value of plant height (cm) as affected by rice husk ash during dry season and, 2015.

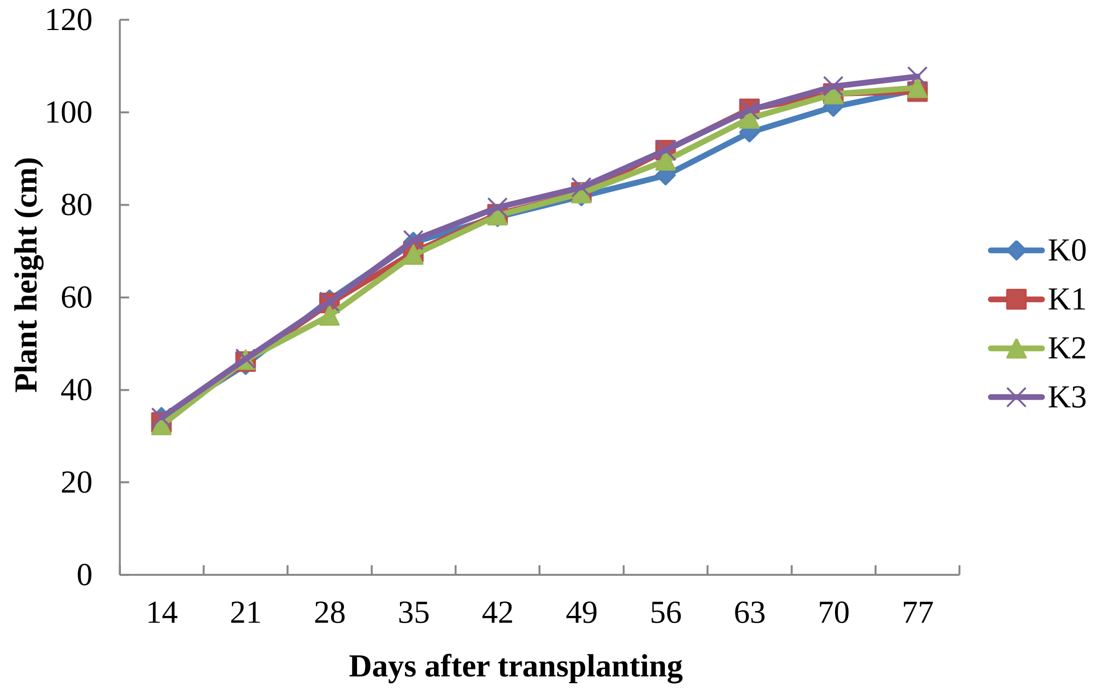

Figure 4.2 Mean value of plant height (cm) as affected by different rates of potassium fertilizer during dry season, 2015.

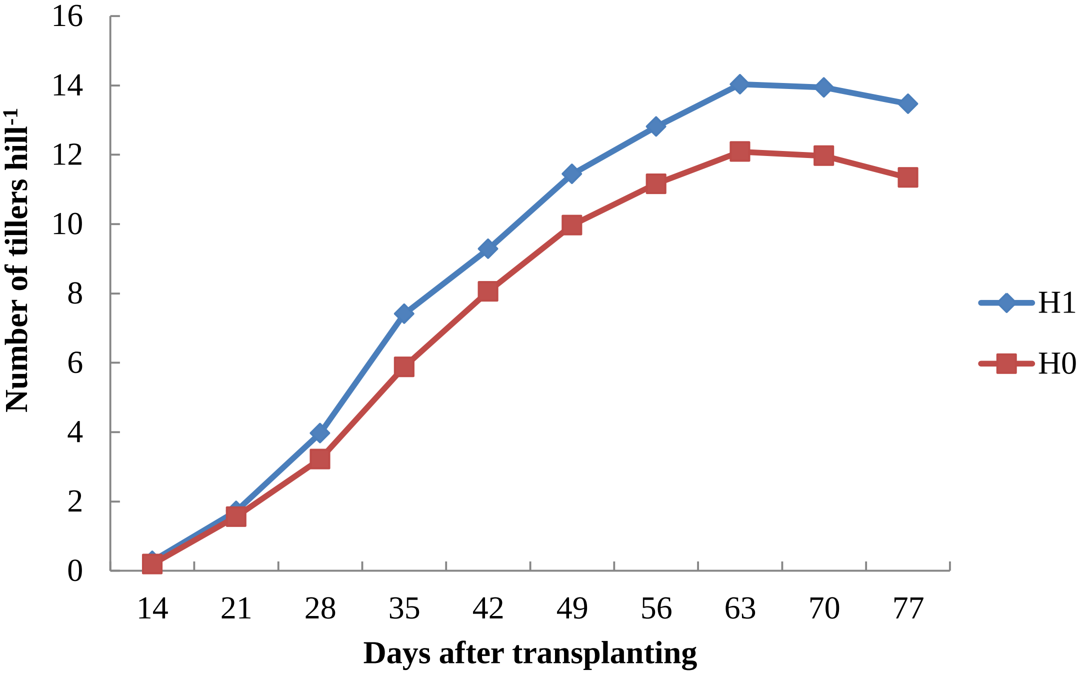

Figure 4.3 Mean value of number of tillers hill^{-1} as affected by rice husk ash during dry season, 2015.

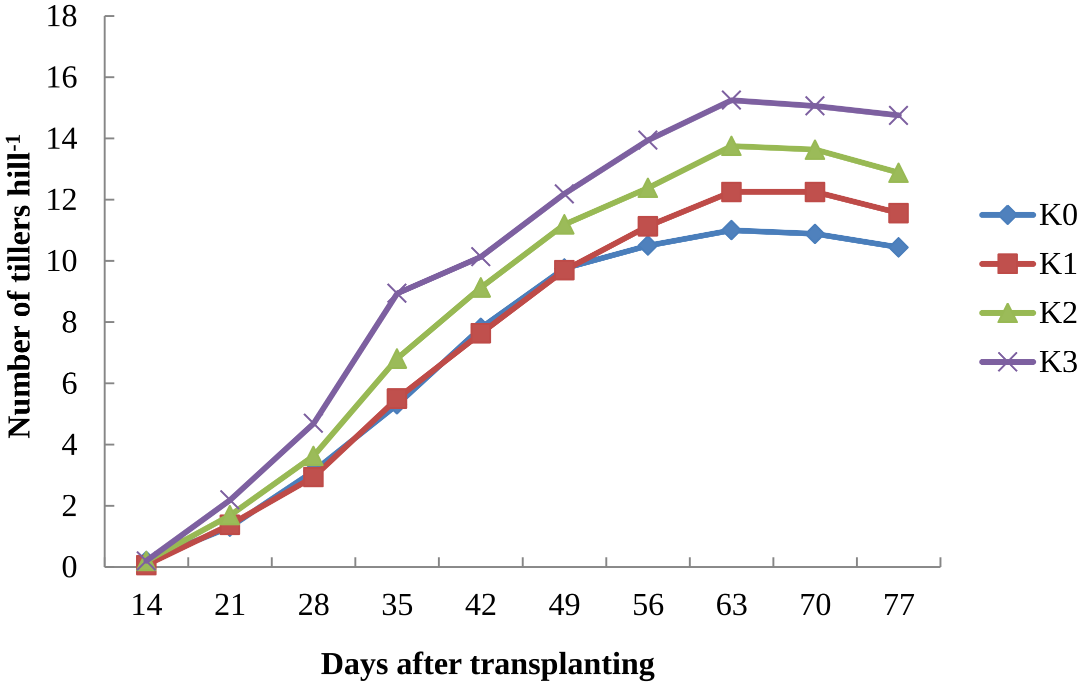

Figure 4.4 Mean value of number of tillers hill^{-1} as affected by different rates of potassium fertilizer during dry season, 2015.

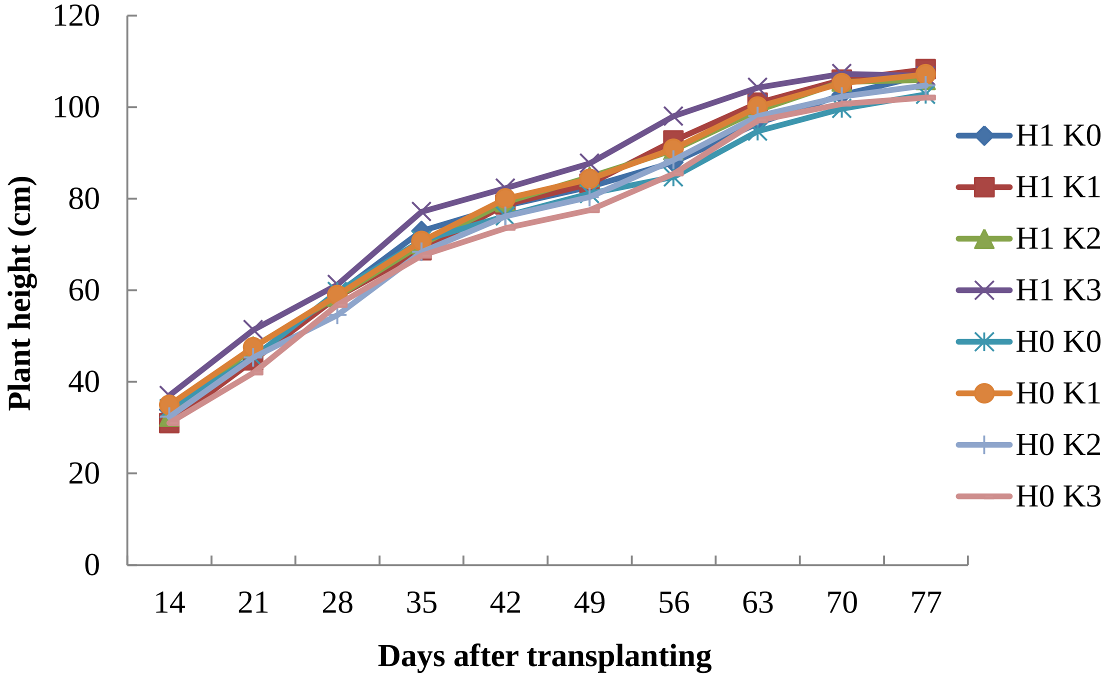

Figure 4.5 Mean value of plant height (cm) as affected by different rates of potassium fertilizer and rice husk ash during the dry season, 2015.

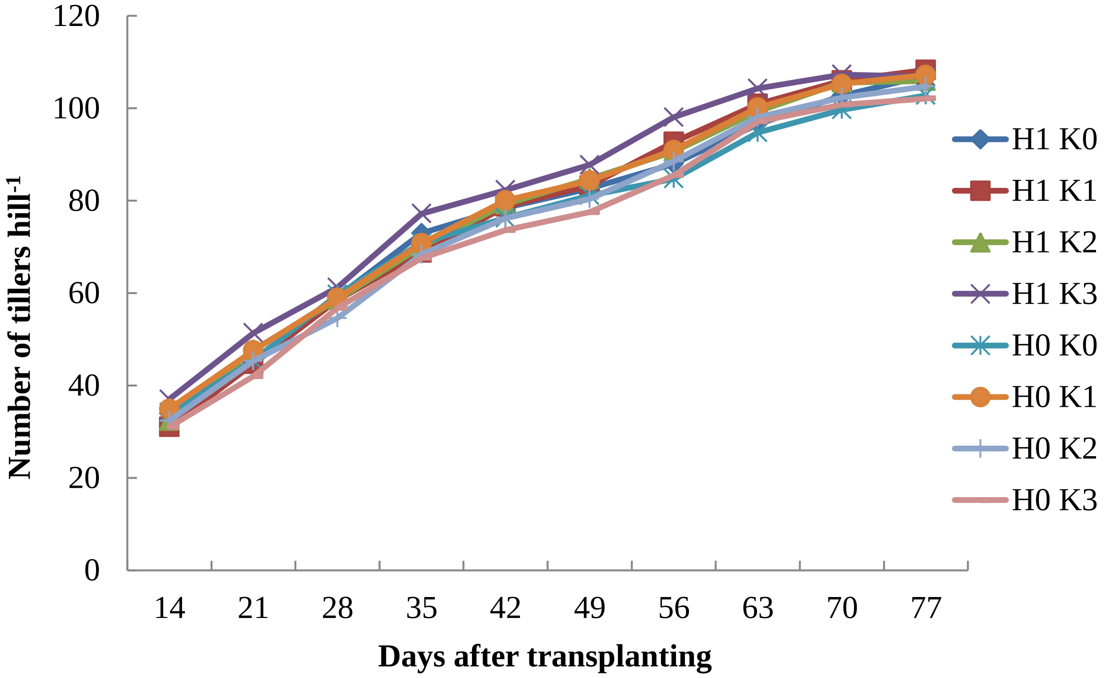

Figure 4.6 Mean value of number of tiller hill^{-1} as affected by different rates of potassium fertilizer and rice husk ash during the dry season, 2015.

Table 4.1 Mean effects of rice husk ash (RHA) and potassium fertilizer on plant height of rice during dry season, 2015

Treatments	Plant height (cm)									
	14 DAT	**21 DAT**	**28 DAT**	**35 DAT**	**42 DAT**	**49 DAT**	**56 DAT**	**63 DAT**	**70 DAT**	**77 DAT**
Without RHA	33.11	45.06	57.25 a	69.39	76.53 a	80.83 a	87.42 a	97.52	102.00 a	104.22 a
With 5 ton ha^{-1} RHA	33.58	47.31	59.42 b	72.23	79.70 b	84.59 b	92.34 b	100.28	105.39 b	107.05 b
K omission	34.03	45.44	59.47 a	71.91	77.38	81.88	86.38 b	95.66 b	101.19 b	104.94
16 kg K ha^{-1}	32.97	46.13	58.75 ab	69.75	77.97	82.66	91.78 a	100.72 a	104.03 a	104.50
24 kg K ha^{-1}	32.38	46.50	56.10 b	69.22	77.72	82.56	89.56 ab	98.69 ab	103.94 ab	105.34
32 kg K ha^{-1}	34.00	46.69	59.03 a	72.38	79.41	83.78	91.81 a	100.53 a	105.63 ab	107.75
Pr ≥ F										
RHA	0.6157	0.0379	0.04	0.0536	0.0098	0.0106	0.0062	0.1044	0.0236	0.0495
Potassium	0.518	0.0948	0.09	0.3139	0.5978	0.792	0.0865	0.1341	0.186	0.3534
$LSD_{0.05}$										
RHA	1.91	2.52	2.03	2.89	2.32	2.79	3.37	3.39	2.89	2.82
Potassium	2.71	3.56	2.87	4.09	3.28	3.95	4.76	4.79	4.08	3.99
CV %	7.80	7.42	4.74	5.56	4.04	4.59	5.09	4.66	3.79	3.63

*Means followed by the same letter in each column are not significantly different

Table 4.2 Mean effects of rice husk ash (RHA) and potassium fertilizer on number of tillers hill^{-1} of rice during dry season, 2015

Treatments	Number of tillers hill^{-1}									
	14 DAT	**21 DAT**	**28 DAT**	**35 DAT**	**42 DAT**	**49 DAT**	**56 DAT**	**63 DAT**	**70 DAT**	**77 DAT**
Without RHA	0.19	1.56	3.22	5.88 a	8.06	9.97 a	11.16 a	12.09 a	11.97 a	11.34 a
With 5 ton ha^{-1} RHA	0.28	1.72	3.97	7.41 b	9.28	11.44 b	12.81 b	14.03 b	13.94 b	13.47 b
K omission	0.19	1.31 b	3.13 b	5.31 b	7.81 b	9.75 b	10.50 b	11.00 c	10.88 c	10.44 c
16 kg K ha^{-1}	0.06	1.38 b	2.94 b	5.50 b	7.63 b	9.69 b	11.13 b	12.25 bc	12.25 bc	11.56 bc
24 kg K ha^{-1}	0.19	1.69 ab	3.63 ab	6.81 b	9.13 ab	11.19 ab	12.38 ab	13.75 ab	13.63 ab	12.88 ab
32 kg K ha^{-1}	0.20	2.19 a	4.69 a	8.94 a	10.13 a	12.19 a	13.94 a	15.25 a	15.06 a	14.75 a
Pr ≥ F										
RHA	0.5519	0.5191	0.1175	0.0252	0.0870	0.0357	0.0225	0.0283	0.0168	0.0081
Potassium	0.2571	0.0641	0.0580	0.0020	0.0534	0.0364	0.0083	0.0089	0.0054	0.0028
LSD $_{0.05}$										
RHA	0.32	0.49	0.96	1.32	1.41	1.36	1.39	1.71	1.58	1.51
Potassium	0.46	0.70	1.35	1.87	1.99	1.92	1.98	2.42	2.23	2.14
CV %	187.12	41.08	36.16	27.06	22.14	17.29	15.87	17.81	16.55	16.56

*Means followed by the same letter in each column are not significantly different

Table 4.3 Combined effects of rice husk ash and potassium fertilizer on plant height of rice during dry season, 2015.

Treatments	**Plant height (cm)**									
	14 DAT	**21 DAT**	**28 DAT**	**35 DAT**	**42 DAT**	**49 DAT**	**56 DAT**	**63 DAT**	**70 DAT**	**77 DAT**
H_0 K_0	31.00 c	42.00 c	56.81 bc	67.563 b	73.625 c	77.50 c	85.50 c	97.13 b	100.75 bc	102.13 b
H_0 K_1	34.94 ab	47.56 ab	58.94 ab	70.750 b	80.063 ab	84.313 ab	90.94 bc	100.12 ab	105.25 abc	107.19 ab
H_0 K_2	32.38 bc	45.31 bc	53.58 c	68.375 b	76.188 bc	80.373 bc	88.50 bc	98.06 ab	102.31 abc	104.75 ab
H_0 K_3	34.13 abc	45.38 bc	59.69 ab	70.875 b	76.25 bc	81.125 bc	84.75 c	94.75 b	99.69 c	102.81 ab
H_1 K_0	33.94 abc	45.50 bc	59.25 ab	72.938 ab	78.50 ab	83.625 abc	88.00 bc	96.56 b	102.69 abc	107.06 ab
H_1 K_1	31.00 c	44.69 bc	58.56 ab	68.750 b	78.75 ab	83.25 ab	92.69 ab	100.94 ab	106.00 ab	105.94 ab
H_1 K_2	32.38 bc	41.69 ab	58.63 ab	70.063 b	79.25 ab	84.75 ab	90.63 bc	99.31 ab	105.56 ab	106.88 ab
H_1 K_3	37.00 a	51.38 a	61.24 a	77.188 a	82.312 a	87.75 a	98.06 a	104.31 a	107.31 a	108.31 a
Pr ≥ F	0.01	0.01	0.10	0.05	0.04	0.04	0.09	0.49	0.54	0.68
LSD $_{0.05}$	3.83	5.04	4.06	5.78	4.64	5.58	6.73	6.78	5.78	5.64
CV %	7.80	7.42	4.74	5.56	4.04	4.59	5.09	4.66	3.79	3.36

*Means followed by the same letter in each column are not significantly different

H_1 – (with rice husk ash), **H_0** – (without rice husk ash), **K_0**– control (K omission), **K_1** – (16 kg K ha^{-1}), **K_2** – (24 kg K ha^{-1}), **K_3** – (32 kg K ha^{-1})

Table 4.4 Combined effects of rice husk ash and potassium fertilizer on number of tillers hill^{-1} during dry season, 2015

Treatments	Number of tillers hill^{-1}									
	14 DAT	**21 DAT**	**28 DAT**	**35 DAT**	**42 DAT**	**49 DAT**	**56 DAT**	**63 DAT**	**70 DAT**	**77 DAT**
H_0 K_0	0.00	1.25 b	2.63 b	4.36 c	6.63	8.38 c	8.88 c	9.38 c	9.38 c	8.75 d
H_0 K_1	0.00	1.38 b	2.50 b	4.75 c	6.88 b	8.88 bc	9.88 bc	10.63 bc	10.63 bc	10.00 cd
H_0 K_2	0.38	1.63 ab	3.88 ab	6.63 bc	8.88 ab	10.88 abc	12.00 ab	13.38 ab	13.13 ab	12.38 abc
H_0 K_3	0.38	2.00 ab	3.88 ab	7.75 ab	9.88 a	11.75 ab	13.88 a	15.00 a	14.75 b	14.25 ab
H_1 K_0	0.38	1.38 b	3.63 ab	6.25 bc	9.00 ab	11.13 abc	12.13 ab	12.63 abc	12.38 abc	12.13 bc
H_1 K_1	0.13	1.38 b	3.38 b	6.25 bc	8.38 ab	10.50 abc	12.38 ab	13.88 ab	13.86 a	13.13 ab
H_1 K_2	0.00	1.75 ab	3.38 b	7.00 bc	9.38 ab	11.50 ab	12.75 a	14.13 a	14.13 a	13.38 ab
H_1 K_3	0.63	2.38 a	5.50 a	10.13 a	10.36 a	12.63 a	14.00 a	15.50 a	15.38 a	15.25 a
Pr ≥ F	0.36	0.95	0.43	0.72	0.72	0.66	0.34	0.48	0.51	0.50
LSD $_{0.05}$	0.64	0.99	1.91	2.64	2.82	2.72	2.79	3.42	3.15	3.02
CV %	187.12	41.08	36.16	27.06	22.14	17.29	15.87	17.81	16.55	16.56

*Means followed by the same letter in each column are not significantly different

H_1 – (with rice husk ash), **H_0** – (without rice husk ash), **K_0**– control (K omission), **K_1** – (16 kg K ha^{-1}), **K_2** – (24 kg K ha^{-1}), **K_3** – (32 kg K ha^{-1})

4.1.2 Effect of rice husk ash (RHA) and different rates of potassium fertilizer on yield and yield components parameters

4.1.2.1 Panicle length (cm)

The panicle length as affected by rice husk ash, different rates potassium fertilizer and their combined effects was presented in Table 4.5 and 4.6. Rice husk ash was not significantly effect on panicle length. The longest panicle length (32.66 cm) was found in with RHA 5 ton ha^{-1}. Potassium fertilizer was not significant effect on panicle length. Although there was no statistical difference, the longest panicle length (33.25 cm) was recorded from 32 kg K ha^{-1} and the shortest panicle length was observed from K omission. This was similar to the finding of Uddin et al. (2007) who showed that increasing potassium rates resulted in the longest panicle of rice. The combined effects of potassium fertilizer and rice husk ash were not significantly different on panicle length (Table 4.5). The longest panicle length (33.47 cm) was obtained from the combined effect of H_1K_3 (32 kg K ha^{-1} with 5 ton ha^{-1} RHA) and the shortest panicle length (31.43 cm) was obtained from the combined effect of H_0K_0 (K omission and without RHA).

4.1.2.2 Number of spikelets panicle^{-1}

Number of spiketlets panicle^{-1} was not significant different among rice husk ash and potassium fertilizer application (Table 4.5). No significant responses were observed among the rice husk ash treatments. Potassium fertilizer treatments exhibited no significant difference between treatments. 32 kg K ha^{-1} showed slightly higher number of spikelet (159.42) than any other treatments. Uddin et al. (2007) reported that potassium helped in proper filling of seeds which resulted higher number of plump seeds and thus increased the number of grains panicle^{-1}. Combined effects of different rates of potassium fertilizer and rice husk ash on spikelets panicle^{-1} ranged from 145.65 to 160.25 (Table 4.6). The highest number of spikelets panicle^{-1} (160.25) was occurred in H_1K_3 (32 kg K ha^{-1} with 5 ton ha^{-1} RHA) and the lowest number of spikelets panicle^{-1} was resulted from H_0K_0 (K omission and without RHA).

4.1.2.3 Filled grain %

Mean effect of rice husk ash and different rates of potassium fertilizer application on percent filled grain was shown in Table 4.5 and 4.6. Percent filled grain was not significant difference in rice husk ash treatments. Among the rice husk ash treatments, the highest filled grain % (84.36) was found in RHA 5 ton ha^{-1}. Talashilkar and Chavan

(1995) stated that using rice husk ash cause to producing more grain and straw in paddy and the yield increase too. No significant difference was observed among potassium fertilizer application. Although percent filled grain was not significantly different between all potassium applications, the maximum percent filled grain (85.37) was recorded from the application of 32 kg K ha^{-1}. Minimum percent filled grain (74.36) was obtained from K omission treatment. Esfehani et al. (2005) showed that potassium fertilizer has positive effect on filled grains in rice while its deficiency caused pollen sterility and decreased the number of filled grains $panicle^{-1}$. Similar results found by Krishnappa et al. (2006) and reported that applied K increased the number of filled grains $panicle^{-1}$.

Combined effect of filled grain percent ranged from 81.87 to 84.33 (Table 4.5). The maximum percent filled grain (84.33) was resulted from H_1K_3 (32 kg K ha^{-1} with 5 ton ha^{-1} RHA) whereas minimum percent filled grain (81.87) was produced by the treatment H_0K_0 (K omission and without RHA).

4.1.2.3 1000 grain weight (g)

1000 grain weight as affected by rice husk ash, different rates potassium fertilizer and their combined effects was shown in Table 4.5 and 4.6. There was no significant difference on 1000 grain weight of rice husk ash treatments. RHA 5 ton ha^{-1} showed slightly higher number of 1000 grain weight (22.42 g) than without RHA (22.14 g). Potassium fertilizer was not significantly different on 1000 grain weight. Application of 32 kg K ha^{-1} gave the maximum 1000 grain weight (22.73 g) and minimum 1000 grain weight (22.02 g) was produced by the treatment K omission. Bansal et al. (1993) who mentioned that potassium fertilizer application can increase grain yield performance, number of filled grains and 1000 grain weight. There was no combined effect between different rates of potassium fertilizer application and rice husk ash. This means that there were no significant changes in 1000 grain weight in two RHA treatments that responded to different potassium fertilizer application. 1000 grain weight ranged from 21.89 to 22.96 (Table 4.6). The maximum 1000 grain weight (22.96) was resulted from H_1K_3 (32 kg K ha^{-1} with 5 ton ha^{-1} RHA) whereas minimum percent filled grain (21.89) was produced by the treatment H_0K_0 (K omission and without RHA).

4.1.2.4 Number of panicles hill^{-1}

Number of panicles hill^{-1} at harvest was presented in Table 4.5 and 4.6. RHA was significant effect on number of panicles hill^{-1}. RHA 5 ton ha^{-1} produced the higher number of panicle hill^{-1} (10.01) than that of without RHA (8.81).

The effect of different rates of potassium fertilizer was significantly different on number of panicles hill^{-1}. The highest number of panicle hill^{-1} was observed in 32 kg K ha^{-1} and the lowest number was found in K omission. Bagheri et al. (2011) who mentioned that panicle number was increased with increasing potassium rate. This finding was analogous with the result of Zayed et al. (2007). There is nonsignificant interaction between potassium fertilizer application and rice husk ash treatments. This result indicates that different rates of potassium fertilizer were not significantly affected by RHA applied and that the potassium effect did not differ significantly with the tested RHA. Mean number of panicles hill^{-1} ranged from 7.63 to 11.63 in all combined treatments (Table 4.6). Maximum number of panicles hill^{-1} (11.63) was obtained from the combined effect of H_1K_3 (32 kg K ha^{-1} with 5 ton ha^{-1} RHA). The minimum number of panicles hill^{-1} was resulted from the combined effects of H_0K_0 (K omission and without RHA).

4.1.2.5 Grain yield (g plant^{-1})

Grain yield of rice husk ash, different rates potassium fertilizer and their combined effects was shown in Table 4.5 and 4.6. Grain yield of rice was highly significant differences among the RHA treatments at ($P < 0.01$). The maximum grain yield (50.42 g plant^{-1}) was observed from with RHA 5 ton ha^{-1} and lowest (42.29 g plant^{-1}) was found in without RHA. These finding was similar to that of Talashilkar and Chavan (1995), Prakash et al. (2007), Sitio et al. (2007), Mohammad Reza et al. (2014) who stated that using rice husk ash cause to producing more grain and straw in paddy and the yield increase too. Using RHA can give higher yield response in this experiment. Applying 5 ton ha^{-1} RHA give over 19% yield advantage over without RHA treatment (Table 4.7).

The highly significant difference among the potassium fertilizer treatments was found at 1% level of significance. The grain yield of rice ranged from (38.84 g plant^{-1}) to (54.13 g plant^{-1}). All treatments produced significantly higher yield than control (K omission). The highest grain yield (54.13 g plant^{-1}) was recorded from 32 kg K ha^{-1} followed by 28 kg K ha^{-1} (49.26 g plant^{-1}), whereas the lowest yield (38.84 g plant^{-1}) was obtained by K omission. This was similar to the finding of Khin Thuzar New (2009) who showed that potassium application significantly increased grain yield of rice. This result is also in agreement with (Arif et al. 2010, Dunn and Stevens 2005, Bansal et al. 1993) who reported that potassium application significantly increased grain yield and yield component of rice. Applying potassium fertilizer significantly increased the grain yield of rice in this experiment. Therefore, using 32 kg K ha^{-1} can give over 39% yield advantages over K omission treatment. 28 kg K ha^{-1} and 16 kg K ha^{-1} can also give over 26% and 11% yield advantages over K omission treatment (Table 4.7).

All of the combined effects were not significantly different on yield (Table 4.6). Grain yields ranged from 34.51 (g plant^{-1}) to 59.40 (g plant^{-1}). Among the combined effect of different rates of potassium fertilizer and rice husk ash, the combined effect of H_1K_3 (32 kg K ha^{-1} with 5 ton ha^{-1} RHA) gave the maximum yield 59.40 (g plant^{-1}). The result found in H_1K_2 (28 kg K ha^{-1} with 5 ton ha^{-1} RHA) was the second highest and the value was 50.93 (g plant^{-1}). The minimum yield 34.51 (g plant^{-1}) was observed in the combined effect of H_0K_0 (K omission and without RHA).

4.1.3 Grain harvest index (GHI)

Harvest index of tested rice variety as affected by rice husk ash, different rates potassium fertilizer and their combined effects is presented in Table 4.8 and 4.9. There was no significant difference in GHI of RHA treatments. Even though there was no significant difference, the number of GHI appeared to be high (0.39) in the treatment with RHA 5 ton ha^{-1} than in treatment without RHA (0.37). Effects of potassium fertilizer were not significantly different on GHI. 32 kg K ha^{-1} and 28 kg K ha^{-1} produced the maximum GHI (0.39) whereas the lowest value was found in K omission. Combined effect of GHI ranged from 0.36 to 0.41 and significant different at 5% level (Table 4.9). Among the combined treatments, the maximum GHI (0.41) was resulted from H_1K_3 (32 kg K ha^{-1} with 5 ton ha^{-1} RHA) whereas minimum GHI (0.36) was recorded from that of K omission and without RHA (H_0K_0).

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, 2015 is shown in Table 4.10. The grain yield was highly and positively correlated with number of panicles hill^{-1}, number of spikelets panicles^{-1}, panicle length, 1000 grain weight and filled grain% at $P<0.01$. Grain yield was also positively correlated with grain harvest index at $P<0.05$. Grain yield was significantly increased with the increase of number of tillers hill^{-1}. Number of spikelets panicle^{-1} also had direct effect on grain yield. Panicle length, 1000 grain weight and filled gain percentage had positive and significant correlation with grain yield.

Table 4.5 Mean effects of rice husk ash (RHA) and potassium fertilizer on yield and yield components of rice during dry season, 2015.

Treatments	Panicle length (cm)	No. of spikelets panicle^{-1}	Filled grain %	1000 grain weight (g)	No. of panicles hill^{-1}	Grain yield (g plant^{-1})
Rice Husk Ash						
Without RHA	31.92	151.72	77.02	22.14	8.81 b	42.29 b
With 5 ton ha^{-1} RHA	32.66	156.89	84.36	22.42	10.03 a	50.42 a
LSD $_{0.05}$	0.99	10.05	8.19	0.76	1.20	5.23
Potassium						
K omission	31.59	149.34	74.36	22.02	8.38 b	38.84 c
16 kg K ha^{-1}	31.95	151.43	78.26	22.10	8.81 b	43.18 bc
24 kg K ha^{-1}	32.38	157.04	84.80	22.28	9.88 ab	49.26 ab
32 kg K ha^{-1}	33.25	159.42	85.37	22.73	10.63 a	54.13 a
LSD $_{0.05}$	1.41	14.21	11.58	0.76	1.70	7.39
Pr ≥ F						
Rice Husk Ash	0.13	0.30	0.08	0.30	0.04	0.002
Potassium	0.11	0.43	0.17	0.24	0.04	0.001

*Means followed by the same letter in each column are not significantly different

Table 4.6 Combined effects of rice husk ash and potassium fertilizer on yield and yield components of rice during dry season, 2015.

Treatments	Panicle length (cm)	No. of spikelets panicle^{-1}	Filled grain %	1000 grain weight (g)	No. of panicles hill^{-1}	Grain yield (g plant^{-1})
H_0 K_0	31.43	145.65	66.86	21.89	7.63	34.51
H_0 K_1	31.55	146.67	73.70	21.93	8.38	38.19
H_0 K_2	31.67	155.95	83.2a	22.26	9.63	47.60
H_0 K_3	33.03	158.60	84.33	22.50	9.63	48.86
H_1 K_0	31.74	153.03	81.87	22.16	9.13	43.16
H_1 K_1	32.35	156.18	82.82	22.26	9.25	48.18
H_1 K_2	33.09	158.13	86.37	22.30	10.13	50.93
H_1 K_3	33.47	160.25	86.40	22.96	11.63	59.40
Pr ≥ F	0.85	0.9217	0.64	0.95	0.80	0.73
LSD $_{0.05}$	1.99	20.10	16.37	0.76	2.41	10.45
CV %	4.19	8.86	13.80	3.28	17.37	15.33

*Means followed by the same letter in each column are not significantly different

H_1 – (with rice husk ash), **H_0** – (without rice husk ash), **K_0**– control (K omission), **K_1** – (16 kg K ha^{-1}), **K_2** – (24 kg K ha^{-1}), **K_3** – (32 kg K ha^{-1})

Table 4.7 Comparison of grain yield and yield increased over control during dry season, 2015.

Treatments	Grain Yield (g palnt^{-1})	Yield increased over control (%)
Without RHA	42.29	0
With 5 ton ha^{-1} RHA	50.42	19.22
K omission	38.84	0
16 kg K ha^{-1}	43.18	11.17
24 kg K ha^{-1}	49.26	26.85
32 kg K ha^{-1}	54.13	39.37

Table 4.8 Mean effects of rice husk ash and potassium fertilizer on grain harvest index of rice during dry season, 2015.

Treatments	Grain harvest index (GHI)
Rice Husk Ash	
Without RHA	0.37
With 5 ton ha^{-1} RHA	0.39
LSD $_{0.05}$	0.03
Potassium	
K omission	0.37
16 kg K ha^{-1}	0.38
24 kg K ha^{-1}	0.39
32 kg K ha^{-1}	0.39
LSD $_{0.05}$	0.04
Pr ≥ F	
Rice Husk Ash	0.07
Potassium	0.77

*Means followed by the same letter in each column are not significantly different

Table 4.9 Combined effects of rice husk ash and potassium fertilizer on grain harvest index of rice during dry season, 2015.

Treatments	Grain harvest index (GHI)
H_0 K_0	0.37
H_0 K_1	0.36
H_0 K_2	0.39
H_0 K_3	0.36
H_1 K_0	0.39
H_1 K_1	0.39
H_1 K_2	0.40
H_1 K_3	0.41
Pr ≥ F	0.71
LSD $_{0.05}$	0.05
CV %	9.04

*Means followed by the same letter in each column are not significantly different

H_1 – (with rice husk ash), **H_0** – (without rice husk ash), **K_0**– control (K omission), **K_1** – (16 kg K ha^{-1}), **K_2** – (24 kg K ha^{-1}), **K_3** – (32 kg K ha^{-1})

Table 4.10 Correlation between yield and yield components of rice as affected by rice husk ash and different rates of potassium fertilizer during the dry season, 2015.

	No. of panicles hill^{-1}	No. of spikelets panicle^{-1}	Grain Harvest Index	Panicle length	1000 grain weight	Filled grain %	Yield
No. of panicles hill^{-1}	1						
No. of spikelets panicle^{-1}	0.9824**	1					
Grain Harvest Index	0.7802*	0.6013	1				
Panicle length	0.8436**	0.8460**	0.5992	1			
1000 grain weight	0.9455**	0.8642**	0.6504	0.8650**	1		
Filled grain %	0.8624**	0.9540**	0.5749	0.7463*	0.7623*	1	
Yield	0.9816**	0.9454**	0.7438*	0.8744**	0.9445**	0.8964**	1

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

4.2 Wet Season Experiment (July – December 2015)

Wet season experiment was carried out as the same layout of dry season experiment to compare the effect of different rates of potassium fertilizer and rice husk ash on the productivity of rice (Sin Thwe Latt). Grain yield, yield components and other growth parameters as affected by different rates of potassium fertilizer and rice husk ash for wet season, 2015 are described and discussed in the following section.

4.2.1 Effect of rice husk ash (RHA) and different rates of potassium fertilizer on growth parameters

4.2.1.1 Plant height (cm)

Mean effect of rice husk ash (RHA) and different rates of potassium fertilizer on plant height was shown in Table 4.11. There was no significant difference in mean number of plant heights among RHA treatments. The mean plant height appeared to be high (84.50 cm) in the treatment with RHA 5 ton ha^{-1} and the lowest (82.66 cm) was found in without RHA. Plant height increased with the application of RHA in this experiment. Anggria et al. (2016) found that plants height increase by using silica containing materials. The results indicated that the effects of different rates of potassium fertilizer were not significant on plant height. The maximum plant height was observed in the application of 32 kg K ha^{-1} (80.60 cm), it was followed by 24 kg K ha^{-1} (84.89 cm), then 16 kg K ha^{-1} (83.38 cm) and minimum plant height was obtained from K omission (81.34). This result is in full agreement with that of Williams and Smith (2001) who stated that increasing K rates resulted in increased plant height, delayed maturity and more yield.

Combined effect of rice husk ash and different rates of potassium fertilizer was presented in Table 4.13. Plant height increased continuously at all growth stages. There was no significant variation among all combined treatments. Mean plant ranged from (103.87 cm) to (112.81 cm). At 14 DAT, 21 DAT and 28 DAT, H_0K_2 showed maximum plant height. But, form 42 DAT to 77 DAT, the highest plant height was obtained from H_1K_3 treatment. At all DAT, H_0K_0 gave the minimum plant height.

4.2.1.2 Number of tillers $hill^{-1}$

Mean effect of rice husk ash and potassium fertilizer managements on number of tillers $hill^{-1}$ was shown in Table 4. There was no significant variation in number of tillers $hill^{-1}$ among RHA treatments. Even though there was no significant difference, the number of tillers hill^{-1} appeared to be high in (7.07) in the RHA 5 ton ha^{-1} treatment. This result is supported by Agusalim (2010) who mentioned that highest number of tillers hill^{-1} can be obtained by using rice husk ash. The number of tillers hill^{-1} was significantly different ($P<0.05$) among the different rates of potassium fertilizer treatments. The majority of total number of tillers hill^{-1} was observed in 32 kg K ha^{-1} (7.95), after that it was in treatment 24 kg K ha^{-1} (7.18), it was followed by 16 kg K ha^{-1} (6.71) and minimum of that was observed in K omission (5.54) treatment. In this experiment, the number of tillers increased with the increasing potassium doses. This result is in conformity with those of Sarkar et al. (2001) and Kalita et al. (2002) who reported that application of potassium significantly increases number of tillers hill^{-1} in rice.

Combined effect of rice husk ash and different rates of potassium fertilizer application on the number of tillers hill^{-1} during the wet season was describe in Table 4.14. Number of tillers hill^{-1} was recorded from 14 DAT to 77 DAT at one week interval. The combined effect of potassium fertilizer and RHA was not significant different on number of tillers hill^{-1}. This result indicates that different rates of potassium fertilizer was not significantly affected by the rice husk ash applied and that the rice husk ash effect did not differ significantly with the tested potassium fertilizer levels. Except from 35 DAT, 56 DAT and 77 DAT, the highest number of tillers hill^{-1} was recorded in H_1K_3 (32 kg K ha^{-1} with 5 ton ha^{-1} RHA) treatment. At all DAT, the minimum number of tillers hill^{-1} was obtained from H_0K_0 (K omission and without RHA) treatment.

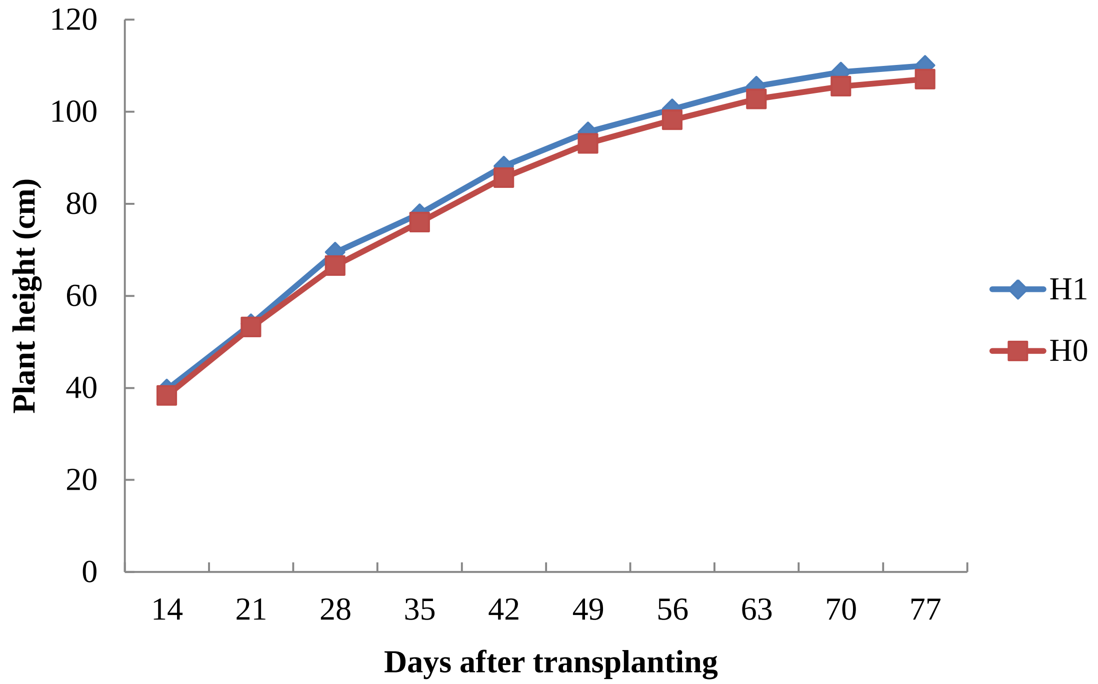

Figure 4.7 Mean value of plant height (cm) as affected by rice husk ash during wet season and, 2015.

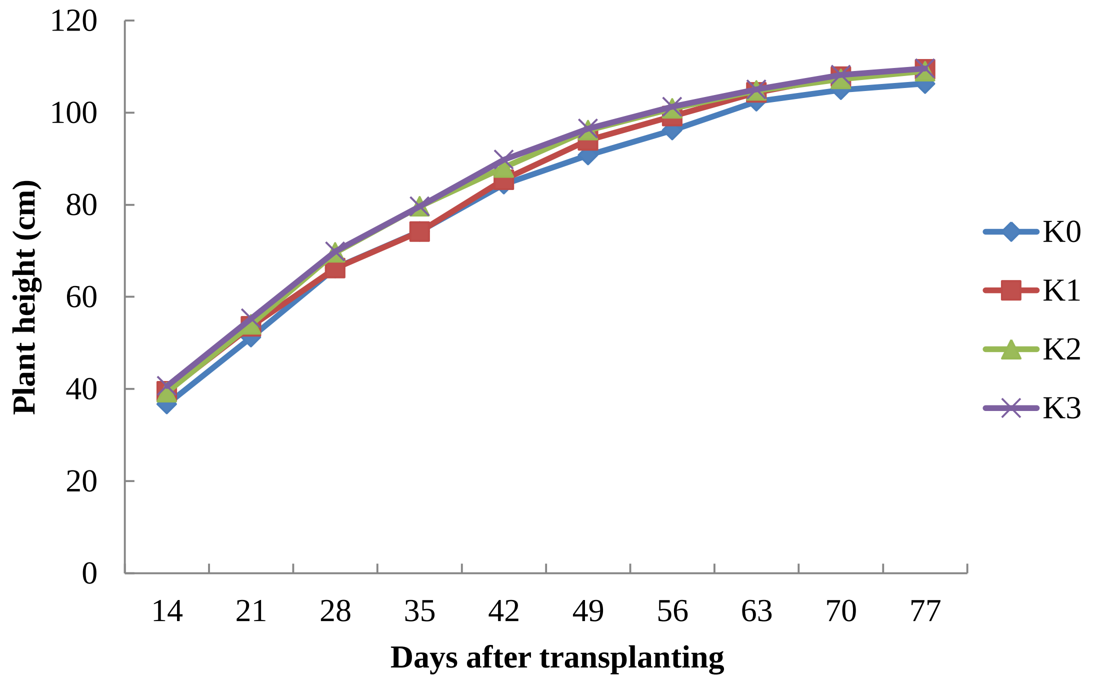

Figure 4.8 Mean value of plant height (cm) as affected by different rates of potassium fertilizer during wet season, 2015.

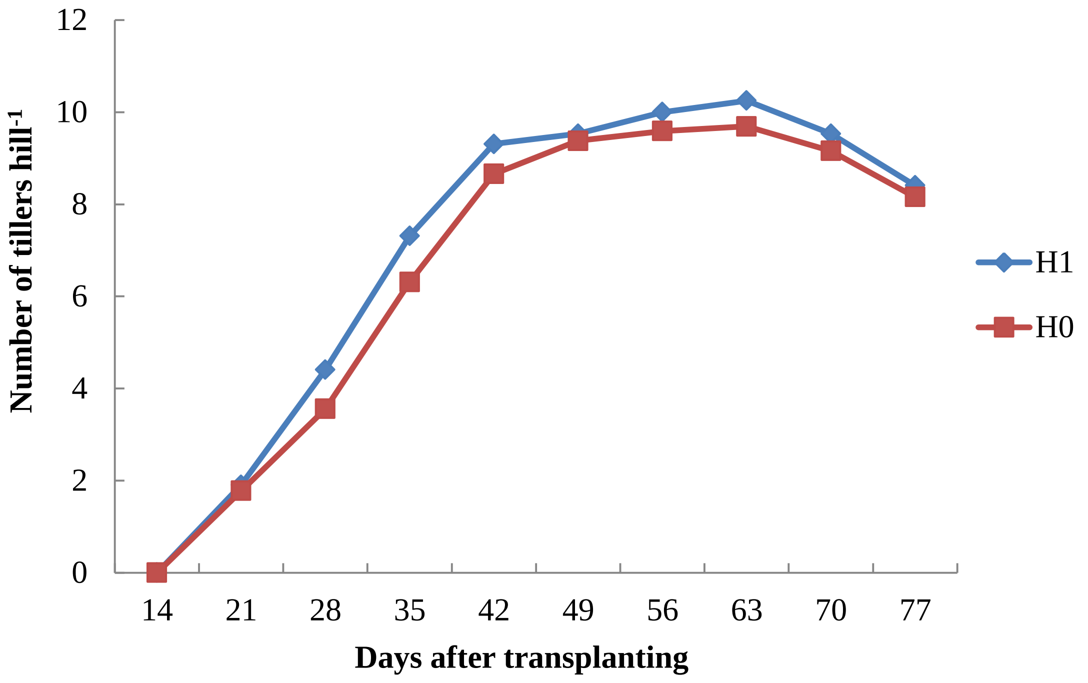

Figure 4.9 Mean value of number of tillers hill^{-1} as affected by rice husk ash during the wet season, 2015.

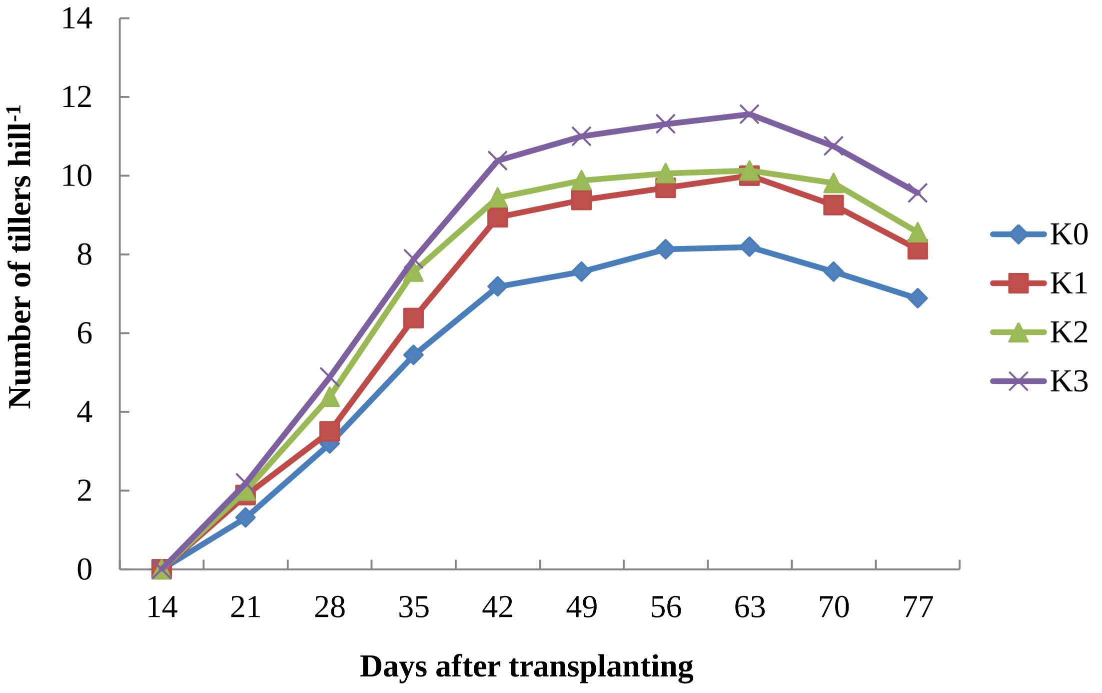

Figure 4.10 Mean value of number of tillers hill^{-1} as affected by different rates of potassium fertilizer during wet season, 2015.

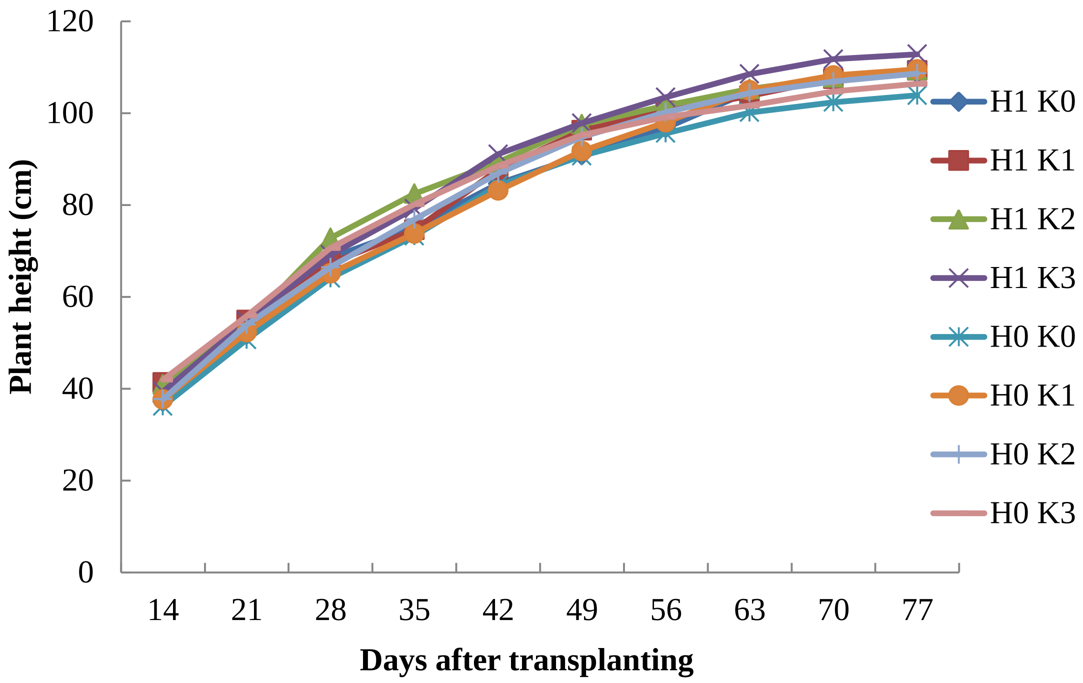

Figure 4.11 Mean value of plant height (cm) as affected by rice husk ash and different rates of potassium fertilizer during the wet season, 2015.

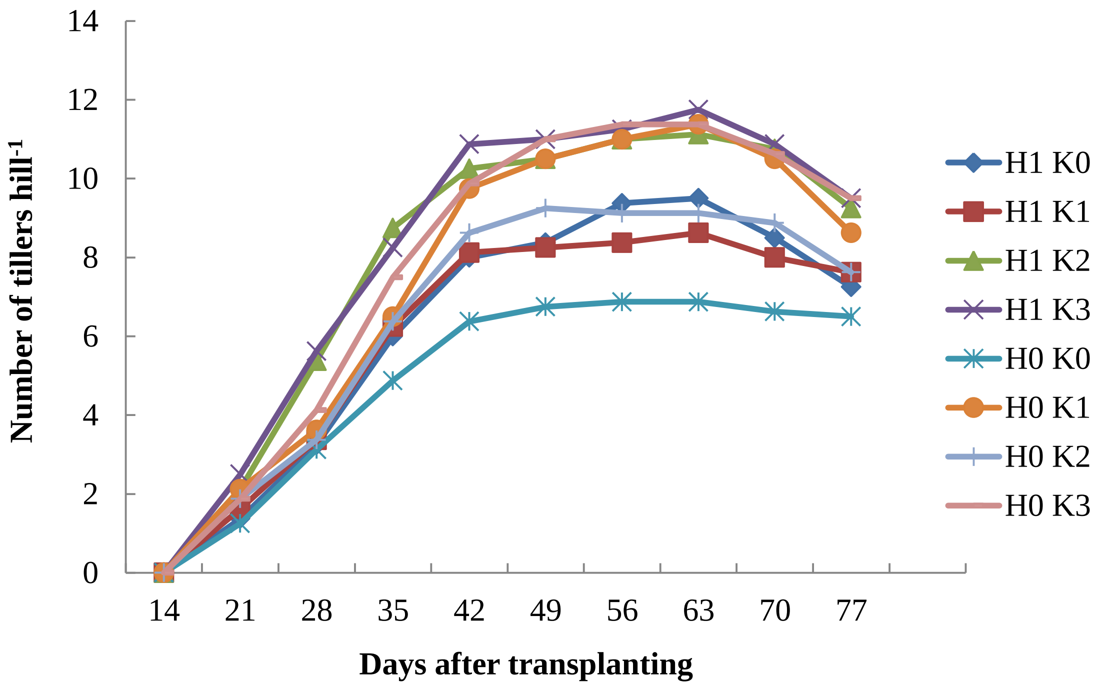

Figure 4.12 Mean value of number of tiller hill^{-1} as affected by rice husk ash and different rates of potassium fertilizer during the dry season, 2015.

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Table 4.11 Mean effects of rice husk ash (RHA) and potassium fertilizer on plant height of rice during wet season, 2015.

Treatments	Plant height (cm)									
	14 DAT	**21 DAT**	**28 DAT**	**35 DAT**	**42 DAT**	**49 DAT**	**56 DAT**	**63 DAT**	**70 DAT**	**77 DAT**
Without RHA	38.36	53.20	66.56	76.00	85.69	93.13	98.23	102.78	105.53 a	107.09 a
With 5 ton ha^{-1} RHA	39.72	53.89	69.44	77.82	88.19	95.61	100.58	105.56	108.62 b	110.05 b
K omission	36.69	51.22	66.28	74.19	84.44	90.75 b	96.19 b	102.44	104.94	106.28
16 kg K ha^{-1}	39.50	53.63	66.22	74.16	85.44	94.00 ab	99.25 ab	104.37	107.84	109.41
24 kg K ha^{-1}	39.31	54.03	69.63	79.66	88.09	96.19 a	100.91 a	104.81	107.31	109.00
32 kg K ha^{-1}	40.66	55.31	69.88	79.65	89.78	96.53 a	101.28 a	105.06	108.22	109.59
Pr ≥ F										
RHA	0.3467	0.7051	0.1414	0.4523	0.2500	0.1664	0.1523	0.0901	0.0493	0.0465
Potassium	0.2679	0.4524	0.3469	0.1856	0.2889	0.1010	0.1233	0.6355	0.4171	0.3247
$LSD_{0.05}$										
RHA	2.94	3.73	3.91	4.96	4.39	3.6	3.28	3.25	3.08	2.9
Potassium	4.15	5.27	5.53	7.02	6.22	5.09	4.65	4.6	4.36	4.1
CV %	10.23	9.47	7.83	8.78	6.88	5.19	4.49	4.25	3.92	3.64

*Means followed by the same letter in each column are not significantly different

Table 4.12 Mean effects of rice husk ash (RHA) and potassium fertilizer on number of tillers hill^{-1} of rice during wet season, 2015.

Treatments	Number of tillers hill^{-1}									
	14 DAT	**21 DAT**	**28 DAT**	**35 DAT**	**42 DAT**	**49 DAT**	**56 DAT**	**63 DAT**	**70 DAT**	**77 DAT**
Without RHA	0.00	1.78	3.56	6.31	8.66	9.38	9.59	9.69	9.16	8.16
With 5 ton ha^{-1} RHA	0.00	1.91	4.41	7.31	9.28	9.53	10.00	10.25	9.53	9.00
K omission	0.00	1.31 b	3.19 b	5.44 b	7.18 b	7.56 b	8.13 b	8.19 b	7.56 b	6.88 b
16 kg K ha^{-1}	0.00	1.88 ab	3.50 b	6.38 ab	8.94 ab	9.38 ab	9.69 ab	10.00 ab	9.25 ab	8.13 ab
24 kg K ha^{-1}	0.00	2.00 ab	4.38 ab	7.56 a	9.44 a	9.88 a	10.06 ab	10.13 ab	9.81 a	8.56 a
32 kg K ha^{-1}	0.00	2.19 a	4.88 a	7.88 a	10.38 a	11.00 a	11.31 a	11.56 a	10.75 a	9.56 a
Pr ≥ F										
RHA	0.00	0.6132	0.0594	0.0911	0.3456	0.8083	0.5685	0.4591	0.5881	0.6339
Potassium	0.00	0.0973	0.0375	0.0223	0.0239	0.0085	0.0332	0.0354	0.0241	0.0122
LSD $_{0.05}$										
RHA	0	0.51	0.88	1.17	1.41	1.32	1.45	1.55	1.41	1.07
Potassium	0	0.72	1.24	1.66	2	1.87	2.06	2.19	2	1.52
CV %	0.00	37.37	30.05	23.44	21.41	19.03	20.24	21.16	20.64	17.67

*Means followed by the same letter in each column are not significantly different

Table 4.13 Combined effects of rice husk ash and potassium fertilizer on plant height of rice during wet season, 2015.

Treatments	Plant height (cm)									
	14 DAT	**21 DAT**	**28 DAT**	**35 DAT**	**42 DAT**	**49 DAT**	**56 DAT**	**63 DAT**	**70 DAT**	**77 DAT**
H_0 K_0	36.19	50.69	64.06	73.25	84.25	90.69	95.63	100.12	102.37	103.87
H_0 K_1	37.63	52.31	65.13	73.75	83.13	91.75	98.00	105.00	108.19	109.50
H_0 K_2	37.69	53.94	66.44	76.88	86.88	94.81	100.19	104.37	106.87	108.63
H_0 K_3	41.94	55.88	70.63	80.13	88.50	95.25	99.12	101.62	104.69	106.37
H_1 K_0	37.19	51.75	68.50	75.13	84.63	90.81	96.75	104.75	107.50	108.69
H_1 K_1	41.38	54.94	67.31	74.56	87.75	96.25	100.50	103.75	107.50	109.31
H_1 K_2	40.94	54.13	72.81	82.44	89.31	97.56	101.63	105.25	107.75	109.37
H_1 K_3	39.38	54.75	69.13	79.19	91.06	97.81	103.44	108.50	111.75	112.81
Pr ≥ F	0.39	0.90	0.50	0.80	0.92	0.85	0.89	0.28	0.25	0.30
LSD $_{0.05}$	5.87	7.45	7.82	9.93	8.79	7.21	6.57	6.51	6.17	5.80
CV %	10.23	9.70	7.83	8.78	6.88	5.19	4.49	4.24	3.92	3.64

*Means followed by the same letter in each column are not significantly different

H_1 – (with rice husk ash), **H_0** – (without rice husk ash), **K_0** – control (K omission), **K_1** – (16 kg K ha^{-1}), **K_2** – (24 kg K ha^{-1}), **K_3** – (32 kg K ha^{-1})

Table 4.14 Combined effects of rice husk ash and potassium fertilizer on number of tillers hill^{-1} during wet season, 2015.

Treatments	Number of tillers hill^{-1}									
	14 DAT	**21 DAT**	**28 DAT**	**35 DAT**	**42 DAT**	**49 DAT**	**56 DAT**	**63 DAT**	**70 DAT**	**77 DAT**
H_0 K_0	0	1.25	3.13	4.88	6.38	6.75	6.88	6.88	6.63	6.50
H_0 K_1	0	2.13	3.63	6.50	9.87	10.50	11.00	11.38	10.50	8.63
H_0 K_2	0	1.88	3.38	6.38	8.63	9.25	9.13	9.13	8.88	7.63
H_0 K_3	0	1.88	4.13	7.50	9.88	11.00	11.38	11.38	10.63	9.88
H_1 K_0	0	1.38	3.23	6.00	8.00	8.38	9.38	9.50	8.50	7.25
H_1 K_1	0	1.63	3.38	6.25	8.12	8.25	8.38	8.63	8.00	7.63
H_1 K_2	0	2.13	5.38	8.75	10.25	10.50	11.00	11.13	10.75	9.50
H_1 K_3	0	2.50	5.63	8.25	10.88	11.00	11.25	11.75	10.88	9.25
Pr ≥ F	-	0.44	0.21	0.44	0.30	0.16	0.07	0.07	0.10	0.21
LSD $_{0.05}$	-	1.01	1.76	2.34	2.82	2.64	2.91	3.10	2.83	2.15
CV %	-	37.37	30.05	23.44	21.41	19.03	20.24	21.16	20.64	17.67

*Means followed by the same letter in each column are not significantly different

H_1 – (with rice husk ash), **H_0** – (without rice husk ash), **K_0**– control (K omission), **K_1** – (16 kg K ha^{-1}), **K_2** – (24 kg K ha^{-1}), **K_3** – (32 kg K ha^{-1})

4.2.2 Effect of rice husk ash and different rates of potassium fertilizer on yield and yield components parameters

4.2.2.1 Panicle length (cm)

The panicle length as affected by rice husk ash (RHA), different rates of potassium fertilizer and their combined effects was presented in Table 4.15 and 4.16. Panicle length is a very important parameter because of its associated with other important yield components such as number of grains and 1000 grain weight. There was no significance difference in mean number of panicle length among RHA treatments. Among RHA treatments, RHA 5 ton ha^{-1} showed slightly higher number of panicle length (32.16) than without RHA (31.60). The panicle length was not significantly affected by different rates of potassium fertilizer application under the study. Although there was no significant difference, the panicle length appeared to be high (32.85) in the 32 kg K ha^{-1} treatment whereas the lowest panicle length (31.13) was found in K omission treatment. This finding was in accordance with the results of Zayed et al. (2007) who showed that increasing potassium rates resulted in the longest panicle of rice which could bear higher number of spikelets $panicle^{-1}$.

Mean numbers of panicle length as affected by combined effects of rice husk ash and potassium fertilizer was shown in Table 4.16. There was no significant difference in mean numbers of panicle length among combined treatments. The plants treated with highest rates of potassium fertilizer in combination with rice husk ash H_1K_3 (32 kg K ha^{-1} with 5 ton ha^{-1} RHA) exhibited maximum panicle length (33.17). Minimum panicle length (31.07) was shown in treatment treated with no potassium fertilizer without rice husk ash H_0K_0 (K omission and without RHA).

4.2.2.2 Number of spikelets $panicle^{-1}$

According to the results, it was indicated that the number of spiketlets $panicle^{-1}$ was not significantly affected by rice husk ash. Although, RHA was not significantly different on number of spiketlets $panicle^{-1}$, RHA 5 ton ha^{-1} gave higher number of spiketlets $panicle^{-1}$ (96.05) than without RHA (90.33). The number of spiketlets $panicle^{-1}$ was significantly increased by potassium fertilizer managements (Table 4.15). The number of spikelets $panicle^{-1}$ ranged from 74.00 to 118.56. Highest number of spikelets $panicle^{-1}$ was achieved from 32 kg K ha^{-1} whiles the lowest from K omission treatment. This result resembled to the finding reported by Bahmaniar and Mashaee (2010) who stated that potassium helped in proper filling of seeds which resulted higher number of plump seeds and thus increased the number of grains panicle^{-1}. Significant difference in number of spiketlets panicle^{-1} was observed only in wet season experiment when potassium fertilizer was applied.

Mean numbers of spiketlets panicle^{-1} as affected by combined effects of rice husk ash and potassium fertilizer was shown in Table 4.16. There was no significant difference in mean numbers of spiketlets panicle^{-1} among combined treatments. The plants treated with highest rates of potassium fertilizer in combination with rice husk ash H_1K_3 (32 kg K ha^{-1}with 5 ton ha^{-1} RHA) exhibited maximum number of spiketlets panicle^{-1} (121.67). Minimum number of spiketlets panicle^{-1} (73.13) was shown in treatment treated with no potassium fertilizer without rice husk ash H_0K_0 (K omission and without RHA). Even though, there was no statistically different, the increased in number of spikelets panicle^{-1} of H_1K_3 was 40 percent over no potassium fertilizer and without rice husk ash treatment (H_0K_0).

4.2.2.3 Filled grain %

Mean effect of rice husk ash and different rates of potassium fertilizer application on percent filled grain was shown in Table 4.15 and 4.16. There was no significant effect of rice husk ash on percentage of filled gain. However, RHA 5 ton ha^{-1} appeared to be having slightly higher mean number of filled grain percentage (91.51) than without RHA (89.90). Based on the results, it was revealed that the effect of potassium fertilizer on the percentage of filled grain was not significant different. The maximum filled grained percentage (93.07) was related to treatment 32 kg K ha^{-1} whereas the lowest number of filled grain percentage (89.20) was observed in K omission treatment. Similar results found by Krishnappa et al. (2006) and reported that applied K increased the number of filled grains.

Percentage of filled grain exhibited no significant difference among combined treatments (Table 4.16), but the highest filled grain percentage (94.77) was recorded in the combined effect of H_1K_3 (32 kg K ha^{-1}with 5 ton ha^{-1} RHA), and the lowest (87.57) was in the combined effect of potassium omission and without rice husk ash treatment (H_0K_0).

4.2.2.3 1000 grain weight (g)

1000 grain weight is a major determinant of the yield of rice. The effect of rice husk ash, different rates of potassium fertilizer and their combined effects were shown in Table 4.15 and 4.16. There was no significant difference in the mean number of 1000 grain weight among rice husk ash treatments but 1000 grain weight seem to be increased with the application of rice husk ash. The highest grain weight (22.09) was found in the RHA 5 ton ha^{-1} treatment and the lowest (21.83) was occurred in the treatment without RHA. The result reveled that there was highly significant difference among the potassium fertilizer treatments. Treatment with application of 32 kg K ha^{-1} showed the highest 1000 grain weight (22.42) which was statistically similar to the treatment 24 kg K ha^{-1} (22.28) followed by the treatment with 16 kg K ha^{-1} (21.62). Significantly lower mean seed weight (21.53) was found in K omission treatment, may be due to lower supplement of potassium. The highest rate of potassium fertilizer treatment 32 kg K ha^{-1} significantly increased 1000 grain weight; however the increase was 4 percent increase over K omission treatment. This result is in agreement with Kalita and Suhrawardy (2002) who reported that increasing K levels significantly affected the 1000 grain weight.

There is a nonsignificant interaction between rice husk ash and different rates of potassium fertilizer treatments. This result indicates that rice husk ash was not significantly affected by the potassium level applied and that the potassium effect did not differ significantly with the tested RHA. Even though, there was no significant difference, the mean grain weight appeared to be high (22.63) in the treatment with highest rates of potassium fertilizer in combination with rice husk ash H_1K_3 (32 kg K ha^{-1} with 5 ton ha^{-1} RHA).

4.2.2.4 Number of panicles $hill^{-1}$

Mean effect of rice husk ash and different rates of potassium fertilizer application on number of panicles $hill^{-1}$ was shown in Table 4.15. Number of panicles $hill^{-1}$ in without RHA was (8.56), while maximum number of panicles $hill^{-1}$ was noted plants treated with RHA 5 ton ha^{-1} treatment. The number of panicles $hill^{-1}$ showed highly significant variation ($P<0.01$) among the potassium fertilizer treatments. Maximum number of panicles $hill^{-1}$ was noted in plants treated with 32 kg K ha^{-1} (10.06), it was followed by 24 kg K ha^{-1} (9.56), afterward plants treated with 16 kg K ha^{-1} (8.25), and minimum of that was occurred from K omission (8.00). Number of panicles hill^{-1} exhibited no significant difference among rice husk ash treatments.

The results indicated that the combined effects of rice husk ash and potassium fertilizer on number of panicles hill^{-1} were not significant difference (Table 4.16). On the interaction of potassium and rice husk ash, treatment H_1K_3 (32 kg K ha^{-1} with 5 ton ha^{-1} RHA) had the maximum number of panicles hill^{-1} (10.36) and the minimum number of panicles hill^{-1} (7.36) related to treatment H_0K_0 (K omission and without RHA).

4.1.2.5 Grain yield (g plant^{-1})

Grain yield of rice husk ash, different rates of potassium fertilizer and their combined effects was demonstrated in Table 4.15 and 4.16. Highly significant difference of grain yield due to rice husk ash application was observed. Maximum grain yield (39.58 g plant^{-1}) was found in plants treated with RHA 5 ton ha^{-1}. The minimum gain yield was noted in the plants treated with without RHA. The significant increase in grain yields with the application of RHA seems to be attributed to the increased availability of nutrients and favorable effects of ash on soil physical conditions and microbial processes (Demeyer et al. 2001). This result was consistent with the findings of (Matte and Kene 1995) who stated that application of rice husk ash and other industrial wastes had a positive effect on grain and straw yield of rice. The finding was in accordance with the results of Prakash et al. (2007) who observed that significant increase in the grain and straw yields of rice with the application of RHA. Using RHA can give higher yield advantage than without using RHA treatment. After the wet season experiment, treatment 5 ton ha^{-1} RHA produced over 12% yield advantage than that of the treatment without RHA (Table 4.16).

It can be clearly seen that there was a highly significant difference on grain yield among the potassium fertilizer treatments tested in this experiment at 1% level. Grain yield of potassium fertilizer treatments ranged from 34.44 g plant^{-1} to 41.01 g plant^{-1}. The highest grain yield (41.01 g plant^{-1}) was noted by 32 kg K ha^{-1} which was statistically similar to that of 24 kg K ha^{-1} (38.63 g plant^{-1}). The highest grain yield was recorded in 32 kg K ha^{-1} because of the highest number of tillers and maximum number of spikelets panicle^{-1} also produced by 32 kg K ha^{-1}. The lowest grain yield (34.44 g plant^{-1}) was obtained from K omission treatment. 16 kg K ha^{-1} produced the second lowest grain yield (35.69 g plant^{-1}). Several workers reported significant response of grain yield of rice to the application of potassium (Quampah et al., 2011; Bahmanyar and Mashaee, 2010). This is also confirmed by Rahmatullah et al. (2007) who reported that potassium application significantly increased the grain yield of rice. These results are in agreement with the finding of Elliot et al. (2010) who concluded that potassium fertilization increased grain yield by 8 to 11% above rice receiving no K. Using potassium fertilizer can give higher yield response over control. After wet season experiment, treatments 32 kg K ha^{-1}, 24 kg K $ha^{-1}$and 16 kg K ha^{-1} give over 19%, 12% and 3% over K omission treatment (Table 4.16).

All of the combined effects were not significantly different on yield (Table 4.15). Grain yields ranged from 33.89 g $plant^{-1}$ to 44.16 g $plant^{-1}$. Among the combined effect of different rates of rice husk ash and potassium fertilizer, the more grain yield (44.16 g $plant^{-1}$) was noted from H_1K_3 (32 kg K ha^{-1} with 5 ton ha^{-1} RHA) which was statistically similar with the treatment H_1K_2 (24 kg K ha^{-1} with 5 ton ha^{-1} RHA) (41.72 g $plant^{-1}$), as well as the minimum amount of grain yield (33.89 g $plant^{-1}$) was identified in plants treated with K omission and without RHA treatment (H_0K_0). Even though, there were no statistically different, the grain yield of H_1K3 was 20% greater than H_1K_0 , 15% greater than H_1K_1 , 5% greater than H_1K_2 , 23% greater than H_0K_0 , 23% greater than H_0K_1 , 19% greater than H_0K_2 and 14% greater than H_0K_3 .

4.2.3 Grain harvest index (GHI)

Harvest index of tested rice variety as affected by rice husk ash, different rates of potassium fertilizer and their combined effects was presented in Table 4.18 and 4.19. Under the study, grain harvest index was not significantly affected by rice husk ash management. Despite the fact there was no significant difference, the harvest index appeared to be high (0.35) in the treatment 5 ton ha^{-1} RHA and the lowest (0.34) was in the treatment without RHA. No significant response was observed among potassium fertilizer treatments. However, the maximum value of harvest index (0.36) was achieved by 32 kg K ha^{-1}, whereas the minimum harvest index (0.32) was recorded from K omission treatment. In an investigation by Esfahani et al. (2008), harvest index was not affected by any kind of fertilizer treatments.

Combined effects of rice husk ash and potassium were significantly difference at 5% level on harvest index. Maximum harvest index (0.37) was recorded in H_1K_3 (32 kg K ha^{-1} with 5 ton ha^{-1} RHA) treatment whereas the lowest harvest index (0.31) was found in the treatment H_0K_0 (K omission and without RHA treatment). Harvest index was highly and positively correlated to grain yield (Sirajul et al. 2010). Increased HI appeared to have resulted from their increased spikelet number and to some extent increased grain weight, which enhanced the sink capacity (Ponnuthurai et al. 1984). The growth season also influenced HI. In the wet season, HI is generally lower due to low irradiance and higher temperature (De Datta et al. 1981).

4.2.4 Correlation between yield and yield components of rice

The correlation between grain yield and yield components of rice during the wet season, 2015 was described in Table 4.20. Grain yield was significantly and positively correlated with number of tillers hill^{-1}, number of spikelets panicle^{-1}, panicle length, 1000 grain weight and filled grains percentage at $P<0.01$. Grain yield was also positively correlated with grain harvest index at $P<0.05$. Number of spikelets panicle^{-1} also had direct effect on grain yield (Figure 4.15. Panicle length, 1000 grain weight and filled gains percentage had positive and significant correlation with grain yield.

Table 4.15 Mean effects of rice husk ash (RHA) and potassium fertilizer on yield and yield components of rice during wet season, 2015.

Treatments	Panicle length (cm)	No. of spikelets panicle^{-1}	Filled grain %	1000 grain weight (g)	No. of panicles hill^{-1}	Grain yield (g plant^{-1})
Rice Husk Ash						
Without RHA	31.60	90.33	89.90	21.83	8.56	35.31 b
With 5 ton ha^{-1} RHA	32.16	96.05	91.51	22.09	9.38	39.58 a
LSD $_{0.05}$	0.95	8.69	2.26	0.37	0.89	1.87
Potassium						
K omission	31.13	74.00 c	89.20	21.53 b	8.00 b	34.44 b
16 kg K ha^{-1}	31.61	79.53 c	89.54	21.62 b	8.25 b	35.69 b
24 kg K ha^{-1}	31.94	100.67 b	91.17	22.28 a	9.56 a	38.63 a
32 kg K ha^{-1}	32.85	118.56 a	93.07	22.42 a	10.06 a	41.01 a
LSD $_{0.05}$	1.34	12.29	3.19	0.52	1.26	2.64
Pr ≥ F						
Rice Husk Ash	0.2325	0.1858	0.1543	0.1636	0.0728	0.0001
Potassium	0.0854	0.0000	0.0637	0.0028	0.0064	0.0002

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

Table 4.16 Combined effects of rice husk ash and potassium fertilizer on yield and yield components of rice during wet season, 2015.

Treatments	Panicle length (cm)	No. of spikelets panicle^{-1}	Filled grain %	1000 grain weight (g)	No. of panicles hill^{-1}	Grain yield (g plant^{-1})
H_0 K_0	31.07	73.13	87.57	21.44	7.36	33.89
H_0 K_1	31.63	77.40	89.76	21.51	8.00	33.92
H_0 K_2	31.19	95.35	90.90	22.18	9.13	35.54
H_0 K_3	32.53	115.45	91.37	22.20	9.75	37.87
H_1 K_0	31.20	74.88	90.48	21.62	8.63	34.99
H_1 K_1	31.59	81.65	89.32	21.73	8.50	37.47
H_1 K_2	32.70	106.00	91.45	22.39	10.00	41.72
H_1 K_3	33.17	121.67	94.77	22.63	10.36	44.16
Pr ≥ F	0.6318	0.8934	0.5501	0.95	0.9300	0.1611
LSD $_{0.05}$	1.89	17.38	4.52	0.74	1.78	3.73
CV %	4.05	12.69	3.39	2.29	13.57	6.77

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

H_1 – (with rice husk ash), **H_0** – (without rice husk ash), **K_0** – control (K omission), **K_1** – (16 kg K ha^{-1}), **K_2** – (24 kg K ha^{-1}), **K_3** – (32 kg K ha^{-1})

Table 4.17 Comparison of grain yield and yield increased over control during wet season, 2015.

Treatments	Grain Yield (g palnt^{-1})	Yield increased over control (%)
Without RHA	35.31	0.00
With 5 ton ha^{-1} RHA	39.58	12.09
K omission	34.44	0.00
16 kg K ha^{-1}	35.69	3.63
24 kg K ha^{-1}	38.63	12.17
32 kg K ha^{-1}	41.01	19.08

Table 4.18 Mean effects of rice husk ash and potassium fertilizer on grain harvest index of rice during wet season, 2015.

Treatments	Grain harvest index (GHI)
Rice Husk Ash	
Without RHA	0.34
With 5 ton ha^{-1} RHA	0.35
LSD $_{0.05}$	0.02
Potassium	
K omission	0.32
16 kg K ha^{-1}	0.33
24 kg K ha^{-1}	0.35
32 kg K ha^{-1}	0.36
LSD $_{0.05}$	0.03
Pr ≥ F	
Rice Husk Ash	0.5169
Potassium	0.1244

*Means followed by the same letter in each column are not significantly different

Table 4.19 Combined effects of rice husk ash and potassium fertilizer on grain harvest index of rice during wet season, 2015.

Treatments	**Grain harvest index (GHI)**
H_0 K_0	0.31
H_0 K_1	0.34
H_0 K_2	0.35
H_0 K_3	0.35
H_1 K_0	0.33
H_1 K_1	0.33
H_1 K_2	0.36
H_1 K_3	0.37
Pr ≥ F	0.8024
LSD $_{0.05}$	0.05
CV %	10.19

*Means followed by the same letter in each column are not significantly different

H_1 – (with rice husk ash), **H_0** – (without rice husk ash), **K_0** – control (K omission), **K_1** – (16 kg K ha^{-1}), **K_2** – (24 kg K ha^{-1}), **K_3** – (32 kg K ha^{-1})

Table 4.20 Correlation between yield and yield components of rice as affected by rice husk ash and different rates of potassium fertilizer during the wet season, 2015.

	No. of panicles hill^{-1}	No. of spikelets panicle^{-1}	Grain Harvest Index	Panicle length	1000 grain weight	Filled grain %	Yield
No. of panicles hill^{-1}	1						
No. of spikelets panicle^{-1}	0.9302**	1					
Grain Harvest Index	0.9271**	0.8766**	1				
Panicle length	0.8520**	0.8903**	0.8271*	1			
1000 grain weight	0.9616**	0.9491**	0.9192**	0.8233*	1		
Filled grain %	0.9071**	0.8510**	0.9205**	0.8128*	0.8814**	1	
Yield	0.8743**	0.8375**	0.8053*	0.9122**	0.8827**	0.8325*	1

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

4.3 Effect of Rice Husk Ash (RHA) on Some Physicochemical Properties of Soil

4.3.1 Effect of RHA on some soil physical properties

Application of rice husk ash improves some of the physical properties of silt loam soil of Rakhine State, Minbya Township (Table 4.21). Bulk density is an indicator of soil compaction and soil health. Compaction generally increase soil bulk density and soil strength, and decrease water infiltration, available water capacity, hydraulic conductivity, soil porosity, plant nutrient availability and soil microorganism activity (Froehlich 1984). Before experiment, bulk density of soil is 1.21 (g cm^{-3}). After experiment I, bulk density decreased from 1.02 to 0.98 in the rice husk treated treatments and decreased up to 0.82 after the experiment II. Among the treatments, rice husk treated soils show lower bulk density values than that of the soils that treated without RHA (Table 2) in both seasons. Generally, loose, well-aggregated, porous soils and those rich in organic matter have lower bulk density. This result is also supported by Masulili et al. (2010) who reported that decreased in soil bulk density of the soil treated with organic soil amendment was, at least partly, due to the formation of soil aggregate.

The initial value of soil porosity before experimental soil is 41.55 %. The application of RHA increases total soil porosity from about 50% to above 60% in all RHA treatments after experiment II (Table 4.21). Similar results were found by Metzger and Yaron (1987). Harris et al. (1966) also stated that the increase in soil porosity with soil aggregation, which in turn will decrease soil bulk density. This process will increase total porosity, and at the same time will increase soil water retention (Sharma and Uehara 1968). In this experiment, soils treated with RHA have been shown to have a lower bulk density, higher effective porosity and superior particle density than without RHA treated soils. The increase in soil porosity was correlated with an increase in rice yields. The lower rice production was noticed when K omission was applied and no RHA was added (H_1K_3). This treatment was also characterized by higher bulk density and lower porosity. From the results of this study it can be concluded that the RHA can help to avoid yield reduction in rice production by increasing the physical properties of silt loam soil of Rhakhing State, Minbya Township.

Table 4.21 Effect of rice husk ash on physical properties of silt loam soil of Minbya Township, Rakhine State.

Treatments		Bulk density (g cm^{-3})	Porosity (%)
Experiment I (Dry season)			
Without RHA	K omission	1.16	49.34
	16 kg K ha^{-1}	1.15	49.34
	24 kg K ha^{-1}	1.16	49.34
	32 kg K ha^{-1}	1.16	49.12
With 5 ton ha^{-1} RHA	K omission	1.02	54.05
	16 kg K ha^{-1}	1.01	55.11
	24 kg K ha^{-1}	0.98	56.25
	32 kg K ha^{-1}	1.01	55.11
Experiment II (Wet Season)			
Without RHA	K omission	1.11	50.45
	16 kg K ha^{-1}	1.09	50.68
	24 kg K ha^{-1}	1.1	50.67
	32 kg K ha^{-1}	1.09	50.68
With 5 ton ha^{-1} RHA	K omission	0.86	60.19
	16 kg K ha^{-1}	0.84	60.93
	24 kg K ha^{-1}	0.82	62.04
	32 kg K ha^{-1}	0.84	60.93

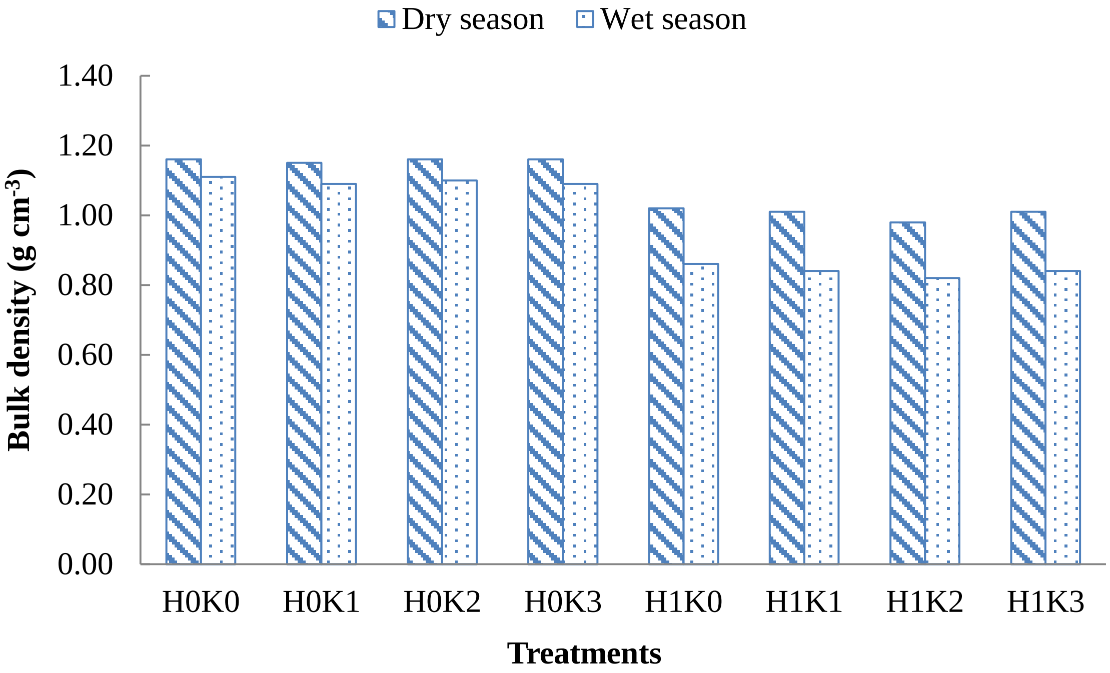

Figure 4.13 Effect of rice husk ash on bulk density (g cm^{-3}) of silt loam soil in dry and wet seasons, 2015.

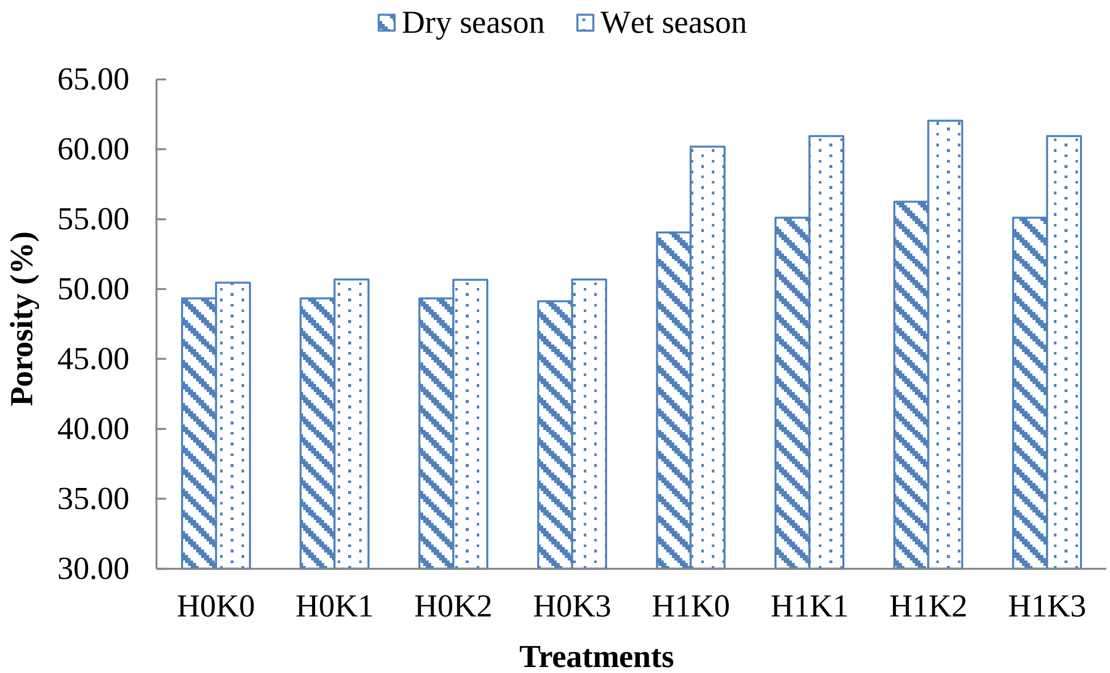

Figure 4.14 Effect of rice husk ash on soil porosity (%) of silt loam soil in dry and wet seasons, 2015.

4.3.2 Effect of RHA on some soil chemical properties

The effect of rice husk ash on the chemical properties of silt loam soil in Minbya Township, Rakhine State during the experiment I and II (Dry and Wet seasons, 2015) are presented in Table 4.22. During the experiment I and II, chemical properties of experimental soils were improved substantially by the application of rice husk ash.

Rice husk ash has a high pH; therefore, it is reasonable that the soil treated with rice husk ash also had a high pH (Table 4.22). The impact of soil pH on nutrient availability is very important both for maximum plant availability and to avoid potentially toxic levels at very low or very high pH. A soil pH of 6.5 to 7.0 is often considered "ideal" for most plants. For the plant nutrients as a whole, good overall nutrient availability is found near pH 6.5 (Henery D. F. 1951). Before experiment, pH value of experimental soil is (5.8). After experiment I, pH values of RHA amendment soils increased up to (6.16). Seripong (1988) noted that RHA improved rice yields, soil pH, and organic matter content of the Thailand acid soils. After the experiment II, pH values increased up to (6.71) to (6.96) in the RHA amended treatments. Selvakumari (2000) reported that uptake of Si by rice would excrete OH^- ions which would tend to rise soil pH. Ratna et al. (1996) also reported that carbonized rice husk can protect the plant from nematode damage and increase soil pH and soil microbial activity.

Cation exchange capacity (CEC) is a measure of the soil's ability to hold positively charged ions. It is a very important soil property influencing soil structure stability, nutrient availability, soil pH and the soil's reaction to fertilizers (Hazleton and Murphy 2007). Soils with high CEC not only hold more nutrients, they are better able to buffer or avoid rapid changes in the soil solution levels of these nutrients. If the CEC of soil was low, the soil has low nutrient retention capacity, which limits the amount of soil nutrients for plant growth (Tansiri and Saifak 1999). The increase in CEC and soil pH with the addition of RHA has been shown elsewhere (Bot and Benites 2005). After the experiment I, soils treated with RHA had the higher values of CEC than untreated soils. Values of CEC increased from (8.06) in (H_0K_0) treatments up to (11.04) in (H_1K_3) treatments. The increase in CEC of the RHA amendment soils would probably due to the negative charge arising from the carboxyl groups of the RHA (Agusalim Masulili 2010). After the experiment II, the results indicated that values of CEC under the application of RHA were higher than those of the soils that do not apply RHA. The values of CEC with RHA treated soil had increased by +6.28, +6.17, +6.67 and +6.71 than that of the initial value of CEC. Pichot and Roche (1972) also stated that addition of organic materials was important in improving or at least maintaining the CEC. The CEC is linked closely to the organic matter content of the soil. It increases gradually with time where organic residues are retained, first in the top soil and later also at greater depth.

Soil organic carbon (SOC) has an important role in improving soil quality and sustainable production. Enhancement of SOC in croplands may help to enhance the cereals production, as well as increasing soil carbon sequestration (Pan and Zhao 2005).The results suggested that SOC can be greatly improved with application of RHA (Table 4.22). After the experiment I, soil organic carbon content of RHA amended soils had increased by +0.13, +0.12, +0.12, and +0.13 than that of the initial SOC. Lal et al. 1998 point out that the value of soil organic C is related to more than its improvement in the water-holding capacity and nutrient availability in the soil. During the experiment II, SOC content of RHA amended increased over +0.49, +0.49, +0.50 and +0.49 than initial soil. Enrichment of soil organic carbon increased the macro pores as well as the total porosity volume (Dinel et al. 1991).

The incorporation of RHA in this study supplied the soil with significant amounts of K. RHA contain large quantities of K, and their recycling can markedly increase K availability in soils (Chatterjee and Mondal 1996; Mubarak et al. 2003; Mubarak and Dawi 2009). After the experiment I, slightly increased in K values were found in RHA treated soils and the increased were +0.3, +3.3 and +6.43 than that of the initial soil K. The availability of K increased markedly with RHA addition (Sahoo and Kar 1998) because rice husk ash contained adequate amounts of K. Higher values of soil K were noted from RHA amended soils and the increase were over +3.3, +7.3 and +9.81 than that of the initial soil K. Apart from the treatment H_0K_0, available K contents of RHA amended soils increased obviously than that of the and initial soil after conducting the experiment II. The immediate release of K from the ash could result in higher K availability in the rice husk biochar amended soils (Tryon 1948).

The results from the experiment I indicated that the available P contents of RHA amended soils were higher than those of amended soils. When compared initial soil P value, the available P content of RHA amended soils had increased by +0.94, +1.25, +1.11 and +1.03. For the P nutrient, this increase could have been as a result of increasing the soil pH due to rice husk ash application (Agusalim 2010). Significant improvement of available P as a result of rice husk ash application is reported in sandy or loamy soils

(Tryon 1948). After the experiment II, RHA amended soils produced higher available P contents. Soils having higher organic matter tended to have higher P availability. RHA treated soils produced higher pH values and better organic carbon contents. Therefore, soils treated with RHA also produced superior values of available P (Table 4.18). AICOAF (2001) reported that husk ash increases the soil pH, thereby increasing available phosphorous, it improves the aeration in the crop root zone and also increases the water holding capacity and level of exchangeable potassium and magnesium.

Table 4.22 Effect of rice husk ash on chemical properties of silt loam soil of Minbya Township, Rakhine State.

Treatments		pH	CEC ($cmol_c\,kg^{-1}$)	Organic carbon (%)	Available K ($mg\,kg^{-1}$)	Available P ($mg\,kg^{-1}$)
Experiment I (Dry season)						
Without RHA	K omission	5.83	8.06	0.94	49.00	17.61
	16 kg K ha^{-1}	5.85	8.14	0.94	54.40	17.75
	24 kg K ha^{-1}	5.84	8.13	0.95	55.70	17.68
	32 kg K ha^{-1}	5.85	8.19	0.94	56.64	17.73
With 5 ton ha^{-1} RHA	K omission	6.16	11.01	1.04	52.00	18.54
	16 kg K ha^{-1}	6.14	11.04	1.03	57.00	18.85
	24 kg K ha^{-1}	6.14	11.04	1.03	60.00	18.71
	32 kg K ha^{-1}	6.12	11.03	1.04	63.13	18.63
Experiment II (Wet Season)						
Without RHA	K omission	5.93	10.12	0.98	44.50	17.77
	16 kg K ha^{-1}	6.03	10.31	0.97	54.00	18.99
	24 kg K ha^{-1}	6.08	10.49	0.98	57.00	18.09
	32 kg K ha^{-1}	6.05	10.38	0.98	59.00	17.25
With 5 ton ha^{-1} RHA	K omission	6.71	12.48	1.40	53.68	20.24
	16 kg K ha^{-1}	6.83	12.37	1.40	60.00	20.56
	24 kg K ha^{-1}	6.96	12.87	1.41	64.00	20.86
	32 kg K ha^{-1}	6.92	12.91	1.40	66.51	20.39

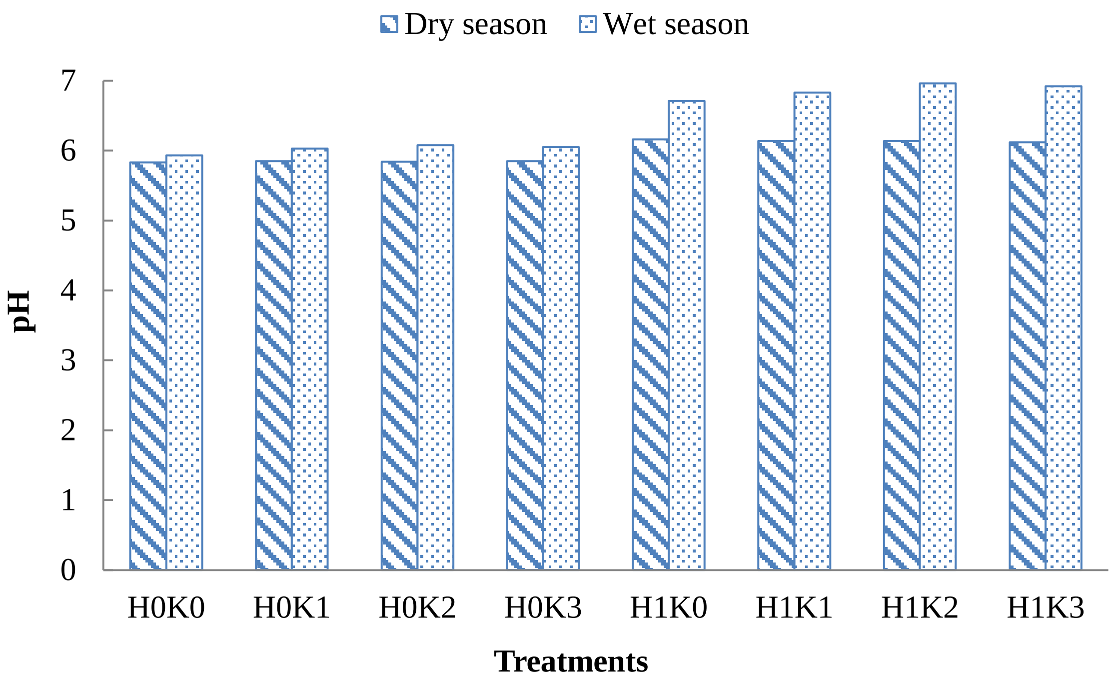

Figure 4.15 Effect of rice husk ash on pH of silt loam soil in dry and wet seasons, 2015.

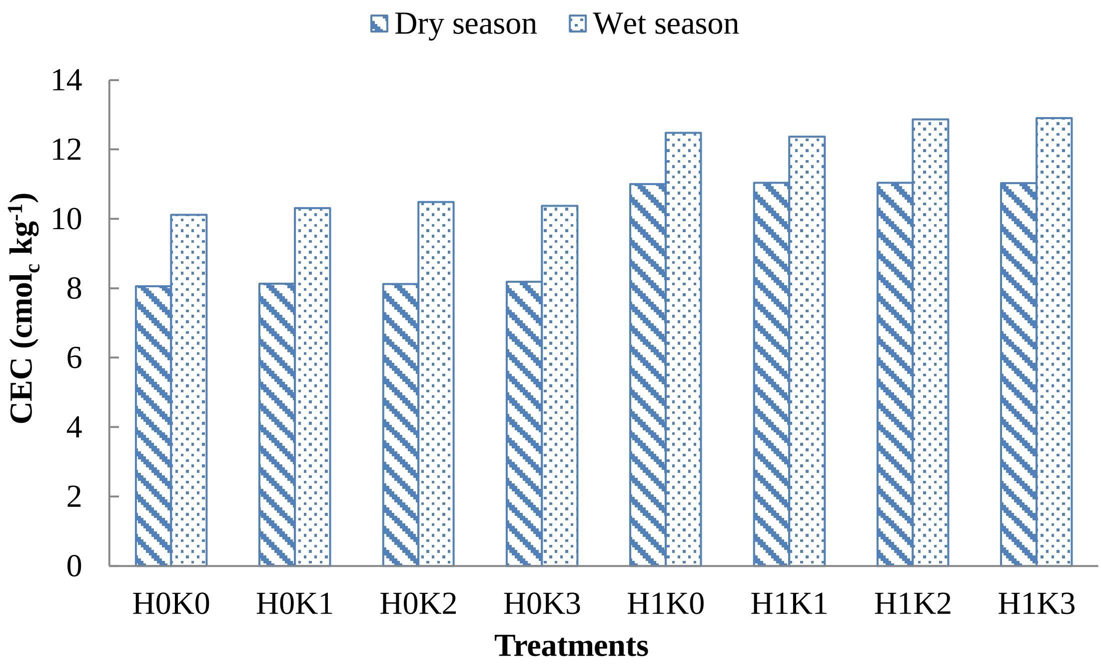

Figure 4.16 Effect of rice husk ash on CEC ($cmol_c$ kg^{-1}) of silt loam soil in dry and wet seasons, 2015.

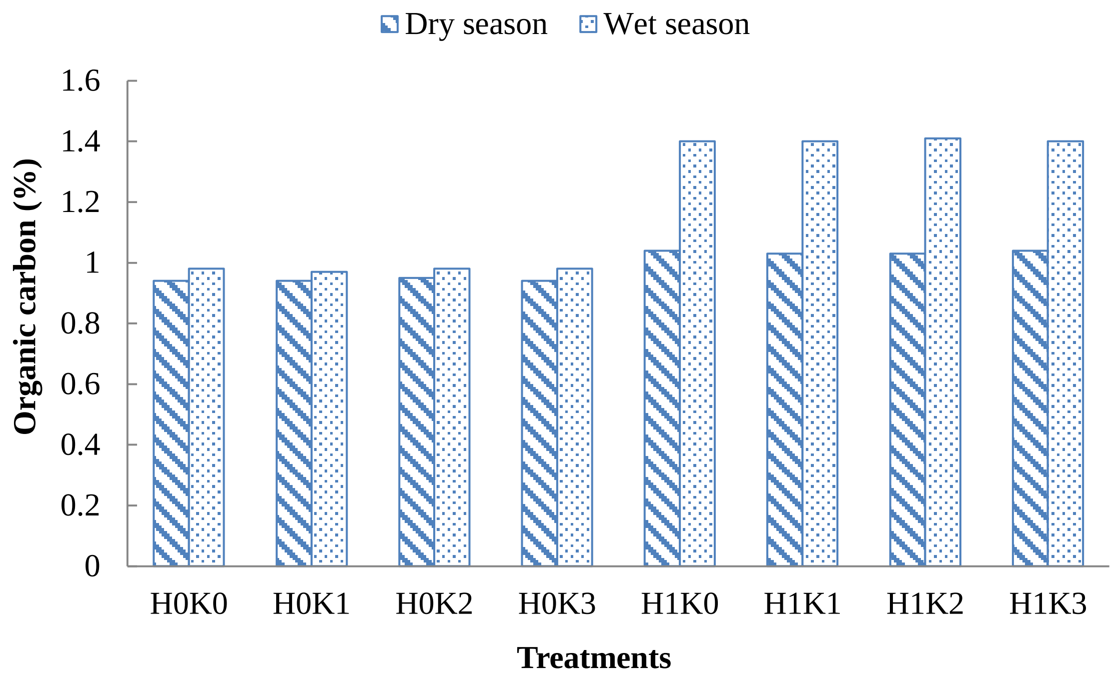

Figure 4.17 Effect of rice husk ash on organic carbon (%) of silt loam soil in dry and wet seasons, 2015.

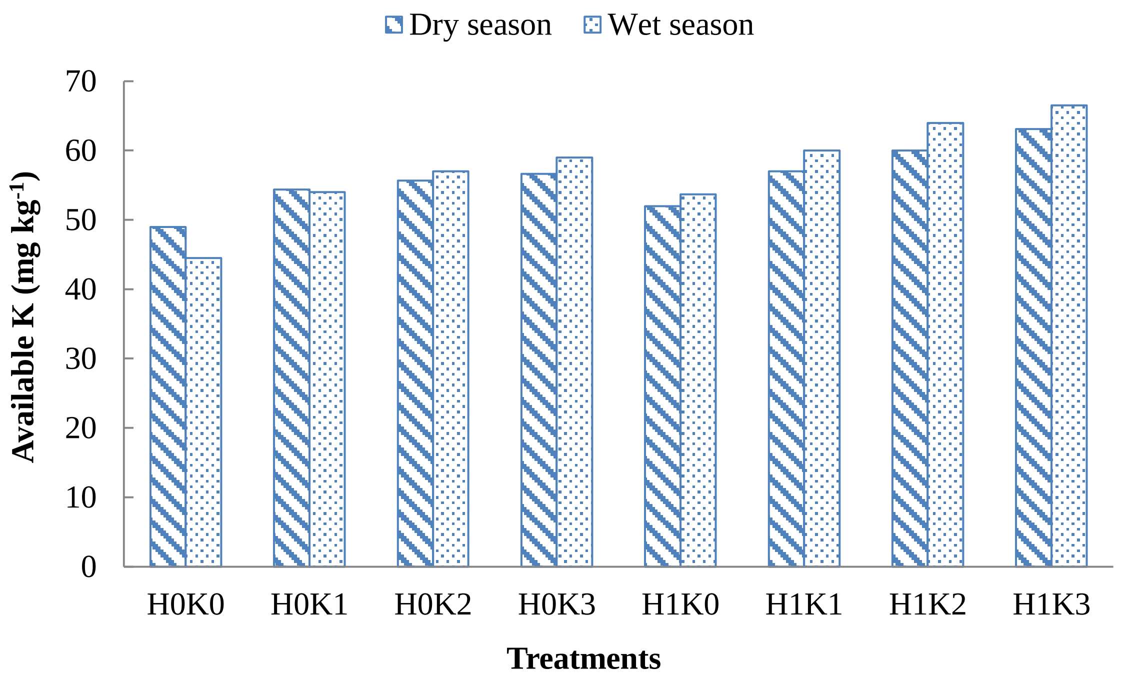

Figure 4.18 Effect of rice husk ash on available K (mg kg^{-1}) of silt loam soil in dry and wet seasons, 2015.

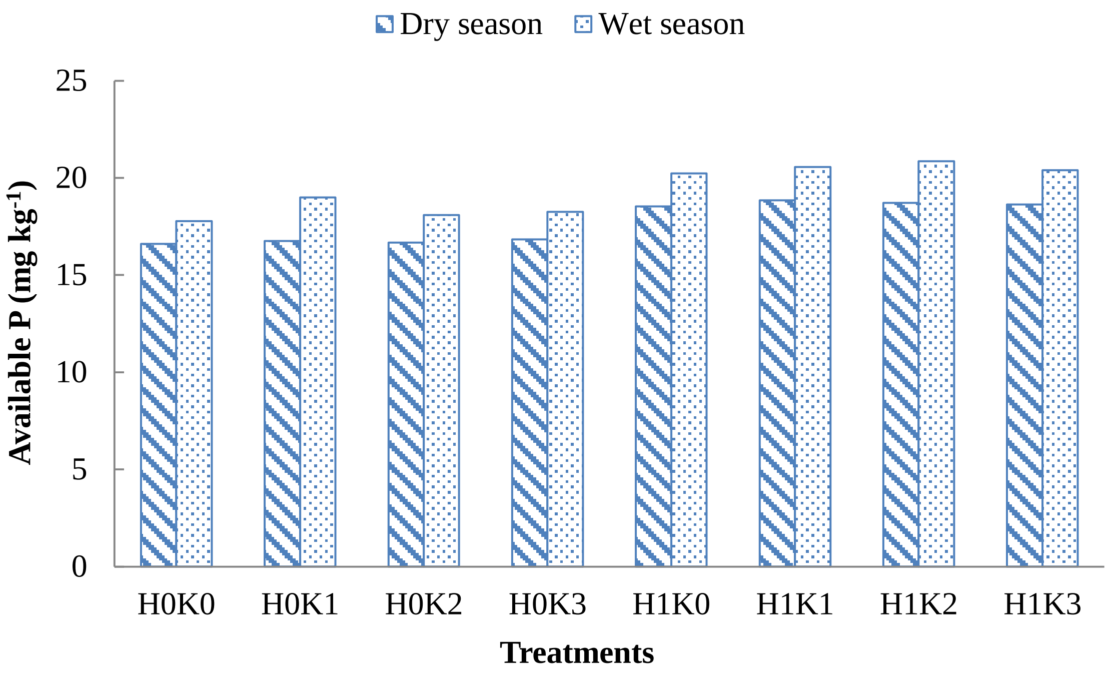

Figure 4.19 Effect of rice husk ash on available P (mg kg^{-1}) of silt loam soil in dry and wet seasons, 2015.

Table 4.23 Improvement of some soil physical and chemical properties as affected by rice husk ash application over soil properties before growing after the experiment I (Dry season).

	Improvement of soil properties over before growing							
	H_0K_0	**H_0K_1**	**H_0K_2**	**H_0K_3**	**H_1K_0**	**H_1K_1**	**H_1K_2**	**H_1K_3**
Soil physical properties								
Bulk density	- 0.05	- 0.06	- 0.05	- 0.05	- 0.19	- 0.20	- 0.23	- 2.00
Particle density	- 0.10	- 0.12	- 0.10	- 0.11	- 0.17	- 0.14	- 0.15	- 0.14
Porosity	+ 7.79	+ 7.79	+ 7.79	+ 7.57	+12.50	+13.56	+14.70	+13.56
Soil chemical properties								
pH	+ 0.03	+ 0.05	+ 0.04	+ 0.05	+ 0.36	+ 0.34	+ 0.34	+ 0.32
CEC	+ 1.86	+ 1.94	+ 1.93	+ 1.99	+ 4.81	+ 4.84	+ 4.84	+ 4.83
Organic carbon	+ 0.03	+ 0.03	+ 0.04	+ 0.03	+ 0.13	+ 0.12	+ 0.12	+ 0.13
Available K	- 7.70	- 2.30	- 1.00	- 0.06	- 4.70	+ 0.03	+ 3.30	+ 6.43
Available P	+ 0.01	+ 0.15	+ 0.08	+ 0.13	+ 0.94	+ 1.25	+ 1.11	+ 1.03

Table 4.24 Improvement of some soil physical and chemical properties as affected by rice husk ash application over soil properties before growing after the experiment II (Wet season).

	Improvement of soil properties over before growing							
	H_0K_0	H_0K_1	H_0K_2	H_0K_3	H_1K_0	H_1K_1	H_1K_2	H_1K_3
Soil physical properties								
Bulk density	- 0.10	- 0.12	- 0.11	- 0.12	- 0.35	- 0.37	- 0.39	- 0.37
Particle density	- 0.15	- 0.18	- 0.16	- 0.18	- 0.23	- 0.24	- 0.23	- 0.24
Porosity	+ 8.90	+ 9.13	+ 9.12	+ 9.13	+ 18.64	+ 19.38	+ 20.49	+ 19.38
Soil chemical properties								
pH	+ 0.13	+ 0.23	+ 0.28	+ 0.25	+ 0.91	+ 1.03	+ 1.16	+ 1.12
CEC	+ 3.92	+ 4.11	+ 4.29	+ 4.18	+ 6.28	+ 6.17	+ 6.67	+ 6.71
Organic carbon	+ 0.07	+ 0.06	+ 0.07	+ 0.07	+ 0.49	+ 0.49	+ 0.50	+ 0.49
Available K	- 12.20	- 2.70	+ 0.30	+ 2.30	- 3.02	+ 3.30	+ 7.30	+ 9.81
Available P	+ 0.17	+ 1.39	+ 0.49	+ 0.65	+ 2.64	+ 2.96	+ 3.26	+ 2.79

CHAPTER V
CONCLUSION

The present study emphasize on the effects of different rates of potassium fertilizer and rice husk ash (RHA) on grain yield and yield components of rice in dry and wet seasons, 2015. From the two strong investigations, the following could be concluded.

Potassium and RHA application were significant effect on plant growth parameters such as plant height and number of tillers hill^{-1} but did not significant effect on some yield components parameters such as panicle length, number of spikelets panicle^{-1}, filled grains % and 1000 grains weight. Potassium fertilizer and RHA application did not cause significant differences in the above listed parameters although all parameters had slightly higher values as compared with the treatment K omission and without RHA application. However, clear and significant effects on number of panicles hill^{-1} and grain yield were detected.

In different rates of potassium treatments, 32 kg K ha^{-1} produced more grain yield in both seasons, it was followed by 24 kg K ha^{-1}, after that it was in 16 kg K ha^{-1}, also the minimum of grain yield was found in K omission treatments. In both seasons, the beneficial effect of applying rice husk ash on grain yield was occurred, whereas with RHA 5 ton ha^{-1} produced the highest grain yield than without RHA. Among the combined effect of potassium fertilizer and rice husk ash, the utmost grain yield was noticed in H_1K_3 (32 kg K ha^{-1} with 5 ton ha^{-1} RHA), afterward plants treated by H_1K_2 (24 kg K ha^{-1} with 5 ton ha^{-1} RHA), and the minimum amount of grain yield was found in H_0K_0 (with K omission and without RHA treatment) in both seasons.

Potassium application significantly increased grain yield of Sin Thwe Latt rice variety under silt loam soil condition of Minbya Township. Since the indigenous soil K availability is low, and thus soil cannot supply K to plants adequately for an indefinite period of time. So the recommended potassium fertilizer rate (16 kg K ha^{-1}) cannot supply the highest amount of grain yield in both seasons. Rice husk ash can significantly increase the number of tillers hill^{-1} and grains yield of Sin Thwe Latt rice variety. The present study pointed out that rice husk ash contains nutrient materials and able to use as a fertilizer.

After harvesting, some physico-chemical properties of silt loam soil were markedly changed due to the RHA application. After experiment II, physical properties of silt loam soil such as bulk density values decreased significantly with an accompanying increase in total porosity and soil particle density at all RHA treatments compared to without RHA treatments. The increase in soil porosity was correlated with an increase in rice yields. The lower rice production was noticed when K omission was applied and no RHA was added (H_0K_0). This treatment was also characterized by higher bulk density, minimum particle density and lower porosity.

Some chemical properties of silt loam soil such as pH, CEC, organic carbon, available K and available P were also noticeably increased due to the RHA application. With respect to the RHA unamended soil, soil treated with RHA amendment showed apparent increases of soil pH, CEC, organic carbon, available K and available P. The improvement of soil properties with RHA applications resulted in an improvement of rice growth as shown by an increase in plant height, and number of tillers hill^{-1}. According to the results of this study, it can be obviously seen that RHA can help to avoid yield reduction in rice production by increasing the physical and chemical properties of silt loam soil condition. Apart from improving soil productivity as shown in this study it will save the farmer the cost of buying chemical fertilizers as RHA can obtain free in the study area. From the economic point of view, farmers can use the combination of rice husk ash and reduced rate of potassium fertilizers to boost the yield of rice.

Future research:

Since this study was tested in pot condition, in Yezin, Naypyitaw, further field study of the treatments used in this experiment should be carried out to ascertain their effects on the yield of other rice varieties under different rice agroecosystems.

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APPENDICES

Appendix 1. Total rainfall, temperature and relative humidity data at Yezin during experimental period (2015).

Month	Temperature (°C)		Rainfall (mm)	Relative Humidity (%)
	Maximum	Minimum		
March	38.7	19.5	0	49
April	38.9	22.9	16	50
May	37.7	24.4	125	61
June	33.9	23.6	132	80
July	31.3	24.1	289	88
August	32.7	24.0	85	85
September	33.3	24.3	108	85
October	32.8	22.7	83	85
November	33.4	19.9	0	72
December	32.2	16.3	7	69

Source: Agrometerological Station, Department of Agricultural Research Yezin (2015)

Appendix 2. Varietal characters of Sin Thwe Latt rice variety

Variety name	Sin Thwe Latt
Grain type	Emata
Day to maturity	135
Plant height (cm)	120
Panicles per hill	9 to 11
Grains per panicle	246
1000 grain weight(g)	27.9
Grain appearance	Translucent
Grain measurement	
Length(mm)	10.06
Breath(mm)	2.32
Length/Breath ratio	4.34
Amylose content(%)	20.4
Eating quality	Good/Soft
Yield (t ha-1)	4.5 to 6
Seed source	DAR

Appendix 3. Effect of rice husk ash and different rates of potassium fertilizer on grain yield of rice during the dry season, 2015.

Treatments	Basket acre^{-1}	Ton ha^{-1}
Rice Husk Ash		
Without RHA	143.23 b	7.16 b
With 5 ton ha^{-1} RHA	185.18 a	9.26 a
LSD $_{0.05}$	24.91	1.25
Potassium		
K omission	131.76 b	6.59 b
16 kg K ha^{-1}	143.62 b	7.18 b
24 kg K ha^{-1}	180.73 a	9.04 a
32 kg K ha^{-1}	200.70 a	10.03 a
LSD $_{0.05}$	35.23	1.76
Pr > F		
RHA	0.0021	0.0021
Potassium	0.0017	0.0017

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

Appendix 4. Combined effects of rice husk ash (RHA) and different rates of potassium fertilizer on grain yield of rice during the dry season, 2015.

Treatments	Basket acre^{-1}	Ton ha^{-1}
H_0 K_0	101.25 d	5.06 d
H_0 K_1	121.61 bc	6.08 bc
H_0 K_2	171.79 b	8.59 ab
H_0 K_3	178.25 ab	8.91 ab
H_1 K_0	162.27 bc	8.11 bc
H_1 K_1	165.61 bc	8.28 bc
H_1 K_2	189.68 ab	9.48 ab
H_1 K_3	223.16 a	11.16 a
LSD $_{0.05}$	49.83	2.49
Pr>F	0.65	0.65
CV%	20.63	20.63

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

H_1 – (with rice husk ash), **H_0** – (without rice husk ash), **K_0** – control (K omission), **K_1** – (16 kg K ha^{-1}), **K_2** – (24 kg K ha^{-1}), **K_3** – (32 kg K ha^{-1})

Appendix 5. Effect of rice husk ash and different rates of potassium fertilizer on grain yield of rice during the wet season, 2015.

Treatments	Basket acre^{-1}	Ton ha^{-1}
Rice Husk Ash		
Without RHA	89.61 b	4.48 b
With 5 ton ha^{-1} RHA	124.47 a	6.22 a
LSD $_{0.05}$	16.60	0.82
Potassium		
K omission	70.82 c	3.54 c
16 kg K ha^{-1}	92.40 c	4.62 bc
24 kg K ha^{-1}	113.65 b	5.68 b
32 kg K ha^{-1}	151.29 a	7.56 a
LSD $_{0.05}$	23.48	1.17
Pr > F		
RHA	0.0248	0.003
Potassium	0.0000	0.0000

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

Appendix 6. Combined effects of rice husk ash (RHA) and different rates of potassium fertilizer on grain yield of rice during the wet season, 2015.

Treatments	**Basket acre^{-1}**	**Ton ha^{-1}**
H_0 K_0	62.92 d	3.15 d
H_0 K_1	75.36 d	3.77 d
H_0 K_2	85.47 cd	4.28 cd
H_0 K_3	143.69 ab	6.74 ab
H_1 K_0	78.71 cd	3.94 cd
H_1 K_1	109.43 bc	5.47 bc
H_1 K_2	141.84 ab	7.09 ab
H_1 K_2	167.88 a	8.39 a
LSD $_{0.05}$	33.21	1.65
Pr>F	0.3771	0.3783
CV%	21.10	21.09

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

H_1 – (with rice husk ash), **H_0** – (without rice husk ash), **K_0** – control (K omission), **K_1** – (16 kg K ha^{-1}), **K_2** – (24 kg K ha^{-1}), **K_3** – (32 kg K ha^{-1})