# FLOWERING RESPONSE OF PARENTAL LINES OF HYBRID RICE (*Oryza sativa* L.) TO POTASSIUM FERTILIZER APPLICATION

**A thesis presented by**

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**to**

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The thesis attached hereto, entitled **"Flowering Response to Parental Lines of Hybrid Rice to Potassium Fertilizer Application"** was prepared under the direction of the chairman of the candidate supervisory committee and has been approved by all members of that committee as a partial fulfillment of the requirements for the degree of **Master of Agricultural Science (Soil Science).**

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## DECLARATION OF ORIGANILITY

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 HLA KYAW AND DAW HLA KYI**

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# FLOWERING RESPONSE OF PARENTAL LINES OF HYBRID RICE (*Oryza sativa* L.) TO POTASSIUM FERTILIZER APPLICATION

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## ABSTRACT

One of the major constraints to the adoption of hybrid rice technology is the unavailability of quality seeds. Among the different factors affecting the success of seed production, obtaining proper synchronization of flowering of the parental lines of hybrid rice is the most important factor.

Two times of pot experiments were conducted at Department of Agricultural Chemistry in Yezin Agricultural University to study the flowering response of parental lines of hybrid rice to the application of potassium fertilizer and to observe the optimum potassium fertilizer rate for parental lines to adjust the flowering. It was laid out as factorial arrangement in completely randomized design with three replications. Factor A was parental lines such as Long 4, Long 6 and Long 8 for both seed parents (A lines) and pollen parents (R lines) and factor B was potassium fertilizer rates. The used fertilizer rate for A and R lines were 0, 30, 40, 50 kg KCl $ha^{-1}$ and 0, 10, 20, 30 kg KCl $ha^{-1}$ respectively. Potassium fertilizer was applied before III stage of panicle initiation (differentiation of the secondary branch primordia and spikelet primordia).

Days to initial heading (5% flowering) is more reliable parameter than days to 50% flowering which become more subjective. The flowering response of parental lines was not statistically different but it was numerically different by potassium fertilizer application before III stage of panicle initiation in both seasons. For initial heading (5% flowering) of A lines, Long 4 variety with 50 kg KCL $ha^{-1}$ flowered 1-3 days earlier than those of other treatments; Long 6 and Long 8 variety with 40 kg KCl $ha^{-1}$ bloomed 2-5 days earlier than those of other treatments. For initial heading of R lines, Long 4 with 30 kg KCl $ha^{-1}$ flowered earlier 2 -5 days; Long 6 and Long 8 variety with 30 kg KCl $ha^{-1}$ flowered 1-3 days earlier than those of other treatments. Based on the findings, 40 kg KCl $ha^{-1}$ for Long 6 A and Long 8 A lines, 50 kg KCl $ha^{-1}$ for Long 4 A line and 30 kg KCl $ha^{-1}$ for all R lines could be applied to adjust the flowering time of parental lines.

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# CHAPTER I

# INTRODUCTION

Rice (*Oryza sativa* L.) is the stable food of more than half of the world population (Ginigaddara and Ranamukhaarachchi 2009). About 90 percent of all total rice grain in the world is produced and consumed in Asia. It feeds more than half of world population. The current world population is 7 billion and will reach 8 billion in 2030. It has been estimated that the world will have to produce 60% more rice by 2030 than what it produce in 1995. Therefore to increase production of rice plays a very important role in food security and poverty alleviation. In order to enhance farm yields, breeding of new rice varieties with higher yield potential should be made (Peng et al. 2008). The yield potential of irrigated rice was further increased by the development of hybrid rice in 1976 in China (Yuan et al. 1994). Peng et al. (1999) reported that indica hybrid rice has increased yield potential by 9% over the best inbred cultivars in tropical irrigated lowlands.

Rice is the life-line for Myanmar because it is not only a dominant food crop, but also plays an important role in her national economy. It is the staple food for more than 70 per cent of world population and a source of livelihood for about 120-150 million rural households. There is no scope for horizontal expansion of cultivable area. Therefore, rice productivity and production have to be raised to meet the future demand by increasing yield. Exploitation of heterosis through the development of hybrid rice is one to improve rice productivity among various strategies. Therefore boosting the rice production and making it available to the consumers at the affordable prices is always on the top political agenda for any national government in the region.

Myanmar started search on hybrid rice in 1997 and released its hybrid seeds. Hybrid rice activities in Myanmar are being pursued by both the public and private sectors. In 2001, the area cultivated in hybrid rice was about 47000 hectares. In accordance with National Planning Targets cultivation of paddy is being implemented, aiming to 7.0 million hectares under monsoon paddy and 1.3 million hectares under summer paddy in 2010-2011. Average yield per acre is also targeted to reach 4.1MT $ha^{-1}$. Paddy sown acre for 2009-2010 is 8.07 million hectares and production was reached to 33 million metric ton. To generate increasing production of paddy, measures are also being under taken in growing high yielding varieties, including introduction of hybrid rice varieties. During the summer season in 2011, total sown area of Pa-le-thwe hybrid seed for seed production reached to 304 hectares in which 40 hectares in Shwe Taung farm, 40 hectares in Yezin Agricultural University, 121 hectares by the financial assistance of International Sun Moon Star Company, 20 hectares by Dagon International Company, 40 hectares by Green Asia Company, 20 hectares by Sin Shwe Li Company, in East Dagon Special Zones for Agricultural Mechanized Farm in Yangon, and 10 hectares in Kayin State and 10 hectares in Mon State (MOAI 2012).

Hybrid rice is any genealogy of rice produced by crossbreeding different kinds of rice. The earliest high-yield rice was cultivated by Henry 'Hank' Beachell in 1966, but it was not until the 1974 that the first hybrid rice varieties were released in China. In 1974, Chinese scientists successfully transferred the male sterility gene from wild rice to create the cytoplasmic genetic male-sterile (CGMS) line and hybrid combination. The first generation of hybrid rice varieties were three-line hybrids and produced yields that were about 15 to 20 percent greater than those of improved or high-yielding varieties of the same growth duration. Utilization of hybrid varieties can increase rice yields by 20-30% over the high yielding variety, at the farm level under irrigated conditions (Lin and Yuan 1980). Rice hybrids yield about 20 per cent increased grain yield over inbred cultivars (Virmani et al. 1991). High-yield crops, like hybrid rice, are one of the most important tools for combating world food crises.

According to the China Daily, in 2011, Yuan Longping developed new hybrid rice that can produce 13.9 tons of rice per hectare. In China, hybrid rice is estimated to be planted on more than 50% of rice-growing land there and it is credited with helping the country increase its rice yields, which are among the highest within Asia. Hybrid rice is also grown in many other important rice producing countries including Indonesia, Vietnam, Myanmar, Bangladesh, India, Sri Lanka, Brazil, USA, and the Philippines. The profitability of hybrid rice in three Indian states varied from being equally profitable as other rices to 34% more profitable (IRRI 2010). In 1974, Chinese scientists successfully transferred the male sterility gene from wild rice to create the cytoplasmic genetic male-sterile (CMS) line and hybrid combination.

Commercial exploitation of hybrid vigor is one of the most important applications of genetics in agriculture. It has not only contributed to food security, but has also benefited the environment (Duvick 1999). Since rice is a self-pollinated crop, hybrid seed production must be based on male sterility systems. These may be cytoplasmic male sterility (CMS), thermo-sensitive genic

(TGMS) or photo-sensitive genic (PGMS). Most of the commercial hybrids used in China and elsewhere are based on a CMS system, although TGMS and PGMS systems are also becoming used commercially. Hybrid seed production technology involving these male sterility systems is complex and labor-intensive.

CMS lines can only set seeds on the condition of getting pollen from R lines or B line in seed production or A line multiplication plot. Synchronization of flowering for parental lines is the key point for hybrid rice seed production. Among the different factors affecting the success of seed production, obtaining proper synchronization of flowering of the parental lines, is the most important (Directorate of Rice Research 1996). Detailed knowledge of the flowering behavior of hybrid rice parental lines is essential to be studied (Shen et al. 2001). Even if the seeding interval between both parents is accurately determined, synchronization of their flowering might not be obtained because of variation in environmental condition and difference in field management. Adjustment of flowering of parental lines can be done by water management, fertilizer management and removal of early panicle (Yuan et al. 2003).

Potassium (K) is an important macronutrient for plant and it is required for physiological processes such as maintenance of membrane potential and turgor, activation of enzymes, regulation of osmotic pressure, stomata movement and tropisms (Golldack et al. 2003 and Marschner 1995). Potassium plays an important role in photosynthesis, water balance, translocation of carbohydrates and resistance against insects and diseases (Brar and Brar 2004).

Furthermore, K is necessary for phloem solute transport and for the maintenance of cation and anion balance in the cytosol as well as in the vacuole. Flowering of parental lines in hybrid rice seed production may be earlier by application 10-20 kg KCl $ha^{-1}$ for male parent and 30-40 kg KCl $ha^{-1}$ for female parent (Hari Prasad 2011).There was no research concerned with the synchronization study in hybrid rice seed production by using potassium fertilizer application in Myanmar. Therefore this study was carried out to study the flowering response of parental lines of hybrid rice to the application of potassium fertilizer and to observe the optimum potassium fertilizer rate to adjust the flowering time for parental lines of hybrid rice.

# CHAPTER II
# LITERATURE REVIEW
## 2.1 Importance of Rice
### 2.1.1 Rice as a Gobal Staple Food

Rice, wheat, and maize are the three leading food crops in the world. Wheat is the leader in area harvested each year with 214 million ha, followed by rice with 154 million ha and maize with 140 million ha. Human consumption accounts for 85% of total production for rice, compared with 72% for wheat and 19% for maize.

Rice provides 21% of global human per capita energy and 15% of per capita protein. Although rice protein ranks high in nutritional quality among cereals, protein content is modest. Rice also provides minerals, vitamins, and fiber, although all constituents except carbohydrates are reduced by milling.

The world average consumption of rice in 1999 was 58 kg, with the highest intake in some Asian countries; Myanmar has the highest annual consumption at 211 kg/person. Rice eaters and growers constitute the bulk of the world's poor approximately 70% of the world's 1.3 billion poor people live in Asia, where rice is the staple food.

### 2.1.2 The Effect of Rice on the Global Economy

Rice is also the most important crop to millions of small farmers and to the many landless workers who derive income from working on these farms. In the future, rice production continues to grow at least as rapidly as the population, if not faster. Rice research that develops new technologies for all farmers has a key role to play in meeting this need and contributing to global efforts directed at poverty alleviation. Rapid population growth puts increasing pressure on the already strained food-producing resources. Asia accounted for 60% of the global population, about 92% of the world's rice production, and 90% of global rice consumption. (www.knowledgebank.irri.org/ericeproduction/Importance_of...importance *of rice)*

## 2.2 Characteristics of Hybrid Rice

Hybrid rice is the commercial rice crop grown from $F_1$ seeds of a cross between two genetically dissimilar parents. Good rice hybrids have the potential of yielding 15-20% more than the best inbred variety grown under similar conditions. To exploit the benefits of hybrid rice, farmers have to buy fresh seeds every cropping season. Yield levels of semi-dwarf varieties of the green revolution era have plateued.

More and more rice has to be produced on less land and with less input. Demand for rice is rapidly increasing with the increased in population especially in less developed countries. Hybrid rice has shown their ability to perform better under adverse conditions of drought and salinity. Hybrid rice technology is most feasible for increasing rice production where resource degradation, shrinking land and water resources and narrowing profitability margin. Therefore, Virmani et al. (2003) reported that hybrid rice is needed to grow.

**2.3 Hybrid Seed Production in Rice**

Since rice is a self-pollinated crop, hybrid seed production must be based on male sterility systems. This utilizes three different lines, namely a cytoplasmic male sterile line (A line or seed parent), a maintainer line (B line), and a restorer line(R line or pollen parent). To succeed hybrid rice seed production, a sufficient number of pollen grains must be deposited on the stigma lobes of each spikelet of the seed parent. It may help if the pollen parent grows to a greater height than the seed parent. In the whole process of hybrid seed production, it requires a set of complicated techniques centering on raising the out crossing rate to obtain a high seed yield.

**2.3.1 Optimum Season for Heading and Flowering**

Favorable climatic conditions for normal flowering of the parental lines are as follows;

(a) a daily mean temperature of 25 - 28˚C

(b) a relative humidity of 70 - 80%;

(c) a difference between the day and night temperature of 8 -10˚C;

(d) sufficient sunshine with no continuous rain for more than 3 days and

(e) breezes.

Under high temperatures with a low humidity or under low temperatures with a high humidity, some glumes will not open. These conditions caused reducing in pollen viability of R lines and the stigma receptivity of CMS lines, resulting in low seed yield. Therefore to coincide the heading and flowering period with the favorable season, close attention should be paid (Yuan et al. 2003).

**2.3.2 Synchronization in Flowering**

As the seed set on CMS lines depend on cross-pollination, it is important to synchronize the heading date of both parents. The CMS lines and R lines are quite different in growth duration. To extend the pollen supply, the restorer line is usually seeded twice at an interval of 5-7 days and planted alternately every two to three hills.

There are three methods used to determine the difference in seeding date for synchronization between the CMS and R lines. In all three methods the first sowing date of the restorer line is taken as the reference date (Yuan et al. 2003).

#### 2.3.2.1 Growth Duration Method

By examining the previous date against the difference in duration from seeding to heading between CMS and R lines, the proper seeding date of both parents in the current year can be determined. It is simple and easy to adopt. However, in some regions where temperatures vary greatly in the vegetative growth period, the early seeded R line will have different growth duration each year. If the seeding date of the CMS line is adjusted according to growth duration only, there will be a great discrepancy in the synchronization of flowering. Therefore it is only used in seasons or regions where the temperature fluctuation is small.

#### 2.3.2.2 Leaf Number Method

Rice varieties are relatively stable in their leaf number. Counting leaves on the main culm is a good way to record a physiologically meaningful age for a rice plant. In this method, the leaf number of the main culm is used as an indicator for determining the difference in seeding date between the two parents.

Table 2.1 Counting starts when the first complete leaf emerges on the main culm.

"Three ratings" for counting leaf number

| Ratings | Description |
|---|---|
| 0.2 | The leaf has just emerged but has not unfolded |
| 0.5 | The leaf has unfolded but not completely |
| 0.8 | The leaf has unfolded completely |

#### 2.3.2.3 Effective Accumulated Temperature (EAT) Method

The EAT from seeding to heading of a variety is relatively stable,although the seeding date is different. In botany, 12˚C is generally taken as the lower temperature limit and 27˚C is as the upper limit. Formula is

$$A = (T - H - L)$$

Where, A = the EAT in a certain growth stage (˚C)

T = daily mean temperature (˚C)

H = the temperature over the upper limit (27˚C). H is computed only for days when daily mean temperature is 28˚C, H = 28 - 27=1

L= the lower limit temperature (12˚C).The EAT is computed only for days when daily mean temperature is greater than 12˚C.

Σ = the accumulation of the temperature from the beginning to the end of a certain growth stage.

It should be pointed out that the EAT of a variety varies by region, so it is better to use the data recorded by the local meteorological station. The growth duration, leaf number and EAT are closely associated with one another. Generally the leaf number method is taken as the main method and the other two are used as reference.

**2.3.3 Prediction and adjustment of Heading Date**

Although the seeding interval between parental lines is accurately determined, synchronization of flowering still might not be obtained because of variations in temperature and differences in field management. So, it is necessary to predict their heading date to take measures as early as possible and make adjustments for good synchronization (Yuan et al. 2003).

**2.3.3.1 Prediction of the Heading Date**

Based on the morphological features, the young panicles are classified into eight developmental stages (Virmani et al.2003).These stages are shown in Appendix 1 and 2.The synchronization in flowering can be predicted by examining the development of young panicles. About 30 days before heading, the CMS line and R line plant are sampled and their young panicles from the main culms are carefully observed by the naked eye or with a magnifying glass every 3 days. The criteria for synchronization of flowering include;

(a) R line (pollen parent), if its growth duration is longer, should be one stage earlier than the CMS line during the first three stages of young panicle differentiation;

(b) Both parents should be in the same stages during the fourth, fifth and sixth differentiation;

(c) CMS line (seed parent) should be slightly earlier than the R line during the last two stages so that the initial flowering of the CMS line can be 1-2 days earlier than R line.

However, if both parents have the same growth duration, the CMS line should be 1-2 days earlier in all of the developmental stages. In other cases, if the CMS line has longer growth duration than R line, the CMS line should be earlier than R line by one stage during the first three developmental stages, 2-3 days in the meiotic division stage, and 1-2 days in flowering (Yuan et al. 2003).

### 2.3.4 Adjustment of Flowering Date

The synchronization of flowering of the two parents is most important factor for obtaining high seed yields in hybrid rice. The earlier developing parent should be treated with quick-releasing nitrogen fertilizer to enhance the flowering time 2 - 3 days, while the later parent should be sprayed with 1% of potassium dihydrogen phosphate ($KH_2PO_4$) solution. If asynchronous flowering is predicted during the later stages of panicle differentiation, a difference of 2-3 days may be adjusted by drainage or irrigation because R lines are more sensitive to water than the CMS lines. If the R line is found to be earlier, draining water from the field will delay the panicle development. In contrast, if the R line is found to be late, a greater depth of standing water can facilitate rapid panicle development.

If the difference in flowering period between the two parents reaches 10 days or more, it is necessary to remove the bracts of panicles from the early developing parent and to apply nitrogen fertilizer unilaterally, thus making its late emerging tillers or non productive tillers produce panicles to achieve synchronization of flowering (Yuan et al. 2003).

## 2.4 Potassium

### 2.4.1 Occurrence of Potassium in Nature

Potassium is abundant in nature, comprising about 2.4 percent of the earth’s crust. The potassium content of soils varies widely, ranging from only a few hundred pounds per acre to over 50,000 pounds per acre or more in fine-textured soils formed from rocks that are high in potassium-bearing minerals. All naturally occurring potassium contained in the soil originated from the disintegration and decomposition of potash-feldspars (orthoclase and microcline) and micas (muscovite and biotite). Much of the natural potassium occurring in soils is not available to plants and crops; therefore, soils containing relatively large amounts of total potassium usually respond to potassium fertilization.

### 2.4.2 Potassium in soil

In most soil, potassium (K) is present in relatively large quantities, potassium concentration of the earth's crust is about 1.9% and its concentration in soil normally varies between about 0.5 to 2.5% and typically is about 1.2%. In tropical soils, the total content of potassium may be quite low because of their origin or strong weathering. Especially high rainfall and continued high temperatures hasten the release and leaching of soil potassium during soil genesis (Tisdale et al. 1985). There are three major forms of K distinguished in soils namely, the unavailable form, the slowly available or fixed form, and the readily available or exchangeable form.

**Relatively Unavailable Potassium**

From 90-98 percent of the total potassium present in soils is found in insoluble primary minerals such as feldspars and micas. These minerals consist of potassium-aluminum silicates which are resistant to chemical breakdown. They release potassium slowly, but in small quantities compared to total needs of growing crops (Tisdale et al. 1985).

**Slowly Available Potassium**

This form comprises 1-10 percent of the total potassium supply and may originate from dissolved primary minerals or from potassium fertilizers. This potassium is attracted to the surface of clay minerals where it may be firmly bound or fixed between the clay layers in a form slowly available to plants. The actual amount available depends on the type and amount of clay present.

**Readily Available Potassium**

Readily available forms of potassium comprise only 0.1 to 2 percent of the total potassium in the soil and consist of potassium dissolved in the soil solution and held on the exchange positions of the clay and organic matter. This potassium is referred to as "exchangeable" because it can be replaced by other positively-charged ions (cations) such as hydrogen, calcium, and magnesium. This exchange happens rapidly and frequently. The potassium in the soil solution may be taken up by the plant or lost from the soil by leaching, especially on sandy coarse-textured soils in regions of high rainfall (Brady and Weil 2002).

### 2.4.3 Potassium in Plants

#### 2.4.3.1 Factors Affecting the Potassium Availability to the Plant

Plants use potassium in the readily available form. This form consists of exchangeable and water soluble potassium. In soil water, small amount of potassium which can be used by plant exists. Rehm (1997) noted that this amount ranged from 5.6 to 45 kg $ha^{-1}$ in the top layer of soils. It is highest in early spring and decreases throughout the growing season due to plant uptake. Availability and uptake of potassium (K) is often complicated by many interacting components. Two factors that have a predominating effect are the soil and plant characteristics involved. A third factor, improved fertilizer and management practices, can be used to modify the inherent characteristics of soils and plants involving K uptake. Soils factors are the soil itself, cation exchange capacity of the soil, the quantity of available K in the soil, the nonexchangeable or slowly available K, the K fixation capacity of the soil, the amount of K in the subsoil and the density or consistency of subsoil layers, soil temperature, soil moisture, soil tilth. Plant factors are the crop, the variety or hybrid, the populations and crop yield. Among them, the most important factors are (a) the type of soil minerals present, (b) the soil organic matter content, (c) the soil reaction, (d) the soil moisture, and (e) the other ions present in the soil solution (Pal 2001).

(a) **Soil Minerals**. The capacity of a soil to supply K to crops over an extended period of time is fundamentally dependent on the K content of primary minerals, the rate of K release by primary minerals, the quantity of clay mineral present and the type of clay mineral. Clay minerals are the most important source of soil K. Montmorilonite and Vermiculite clay minerals release more available K than Kaolinite clay types because of much higher cation exchange capacity (CEC). To retain applied K, the ability of soil is very dependent on the CEC of the soil. The higher the CEC, the greater ability of soil to retain added K (Munson and Nelson 1963).

(b) **Soil organic matter content**. Soil organic matter or humus can constitute a considerable part of CEC and thus hold substantial amounts of exchangeable soil K. Organic matter could increase the capacity of the soil to adsorb K by increasing CEC. Organic matter in soils contains very little potassium but provides a temporary storage for soil K. Application of organic matter to soil increases the plant uptake while decreased in uptake of calcium (Ca) and magnesium (Mg). In tropical soils, where

Kaolinite clay minerals with low CEC predominate, organic matter can largely contribute to K retention capacity.

(c) **Soil reaction**. In very acid soils the exchangeable aluminum (Al) and manganese (Mn) can cause an unfavorable root environment for the uptake of potassium or any other element. In such soils, because hydrogen ion ($H^+$) and other basic cations are tightly held, the absorption of Mg and other basic cations is usually restricted. So this effect will reduce plant growth and potassium uptake and utilization. When the pH increases, the H+ and hydroxyl aluminum ions are neutralized, and potassium ions are moving towards the colloidal surfaces in which they are more susceptible to fixation in 2:1 clays (Tisdale et al. 1985).

(d) **Soil moisture**. Increasing soil moisture from 10 to 28% increased total potassium transport by up to 175%.At low soil water, water films around soil particles are thinner and discontinuous, causing to more tortuous path for $K^+$ movement. Tisdale et al. (1985) noted that the higher moisture content or the increased potassium level the more accelerated potassium was. Alternate wetting and drying, freezing and thawing enhance both the fixation of potassium in nonexchangeable forms and the release of previously fixed potassium to the soil solution (Brady and Weil 2002).The water-related factor affecting the availability of potassium is leaching. The degree of K leaching can be strongly influenced by the amount of organic matter in the soil. Leaching is often a problem on sandy soils (Sparks 1980) and in areas with high rainfall (Tisdale et al. 1985).Potassium leaching is much reduced at pH 6.0 to 6.5 because of enhanced substitution of K for $Ca^{2+}$ than $Al^{3+}$, the latter being more abundant at low pH (Sparks and Huang 1985).

**(e) Fertilizers and management practices increased use of nitrogen (N) and other limiting nutrients**. When adequate K is available, addition of N and/or phosphorus (P) greatly increases K uptake, as yields are increased. Usually the uptake of K by crops closely parallels N uptake and may be greater. So, when the limiting nutrients are added, the demands on soil K increase.

**Applications of K in Fertilizers, Manures or Crop Residues.** To increase K availability, the way is to apply adequate amounts. Potassium is readily available from all these sources and the plant roots can absorb the soluble K.

**Placement of K.** Broadcast plow-down applications of K are more available than surface applied disked-in K. Deep placement or drip irrigation helps move K down. In very fine textured soils gypsum applied with K also helps move K down.

**Conservation Tillage Limits Availability of Surface Applied K.** Soil K levels should be built to high levels before shifting to minimum or conservation tillage. This improves K distribution within the plow layer. In many fine textured soils, surface applied K moves very little in the soil and has low availability, particularly under dry land conditions.

**Drainage Increases K Availability**. Draining soils of excess moisture caused many soils warm up earlier and improves the aeration of the soil. It improves the availability of soil K.

**Weed and Insect Control.** Weeding and insect control reduced competition for moisture and nutrients, so that the crop being produced has relatively more K available.

### 2.4.4 Potassium in Rice

Potassium is an essential plant nutrient for plant growth and reproduction. It occurs in plants in both organic and inorganic salts. All potassium salts are soluble and highly ionized in solution. It is a macronutrient for plants that is required for physiological processes such as the maintenance of membrane potential and turgor, activation of enzymes, regulation of osmotic pressure, stomata movement, and tropisms (Golldack et al. 2003). Nelson (1978) believed that potassium has a positive role in plant growth under saline conditions, because this element plays an essential role in photosynthesis, osmoregulatory adaptations of plant to water stress. Adequate potassium supply is also desirable for the efficient use of Fe, while higher potassium application results to competition with Fe (Celik et al. 2010).

The pattern of K uptake follows most closely that of vegetative growth. Even before the booting stage, 75% of the maximum K content has been taken up, and most of the remaining uptake is completed before grain formation begins, very similar with the pattern of K uptake in wheat. About 20% of the K taken up before full heading is translocated to the panicles and the rest remains in the vegetative parts at maturity (De Datta 1985).

#### 2.4.4.1 Functions of Potassium

Potassium is vital to many plant processes. Its role involves the basic biochemical and physiological systems of plants. While K does not become a part of the chemical structure of plants, it plays many important regulatory roles in development. K increases crop yield and improves quality. It is required for numerous plant growth processes.

**(a) Enzyme Activation**

Potassium activates at least 60 different enzymes involved in plant growth. The K changes the physical shape of the enzyme molecule, exposing the appropriate chemically active sites for reaction. It also neutralizes various organic anions and other compounds within the plant and it helps to stabilize pH between 7 and 8, the optimum value for most enzyme reactions.

**(b) Stomatal Activity (Water Use)**

Plants depend upon K to regulate the opening and closing of stomata. Proper functioning of stomata is essential for photosynthesis, water and nutrient transport, and plant cooling. When K moves into the guard cells around the stomata, the cells accumulate water and swell, causing the pores to open and allowing gases to move freely in and out. When water supply is short, K is pumped out of the guard cells. The stomata closed to prevent loss of water and minimize drought stress to the plant. If K supply is inadequate, the stomata become sluggish and water vapor is lost. As a result, plants with an inadequate supply of K are much more susceptible to water stress. K, thus is involved in regulating stomata and thereby gas exchange. Beringer and Nothdurft (1985) noted that K is the most important inorganic osmotic component and stimulates growth primarily by its effects on cell extension. Bednarz et al. (1998) reported that at the onset of a developing potassium deficiency, stomatal conductance was the principle factor limiting photosynthesis, whereas when the K deficiency became more extreme, non-stomatal or biochemical factors became the overriding reason for the decreased photosynthesis.

**(c) Photosynthesis**

The role of K in photosynthesis is complex. The activation of enzymes by K and its involvement in adenosine triphosphate (ATP) production is more important in regulating the rate of photosynthesis than is the role of K in stomatal activity. The electrical charge balance at the site of ATP production is maintained with K ions. K is essential for attaining full activity of the ATPase enzyme which is of crucial importance for the exchange and metabolites between the apoplast and symplast (Mengel et al.1981). When plants are K deficient, the rate of photosynthesis and the rate of ATP production are reduced, and all of the processes dependent on ATP are slowed down. Conversely, plant respiration increases which also contributes to slower growth and development.

**(d) Transport of Sugars**

Sugars produced in photosynthesis must be transported through the phloem to other parts of the plant for utilization and storage. The transport system uses energy as ATP. If K is inadequate, less ATP is available and the transport system breaks down. This causes photosynthates to build up in the leaves and the rate of photosynthesis is reduced. Marschner (1995) found that the transport rates of photosynthates from source to other organs decline due to a decrease in osmotic potential in the sieves tubes in K-deficient plants. As a result, normal development of energy storage organs such as grain is retarded. An adequate supply of K helps to keep all of these processes and transportation systems functioning in normal.

**(e) Water and Nutrient Transport**

Potassium also plays a vital role in the transport of water and nutrients throughout the plant in the xylem. When K supply is reduced, translocation of nitrates, phosphates, calcium (Ca), magnesium (Mg), and amino acids is depressed. The role of K in xylem transport is in combined with specific enzymes and plant growth hormones. An adequate supply of K is essential to efficient operation of these systems.

**(f) Protein Synthesis**

Potassium is required for protein synthesis. The reading of the genetic code in plant cells to produce proteins and enzymes would be impossible without adequate K. In K deficient plants, proteins are not synthesized despite an abundance of available nitrogen (N). Instead amino acids, amides and nitrate accumulate. The nitrate reductase catalyzes the formation of proteins and K is likely responsible for its activation and synthesis. Mengel (1980) also demonstrated that the transport of amino acids is enhanced by higher $K^+$ levels especially the transport of amino acids to developing seeds.

**(g) Starch Synthesis**

The enzyme for synthesis of starch is activated by K. Therefore, with inadequate K, the level of starch decreases while soluble carbohydrates and N compounds accumulate. Photosynthetic activity also affects the rate of sugar formation for ultimate starch production. Under high K levels, starch is efficiently moved from sites of production to storage organs. Potassium deficiency changes carbohydrate metabolism (Mengel and Kirkby 1987).

**(h) Crop Quality**

Potassium plays significant roles in enhancing crop quality. High levels of available K improve the physical quality, disease resistance, and shelf life of fruits and vegetables used for human consumption and the feeding value of grain and forage crops. It is an essential plant mineral element (nutrient) having a significant influence on many human-health related quality compounds in fruits and vegetables. Although K is not a constituent of any organic molecule or plant structure, it is involved in numerous biochemical and physiological processes vital to plant growth, yield, quality and stress (Cakmak 2005). In addition to stomatal regulation of transpiration and photosynthesis, K is also involved in photophosphorylation, transportation of photoassimilates from source tissues via the phloem to sink tissues, enzyme activation, turgor maintenance and stress tolerance Adequate K nutrition has also been associated with increased yields, fruit size, increased soluble solids and ascorbic acid concentrations, improved fruit color, increased shelf life, and shipping quality of many horticultural crops (Lester et al. 2012)

**(i) Effects of Potassium on Plant Growth and Physiology**

Potassium affects numerous growth characters of rice such as plant height, tiller production and dry matter production. Plant height increases with increasing potassium level. Potassium had appositive effect on tiller production in rice (Kulkarni et al.1975).Potassium deficiency results in reduced rates of net photosynthesis and translocation and increases the rate of dark respiration, resulting in reduced plant growth and dry matter production. Dry matter production was significantly affected by both K and zinc application (Navarro 1988). Ren et al. (1992) and Mehdi et al. (2001) reported that significance increases of grain and straw yields by potassium application. Potassium increased the retention of chlorophyll in the flag leaf and delayed senescence during the active grain filling stage. Potassium rates up to 72 kg $K_2O$ $ha^{-1}$ were flowered earlier than those of control treatment (Zayed et al. 2007).

**2.4.4.2 Potassium Availability in Paddy Soils**

Soil flooding alters the chemistry and availability of soil K. Under reducing conditions, $Fe^{2+}$, $Mn^{2+}$ and $NH_4^+$ are released in the soil by various processes and displace K from the exchange sites, increasing its concentration in the soil solution and its availability to rice (Patrick and Mikkelsen 1971).The increase in soluble $K^+$ after flooding is closely related to the $Fe^{2+}$ ion content of the soil solution. In the field, with adequate drainage, leaching of soil K may be considerable. Chang (1971) suggested that K losses by leaching could be substantial. If the displaced $K^+$ and other basic cations by leaching or by diffusion to the surface and loss in surface runoff, soils become acid when oxidized (Brinkman 1970). Potassium fixation in flooded soils varies with soil characteristics, with maximum values of about 36% found in some clay loam soils. Chang and Feng (1960) reported that alternate flooding did not increase K fixation. In rice research, potassium is less attention than nitrogen although the total K uptake can be greater than N uptake.

**2.4.4.3. Potassium Deficiency Symptoms**

Potassium is a highly mobile element in the plant and is translocated from the older to younger tissue. Consequently, potassium deficiency symptoms usually occur first on the lower leaves of the plant and progress toward the top as the severity of the deficiency increases (Marschner 1995). Potassium deficiency resulted in a characteristic pattern of leaf discoloration by small whitish-yellow spots, followed by scorching or browning of the leaf edges (Bland 1971). In severe cases of potassium deficiency the fired margin of the leaf may fall out. Potassium deficient crops grow slowly and have poorly developed root systems. Halvin et al. (1999) pointed out that another symptom of insufficient K was weakening of straw in small grain crops and lodging. Potassium deficient plants are small, shriveled, and is more susceptible to diseases. Rice deficient in K may show symptoms as stunted plants, a slight reduction in tillering and short, droopy, dark green upper leaves. Yellowing may appear in interveinal areas of lower leaves, starting from the top and eventually drying to a light brown. Long thin panicles and black, deteriorated roots may be related to K deficiency (Thompson 2012).

**2.4.4.4 Potassium Interaction with other nutrients**

Adequate supplies of other nutrients are required to obtain maximum responses to potassium fertilization; however, there are several unique relations between potassium and other nutrients, due to the complementary ion effect that are important in plant nutrition. High potassium fertilization can decrease the availability of magnesium to the plant and may result in magnesium deficiency of crops grown on soils that are already low in magnesium. This is often encountered with crops grown on sandy soils. Conversely, crops grown on soils high in magnesium can suffer potassium deficiency; especially in the soils with high phosphorus and low potassium level.

High levels of potassium fertilization along with ammonical nitrogen ($NH_4$) also depress the magnesium content of forage grasses. Sodium is similar to potassium in its chemical properties. Sodium has been shown to substitute partially for potassium in some crops.

Leaching of potassium on acid sandy soils may be reduced by liming that the soil to a pH of 6.2 to 6.5. However, high application of limestone to a soil with low potassium may induce potassium deficiency of crops growing on these soils. This problem occurs on soils with predominantly 2:1 type clays (such as montmorillonite clays) rather than the 1:1 type (such as kaolinitic clays).

# CHAPTER III

# .MATERIALS AND METHODS

Two-times of pot experiments were conducted from February to April 2012 as first experiment and from August to November 2012 as second experiment.

## 3.1 Experimental Site

The experiment was conducted in screen house of Department of Agricultural Chemistry at Yezin Agricultural University which is located at 15º 52'N and 96º 07'E with the elevation of 213 meters above sea level.

## 3.2 Experimental Design

Experiment was laid out as factorial arrangement in completely randomized design with 3 replications. The diameter and height of plastic pot used in experiment was 30 cm × 30 cm.

## 3.3 Treatment

Factor A was parental lines which were Long 4, Long 6 and Long 8 as seed parent (A line) and pollen parent (R line). Potassium fertilizer rates were treated as factor B.

**Parental Lines** - 6 lines (female = 100 days, male = 120 days)

1. Long 4 - A line
2. Long 4 - R line
3. Long 6 - A line
4. Long 6 - R line
5. Long 8 - A line
6. Long 8 - R line

**Fertilizer rate** - 4 levels

| **For R lines** | **For A lines** |
|---|---|
| $K_0$ = 0 kg KCl $ha^{-1}$ | $K_0$ = 0 kg KCl $ha^{-1}$ |
| $K_1$ = 10 kg KCl $ha^{-1}$ | $K_1$ = 30 kg KCl $ha^{-1}$ |
| $K_2$ = 20 kg KCl $ha^{-1}$ | $K_2$ = 40 kg KCl $ha^{-1}$ |
| $K_3$ = 30 Kg KCl $ha^{-1}$ | $K_3$ = 50 kg KCl $ha^{-1}$ |

**Time of application** – Before stage III (differentiation of the secondary branch primordia and spikelet primordia)

### 3.4 Soil Sampling and Analysis

Soil sample was collected from the upper 0-20 cm layer of the originally rice cultivated field. The sample was analyzed before the experimental set-up at Soil and Water Utilization Division, Department of Agricultural Research (DAR), Yezin, Nay Pyi Taw. The physicochemical properties of experimental soil are shown in Table 3.1

**Table 3.1 Some physicochemical properties of the soil samples before pot study**

| Properties | Rating (content ) |
|---|---|
| Texture | Sandy loam |
| Bulk Density | 1.07 |
| Soil pH | 6.17 |
| Available Nitrogen (ppm) | 81(medium) |
| Available Phosphorus (ppm) | 4 (low ) |
| Available Potassium (ppm) | 125 (low) |
| Organic Matter (%) | 1.54 |
| CEC (cmol $_{(+)}$ kg$^{-1}$) | 1.72 (low) |

### 3.5 Pot Preparation and Crop Management

Soils were ground to pass 2 mm sieve and 13.24 kg each into the plastic pot (30 cm × 30 cm). The soil was filled up 23 cm per pot and it was saturated with water about two weeks. Pots were received 250 kg of N ha$^{-1}$, 50 kg of $P_2O_5$ ha$^{-1}$ and 150 kg of $K_2O$ ha$^{-1}$. Half of nitrogen as urea was applied at basal and the remaining half was applied at maximum tillering stage. All Triple superphosphate and Muriate of potash 150 kg of $K_2O$ as were applied at basal. Twenty fifth-day-old seedlings were transplanted 15 cm x 15 cm with 3 plants per pot in May 7, 2012 in dry season and August 18, 2012 in wet season. Water level was maintained at 2-3 cm above soil surface until maturity. Potassium fertilizer treatments were applied before stage III which is the differentiation of the secondary branch primordia and spikelet primordia. To predict their heading stage, extra three plants for each treatment was grown. About 30 days before heading, these extra plants were sampled and their young panicles from the main culms were carefully observed by the naked eye every 10 days.

### 3.6 Data Collection

During rice cultivation period, tiller number, plant height and initial and 50% flowering were recorded. Plant height and tiller numbers were collected weekly intervals. Leaf number is a reliable parameter for determining seeding intervals between parental lines in hybrid rice seed production. Therefore, leaf number counting was conducted three days interval from the first complete leaf emergence to the time of emergence of flag leaf according to Table 2.1.

### 3.7 Weather Data

All weather data for both seasons were obtained from meteorological station at Department of Agricultural Research in Yezin (Figure 3.1).

### 3.8 Data Analysis

Analysis of variance (ANOVA) to test the statistical significance and Least Significant Difference test (LSD) to compare the treatment mean at 5% probability level were conducted using GenStat ($9^{th}$ Version).

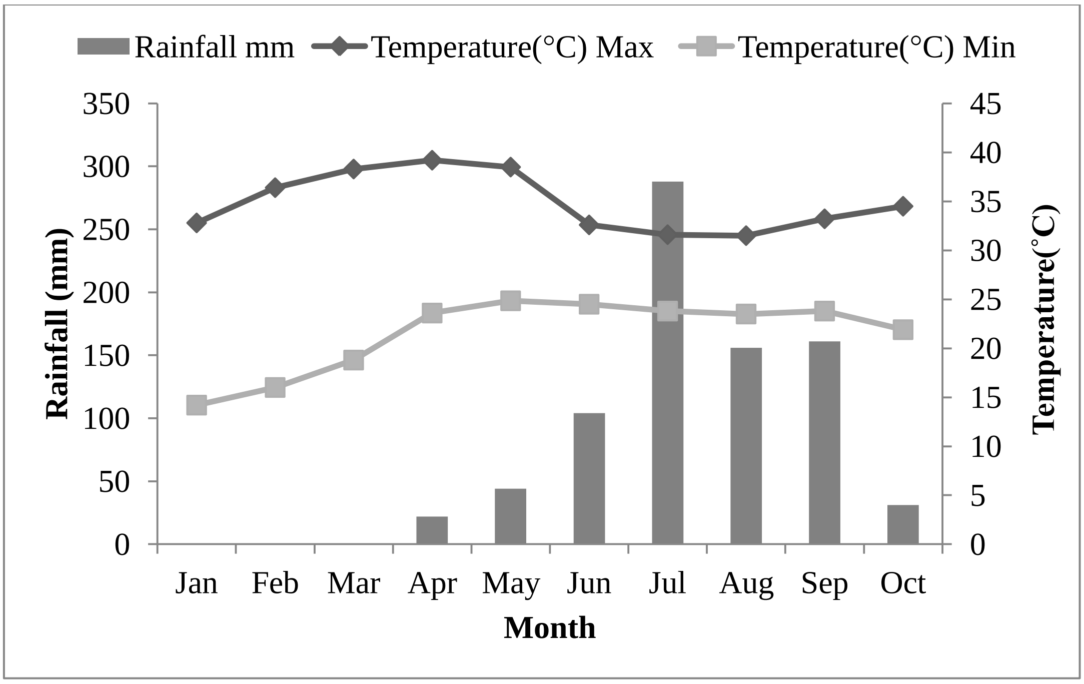


**Figure 3.1 Monthly mean rainfall, minimum and maximum temperature during experimental period in Yezin (February to November 2012)**

# CHAPTER IV

# RESULTS AND DISCUSSION

## 4.1 Experiment in Dry Season, 2012

The experiment was carried out in the screen house of Department of Agricultural Chemistry at Yezin Agricultural University from February to June to examine the flowering time of parental lines of hybrid rice by application of potassium fertilizer.

### 4.1.1 Plant height of Seed Parents (A lines)

The plant height was measured at weekly from 7 days after transplanting (DAT) to 56 DAT. Plant height in all seed parents increased continuously at all growth stages ( Figure 4.1 and 4.2 ). Plant height ranged from 60.6 to 73.4 cm. Maximum plant height (73.4 cm) was recorded from Long 8 A line and the shortest plant height (60.6 cm) was observed from Long 6 A line.

Plant height was not influenced by different potassium fertilizer rates in this study. However the maximum plant height was resulted from control treatment and the plant height of the treatment of 50 kg KCl $ha^{-1}$ showed the minimum plant height but they were not significantly different from that of other treatments.

According to the ANOVA results (Table 4.1), the plant height of all tested seed parents was significantly different. There was no interaction between seed parents and potassium applications from 14 DAT until 70 DAT. This result indicated that plant height of seed parents was not affected by potassium fertilizer applications before III stage of panicle initiation.

### 4.1.2 Plant height of Pollen Parents (R lines)

The plant height was measured at weekly from 7 days after transplanting (DAT) to 70 DAT. Plant height of pollen parents was presented in Figure 4.3 and 4.4. Plant height of pollen parents was significantly different at 7 DAT, 49 DAT and 56 DAT. Plant height ranged from 97.8 to 98.8 cm. The maximum plant height (98.8 cm) was resulted from Long 8 R line and Long 4 R line showed the minimum plant height (97.8 cm).

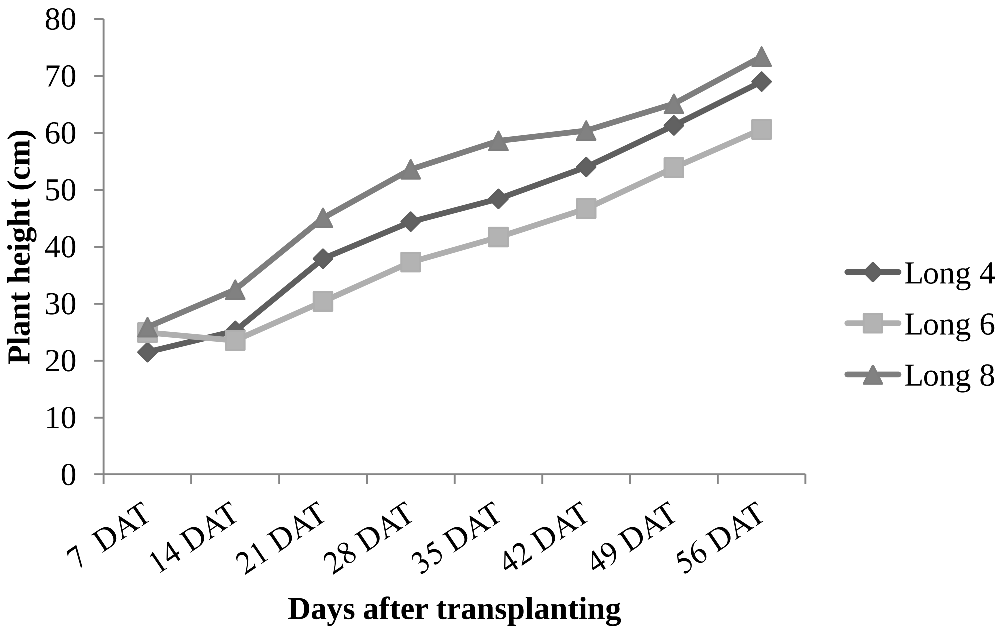


**Figure 4.1 Plant height of seed parents during dry season, 2012**

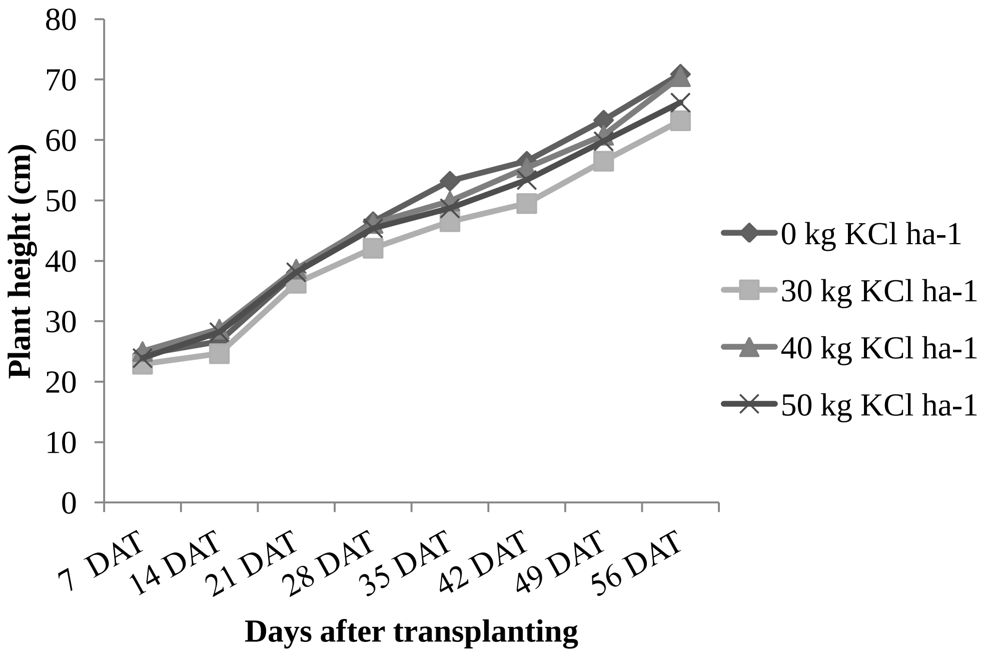


**Figure 4.2 Plant height as affected by potassium fertilizer during dry season, 2012**

**Table 4.1 Mean effect of potassium fertilizer rates on plant height of seed parents (A lines) during dry season, 2012**

| | Plant Height (cm) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Parental lines** | **7 DAT** | **14 DAT** | **21 DAT** | **28 DAT** | **35 DAT** | **42 DAT** | **49 DAT** | **56 DAT** |
| **Long 4** | 21.48 b | 25.22 b | 37.89 b | 44.40 b | 48.40 b | 54.00ab | 61.30 ab | 69.0 ab |
| **Long 6** | 24.92 a | 23.53 b | 30.39 c | 37.30 c | 41.70 c | 46.70 b | 53.90 b | 60.6 b |
| **Long 8** | 25.87 a | 32.45 a | 45.07 a | 53.60 a | 58.60 a | 60.40 a | 65.10 a | 73.4 a |
| **$LSD_{0.05}$** | 2.59 | 3.12 | 4.02 | 5.43 | 6.16 | 7.35 | 7.96 | 9.31 |
| **Potassium** | | | | | | | | |
| **0 kg KCl $ha^{-1}$** | 24.53 | 26.67 ab | 38.04 | 46.50 | 53.20 | 56.50 | 63.30 | 70.9 |
| **30 kg KCl $ha^{-1}$** | 22.91 | 24.66 b | 36.31 | 42.10 | 46.50 | 49.50 | 56.50 | 63.2 |
| **40 kg KCl $ha^{-1}$** | 25.01 | 28.72 a | 38.65 | 46.20 | 49.90 | 55.40 | 60.80 | 70.5 |
| **50 kg KCl $ha^{-1}$** | 23.92 | 28.22 ab | 38.13 | 45.40 | 48.70 | 53.40 | 59.80 | 66.2 |
| **$LSD_{0.05}$** | 2.99 | 3.60 | 4.64 | 6.27 | 7.12 | 8.48 | 9.19 | 10.75 |
| **Parental lines** | 0.005** | <.001** | <.001** | <.001** | <.001** | 0.003** | 0.025* | 0.028* |
| **Potassium** | 0.517 | 0.115 | 0.748 | 0.463 | 0.294 | 0.361 | 0.505 | 0.410 |
| **Parental lines × Potassium** | 0.719 | 0.513 | 0.893 | 0.71 | 0.764 | 0.752 | 0.667 | 0.860 |
| **CV%** | 12.8 | 13.7 | 12.6 | 14.3 | 14.8 | 16.2 | 15.7 | 16.31 |

Mean followed by the same letter in each column are not significantly different at 5% level.*significantly different at 5% level, ** highly significant different at 1% level

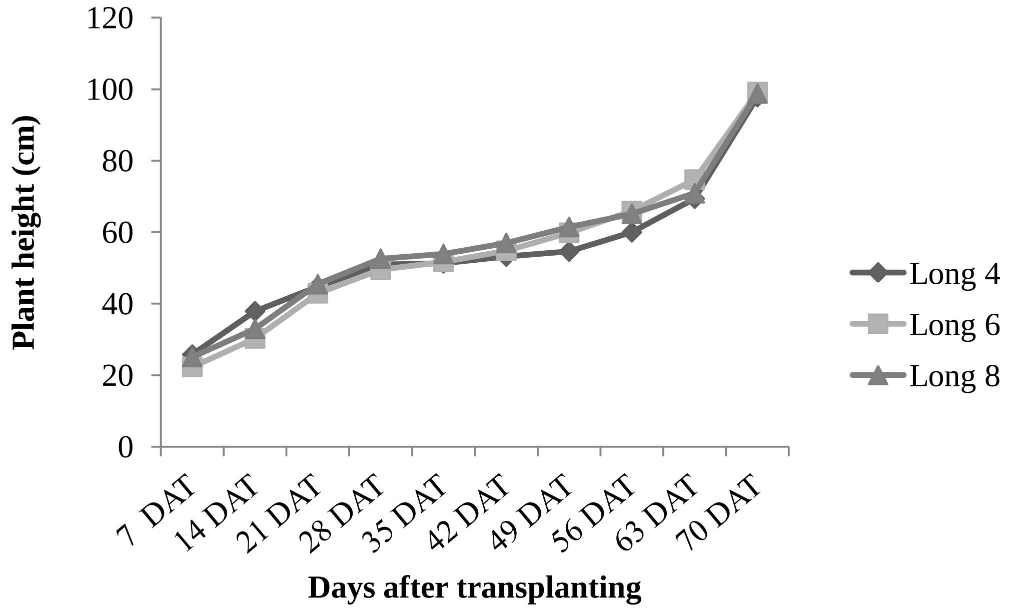


**Figure 4.3 Plant height of pollen parents during dry season, 2012**

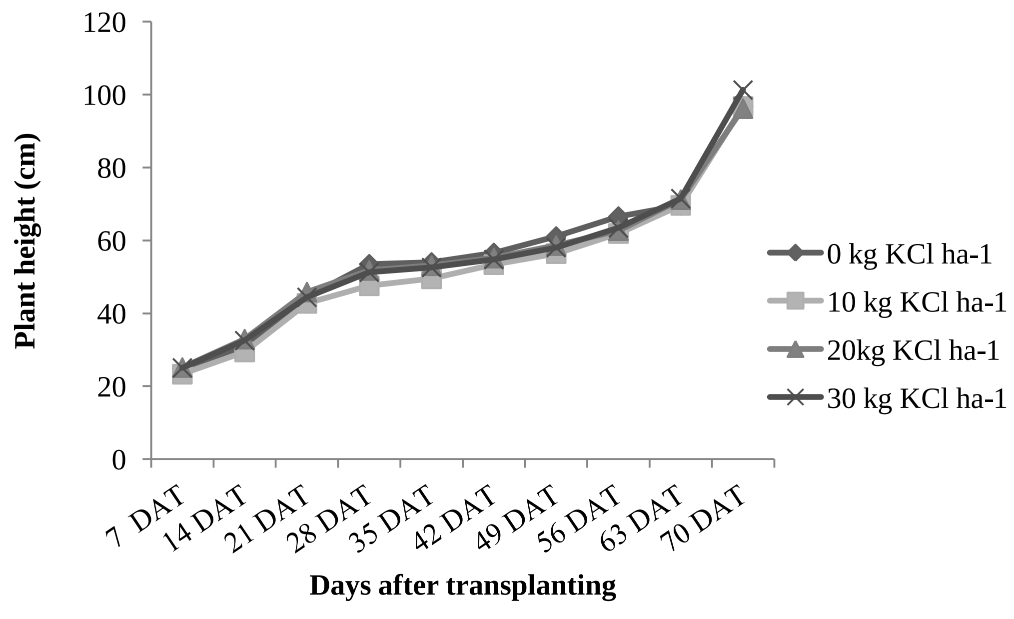


**Figure 4.4 Plant height as affected by potassium fertilizer during dry season, 2012**

**Table 4.2 Mean effect of potassium fertilizer rates on plant height of pollen parents (R lines) during dry season, 2012**

| | Plant Height (cm) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Parental lines** | **7 DAT** | **14 DAT** | **21 DAT** | **28 DAT** | **35 DAT** | **42 DAT** | **49 DAT** | **56 DAT** | **63 DAT** | **70 DAT** |
| **Long 4** | 25.75 | 37.89 | 44.80 | 51.00 | 51.30 | 53.20 | 54.59 | 59.98 | 69.38 | 97.80 |
| **Long 6** | 22.30 | 30.31 | 42.93 | 49.50 | 51.70 | 54.80 | 59.84 | 65.89 | 74.71 | 99.20 |
| **Long 8** | 25.09 | 32.98 | 45.46 | 52.60 | 53.90 | 57.00 | 61.47 | 65.15 | 70.91 | 98.80 |
| **$LSD_{0.05}$** | 3.10 | 4.04 | 3.76 | 6.43 | 6.03 | 5.41 | 4.94 | 5.00 | 4.47 | 7.19 |
| **Potassium** | | | | | | | | | | |
| **0 kg KCl $ha^{-1}$** | 23.95 | 31.23 | 44.50 | 53.50 | 54.00 | 56.60 | 61.10 | 66.59 | 69.65 | 96.80 |
| **10 kg KCl $ha^{-1}$** | 23.33 | 29.44 | 42.77 | 47.60 | 49.50 | 53.40 | 56.42 | 61.94 | 69.65 | 96.80 |
| **20kg KCl $ha^{-1}$** | 25.17 | 32.96 | 45.88 | 51.80 | 53.10 | 55.20 | 58.63 | 62.72 | 71.22 | 96.20 |
| **30 kg KCl $ha^{-1}$** | 25.07 | 32.55 | 44.44 | 51.30 | 52.60 | 54.80 | 58.09 | 63.45 | 71.52 | 101.30 |
| **$LSD_{0.05}$** | 3.57 | 4.67 | 4.34 | 7.42 | 6.96 | 6.24 | 5.70 | 5.77 | 5.16 | 8.31 |
| **Parental lines** | <.001** | 0.40 | 0.37 | 0.63 | 0.65 | 0.35 | 0.02* | 0.05* | 0.06 | 0.91 |
| **Potassium** | 0.748 | 0.418 | 0.542 | 0.432 | 0.566 | 0.764 | 0.466 | 0.383 | 0.338 | 0.514 |
| **Parental lines × Potassium** | 0.893 | 0.758 | 0.363 | 0.999 | 0.942 | 0.988 | 0.942 | 0.925 | 0.839 | 0.62 |
| **CV%** | 15.10 | 15.20 | 10.00 | 14.90 | 13.70 | 11.70 | 10.00 | 9.30 | 7.40 | 8.70 |

Mean followed by the same letter in each column are not significantly different at 5% level. *significantly different at 5% level, ** highly significant different at 1% level

Potassium application could not influence on plant height at all growth stages. However the maximum plant height (101.3 cm) was resulted from 30 kg KCl $ha^{-1}$ and the plant height of the treatment of 20 kg KCl $ha^{-1}$ showed the minimum plant height (96.2 cm). There was no interaction between pollen parents and potassium fertilizer application at all growth stages. This result pointed out that plant height of pollen parents was not significantly affected by the potassium fertilizer application and that the potassium fertilizer effect did not differ significantly with the tested pollen parents (Table 4.2).

### 4.1.3 Number of Tillers of Seed Parents (A lines)

Number of tillers per pot of seed parents as affected by different potassium fertilizer application was shown in Figure 4.5 and 4.6. All seed parents reflected significant difference in number of tiller per pot at all growth stages. Tiller numbers ranged from 12.06 to 19.97. Maximum tillers (18.97) were observed in Long 8 A line. Minimum tillers (12.06) were recorded from Long 6 A line.

There was no significant difference in tiller numbers per pot among the potassium fertilizer applications. However, the maximum tiller numbers (16.7) was found in the treatment of 50 kg KCl $ha^{-1}$ treatment and the minimum tiller numbers (12.37) was observed in 30 kg KCl $ha^{-1}$. Table 4.3 showed that no significant interaction was observed between seed parents and potassium applications on tillers numbers per pot. This result revealed that varietal difference was not significantly affected by the potassium fertilizer application and that the potassium effect did not differ significantly with the parental lines tested.

### 4.1.4 Number of Tillers of Pollen Parents (R lines)

Three pollen parents showed no marked variation in their tillers from 7 DAT to 70 DAT in dry season (Table 4.4). Long 4 R line gave maximum tillers (13.5) and the minimum tiller numbers (11.08) was obtained Long 6 and Long 8 R lines.

Potassium application could not give prounced effect on tiller numbers of pollen parents. Tiller numbers ranged from 11.44 to 13.11. The maximum tiller numbers (13.11) was recorded from control treatment and the minimum tiller numbers (11.44) was observed in 10 kg KCl $ha^{-1}$.In the analysis of variance, interaction was not observed between pollen parents and potassium applications on tillers number per pot.

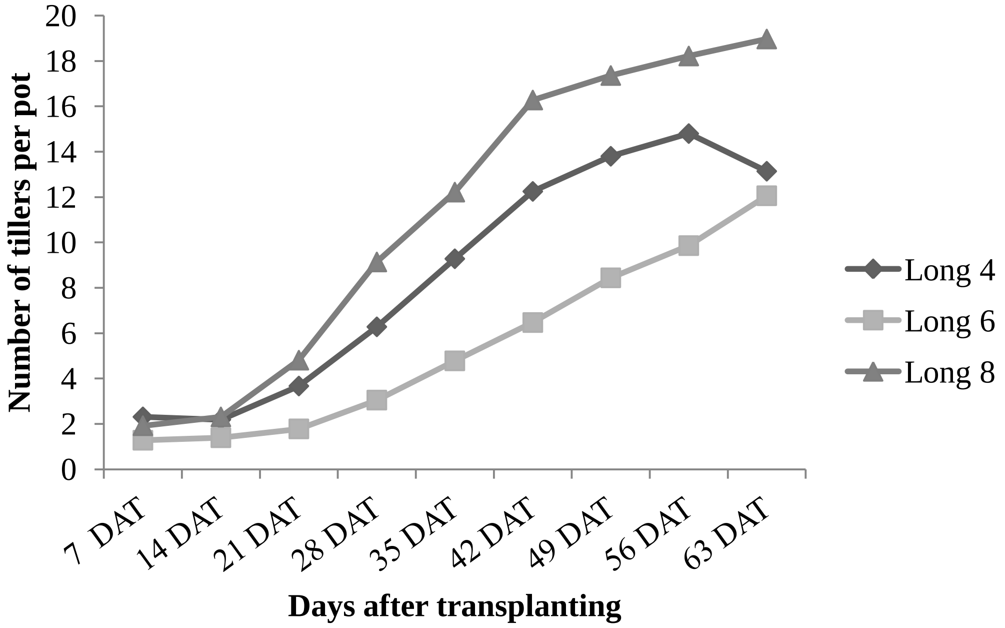


**Figure 4.5 Number of tillers of seed parents during dry season, 2012**

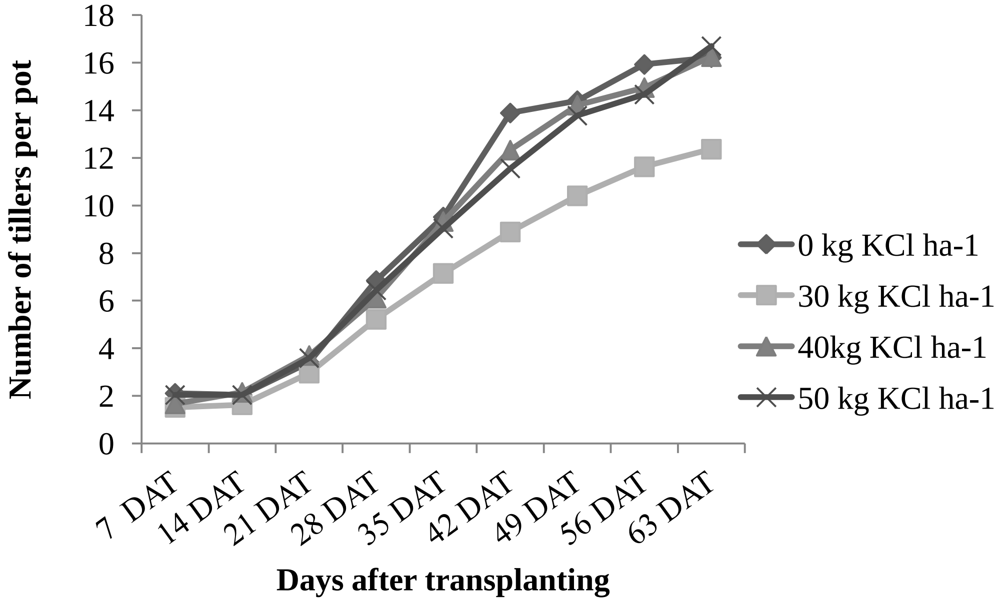


**Figure 4.6 Number of tillers as affected by potassium fertilizer during dry season, 2012**

**Table 4.3 Mean effect of potassium fertilizer rates on number of tillers per pot of seed parents (A lines) during dry season, 2012**

| | Tiller numbers per pot | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Parental lines** | **7 DAT** | **14 DAT** | **21 DAT** | **28 DAT** | **35 DAT** | **42 DAT** | **49 DAT** | **56 DAT** | **63 DAT** |
| **Long 4** | 2.31 a | 2.19 a | 3.67 a | 6.28 b | 9.28 a | 12.25 a | 13.80 a | 14.80 a | 13.14 a |
| **Long 6** | 1.28 b | 1.39 b | 1.78 b | 3.05 c | 4.78 b | 6.47 b | 8.44 b | 9.86 b | 12.06 b |
| **Long 8** | 1.92 ab | 2.31 a | 4.81 a | 9.14 a | 12.22 a | 16.28 a | 17.36 a | 18.22 a | 18.97 a |
| **$LSD_{0.05}$** | 0.69 | 0.66 | 1.38 | 2.74 | 3.34 | 4.67 | 4.31 | 4.69 | 4.52 |
| **Potassium** | | | | | | | | | |
| **0 kg KCl $ha^{-1}$** | 2.11 | 2.04 | 3.41 | 6.85 | 9.52 | 13.89 | 14.41 | 15.93 | 16.22 |
| **30 kg KCl $ha^{-1}$** | 1.52 | 1.63 | 2.96 | 5.22 | 7.15 | 8.89 | 10.41 | 11.63 | 12.37 |
| **40kg KCl $ha^{-1}$** | 1.67 | 2.15 | 3.70 | 6.11 | 9.33 | 12.33 | 14.22 | 14.96 | 16.26 |
| **50 kg KCl $ha^{-1}$** | 2.04 | 2.04 | 3.59 | 6.44 | 9.04 | 11.56 | 13.78 | 14.67 | 16.70 |
| **$LSD_{0.05}$** | 0.79 | 0.76 | 1.60 | 3.17 | 3.86 | 5.39 | 4.97 | 5.41 | 5.22 |
| **Pr>F** | | | | | | | | | |
| **Parental lines** | 0.017* | 0.017* | <.001** | <.001** | <.001** | <.001** | 0.001** | 0.004* | 0.015* |
| **Potassium** | 0.365 | 0.528 | 0.785 | 0.748 | 0.572 | 0.303 | 0.324 | 0.408 | 0.303 |
| **Parental lines × Potassium** | 0.174 | 0.906 | 0.921 | 0.939 | 0.863 | 0.736 | 0.821 | 0.768 | 0.669 |
| **CV%** | 44.50 | 40.00 | 48.00 | 52.80 | 45.30 | 47.50 | 38.70 | 38.90 | 34.90 |

Mean followed by the same letter in each column are not significantly different at 5% level. *significantly different at 5% level, ** highly significant different at 1% level

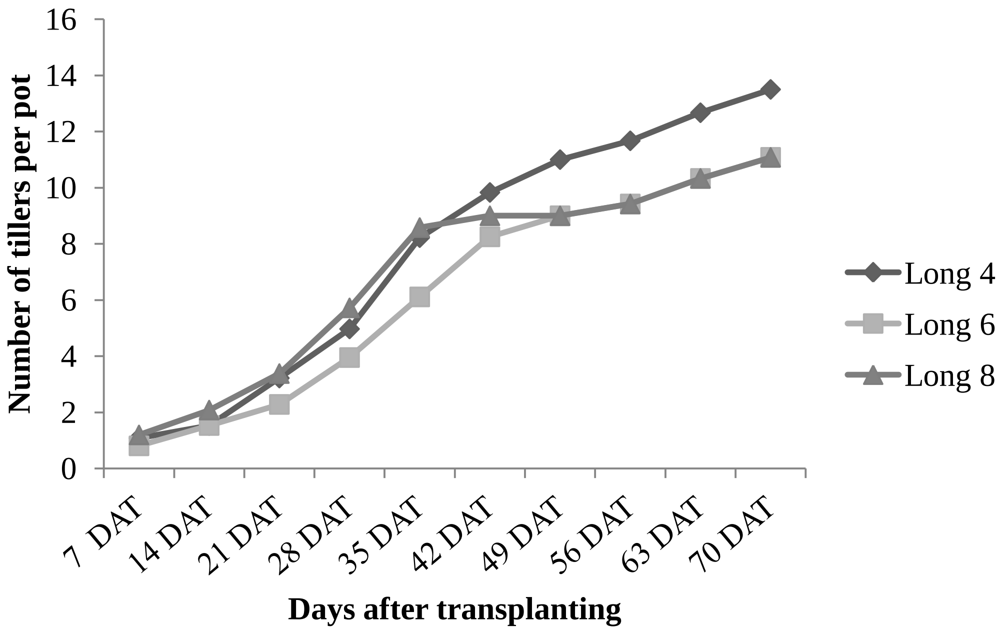


**Figure 4.7 Number of tillers of pollen parents during dry season, 2012**

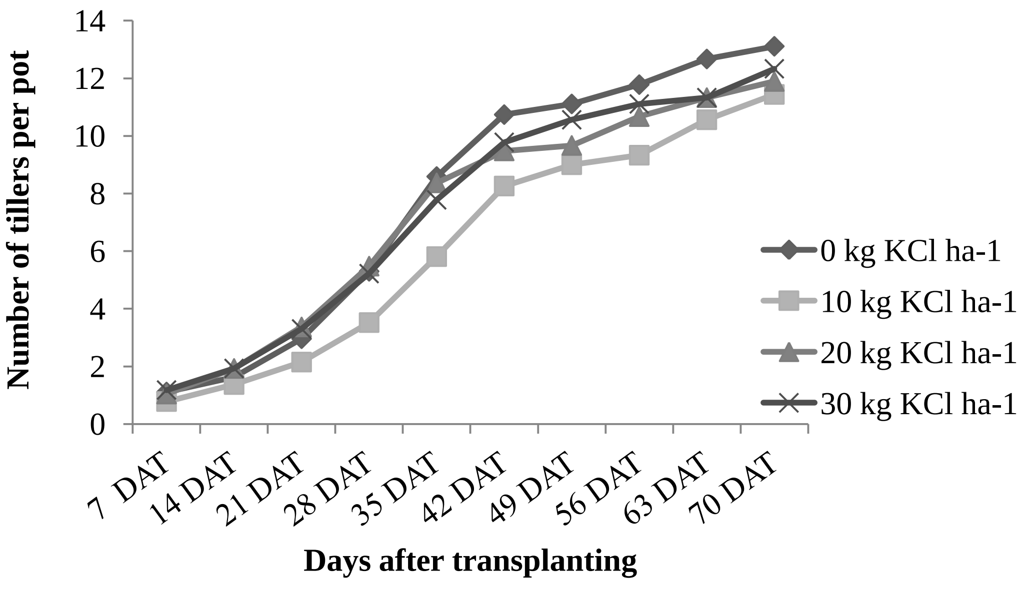


**Figure 4.8 Number of tillers as affected by potassium fertilizer during dry season, 2012**

**Table 4.4 Mean effect of potassium fertilizer rates on number of tillers per pot of pollen parent (R lines) during dry season, 2012**

| | Tiller numbers per pot | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Parental lines** | **7 DAT** | **14 DAT** | **21 DAT** | **28 DAT** | **35 DAT** | **42 DAT** | **49 DAT** | **56 DAT** | **63 DAT** | **70 DAT** |
| **Long 4** | 1.08 | 1.53 | 3.22 | 4.97 | 8.22 | 9.83 | 11.00 | 11.67 | 12.67 | 13.50 |
| **Long 6** | 0.81 | 1.53 | 2.28 | 3.95 | 6.11 | 8.25 | 9.00 | 9.42 | 10.33 | 11.08 |
| **Long 8** | 1.20 | 2.08 | 3.38 | 5.72 | 8.58 | 10.61 | 9.00 | 9.42 | 10.33 | 11.08 |
| **$LSD_{0.05}$** | 0.39 | 1.05 | 1.35 | 2.60 | 3.23 | 3.58 | 3.03 | 3.26 | 3.19 | 2.52 |
| **Potassium** | | | | | | | | | | |
| **0 kg KCl $ha^{-1}$** | 1.11 | 1.63 | 2.96 | 5.30 | 8.59 | 10.74 | 11.11 | 11.78 | 12.67 | 13.11 |
| **10 kg KCl $ha^{-1}$** | 0.78 | 1.37 | 2.15 | 3.52 | 5.81 | 8.26 | 9.00 | 9.33 | 10.56 | 11.44 |
| **20 kg KCl $ha^{-1}$** | 1.04 | 1.93 | 3.37 | 5.48 | 8.37 | 9.48 | 9.67 | 10.67 | 11.33 | 11.89 |
| **30 kg KCl $ha^{-1}$** | 1.18 | 1.93 | 3.30 | 5.22 | 7.78 | 9.78 | 10.56 | 11.11 | 11.33 | 12.33 |
| **$LSD_{0.05}$** | 0.45 | 1.21 | 1.56 | 3.00 | 3.72 | 4.13 | 3.50 | 3.77 | 3.69 | 2.91 |
| **Pr>F** | | | | | | | | | | |
| **Parental lines** | 0.121 | 0.458 | 0.226 | 0.382 | 0.252 | 0.395 | 0.401 | 0.352 | 0.337 | 0.159 |
| **Potassium** | 0.277 | 0.740 | 0.368 | 0.512 | 0.418 | 0.671 | 0.615 | 0.597 | 0.698 | 0.681 |
| **Parental lines × Potassium** | 0.837 | 0.944 | 0.992 | 0.929 | 0.982 | 0.977 | 0.947 | 0.938 | 0.937 | 0.635 |
| **CV%** | 44.50 | 72.40 | 54.30 | 63.30 | 50.10 | 44.40 | 35.60 | 36.10 | 33.00 | 24.60 |

Mean followed by the same letter in each column are not significantly different at 5% level. *significantly different at 5% level, ** highly significant different at 1% level

### 4.1.5 Leaf Number

The leaf number was to determine the optimum seeding intervals for the seed and pollen parents. The effect of potassium fertilizer on total leaf numbers of parental lines in the dry season was given in Table 4.5 and Table 4.6.Total leaf number of seed parents was lower than that of the pollen parents. The total leaf numbers of Long 4 A line was 13-14, the number of total leaves of Long 6 A line was 12-13 and of Long 8 A line was 15 leaves. Total leaves of Long 4 R line were 13-18, Long 6 R line and Long 8 R line were 18-19 and 17-18 respectively in the dry season. Total leaf number of parental lines was different between dry and wet seasons (Table 4.17).

### 4.1.6 Growth Duration (Days to initial heading and 50 % flowering)

Day to initial heading is more reliable parameter than days to 50% flowering which become more subjective. The effect of potassium fertilizers on days to initial heading and 50% flowering of parental lines was given in Table 4.7. Days to flowering of parental lines were significantly different among the varieties. Days to initial heading of seed parents ranged from 87.8 to 94.3. The longest period from seeding to initial heading was recorded from Long 6 A line (94.3 days). The earlier days to initial heading was obtained from Long 8 A line (87.8 days) and Long 4 A line (88.6 days). This result pointed out that Long 8 A line flowered 1 days earlier than Long 4 A and 6 days earlier than Long 6 A line.  Days to 50% flowering ranged from 92.6 to 99.7. The maximum longer period from seeding to 50% flowering (99.7 days) was observed from Long 6 A line. The earliest days to 50% flowering (92.6 days) were recorded from Long 8 A line.

Days to initial heading of pollen parents ranged from 101.8 to 107.2. The longest period from seeding to initial heading (107.2 days) was recorded from Long 6 R line. The earlier days to initial heading (101.8 days) was obtained from Long 8 R line. This result pointed out that Long 8 R line flowered 3 days earlier than Long 4 R line and 5 days earlier than Long 6 R line.  Days to 50% flowering of pollen parents ranged 105.1 to 109.3. The longer period from seeding to 50% flowering (109.3 days) was resulted from Long 4 R line which was not significantly different from Long 6 R line. The earliest days to 50% flowering (105.1 days) was observed from Long 8 variety. This pointed out that Long 8 R line flowered 4 days earlier than other varieties.

**Table 4.5 Total leaf numbers of seed parents (A lines) as influenced by different potassium fertilizer rates during dry season, 2012**

| DAS (days) | Long 4 (A) | | | | Long 6 (A) | | | | Long 8 (A) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 kg KCl ha$^{-1}$ | 30 kg KCl ha$^{-1}$ | 40 kg KCl ha$^{-1}$ | 50 kg KCl ha$^{-1}$ | 0 kg KCl ha-$^{1}$ | 30 kg KCl ha$^{-1}$ | 40 kg KCl ha$^{-1}$ | 50 kg KCl ha$^{-1}$ | 0 kg KCl ha-$^{1}$ | 30 kg KCl ha$^{-1}$ | 40 kg KCl ha$^{-1}$ | 50 kg KCl ha$^{-1}$ |
| **28** | 4.5 | 4.5 | 5.2 | 4.1 | 4.2 | 4.3 | 4.5 | 5.2 | 5.1 | 5.2 | 5.2 | 5.1 |
| **32** | 5.2 | 5.3 | 6.1 | 5.2 | 5.3 | 5.2 | 5.2 | 6.1 | 6.2 | 6.2 | 6.2 | 5.9 |
| **35** | 7.86 | 6.67 | 7.56 | 6.99 | 6.92 | 6.52 | 6.79 | 7.13 | 7.04 | 8.61 | 8.08 | 7.42 |
| **38** | 9.00 | 7.989 | 8.756 | 8.333 | 6.6 | 7.3 | 7.61 | 6.62 | 8.79 | 8.92 | 9.19 | 9.08 |
| **42** | 10.19 | 9.07 | 9.96 | 9.34 | 7.86 | 8.52 | 8.68 | 7.82 | 10.01 | 10.80 | 10.80 | 10.72 |
| **45** | 11.28 | 9.42 | 10.59 | 10.23 | 9.02 | 9.42 | 9.82 | 8.67 | 11.29 | 11.88 | 12.06 | 11.78 |
| **48** | 12.08 | 9.69 | 11.31 | 11.13 | 9.82 | 10.20 | 10.44 | 9.43 | 12.29 | 12.33 | 12.72 | 12.41 |
| **52** | 13.07 | 11.60 | 11.60 | 11.58 | 10.91 | 10.64 | 11.42 | 9.92 | 13.27 | 13.51 | 13.81 | 13.07 |
| **55** | 13.46 | 12.04 | 13.41 | 12.50 | 11.79 | 12.00 | 12.09 | 11.04 | 14.11 | 14.08 | 14.46 | 14.13 |
| **58** | 13.7 | 12.57 | 13.81 | 12.67 | 12.5 | 12.69 | 12.68 | 11.88 | 14.34 | 14.52 | 14.83 | 14.56 |
| **62** | 14 | 13 | 14 | 13 | 13 | 13 | 13 | 12 | 15 | 15 | 15 | 15 |

**Table 4.6 Total leaf numbers of pollen parents (R lines) as influenced by different potassium fertilizer rates during dry season, 2012**

| DAS (days) | Long 4 (R) | | | | Long 6 (R) | | | | Long 8 (R) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 kg KCl ha$^{-1}$ | 10 kg KCl ha$^{-1}$ | 20 kg KCl ha$^{-1}$ | 30 kg KCl ha$^{-1}$ | 0 kg KCl ha$^{-1}$ | 10 kg KCl ha$^{-1}$ | 20 kg KCl ha$^{-1}$ | 30 kg KCl ha$^{-1}$ | 0 kg KCl ha$^{-1}$ | 10 kg KCl ha$^{-1}$ | 20 kg KCl ha$^{-1}$ | 30 kg KCl ha$^{-1}$ |
| **28** | 4.4 | 5.3 | 5.1 | 4.4 | 4.3 | 4.2 | 5.1 | 4.5 | 4.5 | 5.2 | 6.2 | 4.5 |
| **32** | 5.2 | 5.8 | 5.6 | 5.2 | 5.1 | 5.2 | 5.5 | 5.2 | 5.3 | 6.2 | 6.1 | 6.5 |
| **35** | 6.89 | 7.59 | 7.51 | 4.68 | 6.93 | 6.66 | 7.13 | 7.62 | 6.64 | 7.39 | 6.91 | 7.90 |
| **38** | 8.62 | 8.58 | 8.27 | 8.72 | 8.53 | 8.23 | 8.71 | 8.68 | 8.59 | 8.77 | 9.00 | 9.32 |
| **42** | 9.98 | 10.19 | 10.31 | 10.1 | 10.02 | 9.61 | 10.17 | 9.97 | 10.30 | 10.24 | 10.89 | 11.03 |
| **45** | 11.22 | 10.41 | 10.98 | 10.44 | 11.28 | 10.98 | 11.09 | 10.80 | 11.37 | 11.34 | 11.28 | 11.87 |
| **48** | 11.78 | 11.32 | 11.93 | 10.63 | 12.41 | 12.20 | 12.17 | 12.00 | 12.39 | 12.21 | 12.63 | 12.67 |
| **52** | 12.63 | 11.92 | 12.78 | 11.16 | 13.79 | 13.69 | 13.01 | 13.17 | 13.48 | 13.37 | 13.28 | 13.84 |
| **55** | 12.76 | 12.94 | 13.82 | 11.31 | 14.63 | 14.72 | 13.81 | 13.90 | 14.22 | 14.22 | 14.08 | 14.79 |
| **58** | 13.33 | 13.88 | 14.68 | 11.51 | 15.83 | 15.9 | 14.6 | 14.88 | 15.26 | 15.24 | 15 | 15.53 |
| **62** | 14.38 | 14.61 | 14.81 | 11.83 | 16.64 | 16.79 | 15.39 | 15.39 | 16.26 | 16.16 | 15.99 | 16.6 |
| **65** | 15.10 | 15.30 | 15.5 | 12.1 | 16.81 | 17.12 | 15.50 | 15.60 | 16.52 | 16.23 | 16.00 | 16.82 |
| **68** | 15.54 | 15.83 | 17.2 | 12.71 | 18.59 | 18.7 | 17.49 | 17.41 | 17.44 | 16.56 | 16.34 | 17.12 |
| **72** | 16 | 16 | 18 | 13 | 19 | 19 | 18 | 18 | 18 | 17 | 17 | 17 |

The data showed that increasing the rate of potassium fertilizer did not significantly affect on 50% flowering time of seed parents but significant effect was observed on initial heading and 50% flowering of pollen parent at 5% level (Table 4.7). Days to initial heading of seed parents ranged from 88.4 to 92.1. The longer period from seeding to initial heading was recorded from 30 kg KCl $ha^{-1}$ (92.1 days). The earlier days to initial heading were obtained from 40 kg KCl $ha^{-1}$ (88.4 days). Days to 50% flowering of seed parents as affected by potassium fertilizer ranged from 96 to 98. The maximum longer period from seeding to to 50% flowering (98 days) was recorded from 30 kg KCl $ha^{-1}$ of seed parents. The minimum earlier days to 50% flowering (96 days) was obtained from 40 kg KCl $ha^{-1}$ treatment for seed parents but it was not significantly different from other treatments.

Days to initial heading of pollen parents ranged from 103.6 to 107.7. The longest period from seeding to initial heading was recorded from 10 kg KCl $ha^{-1}$ (107.7 days). The earlier day to initial heading was obtained from 30 kg KCl $ha^{-1}$ (103.6 days). Days to 50% flowering of pollen parent as affected by potassium fertilizer ranged from 106.4 to 111.4. The longest period from seeding to 50% flowering (111.4 days) was resulted from the treatment of 10 kg KCl $ha^{-1}$ which was significantly different from others. The minimum earlier days to 50% flowering (106.4 days) was observed from 20 kg KCl $ha^{-1}$ which was not significantly different from control and 30 kg KCl $ha^{-1}$.

In the analysis of variance, significant effects of days to initial heading and 50% flowering were observed among parental lines. There was no interaction between parental lines and potassium fertilizer.

### 4.1.6.1 Growth duration of Long 4 A line

Days to initial heading and 50% flowering of Long 4 A line were not significantly affected by potassium fertilizer application before III stage of panicle initiation (Table 4.9). Days to initial heading ranged from 85.4 to 92.7.The maximum value of period from seeding to initial heading (92.7 days) was observed from 30 kg KCl $ha^{-1}$. The earlier days to initial heading (85.4 days) was obtained from 50 kg KCl $ha^{-1}$. Days to 50% flowering ranged from 93.7 to 102.3. The longer period from seeding to 50 % flowering (102.3 days) was recorded from 30 kg KCl $ha^{-1}$. The earlier period from seeding to 50% flowering (93.7 days) was noticed from 50 kg KCl $ha^{-1}$.

### 4.1.6.2 Growth duration of Long 6 A line

Days to initial heading and 50% flowering of Long 6 variety were not significantly affected by potassium fertilizer application before III stage of panicle initiation (Table 4.9). Days to initial heading ranged from 92.6 to 95.6.The maximum value of period from seeding to initial heading (95.6 days) was observed from control treatment. The earlier days to initial heading (92.3 days) was obtained from 40 kg KCl $ha^{-1}$. This result pointed out that application of 40 kg KCl $ha^{-1}$ flowered 2-3 days earlier than control and 30 kg KCl $ha^{-1}$ and only 1 day earlier than 50 kg KCl $ha^{-1}$. Hari prasad (2011) pointed out that application of 40 kg KCl $ha^{-1}$ flowered 2-3 days earlier in seed parents. Days to 50% flowering ranged from 98 to102. The longer period from seeding to 50 % flowering (102 days) was recorded from control treatment. The earlier period from seeding to 50% flowering (98 days) was recorded from 50 kg KCl $ha^{-1}$.

**Table 4.7 Days to flowering of pollen parents by potassium fertilizer rates, Screen house experiment during dry season, 2012**

| | Seed parents | | Pollen parents | |
|---|---|---|---|---|
| **Parental lines** | **Initial Heading (Days)** | **50% flowering (Days)** | **Initial Heading (Days)** | **50% flowering (Days)** |
| **Long 4** | 88.6 b | 97.1 a | 105.3 a | 109.3 a |
| **Long 6** | 94.3 a | 99.7a | 107.2 a | 109.0 a |
| **Long 8** | 87.8 b | 92.6 b | 101.8 b | 105.1 b |
| **$LSD_{0.05}$** | 3.654 | 2.854 | 2.727 | 2.543 |
| **Potassium** | | | | |
| **K0** | 91.0 ab | 96.0 | 103.9 b | 107.4 b |
| **K1** | 92.1 a | 98.0 | 107.7 a | 111.4 a |
| **K2** | 88.4 b | 95.6 | 103.9 b | 106.4 b |
| **K3** | 89.3ab | 96.2 | 103.6 b | 107.0 b |
| **$LSD_{0.05}$** | 4.219 | 3.259 | 3.148 | 2.937 |
| **Pr>F** | | | | |
| **Parental lines** | 0.002** | <.001** | 0.001** | 0.001** |
| **Potassium** | 0.299 | 0.454 | 0.037* | 0.007** |
| **Parental lines ×** | | | | |
| **Potassium** | 0.630 | 0.104 | 0.579 | 0.611 |
| **CV%** | 4.8 | 3.5 | 3.1 | 2.8 |

Any two means having a common letter are not significantly different at LSD 5% level

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

| **For Seed parents** | **For Pollen parents** |
|---|---|
| K0= 0 kg KCl $ha^{-1}$ | K0= 0 kg KCl $ha^{-1}$ |
| K1= 30 kg KCl $ha^{-1}$ | K0= 10 kg KCl $ha^{-1}$ |
| K2= 40 kg KCl $ha^{-1}$ | K0= 20 kg KCl $ha^{-1}$ |
| K3= 50 kg KCl $ha^{-1}$ | K0= 30 kg KCl $ha^{-1}$ |

**Table 4.8 Mean values of days to flowering of Long 4 A line as affected by potassium fertilizer during dry season, 2012**

| Treatments | Initial Heading (Days) | 50% flowering (Days) |
|---|---|---|
| **0 kg KCl ha$^{-1}$** | 88.2 | 96.3 ab |
| **30 kg KCl ha$^{-1}$** | 92.7 | 102.3 a |
| **40 kg KCL ha$^{-1}$** | 87.8 | 96.0 ab |
| **50 kg KCl ha$^{-1}$** | 85.4 | 93.7 b |
| **LSD$_{0.05}$** | 8.86 | 7.35 |
| **Pr>F** | 0. 36 | 0.117 |
| **CV%** | 5.36 | 4.0 |

**Table 4.9 Mean values of days to flowering of Long 6 A line as affected by potassium fertilizer during dry season, 2012**

| Treatments | Initial Heading (Days) | 50% flowering (Days) |
|---|---|---|
| **0 kg KCl ha$^{-1}$** | 95.6 | 102.0 |
| **30 kg KCl ha$^{-1}$** | 95.1 | 100.0 |
| **40 kg KCL ha$^{-1}$** | 92.6 | 98.7 |
| **50 kg KCl ha$^{-1}$** | 93.3 | 98.0 |
| **LSD$_{0.05}$** | 6.65 | 7.31 |
| **Pr>F** | 0.699 | 0.622 |
| **CV%** | 3.8 | 3.9 |

**4.1.6.3 Growth duration of Long 8 A line**

Days to initial heading and 50% flowering of Long 8 variety were not significantly affected by potassium fertilizer application before III stage of panicle initiation (Table 4.10). Days to initial heading ranged from 84.8 to 89.3.The maximum value of period from seeding to initial heading (89.3 days) was obtained from control treatment. The earlier days to initial heading (84.8 days) was obtained from 40 kg KCl $ha^{-1}$. This result pointed out that application of 40 kg KCl $ha^{-1}$ flowered 4 days earlier than control, 30 kg KCl $ha^{-1}$ and 50 kg KCl $ha^{-1}$. Days to 50% flowering ranged from 91.7 to 94.7. The longer period from seeding to 50 % flowering (94.7days) was recorded from 50 kg KCl $ha^{-1}$. The earlier period from seeding to 50% flowering (91.7 days) was noticed from 30 and 40 kg KCl $ha^{-1}$. Similar results were observed by Zayed et al (2007). He stated that rice plants which were received potassium fertilizer were flowered earlier than the control plant which did not receive potash. Potassium helps plants to form flowering hormones as soon as early resulted in early heading than those of control plants.

**4.1.6.3 Growth duration of Long 4 R line**

Days to initial heading and 50% flowering of Long 4 variety were not significantly affected by potassium fertilizer application before III stage of panicle initiation (Table 4.11). Days to initial heading ranged from 102.8 to 108.8.The maximum value of period from seeding to initial heading (108.8 days) was obtained from 10 kg KCl $ha^{-1}$. The earlier days to initial heading (102.8 days) was recorded from 30 kg KCl $ha^{-1}$. This result pointed out that application of 30 kg KCl $ha^{-1}$ flowered 2-5 days earlier than those of other treatments. Days to 50% flowering ranged from 108.3 to 113.3. The longer period from seeding to 50 % flowering (113.3 days) was recorded from 10 kg KCl $ha^{-1}$. The earlier period from seeding to 50% flowering (108.3 days) was noticed from 20 and 30 kg KCl $ha^{-1}$.

**4.1.6.3 Growth duration of Long 6 R line**

The effect of potassium fertilizer did not significantly affect the initial heading and 50% flowering of Long 6 variety (Table 4.12). Days to initial heading ranged from 105 to 111.7. The maximum value of period from seeding to initial heading (111.7 days) was observed from 10 kg KCl $ha^{-1}$. The earlier days to initial heading (105 days) was obtained from 30 kg KCl $ha^{-1}$. This result pointed out that application of 30 kg KCl $ha^{-1}$ flowered 2-7 days earlier than control and 10 kg KCl $ha^{-1}$ and similar to 20 kg KCl $ha^{-1}$. Days to 50% flowering ranged from 107.3 to 114.7. The longer period from seeding to 50 % flowering (114.7days) was recorded from 10 kg KCl $ha^{-1}$. The earlier period from seeding to 50% flowering (107.3 days) was noticed from 20 kg KCl $ha^{-1}$.

**4.1.6.3 Growth duration of Long 8 R line**

Days to initial heading and 50% flowering of Long 8 variety were not significantly different among the treatment (Table 4.13). Days to initial heading ranged from 100.8 to 102.6.The maximum value of period from seeding to initial heading (108.8 days) was obtained from 10 kg KCl $ha^{-1}$. The earlier days to initial heading (102.6 days) was recorded from 30 kg KCl $ha^{-1}$. This result pointed out that application of 30 kg KCl $ha^{-1}$ flowered 1-2 days earlier than those of other treatments. Days to 50% flowering ranged from 103.7 to 106.3. The longer period from seeding to 50 % flowering (106.3 days) was recorded from 10 kg KCl $ha^{-1}$. The earlier period from seeding to 50% flowering (103.7 days) was noticed from 20 kg KCl $ha^{-1}$.

**Table 4.10 Mean values of days to flowering of Long 8 A line as affected by potassium fertilizer during dry season, 2012**

| Treatments | Initial Heading (Days) | 50% flowering (Days) |
|---|---|---|
| **0 kg KCl ha$^{-1}$** | 89.3 | 92.3 |
| **30 kg KCl ha$^{-1}$** | 88.2 | 91.7 |
| **40 kg KCL ha$^{-1}$** | 84.8 | 91.7 |
| **50 kg KCl ha$^{-1}$** | 89.0 | 94.7 |
| **$LSD_{0.05}$** | 8.94 | 3.805 |
| **Pr>F** | 0.644 | 0.289 |
| **CV%** | 5.4 | 2.2 |

**Table 4.11 Mean values of days to flowering of Long 4 R line as affected by potassium fertilizer during dry season, 2012**

| Treatments | Initial Heading (Days) | 50% flowering (Days) |
|---|---|---|
| **0 kg KCl ha$^{-1}$** | 104.6 ab | 107.0 b |
| **10 kg KCl ha$^{-1}$** | 108.8 a | 113.3 a |
| **20 kg KCl ha$^{-1}$** | 105.0 ab | 108.3 b |
| **30 kg KCl ha$^{-1}$** | 102.8 b | 108.3 b |
| **$LSD_{0.05}$** | 5.287 | 4.892 |
| **Pr>F** | 0.141 | 0.071 |
| **CV%** | 1.5 | 2.4 |

**Table 4.12 Mean values of days to flowering of Long 6 R line as affected by potassium fertilizer during dry season, 2012**

| Treatments | Initial Heading (Days) | 50% flowering (Days) |
|---|---|---|
| **0 kg KCl ha$^{-1}$** | 106.8 b | 109.7 b |
| **10 kg KCl ha$^{-1}$** | 111.7 a | 114.7 a |
| **20 kg KCl ha$^{-1}$** | 105.3 b | 107.3 b |
| **30 kg KCl ha$^{-1}$** | 105.0 b | 108.0 b |
| **LSD$_{0.05}$** | 4.626 | 4.612 |
| **Pr>F** | 0.035* | 0.024* |
| **CV%** | 2.3 | 2.2 |

**Table 4.13 Mean values of days to flowering of Long 8 R as affected by potassium fertilizer during dry season, 2012**

| Treatments | Initial Heading (Days) | 50% flowering (Days) |
|---|---|---|
| **0 kg KCl ha$^{-1}$** | 102.1 | 105.7 |
| **10 kg KCl ha$^{-1}$** | 102.6 | 106.3 |
| **20 kg KCl ha$^{-1}$** | 101.2 | 103.7 |
| **30 kg KCl ha$^{-1}$** | 100.8 | 104.7 |
| **LSD$_{0.05}$** | 7.49 | 7.19 |
| **Pr>F** | 0.951 | 0.838 |
| **CV%** | 4.1 | 3.6 |

## 4.2 Second Experiment in Wet Season

Second experiment was conducted in screen house at Department of Agricultural Chemistry, Yezin Agricultural University using same soil, same treatment and same design from August to November in 2012.

### 4.2.1 Plant Height of Seed Parents (A lines)

Plant height of seed parents showed in Table 4.9. The plant height was measured at weekly from 7 days after transplanting (DAT) to 35 DAT. The tested seed parents showed marked variation in their growth parameters. There was significant difference in plant height between seed parents at all growth stages except 7 DAT and 35 DAT. At 28 DAT, the maximum plant height (62.68 cm) was observed in Long 8 A line. Minimum plant height (55.5cm) was recorded in Long 6 A line. At later stages, plant height was statistically similar.

Plant height was not influenced by increasing rate of potassium fertilizer in this study. Maximum plant height (70.97cm) was obtained from 40 kg KCl $ha^{-1}$. Minimum plant height (69.4 cm) was obtained from 30 kg KCl $ha^{-1}$. Interaction was not observed between seed parents and potassium applications except 7 and 21 DAT. This result showed that plant height of seed parents was not influenced by potassium fertilizer application before III stage of panicle initiation and that the potassium fertilizer effect did not differ significantly with the parental lines tested. Plant height of seed parents was presented in Figure 4.9 and 4.10.

### 4.2.2 Plant Height of Pollen Parents (R lines)

Plant height of pollen parents was described in Table 4.10. Plant height was measured weekly interval from 7 DAT until 42 DAT. Plant height was significant difference among pollen parents. Plant height ranged from 72.84 and 85.45. The highest plant height (85.45 cm) was found in Long 4 R line. The minimum plant height (72.84 cm) was recorded in Long 8 R line. Plant height showed no significant response to increase potassium rates up to 30 kg KCl $ha^{-1}$ except 7 DAT and 42 DAT. At 42 DAT, the maximum plant height (78.84cm) was observed from 30 kg KCl $ha^{-1}$ and the minimum plant height (76.32cm) was recorded from 10 kg KCl $ha^{-1}$ but they were not significantly different from other treatments. According to the ANOVA result, no interaction was observed between pollen parents and potassium fertilizer applications.

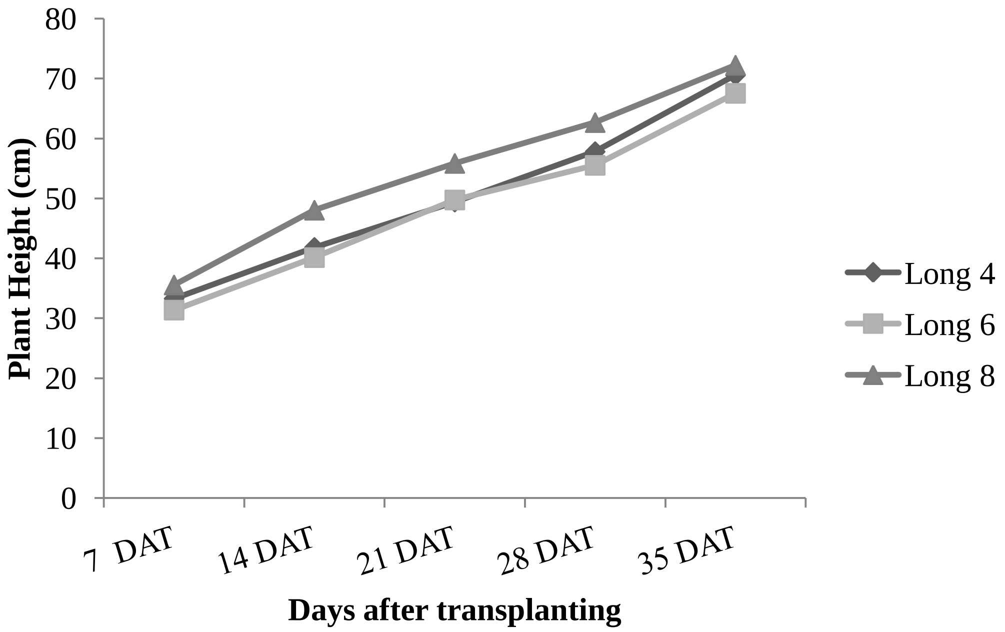


**Figure 4.9 Plant height of seed parents during wet season, 2012**

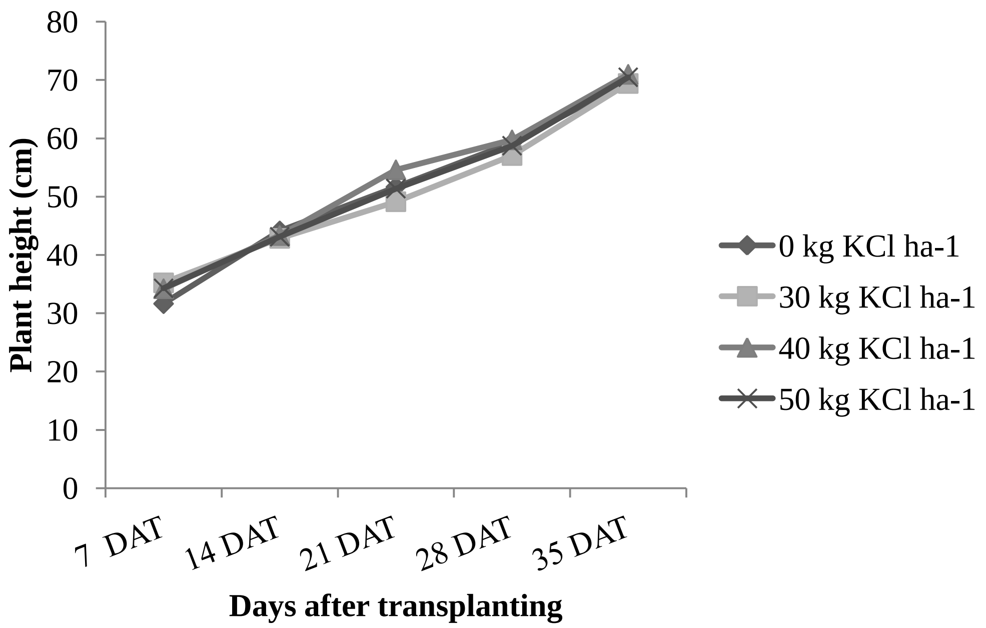


**Figure 4.10 Plant height as affected by potassium fertilizer during wet season, 2012**

**Table 4.14 Mean effect of potassium fertilizer rates on plant height of seed parents (A lines) during wet season, 2012.**

| Plant Height (cm) | | | | | |
|---|---|---|---|---|---|
| **Parental lines** | **7 DAT** | **14 DAT** | **21 DAT** | **28 DAT** | **35 DAT** |
| **Long 4** | 33.29 ab | 41.84 b | `49.42b | 57.83 b | 70.59 b |
| **Long 6** | 31.38 b | 40.14 b | 49.76 b | 55.54 b | 67.56 ab |
| **Long 8** | 35.57 a | 48.05 a | 55.86 a | 62.68 a | 72.25 a |
| **LSD 0.05** | 3.030 | 2.98 | 4.15 | 4.02 | 4.39 |
| **Potassium** | | | | | |
| **0 kg KCl ha$^{-1}$** | 31.63 ab | 44.11 | 51.64 ab | 59.24 | 69.7 |
| **30 kg KCl ha$^{-1}$** | 35.20 b | 42.83 | 49.12 b | 57.04 | 69.4 |
| **40 kg KCl ha$^{-1}$** | 34.20 a | 43.32 | 54.6 a | 59.73 | 70.97 |
| **50 kg KCl ha$^{-1}$** | 34.27 ab | 43.11 | 51.36 ab | 58.73 | 70.47 |
| **LSD 0.05** | 3.498 | 3.44 | 3.6 | 4.65 | 5.07 |
| **Pr>F** | | | | | |
| **Parental lines** | 0.303 | <.001** | 0.001** | 0.004** | 0.103 |
| **Potassium** | 0.170 | 0.884 | 0.083 | 0.658 | 0.913 |
| **Parental lines × Potassium** | 0.032* | 0.758 | 0.035* | 0.334 | 0.634 |
| **CV%** | 10.8 | 8.2 | 8.3 | 8.1 | 7.4 |

Mean followed by the same letter in each column are not significantly different at 5% level

.*significantly different at 5% level

** highly significant different at 1% level

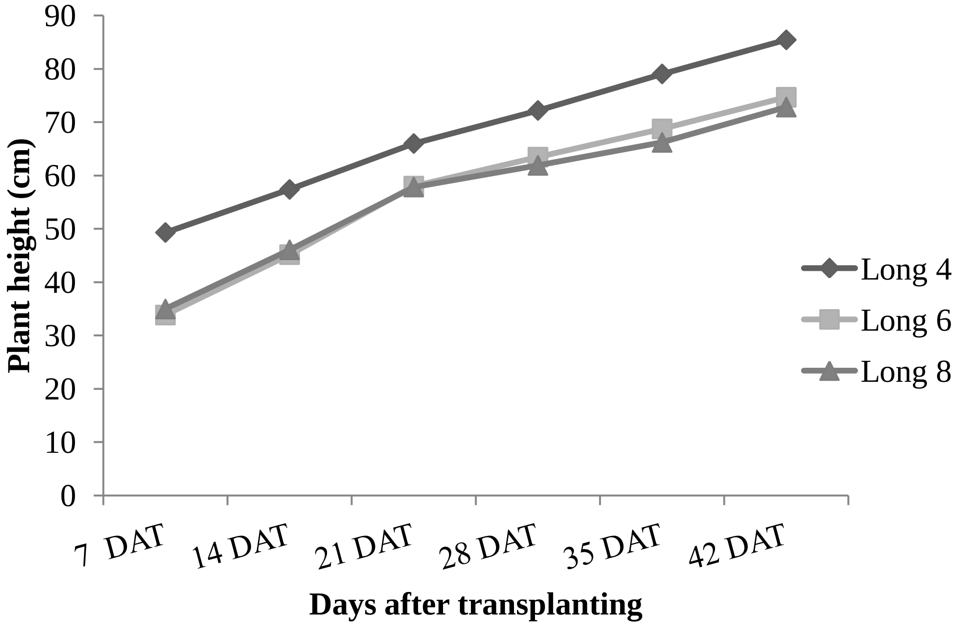


**Figure 4.11 Plant height of pollen parents during wet season, 2012**

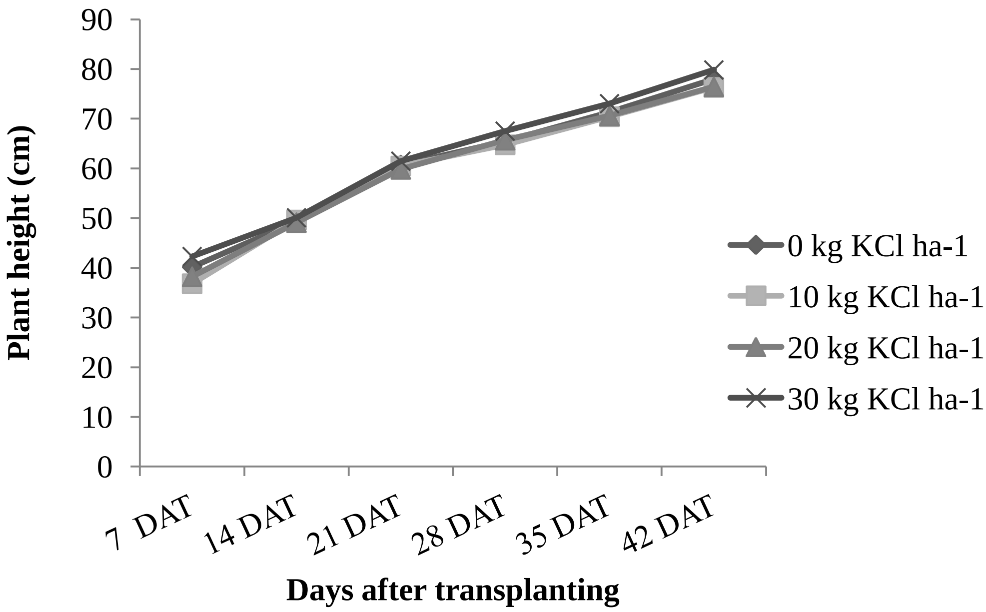


**Figure 4.12 Plant height as affected by potassium fertilizer during wet season, 2012**

**Table 4.15 Mean effect of potassium fertilizer rates on plant height of pollen parents (R lines) during wet season, 2012.**

| Parental lines | Plant height (cm) | | | | | |
|---|---|---|---|---|---|---|
| | 7DAT | 14 DAT | 21 DAT | 28 DAT | 35 DAT | 42 DAT |
| **Long 4** | 49.32 a | 57.40 a | 66.01 a | 72.21 a | 79.06 a | 85.45 a |
| **Long 6** | 33.84 b | 45.17 b | 58.02 b | 63.45 b | 68.74 b | 74.68 b |
| **Long 8** | 34.98 b | 46.08 b | 57.85 b | 61.91 b | 66.22 b | 72.84 b |
| **$LSD_{0.05}$** | 4.24 | 2.19 | 2.24 | 2.8 | 2.79 | 2.96 |
| **Potassium** | | | | | | |
| **0 kg KCl $ha^{-1}$** | 40.17 ab | 49.35 | 60.71 | 65.43 | 71.3 | 78.01 ab |
| **10 kg KCl $ha^{-1}$** | 36.82 b | 49.64 | 60.5 | 64.77 | 70.43 | 76.32 b |
| **20 kg KCl $ha^{-1}$** | 38.24 ab | 49.12 | 59.83 | 65.7 | 70.59 | 76.45 b |
| **30 kg KCl $ha^{-1}$** | 42.29 a | 50.09 | 61.48 | 67.53 | 73.05 | 79.84 a |
| **$LSD_{0.05}$** | 4.89 | 2.53 | 2.59 | 3.23 | 3.22 | 3.42 |
| **Pr>F** | | | | | | |
| **Parental lines** | <.001** | <.001** | <.001** | <.001** | <.001** | <.001** |
| **Potassium** | 0.140 | 0.884 | 0.63 | 0.356 | 0.336 | 0.143 |
| **Parental lines × Potassium** | 0.374 | 0.758 | 0.383 | 0.33 | 0.344 | 0.548 |
| **CV%** | 12.8 | 5.2 | 4.4 | 5 | 4.6 | 4.5 |

Mean followed by the same letter in each column are not significantly different at 5% level, *significantly different at 5% level, ** highly significant different at 1% level

. The comparisons of plant height of pollen parents at different growth stages were shown in Figure 4.11 and 4.12.

### 4.2.3 Number of Tillers of Seed Parents (A lines)

Effect of potassium fertilizer on tiller number of seed parents was showed in Table 4.11. Tiller number was not significant difference among the seed parents from 7 DAT to 35 DAT. At 21 DAT, 28 DAT and 35 DAT, the number of tillers of seed parents were statistically similar. Number of tillers was from 8.33 to 10.17. The maximum number of tillers (10.17) was obtained from Long 4 A line. Minimum number of tillers (8.33) was recorded from Long 8 A line.

Potassium fertilizer could not significantly influence on tiller numbers of seed parents. At 35 DAT, the number of tillers ranged from 7.44 to 10.33. The maximum number of tillers (10.33) was recorded from 50 kg KCl $ha^{-1}$. The minimum number of tillers (7.44) was obtained from 30 kg KCL $ha^{-1}$.At 28 DAT; the number of tillers was statistically similar. In the analysis of variance, no significant effect of tiller numbers was observed among variety and among potassium fertilizer except 14 DAT. No interaction between seed parents and potassium fertilizer applications was observed. This result noticed that potassium fertilizer application before third stage of panicle initiation was not increased the tiller numbers of seed parents because potassium absorbed at the panicle formation stage increases the number of panicles and spikeletes as well as weight of grains (Su 1976). The comparisons of number of tiller of seed parents at different growth stages were shown in 4.13 and 4.14.

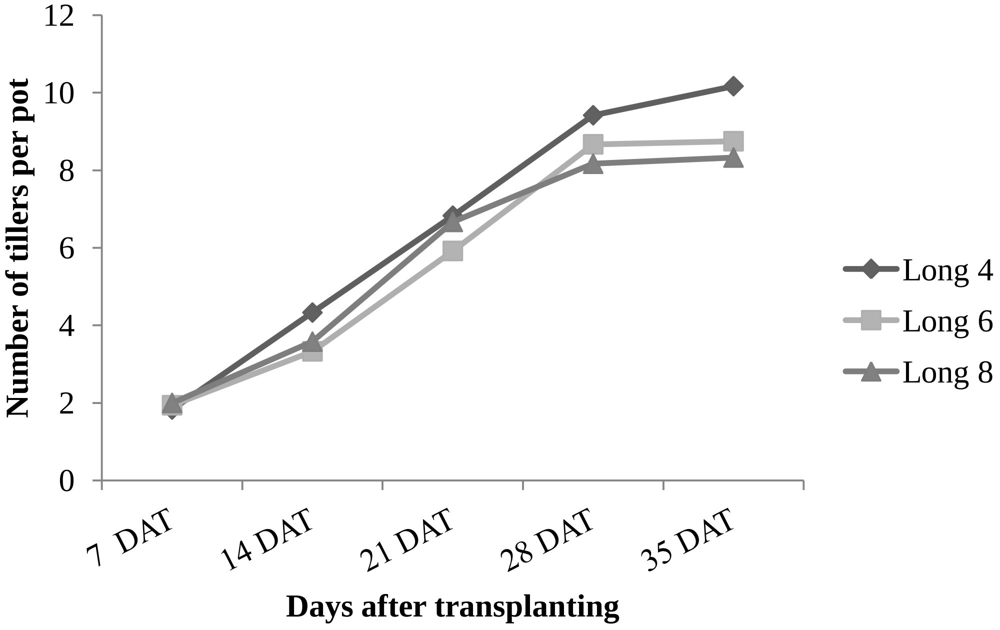


**Figure 4.13 Number of tillers of seed parents during wet season, 2012**

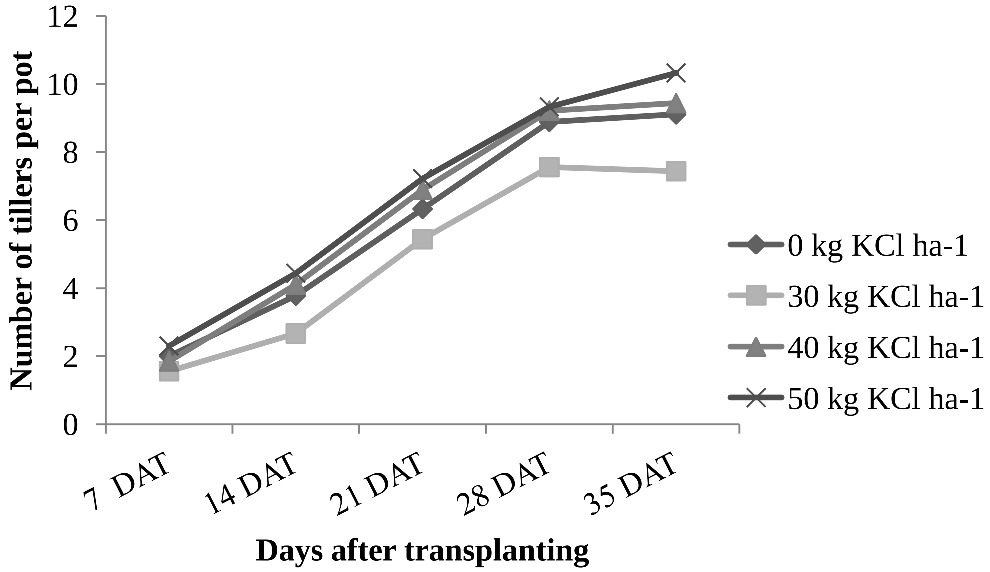


**Figure 4.14Tiller numbers as affected by potassium fertilizer during wet season, 2012**

**Table 4.16 Mean effect of potassium fertilizer rates on tiller numbers per pot of seed parents (A lines) during wet season, 2012.**

| | Tiller numbers per pot | | | | |
|---|---|---|---|---|---|
| **Parental lines** | **7 DAT** | **14 DAT** | **21 DAT** | **28 DAT** | **35 DAT** |
| **Long 4** | 1.83 a | 4.33 a | 6.83 | 9.42 | 10.17 |
| **Long 6** | 1.94 a | 3.33 ab | 5.92 | 8.67 | 8.75 |
| **Long 8** | 2.00 a | 3.58 a | 6.67 | 8.17 | 8.33 |
| **LSD 0.05** | 0.52 | 0.78 | 1.33 | 1.75 | 2.03 |
| **Potassium** | | | | | |
| **0 kg KCl ha$^{-1}$** | 2.00 ab | 3.78 a | 6.33 ab | 8.89 | 9.11 ab |
| **30 kg KCl ha$^{-1}$** | 1.56 b | 2.67 b | 5.44 b | 7.56 | 7.44 b |
| **40 kg KCl ha$^{-1}$** | 1.85 ab | 4.11 a | 6.89 ab | 9.22 | 9.44 ab |
| **50 kg KCl ha$^{-1}$** | 2.30 a | 4.44 a | 7.22 a | 9.33 | 10.33 a |
| **LSD 0.05** | 0.60 | 0.93 | 1.53 | 2.03 | 2.40 |
| **Pr>F** | | | | | |
| **Parental lines** | 0.797 | 0.038* | 0.331 | 0.350 | 0.169 |
| **Potassium** | 0.104 | 0.003** | 0.114 | 0.270 | 0.106 |
| **Parental lines × Potassium** | 0.118 | 0.237 | 0.346 | 0.468 | 0.487 |
| **CV%** | 31.7 | 2.47 | 24.3 | 23.8 | 26.5 |

Mean followed by the same letter in each column are not significantly different at 5% level.

*significantly different at 5% level

** highly significant different at 1% level

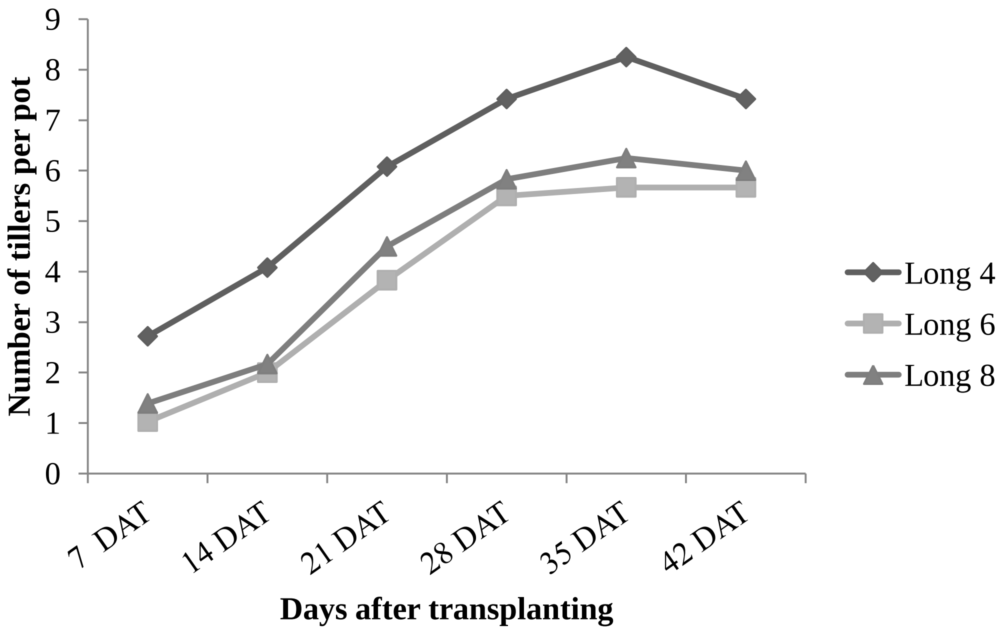


**Figure 4.15 Number of tillers of pollen parents during wet season, 2012**

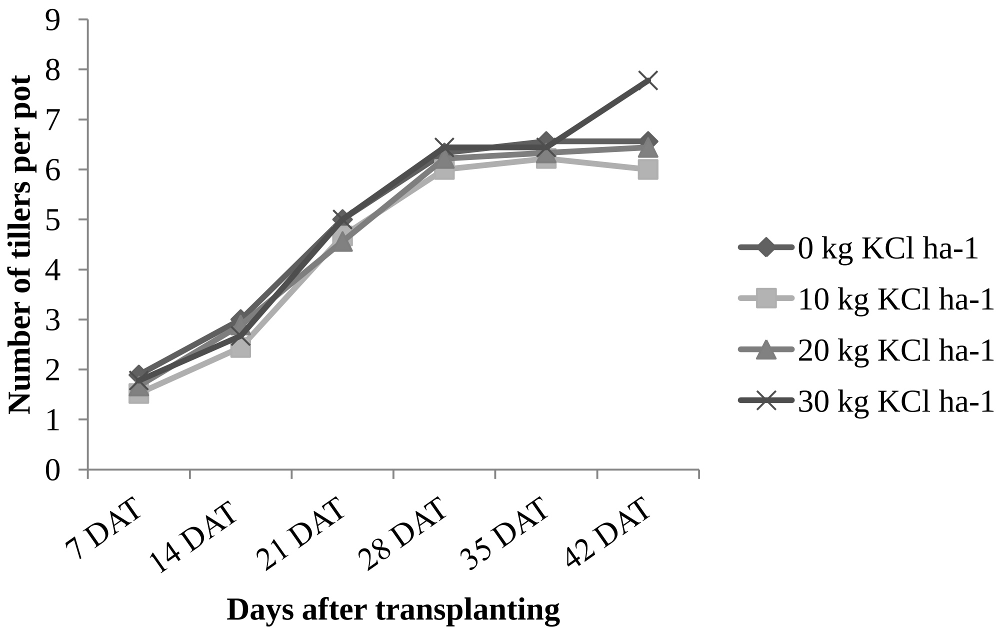


**Figure 4.16 Number of tillers as affected by potassium fertilizer during wet season, 2012**

**Table 4.17 Mean effect of potassium fertilizer rates on tiller numbers per pot of pollen parents (R lines) during wet season, 2012**

| | Tiller numbers per pot | | | | | |
|---|---|---|---|---|---|---|
| **Parental lines** | **7 DAT** | **14 DAT** | **21 DAT** | **28 DAT** | **35 DAT** | **42 DAT** |
| **Long 4** | 2.72 a | 4.08 a | 6.08 a | 7.42 a | 8.25 a | 7.42 a |
| **Long 6** | 1.03 b | 2.00 b | 3.83 b | 5.50 b | 5.67 b | 5.67 b |
| **Long 8** | 1.39 b | 2.17 b | 4.5 b | 5.83 b | 6.25 b | 6.00 b |
| **LSD 0.05** | 0.54 | 0.69 | 0.81 | 0.76 | 1.56 | 0.90 |
| **Potassium** | | | | | | |
| 0 kg KCl $ha^{-1}$ | 1.89 | 3.00 | 5.00 | 6.33 | 6.56 | 6.56 |
| 10 kg KCl $ha^{-1}$ | 1.52 | 2.44 | 4.67 | 6.00 | 6.22 | 6.00 |
| 20 kg KCl $ha^{-1}$ | 1.67 | 2.89 | 4.56 | 6.22 | 6.33 | 6.44 |
| 30 kg KCl $ha^{-1}$ | 1.78 | 2.67 | 5.00 | 6.44 | 7.78 | 6.44 |
| **LSD 0.05** | 0.59 | 0.79 | 0.93 | 0.87 | 1.81 | 1.04 |
| **Pr>F** | | | | | | |
| **Parental lines** | <.001** | <.001** | <.001** | <.001** | 0.006** | 0.001** |
| **Potassium** | 0.616 | 0.496 | 0.676 | 0.756 | 0.284 | 0.699 |
| **Parental lines × Potassium** | 0.691 | 0.626 | 0.380 | 0.395 | 0.148 | 0.671 |
| **CV%** | 35.4 | 29.7 | 19.9 | 14.4 | 27.6 | 16.8 |

Mean followed by the same letter in each column are not significantly different at 5% level.

*significantly different at 5% level

** highly significant different at 1% level

**4.2.4 Number of Tillers of Pollen Parents (R lines)**

Effect of potassium fertilizer on tiller number of pollen parents was presented in Table 4.12. Among the pollen parents, the number of tillers was significantly different from each other at all growth stages. Number of tillers ranged from 5.67 to 7.42. The highest number of tillers (7.42) was recorded from Long 4 R line. The tiller number of Long 6 R line (5.67) showed the minimum value.

Potassium fertilizer could not influence the tiller numbers of pollen parents. At all growth stages, the maximum tillers number was resulted from 30 kg KCl $ha^{-1}$ except 7 DAT and 42 DAT. At 42 DAT, the tiller number decreased because some tiller was dead. The minimum number of tillers was recorded from 10 kg KCL $ha^{-1}$. There was no interaction between pollen parents and potassium fertilizer applications. The comparisons of number of tiller of pollen parents at different growth stages were shown in Figure 4.15 and 4.16.

**4.2.5 Leaf Number**

Increasing rate of potassium fertilizer did not significantly increase the total leaf number of parental lines in wet season (Table 4.13 and 4.14). Total leaf number of Long 4 A and Long 6 A were 12-13 and the total leaf number of Long 8 A was 13-14 (Table 4.17). The total leaf number of Long 4 R, Long 6 R and Long 8 R were 14-15, 15-16 and 14, 15-16 respectively.

**4.2.6 Growth Duration (Days to initial heading and 50% flowering)**

The effect of potassium fertilizers on days to initial heading and 50% flowering of parental lines was given in Table 4.20 Days to initial heading of parental lines ranged from 80.6 to 82.18 and 88.5 to 93.8 in seed parents and pollen parents respectively. The longer period from seeding to initial heading (82.18 days and 93.8 days ) was observed from Long 8 variety in seed parents and Long 6 in pollen parents The earlier days to initial heading (80.6 days and 88.5 days) were obtained from Long 4 variety in both parental lines.Days to 50% flowering of seed parents ranged from 84.4 to 86 and that of pollen parents ranged from 93.1 to 96.4.The longest period from sowing to 50% flowering (86 days) of seed parents was observed from Long 6 A line. The shorter period from sowing to 50% flowering (84.4 days) was recorded from Long 8 A line which was not significantly different from Long 4 (84.6 days).

**Table 4.18 Total leaf numbers of seed parents (A lines) as influenced by different potassium fertilizer during wet season, 2012**

| | Long 4 (A) | | | | Long 6 (A) | | | | Long 8 (A) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DAS (days)** | **0 Kg KCl ha$^{-1}$** | **30 Kg KCl ha$^{-1}$** | **40 Kg KCl ha$^{-1}$** | **50 Kg KCl ha$^{-1}$** | **0 Kg KCl ha$^{-1}$** | **30 Kg KCl ha$^{-1}$** | **40 Kg KCl ha$^{-1}$** | **50 Kg KCl ha$^{-1}$** | **0 Kg KCl ha$^{-1}$** | **30 Kg KCl ha$^{-1}$** | **40 Kg KCl ha$^{-1}$** | **50 Kg KCl ha$^{-1}$** |
| **28** | 5.1 | 5.2 | 5.1 | 6.2 | 6.1 | 6.2 | 6.1 | 6.2 | 5.2 | 6.3 | 6.2 | 6.1 |
| **32** | 6.2 | 6.1 | 6.2 | 7.5 | 7.5 | 7.5 | 7.5 | 7.2 | 6.4 | 7.3 | 7.2 | 7.4 |
| **35** | 7.7 | 7.6 | 7.7 | 8.3 | 7.9 | 8.1 | 8.1 | 8.6 | 7.9 | 8.1 | 8.7 | 8.6 |
| **38** | 8.4 | 8.1 | 8 | 8.8 | 8.6 | 8.5 | 8.6 | 8.9 | 8 | 8.6 | 9 | 9 |
| **42** | 8.7 | 8.3 | 8.6 | 9.1 | 8.9 | 9.3 | 9 | 9.3 | 8.9 | 9.1 | 9.9 | 9.7 |
| **45** | 9.3 | 9.1 | 9 | 9.8 | 9.2 | 9.4 | 9.6 | 9.9 | 9.1 | 9.9 | 10.7 | 10.2 |
| **48** | 9.6 | 9.8 | 9.6 | 9.9 | 9.8 | 9.9 | 10.2 | 10.3 | 9.9 | 10.6 | 10.9 | 10.5 |
| **52** | 10.6 | 10.4 | 10.1 | 10.9 | 10..3 | 10.4 | 10.9 | 11 | 10.9 | 11.3 | 12 | 11 |
| **55** | 11 | 11 | 10.6 | 11.3 | 11.1 | 11 | 11.1 | 11.3 | 11.1 | 11.9 | 12.5 | 11.9 |
| **58** | 11 | 11 | 11.1 | 11.5 | 11.5 | 11 | 11.5 | 11.6 | 11.5 | 12.2 | 12.8 | 12.2 |
| **62** | 11.9 | 11.6 | 11.5 | 12.2 | 11.5 | 11.7 | 11.9 | 12.2 | 12 | 12.9 | 13.1 | 12.8 |
| **65** | 12.7 | 12.1 | 12 | 12.7 | 12 | 12.3 | 12 | 12.8 | 12.8 | 13.4 | 13.4 | 13.1 |
| **68** | 13 | 13 | 12 | 13 | 12 | 13 | 12 | 13 | 13 | 14 | 14 | 14 |

**Table 4.19 Total leaf numbers of pollen parents (R lines) as influenced by different potassium fertilizer during wet season, 2012**

| | Long 4 (R) | | | | Long 6 (R) | | | | Long 8 (R) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DAS (days)** | **0 Kg KCl $ha^{-1}$** | **10 Kg KCl $ha^{-1}$** | **20 Kg KCl $ha^{-1}$** | **30 Kg KCl $ha^{-1}$** | **0 Kg KCl $ha^{-1}$** | **10 Kg KCl $ha^{-1}$** | **20 Kg KCl $ha^{-1}$** | **30 Kg KCl $ha^{-1}$** | **0 Kg KCl $ha^{-1}$** | **10 Kg KCl $ha^{-1}$** | **20 Kg KCl $ha^{-1}$** | **30 Kg KCl $ha^{-1}$** |
| **28** | 7.2 | 7.1 | 7.5 | 7.4 | 5.3 | 5.5 | 5.4 | 5.8 | 6.4 | 5.2 | 6.4 | 5.3 |
| **32** | 8.2 | 8.3 | 8.4 | 8.5 | 6.4 | 6.2 | 6.1 | 6.2 | 7.4 | 6.4 | 7.4 | 6.8 |
| **35** | 9 | 9 | 8.6 | 9.2 | 7.7 | 7.3 | 7.9 | 7.3 | 8.1 | 7.6 | 8.5 | 7.7 |
| **38** | 9.3 | 9.3 | 8.7 | 9.6 | 8.3 | 7.7 | 8.7 | 8 | 8.6 | 8.2 | 9 | 8.3 |
| **42** | 9.9 | 9.9 | 9.1 | 9.8 | 9.4 | 8.4 | 9.1 | 8.3 | 8.9 | 8.7 | 9.6 | 8.8 |
| **45** | 10.3 | 10.4 | 9.6 | 10.6 | 10.3 | 9.3 | 9.9 | 9.2 | 9.6 | 9.3 | 10 | 9.3 |
| **48** | 10.9 | 10.9 | 9.9 | 11.2 | 11.2 | 10.6 | 10.6 | 9.9 | 10.9 | 9.9 | 10.9 | 10.2 |
| **52** | 11.4 | 11.6 | 10.7 | 11.7 | 11.4 | 11.5 | 11.1 | 10.8 | 11.1 | 10.9 | 11.6 | 10.6 |
| **55** | 12.2 | 12 | 11.3 | 12.3 | 12.3 | 11.9 | 11.9 | 11.3 | 11.9 | 11 | 11.6 | 11.3 |
| **58** | 12.5 | 12.4 | 11.5 | 12.6 | 12.6 | 12.1 | 12.3 | 11.5 | 12.5 | 11.6 | 12.2 | 11.6 |
| **62** | 12.6 | 12.9 | 11.7 | 13 | 13.2 | 12.6 | 12.8 | 12.2 | 12.9 | 11.9 | 12.6 | 12 |
| **65** | 13.1 | 13.3 | 12.5 | 13.6 | 13.4 | 13.3 | 13 | 12.4 | 13 | 12.1 | 13 | 12.3 |
| **68** | 13.3 | 13.9 | 12.6 | 13.9 | 14.2 | 13.6 | 13.6 | 12.7 | 13.9 | 12.9 | 13.3 | 13.2 |
| **72** | 13.3 | 14.2 | 13.5 | 14.3 | 14.4 | 13.7 | 14 | 13.3 | 14.5 | 13.7 | 14.2 | 13.4 |
| **75** | 13.3 | 14.7 | 13.9 | 14.3 | 15.1 | 14.5 | 14.5 | 13.8 | 14.9 | 13.8 | 13.7 | 13.7 |
| **78** | 13.3 | 14.7 | 14.7 | 14.3 | 15.7 | 15.3 | 15 | 14.3 | 15.3 | 14.3 | 13.7 | 13.7 |
| **92** | 13 | 15 | 15 | 15 | 16 | 16 | 15 | 16 | 16 | 15 | 14 | 14 |

The longest period from sowing to 50% flowering (96 days) of pollen parents was recorded from Long 6 R line and the shorter period from sowing to 50% flowering (93 days) was observed from Long 8 R line but it was not significantly different from Long 4 variety. This result pointed out that Long 8 A and R Lines flowered earlier than other varieties.

The data showed that increasing the rate of potassium fertilizer did not significantly affect on flowering time. Days to initial heading of seed parents ranged from 78.8 to 82.4.The longer period from seeding to initial heading (82.4 days) was found in 50 kg KCl $ha^{-1}$ and the earlier day to initial heading (78.8 days) was recorded from 40 kg KCl $ha^{-1}$ . Days to 50% flowering of seed parents as affected by potassium fertilizer ranged from 84 to 86.The later period from seeding to 50% flowering was recorded from 30 kg KCl $ha^{-1}$ (86 days) and the earlier days to 50% flowering was resulted from 40 kg KCl $ha^{-1}$ which were not significantly different from control and 50 kg KCl $ha^{-1}$ treatment (85 days). This result indicated that application of 40 kg KCl $ha^{-1}$for seed parents before III stage flowered about 1 day earlier than those of other treatments. Similarly, Virmani et al. (1998) expressed that the two parental lines should be given potassium fertilizer to adjust the flowering date by 2-5 days.

Days to initial heading of seed parents ranged from 89.8 to 92.6.The longer period from seeding to initial heading (92.6 days) was found in control and the earlier day to initial heading (89.8 days) was recorded from 30 kg KCl $ha^{-1}$ . Days to 50% flowering of pollen parents as affected by potassium fertilizer ranged from 94 to 95. The longer period from sowing to 50% flowering was recorded from control treatment (95 days). The shorter period from sowing to 50% flowering (93.4 days) was observed from 30 kg KCL $ha^{-1}$ which was not significantly different from 10 and 20 kg KCl $ha^{-1}$.

In the analysis of variance, interaction was not between parental lines and potassium fertilizer applications. There were about 8 days, 13 days and 8 days in growth duration difference between Long 4 A- R, Long 6 A-R and Long 8 A-R respectively. Therefore pollen parents should be planted 7 to 15 days earlier in order to adjust the flowering time in the wet season.

**Table 4.20 Days to flowering of parental lines by potassium fertilizer rates, screen house experiment during wet season, 2012**

| | Seed parents | | Pollen parents | |
|---|---|---|---|---|
| **Parental lines** | **Initial Heading (Days)** | **50% flowering (Days)** | **Initial Heading (Days)** | **50% flowering (Days)** |
| **Long 4** | 80.6 | 84.6 b | 88.5 c | 93.1 b |
| **Long 6** | 81.3 | 86.0 a | 93.8 a | 96.4 a |
| **Long 8** | 82.1 | 84.4 b | 90.5 b | 93.3 b |
| **LSD 0.05** | 1.956 | 1.264 | 2.12 | 1.302 |
| **Potassium** | | | | |
| **K0** | 81.8 | 84.7ab | 92.6 b | 94.6 |
| **K1** | 82.3 | 85.9 a | 91.1ab | 94.2 |
| **K2** | 78.8 | 84.1 b | 90.3 b | 94.4 |
| **K3** | 82.4 | 85.3ab | 89.8 b | 93.4 |
| **LSD 0.05** | 2.259 | 1.459 | 2.448 | 1.504 |
| **Pr>F** | | | | |
| **Parental lines** | 0.008** | 0.031* | <.001** | <.001** |
| **Potassium** | 0.304 | 0.092 | 0.132 | 0.807 |
| **Parental lines × Potassium** | 0.017 | 0.643 | 0.263 | 0.427 |
| **CV%** | 2.9 | 1.8 | 2.8 | 1.6 |

Any two means having a common letter are not significantly different at LSD 5% level

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

**For Seed parents**

K0= 0 kg KCl $ha^{-1}$

K1= 30 kg KCl $ha^{-1}$

K2= 40 kg KCl $ha^{-1}$

K3= 50 kg KCl $ha^{-1}$

**For Pollen parents**

K0= 0 kg KCl $ha^{-1}$

K1= 10 kg KCl $ha^{-1}$

K2= 20 kg KCl $ha^{-1}$

K3= 30 kg KCl $ha^{-1}$

#### 4.2.6.1 Growth duration of Long 4 A line

The effect of potassium fertilizers on days to initial heading and 50% flowering of Long 4 A line was presented in Table 4.21. Days to initial heading were not significantly different by potassium fertilizer. Days to initial heading ranged from 79.3 to 82.7. The maximum value of period from seeding to initial heading (82.7 days) was observed from 30 kg KCl $ha^{-1}$. The earlier days to initial heading (79.3 days) was obtained from 50 kg KCl $ha^{-1}$. This result pointed out that application of 50 kg KCl $ha^{-1}$ flowered 3 days earlier than control and 40 kg KCl $ha^{-1}$ and 8 days earlier than 30 kg KCl $ha^{-1}$. Days to 50% flowering ranged from 84.3 to 86. The longer period from seeding to 50 % flowering (86 days) was recorded from 30 kg KCl $ha^{-1}$. The earlier period from seeding to 50% flowering (93.7 days) was noticed from 40 and 50 kg KCl $ha^{-1}$.

#### 4.2.6.2 Growth duration of Long 6 A line

Days to initial heading and 50% flowering of Long 6 variety were not significantly affected by potassium fertilizer application before III stage of panicle initiation (Table 4.22). Days to initial heading ranged from 77.3 to 83.The maximum value of period from seeding to initial heading (83 days) was observed from 50 kg KCl $ha^{-1}$treatment. The earlier days to initial heading (77.3 days) was obtained from 40 kg KCl $ha^{-1}$. This result pointed out that application of 40 kg KCl $ha^{-1}$ flowered 3-5 days earlier than those of other treatments. This finding was in agreement with the results reported by Hari prasad (2011). Days to 50% flowering ranged from 85 to 87. The longer period from seeding to 50 % flowering (87days) was recorded from control and 30 kg KCl $ha^{-1}$. The earlier period from seeding to 50% flowering (85 days) was noticed from 40 kg KCl $ha^{-1}$.

**Table 4.21 Mean values of days to flowering of Long 4 A line as affected by potassium fertilizer during wet season, 2012**

| Treatments | Initial Heading (Days) | 50% flowering (Days) |
|---|---|---|
| 0 kg KCl $ha^{-1}$ | 80.3 | 83.7 b |
| 30 kg KCl $ha^{-1}$ | 82.7 | 86.0 a |
| 40 kg KCL $ha^{-1}$ | 80.0 | 84.3 b |
| 50 kg KCl $ha^{-1}$ | 79.3 | 84.3 b |
| $LSD_{0.05}$ | 3.766 | 1.631 |
| Pr>F | 0.269 | 0.053 |
| CV% | 2.5 | 1.0 |

**Table 4.22 Mean values of days to flowering of Long 6 A line as affected by potassium fertilizer during wet season, 2012**

| Treatments | Initial Heading (Days) | 50% flowering (Days) |
|---|---|---|
| 0 kg KCl $ha^{-1}$ | 81.3 ab | 86.0 |
| 30 kg KCl $ha^{-1}$ | 80.7 b | 86.0 |
| 40 kg KCL $ha^{-1}$ | 77.3 b | 85.0 |
| 50 kg KCl $ha^{-1}$ | 83.0 a | 87.0 |
| $LSD_{0.05}$ | 4.707 | 3.522 |
| Pr>F | 0.018 | 0.649 |
| CV% | 3.1 | 2.2 |

**4.2.6.3 Growth duration of Long 8 A line**

Days to initial heading and 50% flowering of Long 8 variety were not significantly affected by potassium fertilizer application before III stage of panicle initiation (Table 4.23). Days to initial heading ranged from 84.8 to 89.3.The maximum value of period from seeding to initial heading (89.3 days) was obtained from control treatment. The earlier days to initial heading (84.8 days) was obtained from 40 kg KCl $ha^{-1}$. This result pointed out that application of 40 kg KCl $ha^{-1}$ flowered 4 days earlier than control, 30 kg KCl $ha^{-1}$ and 50 kg KCl $ha^{-1}$. Days to 50% flowering ranged from 91.7 to 94.7. The longer period from seeding to 50 % flowering (94.7days) was recorded from 50 kg KCl $ha^{-1}$. The earlier period from seeding to 50% flowering (91.7 days) was noticed from 30 and 40 kg KCl $ha^{-1}$.

**4.2.6.3 Growth duration of Long 4 R line**

Days to initial heading and 50% flowering of Long 4 variety were not significantly affected by potassium fertilizer application before III stage of panicle initiation (Table 4.24). Days to initial heading ranged from 102.8 to 108.8.The maximum value of period from seeding to initial heading (108.8 days) was obtained from 10 kg KCl $ha^{-1}$. The earlier days to initial heading (102.8 days) was recorded from 30 kg KCl $ha^{-1}$. This result pointed out that application of 30 kg KCl $ha^{-1}$ flowered 2-5 days earlier than those of other treatments. Days to 50% flowering ranged from 108.3 to 113.3. The longer period from seeding to 50 % flowering (113.3 days) was recorded from 10 kg KCl $ha^{-1}$. The earlier period from seeding to 50% flowering (108.3 days) was noticed from 20 and 30 kg KCl $ha^{-1}$.

**4.2.6.3 Growth duration of Long 6 R line**

The effect of potassium fertilizer did not significantly affect the initial heading and 50% flowering of Long 6 variety (Table 4.25). Days to initial heading ranged from 93 to 94. The maximum value of period from seeding to initial heading (94 days) was observed from control, 10 and 20 kg KCl $ha^{-1}$. The earlier days to initial heading (93 days) was obtained from 30 kg KCl $ha^{-1}$. This result pointed out that application of 30 kg KCl $ha^{-1}$ flowered 1 day earlier than those of other treatments. Days to 50% flowering ranged from 95.7 to 97.3. The longer period from seeding to 50 % flowering (97.3days) was recorded from control treatment. The earlier period from seeding to 50% flowering (95.7 days) was noticed from 20 kg KCl $ha^{-1}$.

**4.2.6.3 Growth duration of Long 8 R line**

Days to initial heading and 50% flowering of Long 8 variety were not significantly different among the treatment (Table 4.26). Days to initial heading ranged from 89 to 93.The maximum value of period from seeding to initial heading (93 days) was obtained from 20 kg KCl $ha^{-1}$. The earlier days to initial heading (89 days) was recorded from 30 kg KCl $ha^{-1}$. This result pointed out that application of 30 kg KCl $ha^{-1}$ flowered 1-4 days earlier than those of other treatments. Days to 50% flowering ranged from 92.3 to 94. The longer period from seeding to 50 % flowering (94 days) was recorded from control and 20 kg KCl $ha^{-1}$. The earlier period from seeding to 50% flowering (92.3days) was noticed from 10 kg KCl $ha^{-1}$ but they were not significantly different from other treatments.

**Table 4.23 Mean values of days to flowering of Long 8 A line as affected by potassium fertilizer during wet season, 2012**

| Treatments | Initial Heading (Days) | 50% flowering (Days) |
|---|---|---|
| 0 kg KCl ha$^{-1}$ | 84.0 a | 84.3 |
| 30 kg KCl ha$^{-1}$ | 83.7a | 85.7 |
| 40 kg KCL ha$^{-1}$ | 78.7 b | 83.0 |
| 50 kg KCl ha$^{-1}$ | 82.0 ab | 84.7 |
| $LSD_{0.05}$ | 4.58 | 0.298 |
| Pr>F | 0.094 | 1.9 |
| CV% | 3.0 | 1.9 |

**Table 4.24 Mean values of days to flowering of Long 4 R line as affected by potassium fertilizer during wet season, 2012**

| Treatments | Initial Heading (Days) | 50% flowering (Days) |
|---|---|---|
| 0 kg KCl ha$^{-1}$ | 88.0 a | 92.3 |
| 10 kg KCl ha$^{-1}$ | 90.3 a | 94.0 |
| 20 kg KCl ha$^{-1}$ | 90.7 a | 93.7 |
| 30 kg KCl ha$^{-1}$ | 83.0 b | 92.3 |
| $LSD_{0.05}$ | 3.216 | 3.522 |
| Pr>F | 0.002** | 0.600 |
| CV% | 1.9 | 2.0 |

**Table 4.25 Mean values of days to flowering of Long 6 R line as affected by potassium fertilizer during wet season, 2012**

| Treatments | Initial Heading (Days) | 50% flowering (Days) |
|---|---|---|
| 0 kg KCl $ha^{-1}$ | 94.3 | 97.3 |
| 10 kg KCl $ha^{-1}$ | 94.0 | 96.3 |
| 20 kg KCl $ha^{-1}$ | 94.0 | 95.7 |
| 30 kg KCl $ha^{-1}$ | 93.0 | 96.3 |
| $LSD_{0.05}$ | 6.75 | 2.549 |
| Pr>F | 0.97 | 0.541 |
| CV% | 3.9 | 1.4 |

**Table 4.26 Mean values of days to flowering of Long 8 R line as affected by potassium fertilizer during wet season, 2012**

| Treatments | Initial Heading (Days) | 50% flowering (Days) |
|---|---|---|
| 0 kg KCl $ha^{-1}$ | 90.0 b | 94.0 |
| 10 kg KCl $ha^{-1}$ | 90.0 b | 92.3 |
| 20 kg KCl $ha^{-1}$ | 93.0 a | 94.0 |
| 30 kg KCl $ha^{-1}$ | 89.0 b | 93.0 |
| $LSD_{0.05}$ | 2.824 | 2.549 |
| Pr>F | 0.052 | 0.407 |
| CV% | 1.7 | 1.5 |

**Table 4.27 Total leaf numbers of parental lines from dry season and second season, 2012**

| | Total leaf numbers (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Parental Lines** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** |
| **Dry season (February - June)** | | | | | | | | |
| **Long 4 A** | | 50 | 50 | | | | | |
| **Long 6 A** | 25 | 75 | | | | | | |
| **Long 8 A** | | | | 100 | | | | |
| **Long 4 R** | | 25 | | | 50 | | 25 | |
| **Long 6 R** | | | | | | | 50 | 50 |
| **Long 8 R** | | | | | | 75 | 25 | |
| **Wet season (August- November)** | | | | | | | | |
| **Long 4 A** | 50 | 50 | | | | | | |
| **Long 6 A** | 50 | 50 | | | | | | |
| **Long 8 A** | | 25 | 75 | | | | | |
| **Long 4 R** | | | 25 | 75 | | | | |
| **Long 6 R** | | | | 50 | 50 | | | |
| **Long 8 R** | | | 50 | 25 | 25 | | | |

# CHAPTER V

# CONCLUSION

The present study observed the flowering response of parental lines of hybrid rice to potassium fertilizer application in dry and wet season. In both seasons, plant height and tiller numbers of parental lines were significantly difference between parental lines at all growth stages. In dry season, Long 8 A and R lines were highest in plant height and tiller numbers. In wet season, Long 4 A and R lines were highest in plant height and number of tillers. However increasing the rate of potassium fertilizer before third stage of panicle initiation did not significantly affect the plant height and tiller numbers. According to leaf number and growth duration of parental lines, Long 4 A line can be sown 12 days in dry season and 8 days in wet season after sowing R line or when R line produces 2.5 leaves and 1.5 leaves in dry and wet season respectively, in the nursery. Long 6 A line can be sown 10 days after sowing R line or when R line produces 2.5 leaves in the nursery. Long 8 A line can be sown 12 days in dry season and 9 days in wet season after sowing R line or when R line produces 3.5 leaves and 1.5 leaves in dry and wet season, respectively.

In both seasons, the flowering response of parental lines was not statistically different by increasing the rate of potassium fertilizer before III stage of panicle initiation. According to analysis of experimental soil, available potassium content is low (125 ppm). It is assumed that the amount of potassium fertilizer applied as basal might be sufficient. Although increasing rate of fertilizer applied before stage III panicle initiation, therefore the flowering date of parental lines in treated pot was significantly different from those of control. However the flowering date is numerically different from each other. The flowering of seed parents (A lines) was earlier 3-8 days by application of 40 kg KCl ha$^{-1}$ than those of other treatments. Application of 30 kg KCl ha$^{-1}$ in pollen parents ( R lines) flowered about 1-7 days earlier than those of other treatments. Based on the findings, it can suggest that 40 kg KCl ha$^{-1}$ for Long 6 A line and Long 8 A line, 50 kg KCl ha$^{-1}$ for Long 4 A line and 30 kg KCl ha$^{-1}$ for all pollen parents could be used to adjust the flowering time. However, it needs further investigation in subsequent studies, involving a greater number of replication or a greater rate of potassium fertilizer.

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**Appendix 1**

## APPENDICES

**Table 1.Duration of each developmental stage of young panicles**

| Stage | Developmental stages | Duration of stage (days) | Days before heading | Approx. panicle length (mm) |
|---|---|---|---|---|
| I | Panicle primordia | 2 | 30 | 0.2 |
| II | Differentiation of the primary branch primordia | 3-4 | 27 | 0.4 |
| III | Differentiation of the secondary branch primordia and spikelet primordia | 5-6 | 24 | 1.5 |
| IV | Differentiation of stamen and pistil primordia | 4-5 | 20 | 2 |
| V | Formation of pollen mother cells | 3 | 17 | 10-25 |
| VI | Meiotic division of pollen mother cells | 3-4 | 12 | 80 |
| VII | Filling stage of pollen | 5-6 | 6 | 190–250 |
| VIII | Ripe stage of pollen | 2 | 4 | 260 |
| XI | Completed spikelets | | 1-2 | 270 |
| X | Flowering | | - | |

Source: Yuan et al. (2003)

**Appendix 2**

**Table 2. Morphological stages in rice panicle development**

| Morphological character | Morpho-physiological stages of rice panicle development (equivalent) |
|---|---|
| Invisible | First bract primordium differentiation (stage I) and primary branch primordium (stage II) |
| Little white hairs | Secondary branch primordium differentiation (stage III) |
| More large hairs | Stamen and pistil primordium differentiation (stage IV) |
| Can see the spikelet individually | Mid meiotic stage (stage V) |
| The lemma and palea are visible | Late meiotic stage (stage VI) |
| Spikelet has full size | Pollen tetrad stage (stage IV) |
| Panicle has green color | Pollen maturation (stage VII) |
| Panicle is enclosed in leaf sheath and is about to emerge | Heading stage (stage VIII, stage IX) |

Source: Yuan et al.(2003)