EFFECT OF DIFFERENT LEVELS OF POTASSIUM ON NODULATION, QUALITY, YIELD AND NUTRIENT UPTAKE OF MUNGBEAN

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This is to certify that the research work entitled, **"Effect of different levels of potassium on nodulation, quality, yield and nutrient uptake of mungbean"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial implementation of the prerequisite for the degree of **Master of Science** in **Department of Agricultural Chemistry**, encapsulates the outcome of a piece of legitimate research work performed by **Md. Arif Islam**, Registration number: **12-05094** under my supervision and guidance. No segment of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has duly been acknowledged

Dated:
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Dedicated To
My Beloved
Mother

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ABSTRACT

A field experiment was conducted at the Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh during the period from March to May 2017 to study the effect of different levels of potassium on yield contributing characters of mungbean. The experimental soil was Deep Grey Terrace Soil having pH of 6.4. Six levels of potassium (0, 30, 40, 50, 60 and 70 kg ha^{-1}) were used in the study. The experiment was carried out in Randomized Complete Block Design with three replications. Results revealed that grain and stover yield of mungbean (BARI Mung-6) increased with increasing the levels of potassium. The maximum significant grain yield (1209 kg ha^{-1}) and stover yields (2742 kg ha^{-1}) were obtained with the treatment T_5 (60 kg K ha^{-1}) and also gave the highest pods $plant^{-1}$, pod length, seeds pod^{-1}, 1000 seed weight, nodule $plant^{-1}$, nutrient contents in seed and stover. Among the six treatments, the T_5 (60 kg ha^{-1}) treatment with BARI Mung-6 showed the best performance with maximum yield. The N, P and K contents of mungbean plant increased significantly at maturity stage with the highest doses of potassium fertilizers. Application of potassium fertilizers increased organic matter, N, P, K and B status of post-harvest soil significantly.

CONTENTS

CONTENTS (Contd.)

CONTENTS (Contd.)

CONTENTS (Contd.)

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

Continued.

Continued.

LIST OF ABBREVIATION AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
CV%	=	Percentage of coefficient of variance
DAS	=	Days after sowing
FAO	=	Food and Agricultural Organization
LSD	=	Least Significant Difference
MOP	=	Muriate of Potash
NPK	=	Nitrogen, Phosphorus and Potassium
RCBD	=	Randomized Complete Block Design
SRDI	=	Soil Resources and Development Institute
TSP	=	Triple Super Phosphate
i.e.	=	Ed est (means that is)
e.g.	=	Exempli gratia (by way of example)
etc.	=	Etcetera
ha^{-1}	=	Per hectare
kg	=	Kilogram
g	=	Gram (s)
mm	=	Milli-meter
β	=	Beta
ppm	=	Parts per million
wt	=	Weight
^{0}C	=	Degree Celsius
%	=	Percent

CHAPTER-I

INTRODUCTION

Legumes are grown agriculturally for their grain seed called pulse, plants for livestock forage and silage, and as soil-enhancing green manure. Legumes provide valuable and nutritive foods because the food stored for the embryo in the seed is rich in protein. Nitrogen-fixing bacteria dwelling in nodules of the roots of most legumes fix free nitrogen from the air into the nitrogenous compounds needed by all forms of life for building proteins (Wagner, 2011).

Mungbean (*Vigna radiata*) is alternatively known as the mung bean, green gram, or mugdal. The mungbean is a fast-growing warm-season legume and has a diploid chromosome number of 2n = 22. Grains of mungbean contains 19.5% to 28.5% protein. It contains 59.9% carbohydrate, 348 kilo calorie energy, 1.2 gm fat, 49 mg β-carotene, 75 mg calcium, 8.5 mg iron and 0.72 mg thiamine per 100 g of split dal (Afzal *et al.*, 2004). Mungbeans possess enzymes, nutrients and antioxidants which are essential for maintaining good health. The presence of medicinal properties in the mungbean assists to enhance the health. It is good for the health of eyes, hair, nails and liver. It also enhances the blood circulation. It is loaded with high amount of fiber and low in calories. Mungbeans are used in traditional Chinese medicine for the therapeutic uses such as to detoxify body and eliminate heat (Source 1).

Mungbean is an important food and cash crop in the rice based farming systems of South and Southeast Asia, mungbean is an important food and cash crop. It is cultivated on more than 6 million ha throughout the world (about 8.5% of global pulse area). The production of mungbean extends across a wide range of area (latitudes 40˚ N or S). Condensed mainly in East, Southeast and South Asia, yearly production is near about 3 million t of mungbean grain (5% of global pulse production). Major area of mungbean cultivation is being replaced by cereals (Abedin *et al.*, 1991).

Mungbean is grown three seasons in our country. In Bangladesh total cultivable land is 148.46 lakhs ha^{-1}. In 2011-12, 1.70 lakh hectare area cultivated with mungbean and contributing yield was to 1.45 M ton ha^{-1} (khrisi dairy-2013).

Required consumption rate of pulse is 45 g per day per human where in our country average rate is only 10 g per day (BBS-2015). Nowadays, it is being cultivated after harvesting of Rabi crops such as wheat, mustard, lentil, etc. As mungbean is a short duration crop, mungbean can well fit as a cash crop between major cropping seasons (Alam *et al.*, 2014). Mungbean is a warm season crop entailing 70–120 days of frost-free conditions from the time of planting to maturity (depending on the variety). For growth of mungbean the optimum range of temperature is between 27 °C and 30 °C. This means that this crop is usually cultivated during summer season. When the minimum temperature is higher than 15°C seed may be planted. Mungbeans are very responsive to daylight length. Short days result in early flowering, while long days result in late flowering. However, mungbean varieties differ in their photoperiod response. Mungbean is contemplated to be heat and drought tolerant. The likelihood of mungbean production in summer are being experimented and some successes have already been made in Bangladesh. Bangladesh Agricultural Research Institute (BARI) and Bangladesh Institute of Nuclear Agriculture (BINA) have developed a number of cultivars of mungbean.

Fertilizer is one among the foremost imperative factors that have an effect on crop production. Fertilizer recommendation for crops and soils is a dynamic process (Rafiqul Hoque *et al.,* 2004; Singh and Kumar, 2009; Singh *et al.,* 2013) and the management of fertilizers is one among the necessary factors that greatly have an effect on the expansion, development and yield of mungbean (Asaduzzaman *et al.,* 2008).

Mungbeans do best on fertile sandy loam soils having prominent internal drainage. Their performance is poor on clay soils with poor drainage system. Performance is best on soils with potassium (K) application even under drought. Potassium is the third macronutrient demanded for plant growth, after nitrogen (N) and phosphorus (P) and also plays a vital role as macronutrient in plant growth and sustainable production of crop (Mrschner, 1996 and Baligar, 2001). It maintains turgor pressure of cell which is imperative for cell expansion. Abeting in gap and shutting of stomata. It helps in osmoregulation of plant cell (Yang *et al.,* 2003). Potassium also performs a vital role in the activation of quite sixty enzymes (Tisdale *et al.,* 1990; Bushkh *et al.,* 2011).

Adequate supply of K during growth period improves the water relations of plant and photosynthesis that creates resistance against the pest attack and diseases and enhances the mungbean yield. According to Zublena (1997) K removal by crops under good growing conditions is usually high, is often three to four times that of P, and is equal to that of N. However, it is well-known that the availability of K to plants does not only depend on the size of the available pool in the soil, but also on the transport of K from soil solution to the root zone and from the root zone into plant roots (Barber, 1995).

Mungbean has phosphorus, potassium, calcium, magnesium and sulfur requirements similar to other legumes which must be met by fertilizer additions if the soil is deficient in these element.

In Bangladesh, many studies have been conducted on nutrient demand of mungbean but reports are very few on potassium. The present study was therefore, undertaken with the following objectives:

- To determine proper dose of potassium for nodulation, quality and yield maximization of mungbean
- To measure the apparent nutrients balance of mungbean

CHAPTER- II

REVIEW OF LITERATURE

A good number of research works on mungbean have been performed extensively in several countries especially in the South East Asian countries for improvement of yield and quality. In Bangladesh, little attention has so far been given for the improvement of mungbean variety or its cultural management. Currently the Bangladesh Agricultural Research Institute (BARI) and the Bangladesh Institute of Nuclear Agriculture (BINA) have started extensive research on varietal development and improvement of this crop. Findings of various experiments related to the present study in home and abroad have been reviewed and discussed in this chapter.

2.1 Effect of potassium on crop production

Sparks and Hung (1985) stated that potassium (K) is essential for plant and animal life with many vital nutritional roles. In plants, K and nitrogen (N) are the two elements required in greatest amounts, while in animals and humans, K is the third most abundant element after calcium (Ca) and phosphorus (P). Potash, the fertilizer trade term referring to fertilizer materials containing atomic number 19, has become associated in nursing vital input for satisfying demands of an increasing population for food, fiber and other commodities. Potassium is the seventh most abundant element in earth's crust. Potassium promotes root water absorption and prevents unnecessary water loss by transpiration.

Nitoses and Evans (1969) studied that potassium is very mobile in plant tissues moves promptly from older tissues to the growing points of the root and foliage. Moreover, K is a major plant nutrient needed in sugar beet for best plant growth and production. It is important to photosynthesis, activating starch synthetase enzymes and the sugar yield, which is produced, relies on K for movement to the storage root.

Draycott (1993) observed K improves performance by increasing leaf area, this allows the crop to intercept more radiation and gives proportional increases in sugar yield. Potassium has important financial implications because, for a given weight of sugar produced, growers are often paid commensurately more for high sugar percentage in roots. In addition, costs are decreased because, for a given weight of sugar, less weight of roots has to be harvested and transported.

Beringer *et al.* (1988) in Germany, found that increasing K supply led to higher root weights plant^{-1}.

Kandil (1993) in Egypt, showed that K fertilization exerted significant increase in all studied characteristics (root weight, length and width, number of leaves plant^{-1}, weight of leaves plant^{-1} and blade leaf area) compared to the control treatment (without K fertilizer). With exception for purity percentage, which cleared opposite trend.

Nigrila *et al.* (1994) in Romania, decided that application of K fertilizer at the rate of 70 kg K_2O ha^{-1} increased root yield from 80 to 83 t ha^{-1}.

2.2 Effect on physiological role of potassium in plants

Eakin (1972), Mengel and Kirkby (1987), Mullins and Burmester (1998) studied the total amount of potassium absorbed by the crop during the growing season depend upon the crop species being grown, the amount of native soil K^+, the amount of fertilizer K ion applied, K availability in the soil, the environmental conditions during the growing season and the management practices employed.

Hsiao and Lauchli (1986) found conclusion the actual amount removed from the field by a crop species depend upon the plant part or parts removed during harvest.

Suelter (1970) observed that, K is important in regulating more than 60 enzymes that catalyze a great number of metabolic activities.

Talbott *et al.* (1998), Fischer (1968) and Fischer and Hsiao (1968) demonstrated how the reversible K flux into and out of stomatal guard cells controlled stomatal aperture by affecting osmotic potential of the guard cells, with malate and Cl^-, serving as major counter ions.

Hoth *et al.* (1997) observed that guard cell uptake is mediated by K specific uptake channels and is coupled with proton extrusion into the apoplast.

Tabott and Zeiger (1996) reported that stomatal opening during the course of the day is thought to be a two phase process with promoting opening early in the day and then giving way to sucrose as the principle driving osmotic force around midday.

Bednarz *et al.* (1998), Longstreth and Nobel (1980) concluded of the close coordination between K^+ guard cell concentration and stomatal aperture, insufficient leaf levels of K^+ can lead to decreased stomatal conductance.

Bednarz *et al.* (1998), Longstreth and Nobel (1980), Pier and Berkowitz (1987) and Wolf *et al.,* (1976) expected with this decrease in stomatal conductance, insufficient K levels also lead to decreased photosynthesis per unit leaf area.

Basile *et al.* (2003), Bednarz *et al.*, 1998; Huber (1985), Tester and Blattn (1989) reported photosynthetic decline with lower K levels decreased stomatal conductance.

Bednarz *et al.* (1998) reported that the onset of a developing K deficiency was the principal factor limiting photosynthesis, whereas when the K deficiency became more extreme, non-stomatal or biochemical factors became the overriding reason for the decreased photosynthesis.

Ashley and Goodson (1972), Mengel and Haeder (1977), Mengel and Viro (1974) stated that to the reduced stomatal conductance and photosynthesis observed under K^+ deficient conditions, the transport of photosynthetic assimilates away from source tissue via the phloem is also restricted.

Bednarz and Oosterhuis (1999), Huber (1985), Pettigrew (1999) reported that the restriction on the transport of photosynthates can lead to accumulation of sugars in the leaf tissue of K deficient plants.

Pettigrew (1999), Pettigrew and Meredith (1997) suggested the accumulation of sugars undoubtedly contributes small proportion to the increased specific leaf weights observed when cotton plants were grown under conditions of low soil K.

Mengel (1997) observed that potassium is known to be taken up by plant roots at high rates and is quickly transported to upper plant parts. The downward transport of K^+ from tops to roots is also a rapid process, so that once K^+ absorbed, it is rapidly distributed throughout the entire plant. Long distance transport of K^+ has a direct impact on water transport and is also related to the movement of assimilates in the phloem. This long distance transport is essentially dependent on K^+ transport across plant membranes and it is also necessary for various physiological processes. Potassium plays an important role in the transport of assimilates and nutrients. The photosynthesis products (photosynthates) must be transported from the leaves (sources) to the site of their use or storage (sinks). Potassium promotes phloem transport of photosynthates mainly sucrose and amino acids to the physiological sinks (fruits, roots, tubers, seeds and grains).

Herlihy (1989) reported K plays a positive role in phloem loading with sucrose, in increasing the transport rate of phloem sap solutes and in phloem unloading. This role of K is related to its contribution to the osmotic potential in the sieve tubes and to its function in ATP synthesis which provides the energy for the loading of photosynthates.

Marschner (1995) reported in plants well supplied with K, the concentration of K, the osmotic potential of the phloem sap and the volume flow rate, are all higher than in plants supplied with a lower K level. As a result, sucrose concentration in the phloem sap is increased.

Mengel and Kirkby (1987) observed K not only promotes the translocation of newly synthesized photosynthates but also has a beneficial effect on the mobilization of stored material.

Marschner (1995) concluded after nitrate reduction in shoot, charge balance has to be maintained by corresponding net increase in organic acid anions. Part of these organic anions (mainly malate) can be re-translocated with K as the accompanying cation through the phloem to the roots.

2.3 Effect of potassium on yield and yield contributing characters of mungbean

Biswash *et al.*, (2014) conducted an experiment at the farm of Sher-e-Bangla Agricultural University to study K fertilizer and vermicompost effect on growth, yield and nutrient contents of mungbean (BARI Mung 5). During the experiment, following treatments were included: K_0 Control, K_1-K_2O @ 10 kg ha^{-1}, K_2- K_2O @15 kg ha^{-1}, K_3 - K_2O @ 20 kg ha^{-1} and V_0- No Vermicompost, V_1- Vermicompost @ 4 t ha^{-1}, V_2- Vermicompost @ 6 t ha^{-1}, V_3 – Vermicompost @ 8 t ha^{-1}. At harvest highest plant height, number of leaves and branches $plant^{-1}$, average dry weight $plant^{-1}$, number of pods $plant^{-1}$, number of seeds pod^{-1}, number of seeds $plant^{-1}$, 1000-seed weight, seed yield and stover yield were recorded in K_3 (K_2O @ 20 kg ha^{-1}) and it was either closely followed by or statistically similar with the application of K_2O @15 kg ha^{-1} (K_2) and subsequently followed by K_1 (K_2O @ 10 kg ha^{-1}). Nitrogen, P and K content in seed were recorded in K_3 (K_2O @ 20 kg ha^{-1}) and it was followed by the application of K_2O

@15 kg ha^{-1} (K_2) and then K_1 (K_2O @ 10 kg ha^{-1}). Lowest results for above parameters were found from the treatment using no K fertilizer (K_0). Similarly, the highest values for highest plant height, number of leaves and branches $plant^{-1}$, average dry weight $plant^{-1}$, number of pods $plant^{-1}$, number of seeds pod^{-1}, number of seeds $plant^{-1}$, 1000-seed weight, seed yield and stover yield were recorded in V_3 (vermicompost @ 8 t ha^{-1}) which was either closely followed by or statistically similar with Vermicompost @ 6 t $ha^{-1}$and then followed by Vermicompost @ 4 t ha^{-1}. Lowest results were found from the treatment using no vermicompost (V_0).

Singh*et al.*, (1993) found significant increase of N concentration in mungbean due to the application of increasing level of K fertilizer.

Asghar *et al.*, (2006) laid out a field experiment to determine the effect of different levels of K (0, 25, 50, 75 and 100 kg ha^{-1}) on growth, yield and quality of two mungbean genotypes (NM-92 and NM-98) which was studied in the Department of Agronomy, University of Agriculture, Faisalabad during 2003. Different K levels significantly affected the seed yield and protein contents. Maximum seed yield (1458 kg ha^{-1}) with 25.3 percent in contents was obtained with 100 kg K per hectare. Genotype NM-98 produced higher seed yield than NM-92.

Abraham and Lal (2003) conducted field experiments from 1997 to 1999 to investigate the effects of NPK fertilizer, organic manures (farm compost + vermicompost and farm compost + poultry manure) and biofertilizer on the productivity of black gram-wheat-greengram cropping system; black gram and green gram and grain yield for wheat were highest with highest grain yield compost + poultry manure, but the highest seed yield was recorded with farm compost + vermicompost in black gram in the first year. The treatment biofertilizer + cow's urine recorded higher values of pod count in the first year and seed yield in the second year in green gram.

Oad and Buriro (2005) laid out a field experiment to determine the effect of different NPK levels on the growth and yield of mung bean *cv. ARM 96* and showed that the 10-30-30 kg N-P-K ha^{-1} was the best treatment recording plant height of 56.3 cm, pod length of 5.02 cm, seed weight per plant of 10.5 g and the highest seed yield of 1205 kg ha^{-1}.

Kumer *et al.* (2012) observed that K application is directly related to growth, plant biomass and yield in crops. Different K levels significantly affected the seed yield and yield contributing parameters except number of plants per plot. Maximum seed yield (753 kg ha^{-1}) was obtained with the application of 90 kg K per hectare. The interactive effect of mungbean varieties and K level was found significant in parameter of protein contents (%). Maximum protein contenis were observed with application of 90 kg K per hectare.

Tawfik *et al.* (2008) conducted a pot experiment to study the effect of extension of irrigation interval (2, 5, and 10 days) on growth, yield and metabolic changes in mungbean (*Vigna radiala* L.) var. VC 1000 in addition to K application. Generally, fresh and dry weights and yield were significantly reduced under water stress condition. Treatment with K biofertilizer to some extent mitigated the effect of drought stress. The greatest vegetative growth was obtained in plants irrigated every two days and treated with potassium, while the greatest seed yield was obtained from plant irrigated every live days and treated with potassium. Osmoprotectants such as total soluble sugars, proline and glycine betaine increased in plants subjected to water stress. It could be concluded that to maximize mungbean yield irrigation should be extended through all phenological stages, specially in flowering and pod-filling stages.

Abbas *et al.* (2011) observed that mineral nutrients plays a significant role in improving plant growth and development. Results showed significant impacts of applied K on plant height, number of grain pod^{-1} and grain yield as compared to control. Among different treatments, 14 (K 2804 @ 75 kg ha^{-1}) caused more prominent increase in yield and yield contributing parameters. It was concluded that K helped to improve the growth and yield of mungbean which played an important role in maintaining soil fertility.

Jahan *et al.* (2009) reported that grain and stover yield of all varieties were increased with the increase of potassium application up to 35 kg ha^{-1}. The highest grain yield (2.16 t ha^{-1}) was found at 35 kg K ha^{-1} and the lowest grain yield (1.61 t ha^{-1}) was exhibited from control potassium level and the highest stover yield (3.89 t ha^{-1}) was also found in 35 kg K ha^{-1} and the lowest (3.32 t ha^{-1}) was found in control potassium level. In case of interaction, the highest seed yield (2.58 t ha^{-1}) was produced by BARtrnasur-6 with 35 kg K ha^{-1}. Therefore, fertilization of all the varieties with 35 kg K ha^{-1} appeared as the best rate of potassium in respect of grain and stover yield.

Ahmad *et al.* (2003) conducted an experiment on mungbean with N P K at 50 0: 0 (F_1). 50: 100: 0 (F_2) and 50 : 100 : 50 kg ha^{-1} (F_3) and revealed that no significant differences in the number of pods per plant, number of grains per plant, grain yield and straw yield were observed in plants under F_1, F_2 and F_3, where F_3 resulted in the highest grain yield value and costs, and lowest net field benefit.

Oad *et al.* (2003) conducted a field experiment on the growth and yield performance of mungbean (*Vigna radiata*) and showed that mungbean varieties were significantly influenced by phosphorus and potassium except pod number, seed weight per plant and seed index were non-significant. However, 100 kg P ha^{-1} and 100 kg K ha^{-1} showed an increase in the yield other crop.

Chanda *et al.* (2002) carried out a field experiment on mungbean and showed that seed yield, protein content and net production value increased with increasing rates of K and S similarly, the status of N and P in soil decreased with increasing rates of K and S.

Das *et al.* (2002) studied the effects of vermicompost and chemical fertilizer application on the growth and yield of green gram (V. *radiata* cv. *Sujala*). The dry matter and pod yield of green gram were increased with the application of vermicompost applied in integrated form. The yield was highest with 100% enriched vermicompost compared to sole organic manure. Greater dry matter content, pod yield, nutrient uptake (N, P and K), plant height, leaf area, root volume, number of nodules and fresh weight of nodules were obtained with treatments containing vermicompost. Flowering was earlier by 7 days in vermicompost treated plants compared with the control.

Kumar *et al.* (2014), conducted to study the effect of different potassium levels on mungbean under custard apple based agri-horti system at Agricultural Research Farm of Rajiv Gandhi South Campus, Barkachha, Mirzapur. These treatments were different doses of potassium, that is, 0 kg ha^{-1} (T_1), 20 kg ha^{-1} (T_2), 40 kg ha^{-1} (T_3), 60 kg ha^{-1}

(T_4), 80 kg ha^{-1} (T_5), 100 kg ha^{-1} (T_6) and 120 kg ha^{-1} (T_7). Results showed that application of different potassium levels gave varying yield. Lowest yield (700 kg ha^{-1}) was obtained with the application of 0 kg $ha^{-1}$and highest yield (1096 kg ha^{-1}) was obtained with the application of 120 kg ha^{-1} potassium. It is concluded that the application of 80 kg ha^{-1} potassium gave highest Benefit/Cost ratio of mungbean and looks more remunerative in Vindhyan region.

Cobindar and Thirumurugan (2000) conducted an experiment and observed that 1.0 % KCl + 1.0% KNO_3gave the highest values for plant height at harvest (48.6 cm), leaf area index at 60 DAS (6.83), number of branches $plant^{-1}$ (2.89), number of pods $plant^{-1}$ (20.6), pod length (8.12cm), number of grains pod^{-1} (10.77). 100-grain weight (4.0 g), gain yield (777 kg ha^{-1}), dry matter production at harvest (2783 kg ha^{-1}) and benefit: cost (2.53).

Sangakara *et al.* (2001) carried out a field experiment to determine the benefits of potassium in overcoming water stress in mungbean. They found that potassium increased the shoot growth, root growth and as a significant factor in overcoming soil moisture stress in tropical cropping systems.

Prasad *et al.* (2000) conducted a pot experiment to study the effects of potassium on yield, water use efficiency and K-uptake by summer mungbean. They observed that total biomass production, grain yield, the water use efficiency and potassium uptake significantly increased with 20 and 30 kg K as compared to other levels of potassium.

Maiti *et al.* (1988) reported that 60 or 100 kg ha^{-1} each of P_2O_5 and K_2O increased seed yield in *Vigna radiata* and lentils.

Ram and Dixit (2000) conducted a field experiment on summer greengram cv. kES I and revealed that nodulation. N, P and K uptake and yield increased with increasing P rate.

Sardana and Verma (1987) made a field trial in Delhi, India with combined application of aldicarb (for the control of various insect pests) with nitrogen, phosphorus and potassium and reported that plant height, leaf surface area, number and length of pods. 100-grain weight and yield of green gram were significantly increased.

Chaudhury and Mahmood (1999) laid out a field experiment to study the effect of optimum potassium levels on growth, yield and quality of mungbean and reported that 50 kg K_2O gave the highest seed yield (832 kg ha^{-1}) and also reported that the optimum level of K_2O was between 50 to 100 kg per hectare.

Reddy *et al.* (1998) carried out a field trial during kharif of 1995 at Attibele, Karnataka. India, on peas cv. Selection lt1 with 0, 50 or 100% of the recommended rates of NPK (37.5: 60: 50 kg ha^{-1}) and 0, 5 or 10 t farmyard manure and/or vermicompost ha^{-1}. Plant height at harvest, days to initial flowering, number of branches per plant, number of pods per plant, number of seeds per pod and yield were highest with 10 t vermicompost + 100% recommended NPK.

Sushil *et al.* (1997) conducted an experiment to study the effect of sulphur, potassium and phosphorus supply (0. 25, 50 and 100 mM) on seed protein of *Vigna radiata*. They reported that the amount of globulin and albumin were increased with increasing concentrations of K. Tryptophan in all the protein fractions also increased with higher K levels.

Chatterjee and Mandal (1996) carried out a field experiment on integrated fertilizer management with or without application of potassium and organic matter or manure. They observed that maximum crop productivity was achieved using 150% of the recommended doses of N. P and K in rice-potato-sesame, rice-potatomungbean and rice-potato-groundnut systems and the available K status was improved in 0-15 cm soil depth.

Ahd-EI-Lateef *et al.* (1998) carried out a field experiment with 0, 15.5 or 31 kg P_2O_5 and 0 or 24 kg K_2O feddan^{-1} and observed that seed yield increased by the application of K and the lower rates of P (1 feddan = 0.42ha).

Sangakkara. U. R. (1990) observed in an experiment that K application increased plant growth rate, flowers plant^{-1}, percentage pod set, seeds pod^{-1}, 100-seed wt and yield plant^{-1}. In the short maturing cv. Ml 5, seed yield and quality increased with a basal application of up to 80 kg K ha^{-1} and a split application of up to 60 kg K ha^{-1}. In the long maturing cv. Type 61, seed yield and quality increased with a basal application of up to 100 kg K ha^{-1} or a split application of up to 80 kg K ha^{-1}.

2.4 Effect of potassium on metabolism

Dibb and Thompson (1985) reported potassium plays several roles in plant metabolism, and performs these roles positively; it should interact positively with other nutrients. Positive interactions of K with N and P have been reported.

Dibb and Thompson (1985); Fageria *et al.* (1997) reported Rapid assimilation of absorbed NH_4^+ ions, maintaining a low, nontoxic level of NH_3, allowed by high K.

Ruan *et al.* (1999); Pettigrew and Meredith (1997) observed the relationship of potassium with nitrogen metabolism is well documented.

Rufty *et al.* (1981) reported the stimulating effect of on nitrate metabolism is due to an increase of nitrate export in xylem.

Casadesus *et al.* (1995) observed a coupled loading of potassium and nitrate into the xylem since K is proposed as a transporter of photo assimilates from the source to the sink and acts fundamentally as a nitrate co-transporter in its uptake, through xylem transport, and it's recycling through phloem transport.

Ashley and Goodson (1972) concluded NO_3^- is taken up by plant roots via an active process therefore, the uptake may be affected through the influence of K on the translocation of photosynthetic assimilates needed to support this active uptake process.

Ruiz and Romero (2002) reported that by increasing the rates of K^+ application, the uptake and transport of nitrate towards the aerial parts of the plants may be increased.

Siebrecht and Tischner (1999) the plants grown under the deficient K supply fail to transport nitrate efficiently into shoots, the excess nitrogen supply in the soil leads to the leaching of nitrate, thus causing the surface and ground water pollution. Withdrawal of K from the soil affects NO_3^- assimilation since nitrate is assimilated largely by roots.

The study by Krauss (2004) clearly demonstrated that K-deficient plants have a repressed activity of enzyme nitrate reductase. Thus the plants receiving inadequate supply of K would absorb small amount of nitrate from the soil and therefore there would be less conversion into proteins. Both nitrate and protein are important for the crop quality.

2.5 Effect of potassium on critical limit

Adams (1967); Egli (1998) reported there is critical period during crop development when seed number is determined, before and after the critical period; seed number is not directly affected by environmental conditions.

2.6 Effect of potassium deficiency in crops

Marshner (1995) suggested potassium deficiency is recognized as an important limiting factor in crop production. At its early stages, potassium deficiency is reflected mostly in yield decreases. This early stage is called "hidden hunger" since no specific symptoms appear in the plant. As the intensity of the deficiency increases, significant symptoms appear; less strength of plant structures, less resistance to low water availability and less resistance to fungus diseases. Generally, optimal plant tissue K is in the range of 2-5% based on plant dry weight.

Armstrong (1998) stated that potassium deficiency symptoms, such as thin cell walls, weakened stalks and stems, and accumulation of sugars and unused N in leaves, encourage disease infection.

Marshner (1995) addition throughout the entire life cycle of most plants, this nutrient plays an important role in many physiological plant functions. Under severe potassium deficiency, significations of vascular bundles are reduced contributing to high lodging.

Cassman *et al.* (1989); Ebelhar and Varsa (2000); Heckman and Kamprath (1992); Mullins *et al.* (1994); Pettigrew and Meredith (1997) observed the more visually obvious consequences on plant growth from insufficient levels of plant potassium is a reduction in plant stature.

Jordon-Meile and Pellerin, (2004); Kimbrough *et al.* (1971); Pettigrew and Meredith (1997) concluded potassium that reduction in biomass because of deficiency is often accompanied by a reduction in leaf area.

Huber (1985) studied in sufficient K^+levels reduced leaf area expansion leading to reduced leaf size in soybean.

2.7 Effect of potassium status in soils

Moody and Bell (2006) studied many soils lack sufficient quantities of available potassium for satisfactory yield and quality of crops. For this reason available soil potassium levels are commonly supplemented by potash fertilization to improve the potassium nutrition of plants, particularly for sustaining production of high yielding crop species and varieties in modern agricultural systems. Soil K can be assigned to four distinct pools differing in availability to plants: (1) soil solution K, (2) exchangeable K, (3) non-exchangeable K (Positioned in interlayers of clay minerals, especially those of the 2:1:1 type) and (4) structural K.

Steingrobe and Classen (2000) observed plants take up K exclusively from the soil solution pool, which is in a dynamic equilibrium with the exchangeable and, to a lesser extent, the non-exchangeable pools. Exchangeable K can be rapidly released from exchange sites on the surface of clay minerals and organic matter to replenish K depleted soil solution.

Pal *et al.* (2001 and 2002) reported that release of non-exchangeable K from interlayer sites of clay minerals is a slow process and is mostly important in contributing to the replenishment of the soil solution and exchangeable pools in the long term (e.g. over successive crops). The release of structural K into soil solution can be affected only by weathering of clay materials; hence it is an exceedingly slow process with no discernible effect during a single crop cycle.

El-Dessougi *et al.* (2002); Trehan, (2005) suggested soil with significant K clay fraction and therefore a potentially extensive non-exchangeable K pool, the capacity of a genotype influence the dynamics of K release from that pool to the soil solution can influence the efficiency of K uptake.

CHAPTER-III
MATERIALS AND METHODS

The experiment was conducted on the Farm of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh during the period from March to May 2017 to study the effect of different levels of potassium (K) yield contributing characters of mungbean. This materials and methods chapter includes materials and methods that were used in conducting the experiment. The details are presented below under the following headings-

3.1 Experimental site

The research work relating to the study of the effect of K on the yield of mungbean was conducted during the Kharif-1 season of 2017 at the Pulse Research Sub-Station, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur (24^{o} 0′N latitude and 90^{o}25′ E longitude) lies at an elevation of 8.4 m above sea level. Gazipur belongs to the Chhiata series under the Agro-ecological Zone, Madhupur Tract (AEZ-28) (Appendix-1).

3.2 Climate

The climate of experimental site was subtropical, characterized by three distinct seasons. The annual precipitation of the site is 1875 mm and the average maximum temperature is 32°C and average minimum temperature is 25 °C. Meteorological data related to the temperature, relative humidity and rainfalls during the period of the experiment presented in (Appendix 2).

3.3 Soil

Before land preparation, initial soil samples (0-15 cm depth) were collected from different spots of the field. The morphological characteristics of the soil have been presented in Table-3.1.

Table 3.1. Morphological characteristics of experimental field

Character	BARI farm
Location	PRSS, BARI farm Gazipur
Geographical position	24.0^{o} North Latitude 90.25^{o} East Longitude 8.4 m high above sea level
Agro Ecological Zone	Madhupur Tract (AEZ-28)
General soil type	Deep Grey Terrace Soil
Taxonomic soil classification	
Order	Alfisols
Sub-order	Ustalf
Great group	Rhodustalf
Sub-group	Udic Rhodustalf
Soil series	Chhiata
Parent materials	Madhupur clay
Topography	Flat or Level
Drainage	Moderate
Flood level	Above flood level
Land type	High land

The composite soil sample was made and brought to the laboratory and then spread on a brown paper for air–drying. The air-dry soil samples were ground and passed through a 2 mm sieve. After sieving, the prepared soil samples were kept into plastic containers with proper level for analyzing the physical and chemical properties of soil. The soil were analyzed for physical and chemical properties following the standard methods and the results have been presented in Table-3.2.

Table 3.2. Initial characteristics of the soil in experimental field

Particle size analysis of soil	
%Sand	26.28
% Silt	38.20
%Clay	35.52
Soil texture(0-15 cm)	Clay Loam
Partical density (g cm^{-3})	2.51
Bulk density (g cm^{-3})	1.35
Porosity (%)	46.22
Soil pH	6.4
Exchangeable K (meq. $100g^{-1}$)	0.10
Exchangeable Ca (meq. $100g^{-1}$)	6.01
Exchangeable Mg (meq. $100g^{-1}$)	2.02
Organic carbon (%)	1.27
Total N (%)	0.057
Available P (µg g^{-1})	23.5
Available S (µg g^{-1})	26.0
Available Zn (µg g^{-1})	1.31
Available B (µg g^{-1})	0.16
Available Mo (µg g^{-1})	0.072

3.4 Description of the mungbean variety

BARl Mung-6, a high yielding variety of mungbean. BARI released it in 2003. It is photo insensitive, semi synchronous maturity, short lifespan (60 to 65 days) and hold seeded crop. Its yield potentiality is about 2 t ha^{-1}. This variety is resistant to yellow mosaic virus diseases, insects and pest attack.

3.5 Preparation of the field

The plot selected for the experiment was opened by a tractor and prepared thoroughly by ploughing with a power tiller; afterwards the land was ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubbles were removed and the large clods were broken into smaller pieces to obtain a desirable tilth of soil for sowing of seeds. Finally, experimental land was divided into unit plots following the design of experiment.

3.6 Experimental design and layout

The experiment was laid out following Randomized Complete Block Design (RCBD) and three replications were maintained. The total number of plots were 18. Each plot was 4 m × 3 m (12 m^2) in size. The treatment of the experiment was assigned at random into 6 plots of each at 3 replications. The distance maintained between two plots was 0.75 m and between blocks was 1m. The layout of the experiment is presented in (Appendix 3).

3.7 Treatments

The experiment consists of 6 potassium fertilizer doses including blanket dose. The treatments of the experiment are as follows-

T_1 = Blanket dose without Potassium (K)

T_2 = Blanket dose **+ 30kg K ha^{-1}**

T_3 = Blanket dose **+ 40kg K ha^{-1}**

T_4 = Blanket dose **+ 50kg K ha^{-1}**

T_5 = Blanket dose **+ 60kg K ha^{-1}**

T_6 = Blanket dose **+ 70kg K ha^{-1}**

Blanket dose = N-15 kg ha^{-1}, P-20 kg ha^{-1}, S- 10 kg ha^{-1}, Zn-2 kg ha^{-1}, B -1.5 kg ha^{-1}

3.8 Application of fertilizers

The required amounts of K fertilizers from Muriate of Potash were applied at the time of final land preparation as per treatment of the experiment. The recommended basal doses of N, P, S, Zn, B were applied in each plot from Urea, TSP, gypsum, Zinc sulfate and Boric acid respectively.

3.9 Seed sowing

Mungbean seeds were sown on the 7th March 2017 in lines following the assigned line to line distance of 30 cm and plant to plant distance of 10 cm. The seeds were sown in solid rows in the furrows having a depth of 2-3 cm at the rate of 33 kg ha^{-1}. The seeds were treated by Provex 200 at the rate of 3 g per kg seed before sowing to control diseases.

3.10 Cultural and management practices

3.10.1 Thinning

Seeds germinated four days after sowing (DAS). Thinning was done two times; first thinning was done at 8 DAS and second at 15 DAS to maintain proper plant population in each plot.

3.10.2 Irrigation and weeding

Irrigation was done as per needed. Irrigation can also be added. The crop field was weeded twice; first weeding was done at 15 DAS and the second at 30 DAS.

3.10.3 Protection against insect and pest

The plants were infested with cutworm, which was removed by applying Sumithion or Malathion 50EC at the rate of 2 Liter ha^{-1} or Dimacron 50 EC was sprayed at the rate of 1 Liter ha^{-1}. Special care was taken to protect the crop from birds especially after sowing and germination stages.

3.11 Harvest and post-harvest operations

Harvesting was done when 90% of the pod matured. The crop was harvested at two phase, firstly the pre-marked space (1 m^2) crops were harvested and then rest of crops were harvested from all plots. First harvest was done on 3rd June and second on 15th June 2017. The harvested crop of each plot was gathered separately. Grain and stover yields were recorded plot wise and the yields were expressed in kg ha^{-1}.

3.12 Collection of experimental data

Ten plants from each plot were selected at random and were tagged for the data collection. The sample plants were cut down to ground level prior to harvest and dried properly in the sunlight. The seed yield were adjusted at 9% moisture level. The seed and stover yield (kg ha^{-1}) per plot were recorded while cleaning up and sun-drying. Seed and stover were dried and ground for chemical analysis.

3.12.1 Plant height

The plant height (cm) was measured from the ground level to the top of the canopy of 10 randomly selected plants from each plot and averaged. It was done at the maturity stage of the crop.

3.12.2 Number of pods plant^{-1}

At maturity stage of plant 10 plants were selected randomly from every plot pods per plant was counted and average of the result was done.

3.12.3 Pod length

At maturity stage of pod 10 pods were collected randomly from every plot and their length (cm) was measured and average of the result was done.

3.12.4 Number of seeds pod^{-1}

The number of seeds pod^{-1} from 10 randomly selected pods from each plot were counted and average of the result was done.

3.12.5 Weight of thousand seed

Weight of thousand seeds of mungbean were measured and then noted plot wise.

3.12.6 Seed yield

Grains obtained from 1 m^2 area from the center of each individual plot was dried, weighed carefully and then converted into kg ha^{-1} as yield.

3.12.7 Stover yield

Stover obtained from 1 m^2 area from the center of each individual plot was dried, weighed carefully and expressed in kg ha^{-1}.

3.12.8 Number of nodules plant^{-1}

Nodules were collected from 10 randomly selected plants from each plot. They were counted and averaged.

3.13 Collection and preparation of soil samples

After completion of harvesting, soil samples were collected (0-15 cm depth) from the same plots. The composite soil sample of each plot was brought to the laboratory and spread on a brown paper for air drying. The air-dry samples were ground properly and pass through 2mm sieve. After sieving, the prepared soil samples were kept into plastic containers with a proper label for analyzing the chemical properties following the standard methods.

3.14 Laboratory methods

The soil samples were analyzed by following standard methods as follows:

3.14.1 Texture

Particle size analysis of soil was done by hydrometer method (Black, 1965). The textural class was determined using Marshall's Triangular Coordinates of USDA system.

3.14.2 Particle density

Particle density was determined by volumetric flask method (Black, 1965) using the following formula.

$$\text{Particle Density } (D_p) = \frac{Ms}{Vs} \text{ g cm}^{-3}$$

Where,

Dp = Particle density (g cm^{-3})

Vs = Volume of the soil solid (cm^3)

Ms = Weight of the soil solid (g)

3.14.3 Bulk density

Bulk density was determined by core sampler method (Black, 1965) using following formula:

$$\text{Bulk Density (Db)} = \frac{Ms}{Vt} \text{ g cm}^{-3}$$

Where,

Db= Bulk density (g cm^{-3})

Ms= Mass of soil solid (g)

Vt= Total volume of the soil (cm^3)

3.14.4 Soil porosity

It was calculated from the results of the particle density and bulk density as:

$$\text{Soil Porosity} = \left(\frac{Dp-Db}{Dp}\right) \times 100$$

Where,

Dp = Particle density (g cm^{-3})

Db= Bulk density (g cm^{-3})

3.14.5 Soil pH

Soil pH was measured by glass electrode pH meter using soil: water ratio of 1:2.5 (Page *et al.*, 1982).

3.14.6 Organic carbon and organic matter

Organic carbon of soil was determined by wet oxidation method (Black, 1965). The organic matter content was calculated by multiplying the percent organic carbon with the Van Bemmelen factor 1.73 (Piper, 1995).

3.14.7 Total Nitrogen

Total nitrogen content was determined by Micro Kjeldahl method (Bremner, 1960). Soil sample was digested with conc. H_2SO_4 in presence of K_2SO_4 catalyst mixture (K_2SO_4: $CuSO_4$ $5H_2O$: Se =10: 1: 0.1). Nitrogen in the digest was estimated by distilling the digest with 10N NaOH followed by titration of the distillate trapped in H_3BO_3 indicator solution with 0.01N H_2SO_4.

3.14.8 Available Phosphorus

Available phosphorus in the soil samples was extracted with 0.5 M $NaHCO_3$ solution at a nearly constant pH of 8.5 following the method described by Watanable and Olsen (1965). Spectrophotometer was used to measure the intensity of the color developed by ascorbic acid method.

3.14.9 Available Sulphur

Available sulphur in the soil was extracted by 500 ppm P containing solution of monocalcium biphosphate and estimated by turbidity method using $BaCl_2$ (Fox *et al.*, 1964).

3.14.10 Exchangeable Potassium

Exchangeable potassium was extracted by 1N NH_4OAc (Ammonium Acetate) as described by Jackson (1973) and was measured by Atomic Absorption Spectrophotometer (AAS) (Model No. VARIN SpectraAA 55B, Australia).

3.14.11 Available Zinc

Soil sample were extracted with DPTA solution (5m DPTA + 10 m M $CaCl_2$ + 0.1 M triethanolamine) and the concentration of Zn in the extract was directly measured by AAS (Lindsay and Norvell, 1969).

3.14.12 Available Boron

Available boron was determined by mono-calcium bi-phosphate extraction method. The extracted B was determined by spectrophotometer following azomethine-H method (Page *et al.*, 1982).

3.15 Preparation of plant sample for chemical analysis

Grain and stover were separated and collected at the time of threshing. The plant (Grain and stover) samples were oven dried at 65-70^oC for 72 hours. The dried samples were finely ground by using a Wiley-Mil with stainless contact points to pass through a 60 mesh sieve. The samples were stored in a plastic vials for analysis of N, P, K, S, Zn and B contents. The standard methods used for plant analysis were as follows:

3.15.1 Preparation of plant extract

Ground plant were digested with di-acid mixture (HNO_3-$HClO_4$) (5:1) as described by Piper (1966) for determination of P, K, S, Ca, Mg, Zn and B. Oven-dried plant sample of 0.5 g was taken in a 50 mL digestion flask, 5 ml of di-acid mixture (HNO_3 and $HClO_4$) was added to the flask. The flask was placed on cool hot plate and the temperature was raised upto 375^oF temperature and the digestion was done for 2 hours. The flask was then removed and allowed to cool down at room temperature. The contents were diluted with distilled water swiftly and filtered through a filter paper (Whatman No. 42) in a 100 mL volumetric flask and volume upto the mark.

Phosphorus: The total P was determined colorimetrically using venadomolybdate blue ascorbic acid method by spectrophotometry (Olsen and Sommers, 1982)

Potassium: The K concentrations in the digest were directly measured by Atomic Absorption Spectrophotometer (Model No. VARIAN SpectrAA 55B, Australia).

Zinc: The Zn concentrations in the digest were directly measured by Atomic Absorption Spectrophotometer (Model No. VARIAN SpectrAA 55B, Australia).

Sulphur: The concentration of S in the digest was determined by turbidity method using $BaCl_2$ by spectrophotometer (Chapman and Pratt, 1961).

Boron: The concentration of B in the digest was determined by spectrophotometer following azomethine-H method (Page *et al.*, 1982).

3.16 Cost and return analysis

Added cost and added benefit were calculated. Besides, the gross return was calculated on the basis of different treatments which were directly related to the price that received from, the product. Cost of calculation was involved with wage rate (land preparation, weeding, seed sowing, and fertilizers application), pesticides, irrigation, fertilizers cost. Land used cost or rental value of land was not considered here. Benefit cost ratio (BCR) of different treatments were calculated as follows:

$$BCR = \frac{\text{Gross return}}{\text{Cost of cultivation}}$$

3.16 Statistical analysis

Data recorded for different parameters of plant were processed by Microsoft Office Excel (2010). The recorded experiment data were statistically analyzed by “Statistics 10” software. The treatment means were compared by Least Significant Difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984)

CHAPTER- IV
RESULTS AND DISCUSSION

This chapter comprises the presentation and discussion of the results obtained from the experiment. The experiment was conducted to determine the effects of six levels of potassium (K) and their effects on growth, nodulation and yield of mungbean (BARI Mung-6). The growth and yield components such as plant height, number of pods plant^{-1}, pod length, and yield of mungbean as influenced by K are presented in Figures. The results of each parameter have been adequately discussed and possible interpretations whenever necessary have been given under the following headlines:

4.1. Yield and yield contributing characters

4.1.1 Plant height

The effects of K on the plant height (cm) of mungbean are presented in (Figure 4.1.1). The plant height was significantly influenced by different levels of K at different doses. Among the different doses of K, T_6 (70 kg K ha^{-1}) showed the highest plant height (34.2 cm). On the other hand, the lowest plant height (30.2 cm) was observed in the T_1 treatment where no K was applied (Appendix- 4.1.1). The taller plants at the highest doses received more nutrients which might have encouraged more vegetative growth. The result is agreed with the findings of Abbas *et al.*, (2011) who observed significant increase in plant height of mungbean due to the application of increasing level of K fertilizer. Minimum plant height (41.3 cm) was obtained in plots where no potash was applied might be due to the reason that high root shoot ratio is associated with K uptake (Yang *et al.*, 2004). These results are in line with Hussain (1994) and Ali *et al.*, (1996) who observed significantly higher plant height in mungbean crop when fertilized at the rate of 60-100-100 NPK kg ha^{-1}.The results contradict the findings of Aslam *et al.*, (2004) where non-significant differences were observed among mungbean genotypes. However, these contradictory results might be due to varying genetic makeup of varieties or fertility status of soil.

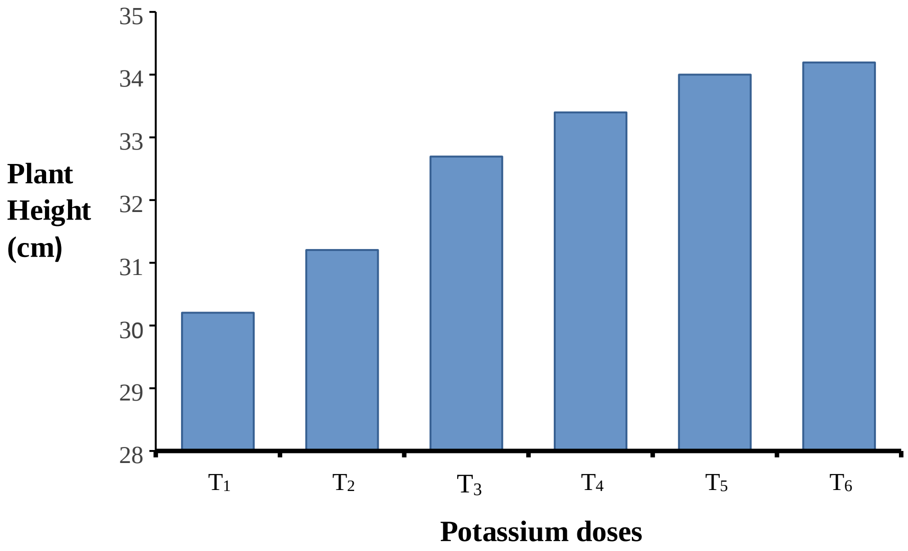

Figure 4.1.1: Plant height at different potassium doses

Here, Treatment T_1 = control, T_2 = potassium 30 kg ha^{-1}, T_3 = potassium 40 kg ha^{-1}, T_4 = potassium 50 kg ha^{-1}, T_5 = potassium 60 kg ha^{-1}, T_6 = potassium 70 kg ha^{-1}.

4.1.2 Number of pods plant^{-1}

Significant variation was observed in number of pods plant^{-1} of mungbean when different doses of K were applied (Figure 4.1.2). The highest number of pods plant^{-1} (15.09) was recorded in T_5 (60 kg K ha^{-1}). The lowest number of pods plant^{-1} (10.65) was recorded in the T_1 (control) treatment where K was not applied (Appendix- 4.1.2). The results clearly indicated that the number of pods per plant increased with the increasing levels of K up to 60 kg ha^{-1} but their variation was significant. Similar findings were recorded by Ali *et al.* (1996) who studied the effect of different K levels (0, 25, 75,100 and 125 Kg ha^{-1}) on yield and quality of mungbean and reported that number of pods plant^{-1}, number of seeds per pod was influenced significantly by K application. The variation among varieties was also significant and Chakwal Mung-6 produced more no of pods plant^{-1} than NM-92. However, Khan *et al.* (1999) reported that genotypes did not differ significantly from each other. These contradictory results might have been due to differences in genetic make-up or climatic conditions of crop plants. Biswash *et al.* (2014), Thesiya *et al.* (2013) and Ali *et al.* (1996) also found similar results on blackgram.

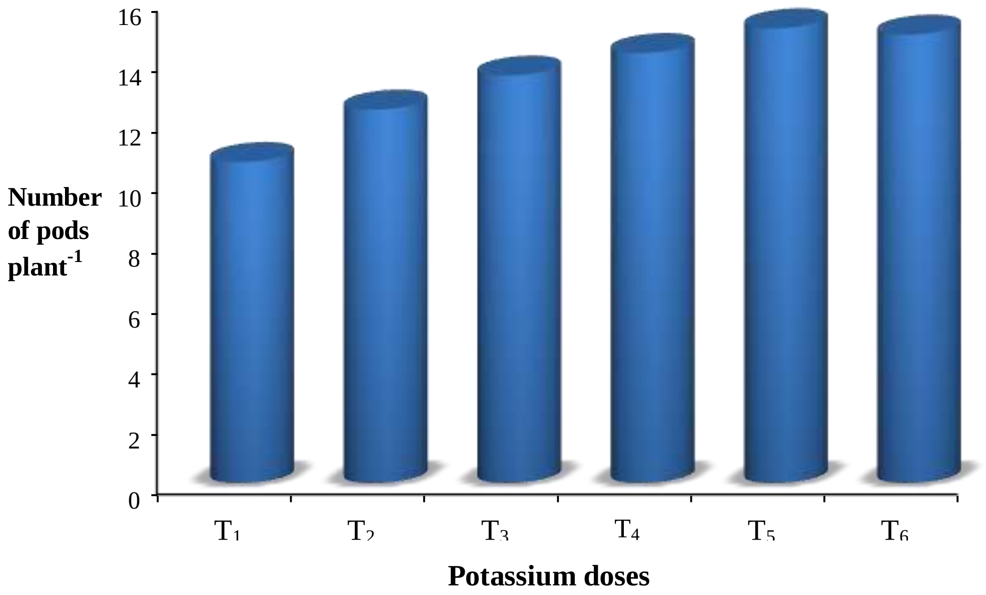

Figure 4.1.2: Number of pods plant^{-1} at different potassium doses

Here, Treatment T_1 = control, T_2 = potassium 30 kg ha^{-1}, T_3 = potassium 40 kg ha^{-1}, T_4 = potassium 50 kg ha^{-1}, T_5 = potassium 60 kg ha^{-1}, T_6 = potassium 70 kg ha^{-1}.

4.1.3 Pod length

Pod length (cm) as affected by different doses of K showed a statistically significant variation (Figure. 4.1.3). Among the different doses of K the highest pod length (9.06 cm) was observed in T_5 (60 kg K ha^{-1}). On the other hand, the lowest length (8.30 cm) was recorded in the T_1 treatment where K was not applied (Appendix-4.1.3). Abbas *et al.*, (2011) found significant increase on pod length of mungbean with successive increase in K_2SO_4 levels at 75 kg ha^{-1}. Thesiya *et al.*, (2013) also found highest yield of blackgram at 30 kg K ha^{-1} lowest pod length at no K treatment.

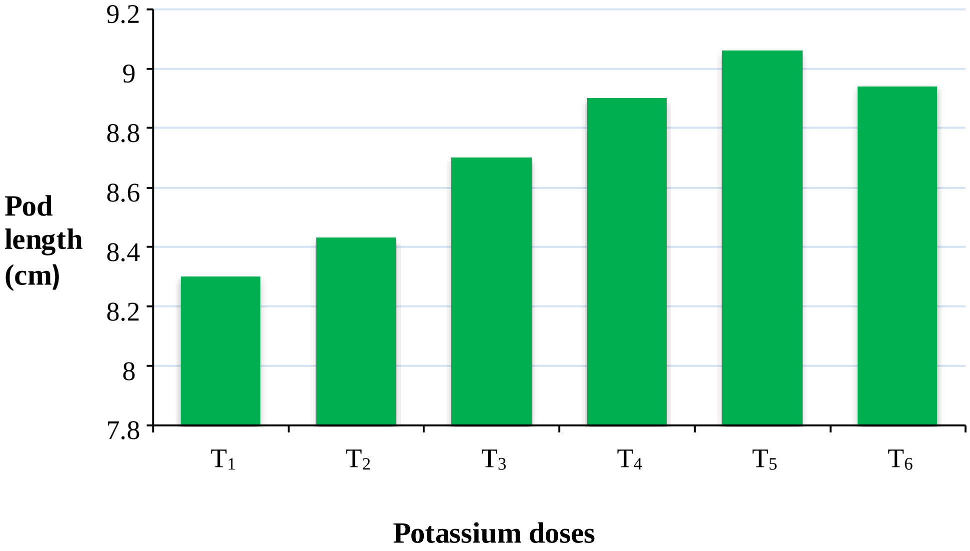

Figure 4.1.3: Pod length at different potassium doses

Here, Treatment T_1 = control, T_2 = potassium 30 kg ha^{-1}, T_3 = potassium 40 kg ha^{-1}, T_4 = potassium 50 kg ha^{-1}, T_5 = potassium 60 kg ha^{-1}, T_6 = potassium 70 kg ha^{-1}.

4.1.4 Number of seeds pod^{-1}

There was significant variation in the number of seed per pod in mungbean when different doses of K fertilizer were applied (Fig. 4.1.4). The highest number of seed pod^{-1} (9.37) was recorded in T_5 (60 kg K ha^{-1}) treatment. The lowest number of seed pod^{-1} (8.90) was recorded in the T_1 treatment where potassium fertilizer was not applied (Appendix-4.1.4). Potassium application not only enhanced the availability of other nutrient but also increased the transportation of photosynthates protein synthesis from source to sink might be the main reason for increase in number of seeds pod^{-1} (Mengel & Kirkby, 1987). Significant differences for no of seeds per pod due to K application have also been reported earlier Smiullah & Khan (2003).

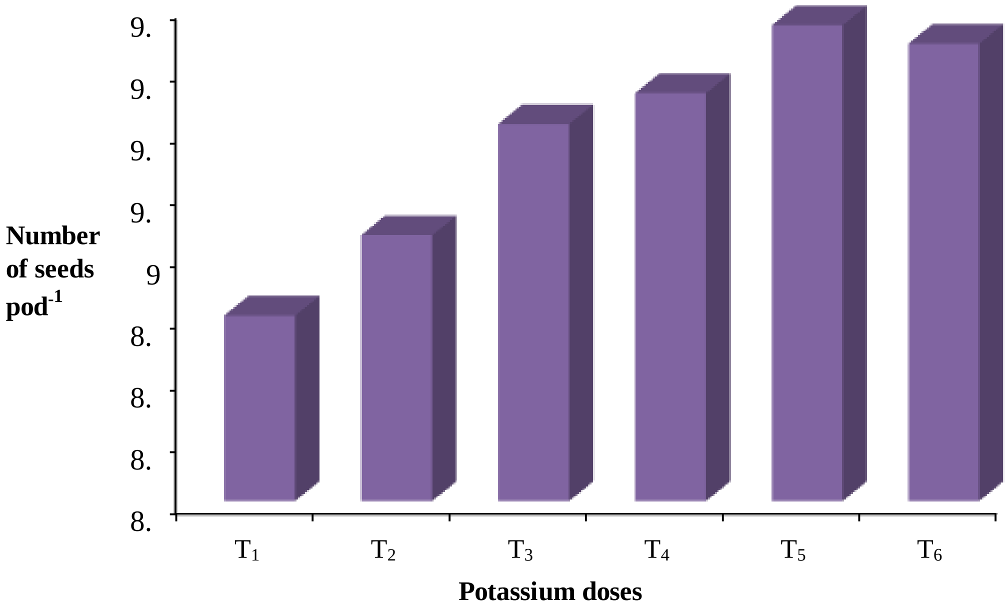

Figure 4.1.4: Number of seeds pod^{-1} at different potassium doses

Here, Treatment T_1 = control, T_2 = potassium 30 kg ha^{-1}, T_3 = potassium 40 kg ha^{-1}, T_4 = potassium 50 kg ha^{-1}, T_5 = potassium 60 kg ha^{-1}, T_6 = potassium 70 kg ha^{-1}.

4.1.5 Thousand seed weight

Significant differences for 1000 seed weight (g) were also noted when different doses of K fertilizer were applied (Fig. 4.1.5). The highest thousand seed weight (49.2 g) was recorded in T_5 (60 kg K ha^{-1}) treatment. The lowest thousand seed weight (44.1 g) was recorded in the T_1 treatment where K fertilizer was not applied (Appendix-4.1.5). Hussain (1994) also concluded that the maximum 1000 seeds weight (61.9 g) was obtained where the mungbean crop was fertilized at the rate of 60- 100-100 NPK kg ha^{-1}. Ali *et al.* (1996) have also reported that significant differences for 1000 seeds weight in mungbean genotypes.

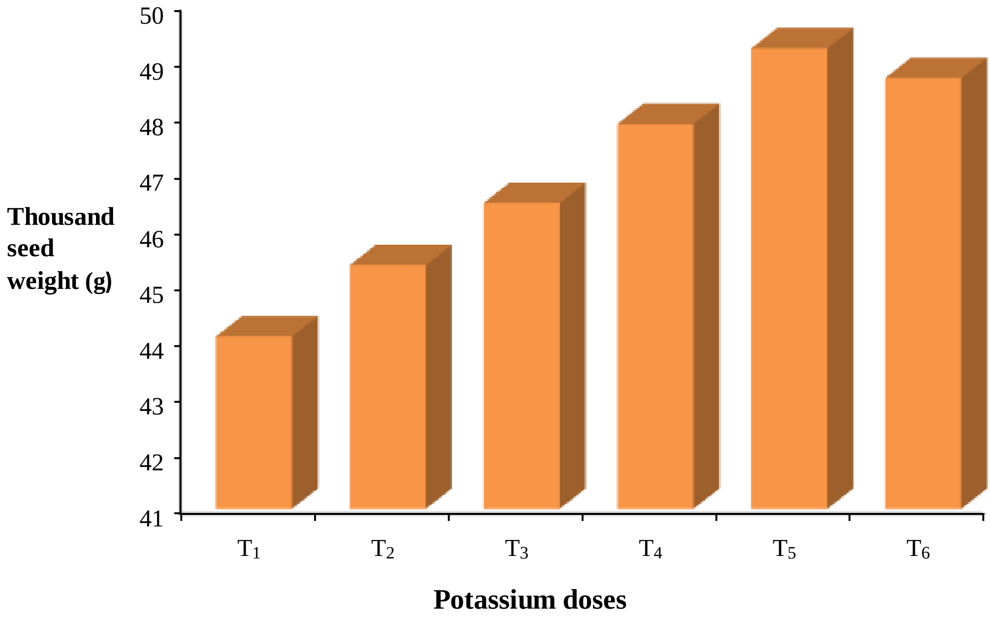

Figure 4.1.5: Thousand seed weight at different potassium doses

Here, Treatment T_1 = control, T_2 = potassium 30 kg ha^{-1}, T_3 = potassium 40 kg ha^{-1}, T_4 = potassium 50 kg ha^{-1}, T_5 = potassium 60 kg ha^{-1}, T_6 = potassium 70 kg ha^{-1}.

4.1.6 Seed yield

Significant variation was observed on the seed yield (kg ha^{-1}) of mungbean when different levels of K fertilizer were applied (Fig. 4.1.6). The most satisfactory seed yield (1209 kg ha^{-1}) was recorded in the treatment T_5 (60 kg K ha^{1}). The lowest seed yield (875 kg ha^{-1}) was recorded in the T_1 treatment where K fertilizer was not even applied (Appendix- 4.1.6). The results are in agreed to those of Ali *et al.*, (1996) and Hussain (1994). These are also similar with some other researcher's findings, Jahan *et al.*, (2009) who obtained highest grain yield of mungbean due to the application of 35 kg K ha^{-1}. Kurhade *et al.*, (2015) and Thesiya *et al.*, (2013) observed magnificent increase in grain yield through the application of K fertilizer.

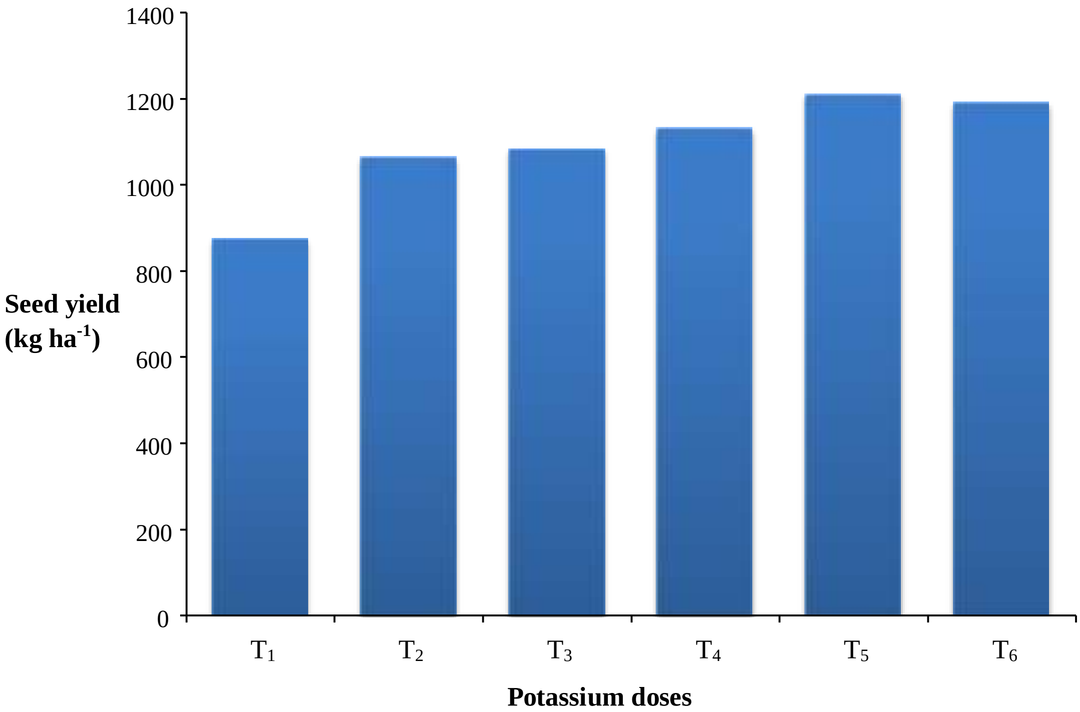

Figure 4.1.6: Seed yield (kg ha^{-1}) at different potassium doses

Here, Treatment T_1 = control, T_2 = potassium 30 kg ha^{-1}, T_3 = potassium 40 kg ha^{-1}, T_4 = potassium 50 kg ha^{-1}, T_5 = potassium 60 kg ha^{-1}, T_6 = potassium 70 kg ha^{-1}.

4.1.7 Stover yield

Variation was observed on the stover yield (kg ha^{-1}) of mungbean when different levels of potassium fertilizer were applied (Fig. 4.1.7). The most satisfactory stover yield (2742 kg ha^{-1}) was recorded in the treatment T_6 (70 kg K ha^{-1}) and the lowest seed yield (2313 Kg ha^{-1}) was in the treatment T_1 where K fertilizer was not even applied (Appendix- 4.1.7). The current status is in agreement with that of Jahan *et al.,* (2009). Biswash *et al.,* (2014) and Thesiya *et al.,* (2013) also observed similar kind of incident in mungbean and blackgram, respectively.

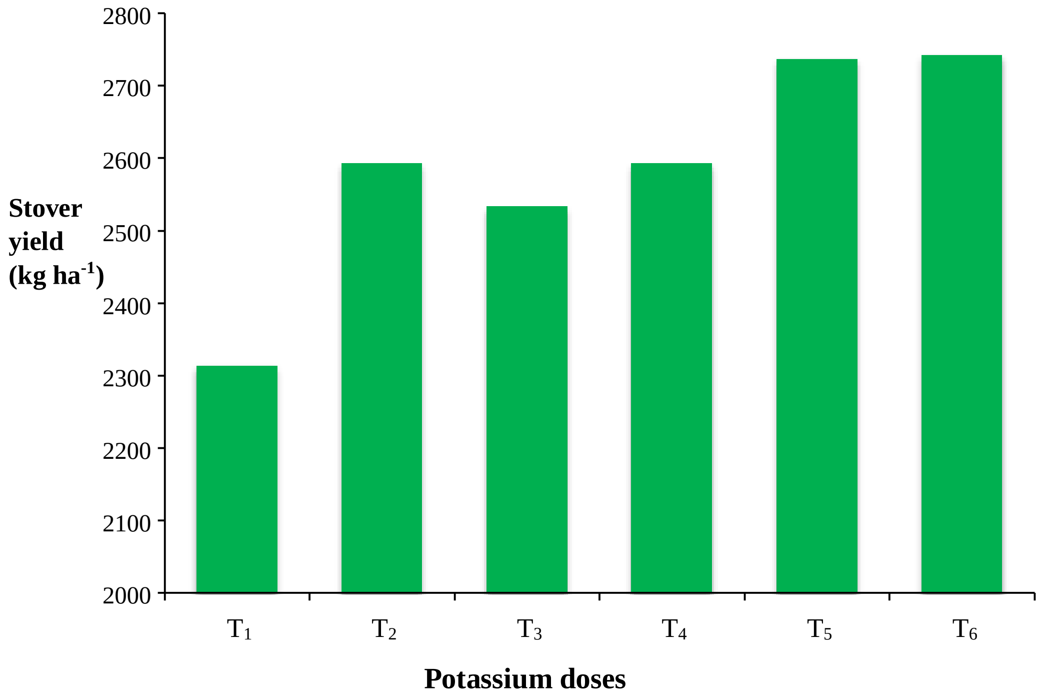

Figure 4.1.7: Stover yield (kg ha^{-1}) at different potassium doses

Here, Treatment T_1 = control, T_2 = potassium 30 kg ha^{-1}, T_3 = potassium 40 kg ha^{-1}, T_4 = potassium 50 kg ha^{-1}, T_5 = potassium 60 kg ha^{-1}, T_6 = potassium 70 kg ha^{-1}.

4.1.8 Number of nodule plant^{-1}

Significant variation was observed on nodule per plant of mungbean when different doses of K fertilizer were applied (Fig.4.1.8). The highest number of nodule per plant was recorded in T_5 (60 kg K ha^{-1}) treatment. The lowest number of nodule per plant was recorded in the T_1 treatment where fertilizer was not applied (Appendix- 4.1.8). Roots of *Trifolium pratense* and *Medicago sativa* were found to have higher starch and sucrose contents when supplied with optimum levels of K than the plants supplied with low levels of K (Mengel *et al.*, 1974). Availability of K influenced the efficiency of *Rhizobium* for the crop and improved its nodulation potential. Potassium plays important role as an activator of enzymes that are essential for the production of proteins and sugars. Soluble protein content in leaves and nodules was increased by K supplementation. As per literature protein synthesis and enzyme activation required adequate amount of K^+ (Marshner, 1995). The significant effect of K application might be due to better K utilization which improves the uptake and assimilation of N to end up with a greater protein synthesis.

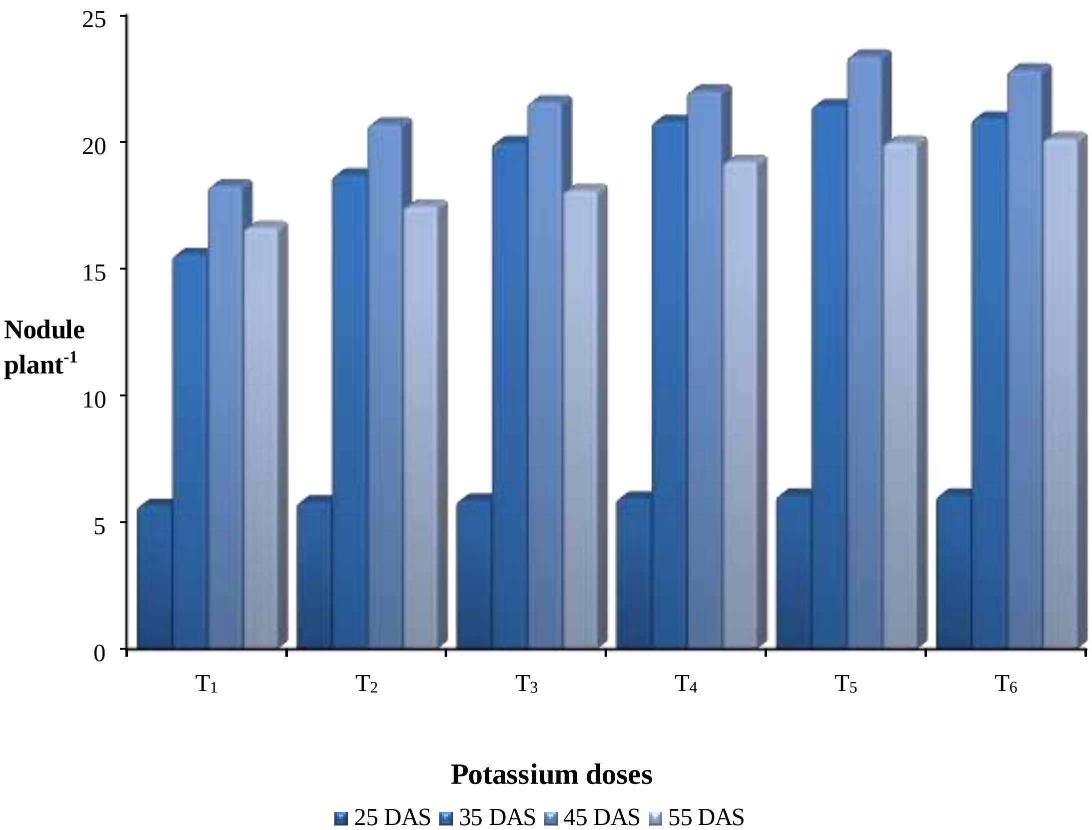

Figure 4.1.8: Number of nodule plant^{-1} at different potassium doses

Here, Treatment T_1 = control, T_2 = potassium 30 kg ha^{-1}, T_3 = potassium 40 kg ha^{-1}, T_4 = potassium 50 kg ha^{-1}, T_5 = potassium 60 kg ha^{-1}, T_6 = potassium 70 kg ha^{-1}.

4.2: Nutrient contents in mungbean seed

4.2.1 Nitrogen

Nitrogen (N) content (%) in seed was significantly influenced by application levels of K (Fig. 4.2.1). The highest nitrogen concentration in mungbean seed (3.56 %) was recorded in T_5 (60 kg K ha^{-1}) treatment. On the other hand, the lowest N concentration in mungbean seed (3.22 %) was recorded in T_1 (control treatment) treatment (Appendix 4.2.1). The percentage of N in seeds was significantly affected in this study and it was correlated with number of nodules. Bacterial inoculation and K application resulted in higher number of nodules which may have resulted in higher biological N fixation and hence greater translocation of N to seeds. Potassium nutrition has been associated with grain quality and protein content in various agricultural crops (Tiwari *et al.*, 2012). This might be due to its role in enhancing N use efficiency and translocation of the biologically fixed N. Interactive effect of K and Rhizobium was more pronounced on protein content. This could be due to enhanced N-fixation by inoculated plants and subsequent translocation of the biologically fixed N to the seeds. Singh *et al.,* (1993) found significant increase of nitrogen concentration in mungbean due to the application of increasing level of K fertilizer. Chanda, *et al.,* (2002) stated that the significant increase of N concentration in mungbean seed due to the application of K fertilizer. Sangakkara, *et al.,* (1996) reported increased total N concentrations in *Vicia faba* and *Phaseolus vulgaris* by K application. The percentage of N in seeds was significantly affected in this study and it correlated with number of nodules. Bacterial inoculation and K application resulted in higher number of nodules which may have resulted in higher biological N fixation and hence greater translocation of N to seeds. Potassium nutrition has been associated with increasing grain quality and protein content in various crops (Tiwari *et al.*, 2012).

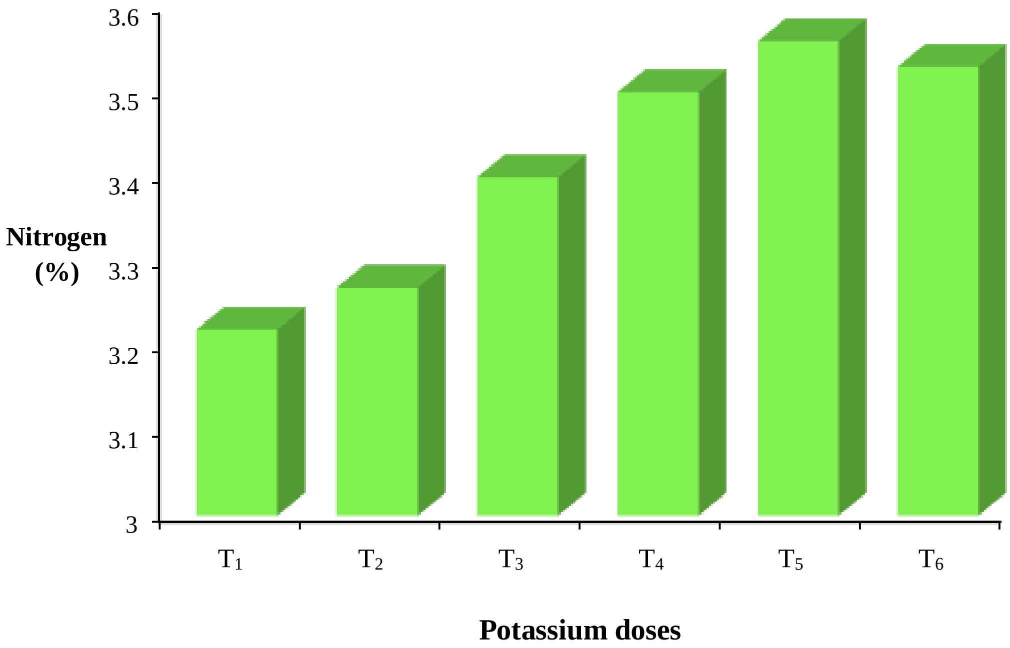

Figure 4.2.1: Nitrogen contents at different potassium doses

Here, Treatment T_1 = control, T_2 = potassium 30 kg ha^{-1}, T_3 = potassium 40 kg ha^{-1}, T_4 = potassium 50 kg ha^{-1}, T_5 = potassium 60 kg ha^{-1}, T_6 = potassium 70 kg ha^{-1}.

4.2.2 Phosphorus

Phosphorus (P) contents (%) in seed was significantly influenced by application different levels of K (Fig. 4.2.2). The highest P concentration in mungbean seed (0.54 %) was recorded in T_5 (60 kg K ha^{-1}) treatment. On the other hand, the lowest P concentration in mungbean seed (0.42 %) was recorded in K untreated plot (Appendix-4.2.2). Increased P concentration in mungbean seed was also reported by Kaushik *et al.,* (1996) found significant increase of P concentration in mungbean seed due to the application of K_2SO_4.

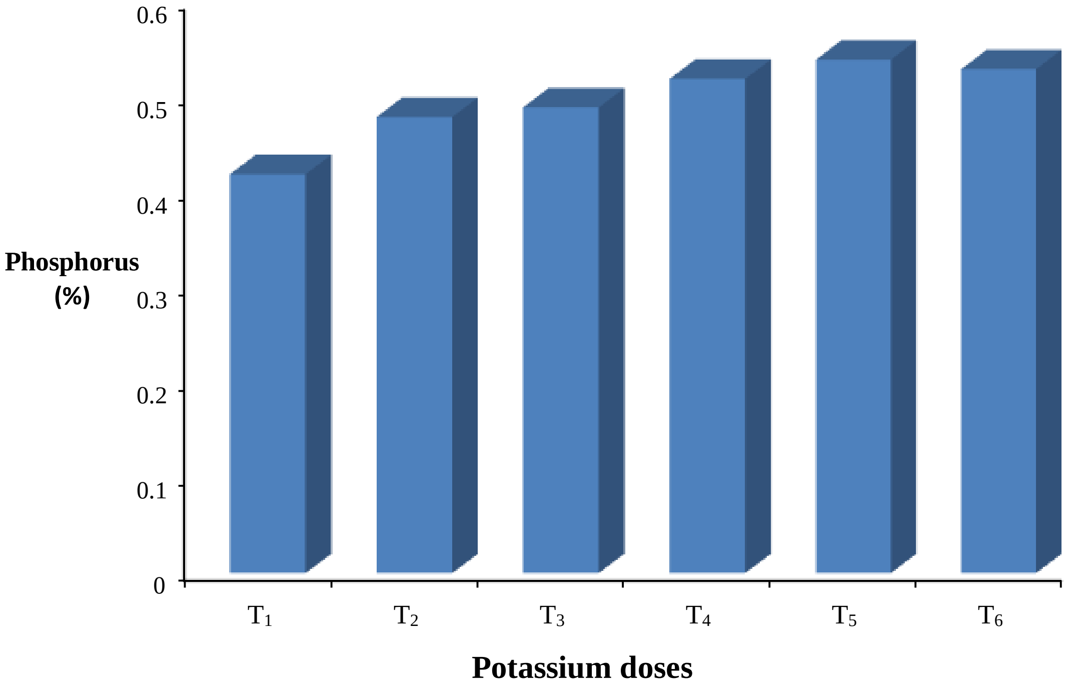

Figure 4.2.2: Phosphorus contents at different potassium doses

Here, Treatment T_1= control, T_2= potassium 30 kg ha^{-1}, T_3= potassium 40 kg ha^{-1}, T_4= potassium 50 kg ha^{-1}, T_5= potassium 60 kg ha^{-1}, T_6 = potassium 70 kg ha^{-1}.

4.2.3 Potassium

Potassium (k) contents (%) in seed was significantly influenced by different application levels of K (Fig. 4.2.3). The highest amount of K present in mungbean seed (1.51%) was recorded in T_6 (70 kg K ha^{-1}) treatment. On the other hand, the lowest amount of K was present in mungbean seed (0.77 %) was recorded in potassium control treatment (Appendix- 4.2.3). Potassium is requisitory for the uptake and translocation of various nutrients. Blevins *et al.*, (1978) concluded that K has an important role as a counter ion for the uptake and translocation of nitrate (NO_3^-) within the plant. On the other hand, enriched K soil may cause increased antagonism among nutrient cations competing for uptake and translocation. Classen and Wilcox (1974) found that increasing K levels decreased the Mg and Ca in the tissue of corn. Very high levels of K can cause Mg deficiency and eventually Ca deficiency (Jones *et al.*, 1991; Senclair, 1993).

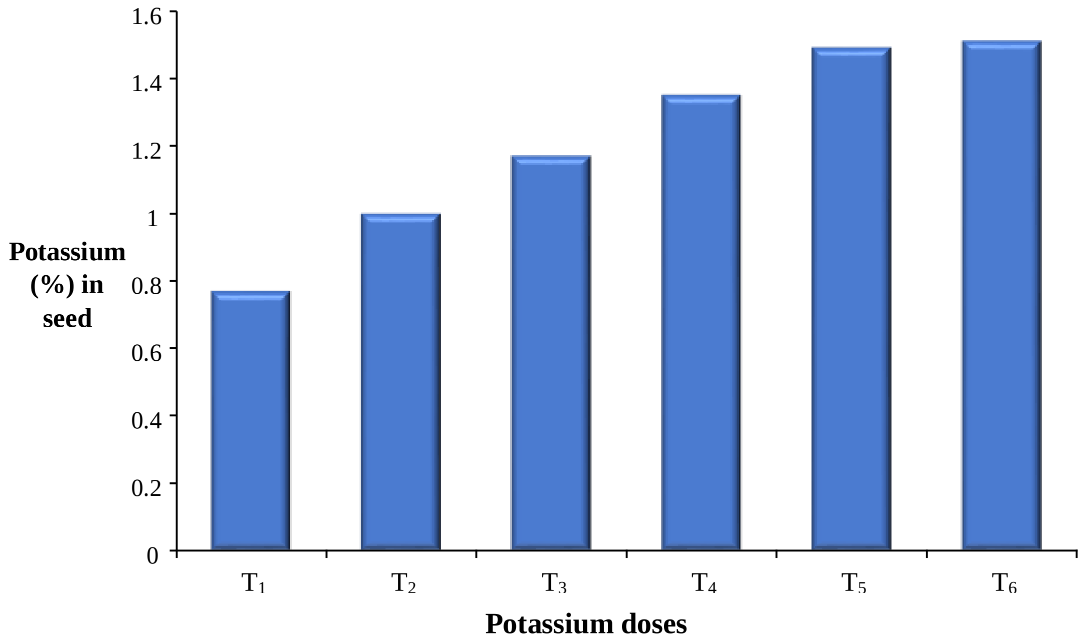

Figure 4.2.3: Potassium contents in seed at different potassium doses

Here, Treatment T_1 = control, T_2 = potassium 30 kg ha^{-1}, T_3 = potassium 40 kg ha^{-1}, T_4 = potassium 50 kg ha^{-1}, T_5 = potassium 60 kg ha^{-1}, T_6 = potassium 70 kg ha^{-1}.

4.2.4 Sulphur

Sulfur (S) content (%) in seed was significantly influenced by application levels of K (Fig. 4.2.4). The highest S concentration in mungbean seed (0.199%) was recorded in T_6 (70 kg K ha^{-1}) treatment. On the other hand, the lowest S concentration in mungbean seed (0.131 %) was recorded in K control (T_1) treatment (Appendix- 4.2.4).

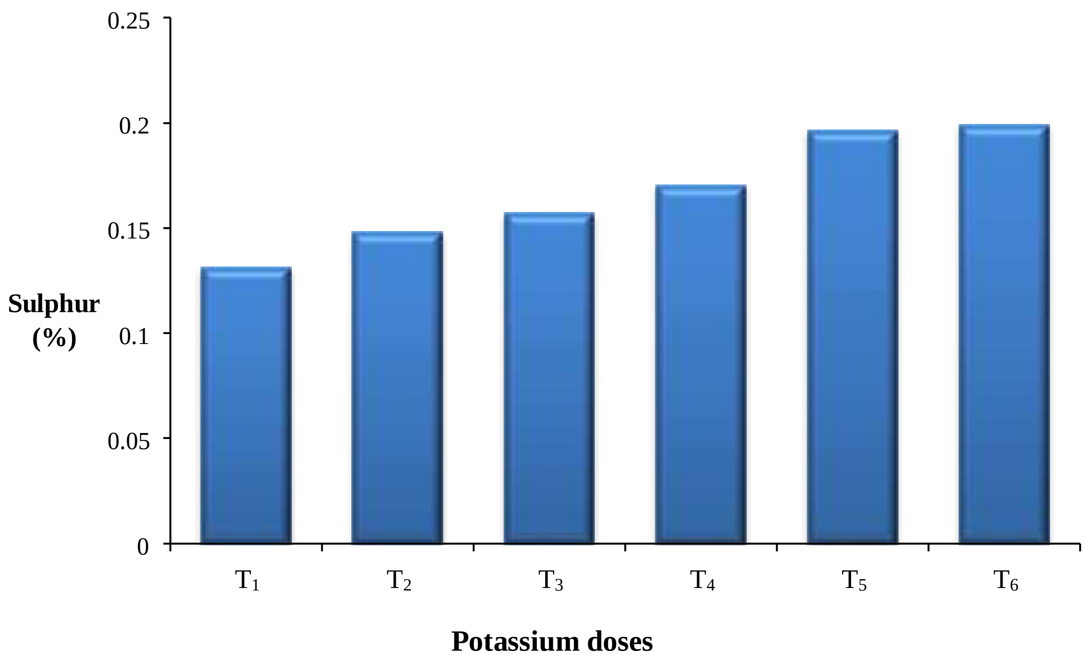

Figure 4.2.4: Sulphur content in seed at different potassium doses

Here, Treatment T_1 = control, T_2 = potassium 30 kg ha^{-1}, T_3 = potassium 40 kg ha^{-1}, T_4 = potassium 50 kg ha^{-1}, T_5 = potassium 60 kg ha^{-1}, T_6 = potassium 70 kg ha^{-1}.

4.2.5 Zinc

Zinc (Zn) content (ppm) in seed was significantly influenced by application levels of K (Fig. 4.2.5)The highest amount of Zn availed in mungbean seed (38.1 ppm) was noted in T_6 (70 kg K ha^{-1}) treatment. On the other hand, the lowest amount of Zn availed in mungbean seed (27.6 ppm) was recorded in T_1 treatment where K was not even applied (Appendix- 4.2.5).

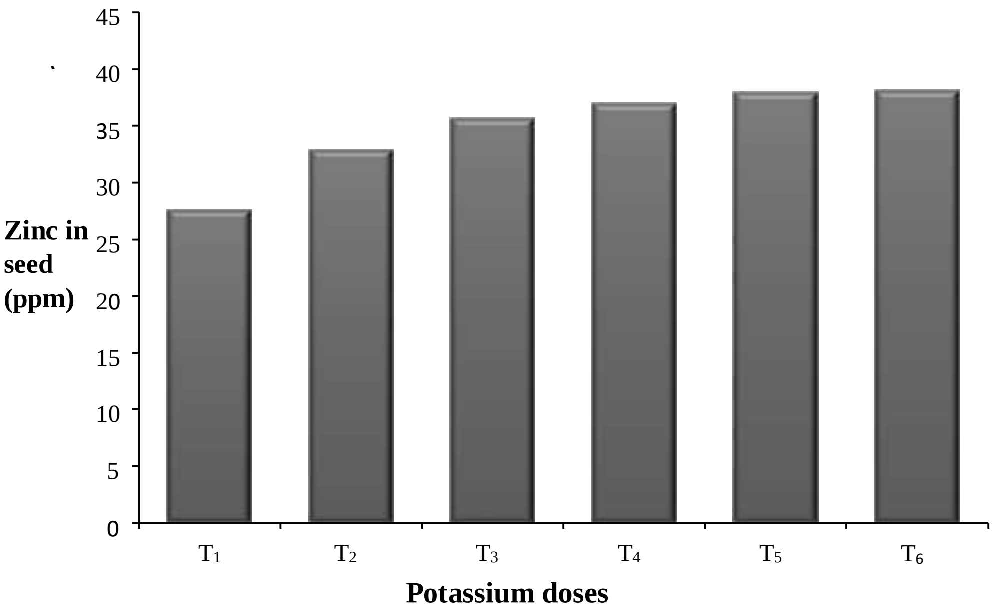

Figure 4.2.5: Zinc contents in seed at different potassium doses

Here, Treatment T_1= control, T_2= potassium 30 kg ha^{-1}, T_3= potassium 40 kg ha^{-1}, T_4= potassium 50 kg ha^{-1}, T_5= potassium 60 kg ha^{-1}, T_6 = potassium 70 kg ha^{-1}.

4.2.6 Boron

Boron (B) contents (ppm) in seed was significantly influenced by application of different levels of K (Fig. 4.4.6). The highest B concentration in mungbean seed (29.7 ppm) was recorded in T_5 (60 kg K ha^{-1}) treatment. On the other hand, the lowest B concentration in mungbean seed (21.5 ppm) was recorded in K control treatment (Appendix- 4.2.6).

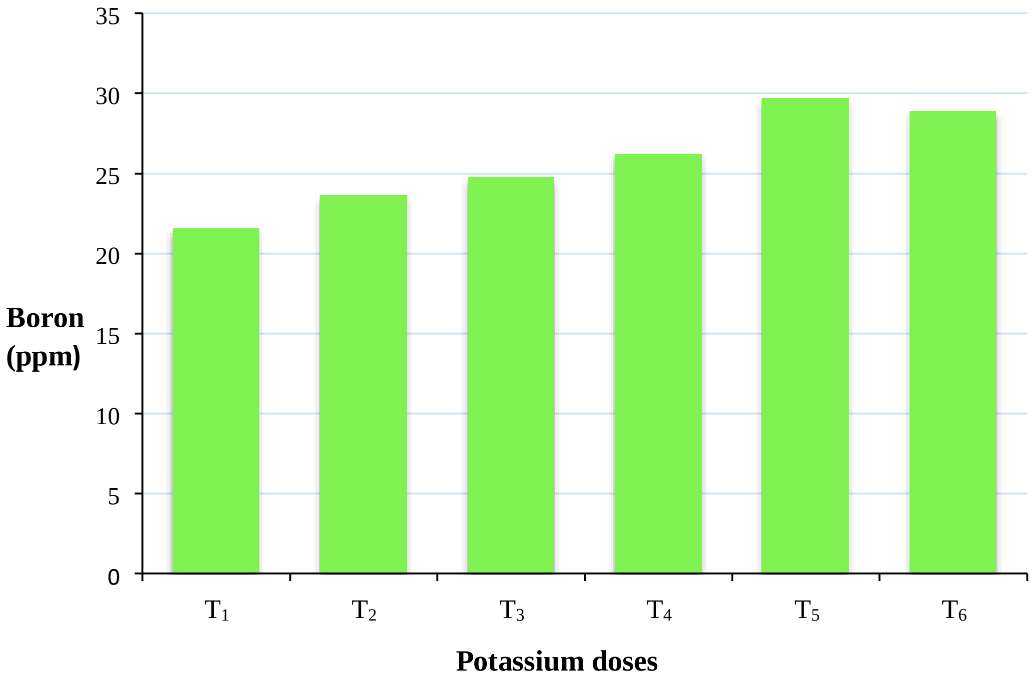

Figure 4.2.5: Boron contents in seed at different potassium doses

Here, Treatment T_1= control, T_2= potassium 30 kg ha^{-1}, T_3= potassium 40 kg ha^{-1}, T_4= potassium 50 kg ha^{-1}, T_5 = potassium 60 kg ha^{-1}, T_6 = potassium 70 kg ha^{-1}.

4.3 Nutrient contents in mungbean stover

4.3.1 Nitrogen

Nitrogen content (%) of stover was significantly impacted by the different levels of K (Fig. 4.3.1). The highest amount of N present in mungbean stover (1.78 %) was noted in T_5 (60 kg K ha^{-1}), which showed nearest result with T_6 (70 kg K ha^{-1}) treatment beat differ other K treated (T_1, T_2, T_3, T_4) treatment. On the other hand, the lowest N concentration in mungbean stover (1.48%) was recorded in T_1 treatment where K was not applied (Appendix- 4.3.1).

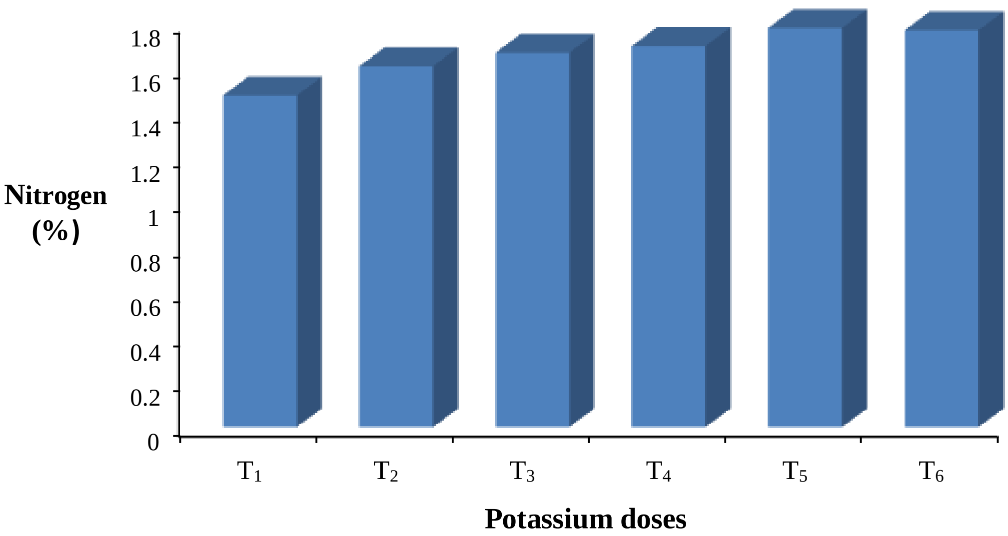

Figure 4.3.1: Nitrogen contents in stover at different potassium doses

Here, Treatment T_1= control, T_2= potassium 30 kg ha^{-1}, T_3= potassium 40 kg ha^{-1}, T_4= potassium 50 kg ha^{-1}, T_5= potassium 60 kg ha^{-1}, T_6 = potassium 70 kg ha^{-1}.

4.3.2 Phosphorus

The effect of different doses of K fertilizer showed a statistically significant variation in the P content (%) in stover (Fig. 4.3.2) of mungbean. Among the different doses of K fertilizer T_5 (60 kg K ha^{-1}) treatment showed the highest P concentration (0.34 %) in stover. The lowest value was 0.23 % under K control treatment (T_1) (Appendix-4.3.2).

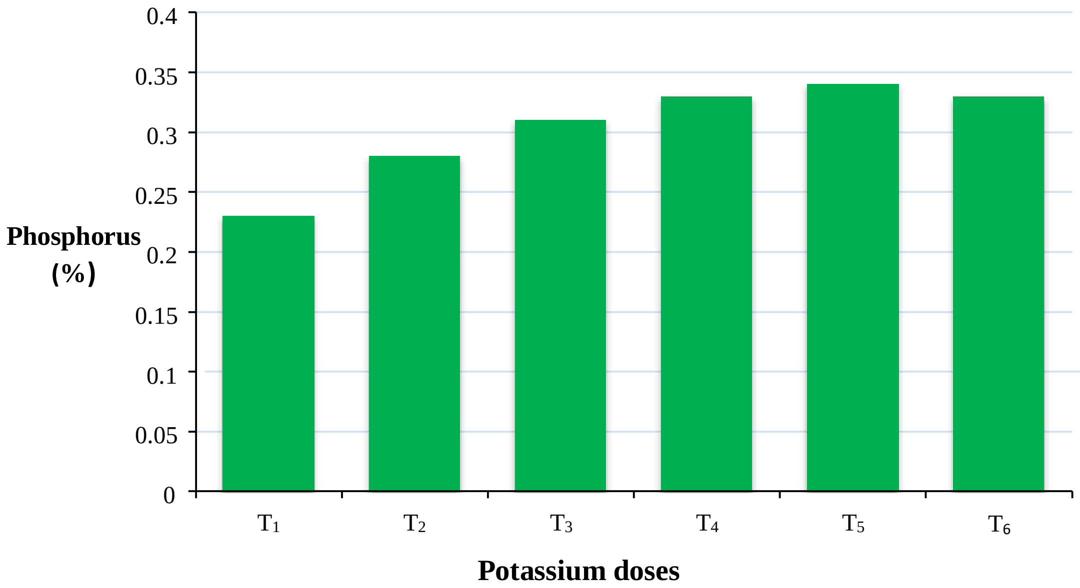

Figure 4.3.2: Phosphorus contents in stover at different potassium doses

Here, Treatment T_1 = control, T_2 = potassium 30 kg ha^{-1}, T_3 = potassium 40 kg ha^{-1}, T_4 = potassium 50 kg ha^{-1}, T_5 = potassium 60 kg ha^{-1}, T_6 = potassium 70 kg ha^{-1}.

4.3.3 Potassium

Potassium content of stover was significantly influenced by application different levels of K (Fig. 4.3.3). The highest K concentration in mungbean stover (1.69 %) was recorded in T_5 (60 kg K ha^{-1}) treatment. On the other hand, the lowest K concentration in mungbean stover (1.11 %) was recorded in T_1 treatment where K was not applied (Appendix- 4.3.3).

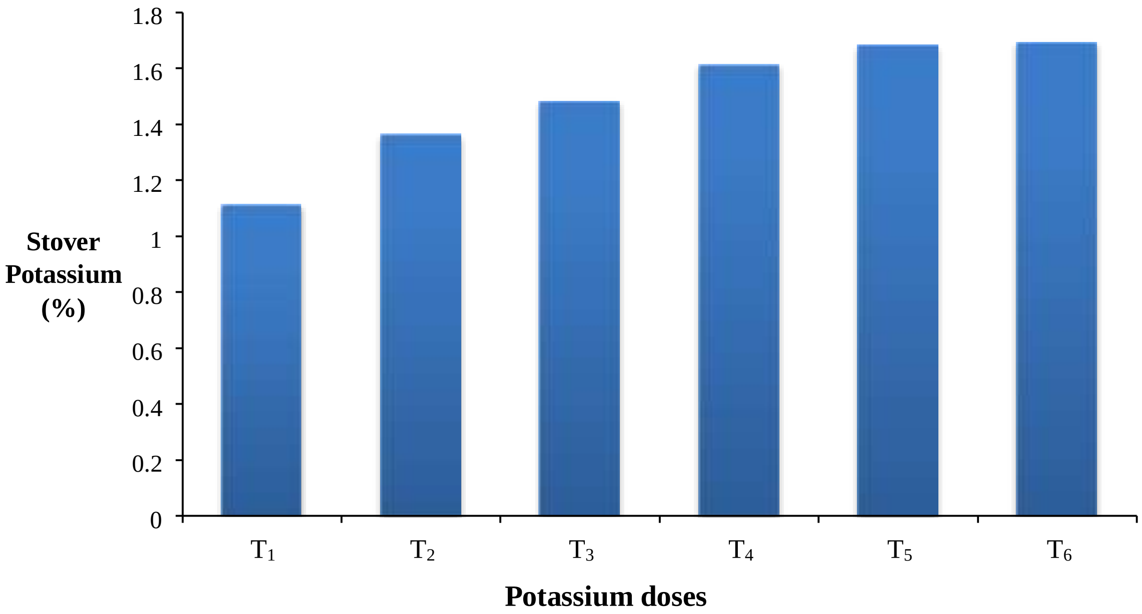

Figure 4.3.3: Potassium contents in stover at different potassium doses

Here, Treatment T_1 = control, T_2 = potassium 30 kg ha^{-1}, T_3 = potassium 40 kg ha^{-1}, T_4 = potassium 50 kg ha^{-1}, T_5 = potassium 60 kg ha^{-1}, T_6 = potassium 70 kg ha^{-1}.

4.3.4 Sulphur

Sulphur contents (%) of stover was significantly influenced by application different levels of K (Figure 4.3.4). The highest S concentration in mungbean stover (0.25 %) was recorded in T_5 (60 kg K ha^{-1}) treatment. On the other hand, the lowest S concentration in mungbean stover (0.21 %) was recorded in T_1 treatment where K was not applied (Appendix- 4.3.4).

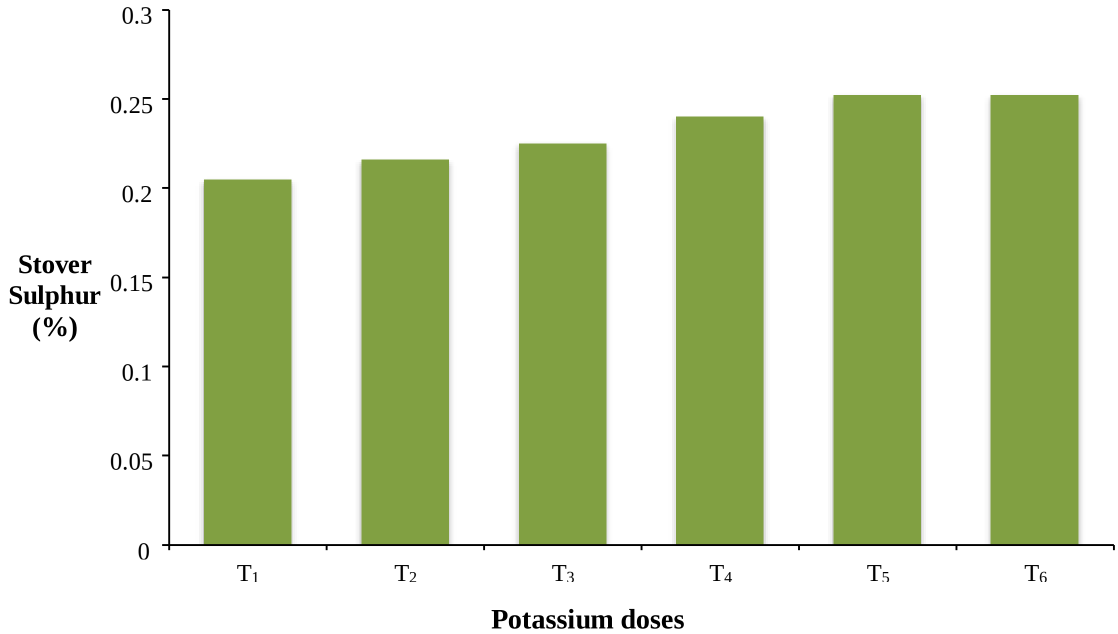

Figure 4.3.4: Sulphur contents in stover at different potassium levels

Here, Treatment T_1 = control, T_2 = potassium 30 kg ha^{-1}, T_3 = potassium 40 kg ha^{-1}, T_4 = potassium 50 kg ha^{-1}, T_5 = potassium 60 kg ha^{-1}, T_6 = potassium 70 kg ha^{-1}.

4.3.5 Zinc

Zinc contents (ppm) of stover was significantly influenced by application different levels of K (Fig. 4.3.5). The highest Zn concentration in mungbean stover (37.33 ppm) was recorded in T_5 (60 kg K ha^{-1}) treatment. On the other hand, the lowest Zn concentration in mungbean stover (27.50 ppm) was recorded in K untreated (T_1) treatment (Appendix- 4.3.5).

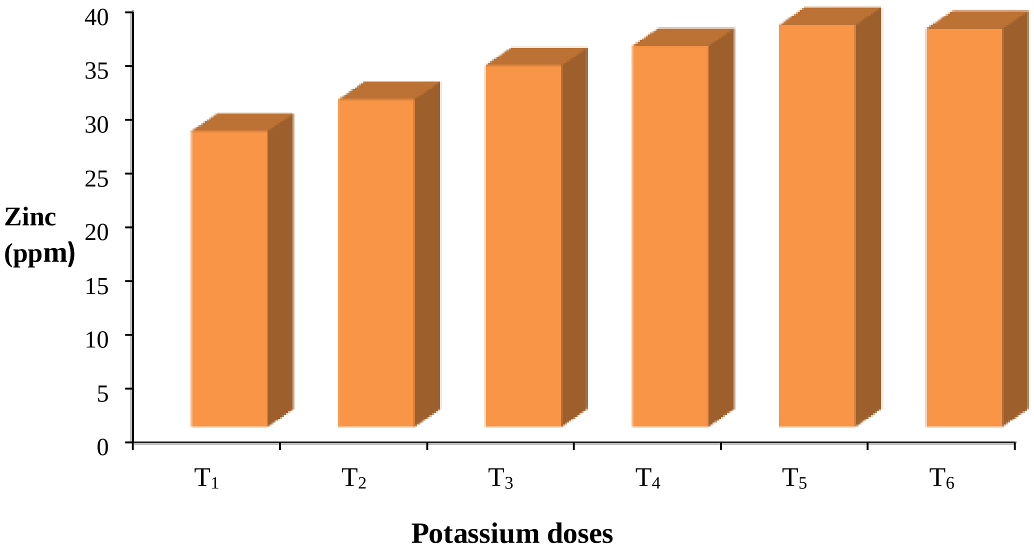

Figure 4.3.4: Zinc contents in stover at different potassium doses

Here, Treatment T_1 = control, T_2 = potassium 30 kg ha^{-1}, T_3 = potassium 40 kg ha^{-1}, T_4 = potassium 50 kg ha^{-1}, T_5 = potassium 60 kg ha^{-1}, T_6 = potassium 70 kg ha^{-1}.

4.3.6 Boron

Boron contents (ppm) of stover was significantly influenced by application different levels of K (Fig. 4.3.6). The highest B concentration in mungbean stover (28.6 ppm) was recorded in T_6 (70 kg K ha^{-1}) treatment. On the other hand, the lowest B concentration in mungbean stover (21.3 ppm) was recorded in T_1 treatment where K was not applied (Appendix- 4.3.6).

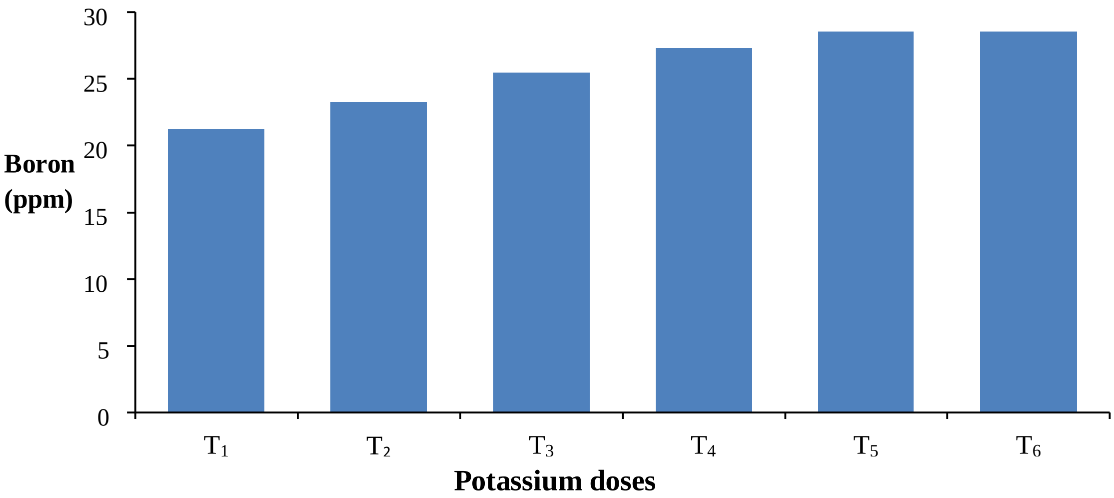

Figure 4.3.6: Boron contents in stover at different potassium doses

Here, Treatment T_1 = control, T_2 = potassium 30 kg ha^{-1}, T_3 = potassium 40 kg ha^{-1}, T_4 = potassium 50 kg ha^{-1}, T_5 = potassium 60 kg ha^{-1}, T_6 = potassium 70 kg ha^{-1}.

4.4 Economic analysis

Gross returns varied in different treatments which were directly related to the price that received from the product.

Table 4.4 Effects of potassium on partial economy of mungbean at Kharif-I

Treatments	Yield (kg ha^{-1})	Cultivation cost (Tk. ha^{-1})	Added cost (Tk. ha^{-1})	Gross return (Tk. ha^{-1})	Added benefit (Tk. ha^{-1})
T_1	875	33323	-	70000	-
T_2	1063	34122	799	85040	15040
T_3	1083	34395	1072	86640	16640
T_4	1131	34651	1328	90480	20480
T_5	1209	34923	1600	96720	26720
T_6	1190	35196	1873	95200	25200

Here, Treatment T_1 = control, T_2 = potassium 30 kg ha^{-1}, T_3 = potassium 40 kg ha^{-1}, T_4 = potassium 50 kg ha^{-1}, T_5 = potassium 60 kg ha^{-1}, T_6 = potassium 70 kg ha^{-1}.

Cost of cultivation was involved within wage rate, seed cost, pesticides and fertilizers cost. The gross returns ranged from 70000-95200 taka ha^{-1} $year^{-1}$ where the highest return was found at T_5 followed by T_6, T_4, T_3 and T_2 treatment. The lowest gross return was found at T_1 (K control) (Table 4.4). Data of cost and return analysis showed that the highest gross margin ranged from 15040-25200 where highest at T_5 followed by T_6, T_4, T_3 and T_2 treatment and lowest found at control (T_1) treatment.

Table 4.4 Effects of potassium on partial economy of mungbean at Kharif-I (continued)

Treatments	Net return (Tk. ha^{-1})	BCR
T_1	36677	2.10
T_2	50918	2.49
T_3	53345	2.51
T_4	55829	2.61
T_5	61797	2.77
T_6	60004	2.70

Here, Treatment T_1 = control, T_2 = potassium 30 kg ha^{-1}, T_3 = potassium 40 kg ha^{-1}, T_4 = potassium 50 kg ha^{-1}, T_5 = potassium 60 kg ha^{-1}, T_6 = potassium 70 kg ha^{-1}.

Output price: Mungbean seed @ Tk. 80 kg^{-1}

Input price: Urea=Tk. 20 kg^{-1}, T.S.P= Tk. 22 kg^{-1}, MoP= Tk. 15 kg^{-1}, Gypsum= Tk. 24 kg^{-1}, Zinc sulphate= Tk. 200 kg^{-1}, Boric acid= Tk. 200 kg^{-1}, wage rate==Tk. 500 day^{-1}, mungbean seed= 80 Tk. kg^{-1}.

Regarding BCR, the highest benefit cost ratio 2.77 found in T_5 treatment followed by T_6, T_4, T_3 and T_2 treatment. However net return 61797 Tk. was highest in T_5 treatment. It was found that the unit cost of fertilizer is higher in T_5 than the unit cost of other fertilizer except T_6. Therefore, BCR were increased remarkably in T_6, T_4, T_3 and T_2 treatment. Considering the highest gross margin T_5 treatment is economically viable.

4.5 Changes of post-harvest soil properties

Soil sample were collected from each treated plot for analyzing different soil properties viz. soil pH, organic matter, total N, available P, K, S, Ca, Mg, Zn and B. The results are presented in Table 4.5. Initially soil pH was 6.6 and after completion of experiments, soil pH remain unchanged. After experiment minor change was found on soil fertility from initial status. The effect of application of K slightly increased of soil organic matter, total N, Zn, B and slightly decreased of S and Mg in all plots over initial status. Prasad *et al.,* (2000) found significant increase of K concentration in the post-harvest soil of summer mungbean field due to the application of 20-30 kg K ha^{-1}.

Table 4.5 Changes of post-harvest soil properties

Treatment	pH	OM %	Total N%	Ca	Mg	K	P	S	Zn	B
				meq. 100 g^{-1}			µg g^{-1}			
Initial	6.4	1.27	0.057	6.01	2.02	0.10	23.5	26.0	1.3	0.16
T_1	6.3	1.30	0.061	5.90	2.00	0.09	24.0	25.2	1.2	0.14
T_2	6.5	1.35	0.063	6.01	2.00	0.12	24.5	25.3	1.4	0.16
T_3	6.5	1.37	0.065	6.01	2.01	0.14	24.6	25.5	1.3	0.18
T_4	6.6	1.38	0.065	6.0	2.02	0.15	24.8	25.8	1.4	0.19
T_5	6.5	1.38	0.065	5.89	2.00	0.16	24.7	25.7	1.4	0.21
T_6	6.6	1.38	0.068	5.91	2.01	0.17	24.6	25.6	1.3	0.22

Here, Treatment T_1 = control, T_2 = potassium 30 kg ha^{-1}, T_3 = potassium 40 kg ha^{-1}, T_4 = potassium 50 kg ha^{-1}, T_5 = potassium 60 kg ha^{-1}, T_6 = potassium 70 kg ha^{-1}. meq. 100g^{-1} = mili equivalent per 100 gm, µg g^{-1} = micro gram per gram soil.

CHAPTER-V

SUMMARY AND CONCLUSION

The experiment was conducted at the research farm of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh during the period from March, 2017 to May, 2017 to study influence of potassium on nodulation, quality, yield and nutrient uptake of mungbean. In experiment, the treatment consisted of six potassium levels viz. T_1 (0 kg K ha^{-1}), T_2 (30 kg K ha^{-1}), T_3 (40 kg K ha^{-1}), T_4 (50 kg K ha^{-1}), T_5 (60 kg K ha^{-1}) and T_6 (70 kg K ha^{-1}). Basal application was made with N, P, S, Zn and B at the rate of 15 kg ha^{-1}, 20 kg ha^{-1}, 10 kg ha^{-1}, 2 kg ha^{-1} and 1.5 kg ha^{-1} respectively. The experiment field belongs to the AEZ-28 (Madhupur Tract) and it falls under Chhaita soil seris. Characteristically, the soil was clay loam having 6.4 pH, total N% 0.057, 0.10% available K and 0.16 ppm available boron. The treatments were randomly distributed in each block. The size of each plot was 4 m x 3 m (12 m^2) and total numbers of plots were 18. The spacing between blocks and units were 0.75 m and 1m respectively. Potassium rate treatments were placed at each of the sub plots.

In the field experiment, it was observed that the plant height was affected due to the different level of K. The tallest plant height (34.2 cm) was obtained from level of K T_6 (70 kg ha^{-1}).

Number of pods $plant^{-1}$ was influenced by different levels of K. The highest number of pods per plant (15.09) was observed from T_5 (60 kg k ha^{-1}).

Pod length was influenced by different levels of K. At 60 kg K ha^{-1} found highest pod length (9.03 cm).

Number of seeds pod^{-1} was influenced by level of K fertilizer treatment, where the highest number of seeds pod^{-1} (9.37) at 60 kg ha^{-1} K treatment.

Thousand seed weight and seed yield (kg ha^{-1}) as impacted by different doses of K treatment, where the highest result 49.24 g and 1209 kg ha^{-1}, respectively at 60 kg potassium ha^{-1}. Stover yield also impacted by different K doses. The highest stover yield found 2742 kg ha^{-1} at 70 kg K ha^{-1}. Number of nodules was significantly influenced by level of K fertilizer. The highest number of nodules 6.08, 21.4, 23.4 found at 25DAS, 35 DAS and 45 DAS, respectively. Above all, the highest number of nodule was recorded at 60 kg ha^{-1} (T_5) K levels.

Nutrient contents in seed influenced by different K doses. Nitrogen contents (%) in seed highest at 60 kg ha^{-1} (T_5) K level. Phosphorus (0.54%) was highest at 60 kg ha^{-1} (T_5) K. Potassium also significantly influenced by different K doses. Higher potassium (1.51%) was found at 70 kg ha^{-1} (T_6). The highest S (0.199%) and Zn (0.199 ppm) was found at 70 kg ha^{-1} (T_6) treatment. B contents increase with the increase of K doses up to 60 kg ha^{-1} (T_5). The highest B content in seed was 29.7 ppm.

Nutrient content in stover is also impacted by different K doses. Nitrogen content (%) in stover was highest (1.78%) at 60 kg ha^{-1} (T_5) K level. Phosphorus (0.34%) was highest at 60 kg ha^{-1} (T_5) K. Potassium also influenced by different K doses. The highest

K (1.69%) was found at 70 kg ha^{-1} (T_6). The highest S (0.25%) and Zn (37.3 ppm) in stover were found at 60 kg ha^{-1} (T_5). Boron contents increase with the increase of K doses up to 70 kg ha^{-1} (T_6). Highest B content in seed was 28.6 ppm.

Economic analysis of the different treatments showed that highest gross return (96720 tk.), highest net return (61797 tk) and highest BCR (2.77) were also found in T_5 (60 kg K ha^{-1}) treatment.

From the above discussions, it may be concluded that application of potasssic fertilizer influenced mungbean growth and yield as well as production. Although K played important role on growth, development and yield of mungbean (BARI Mung-6). Therefore, judicious application of the potassium through MoP fertilizers is needed and based of this research results it could be suggested that application of 60 kg K ha^{-1} to be a promising practice for mungbean cultivation in Bangaldesh. However, to reach a specific conclusion and recommendation, more research work on the application of K fertilizer in mungbean cultivation should be done in different Agro-Ecological Zones.

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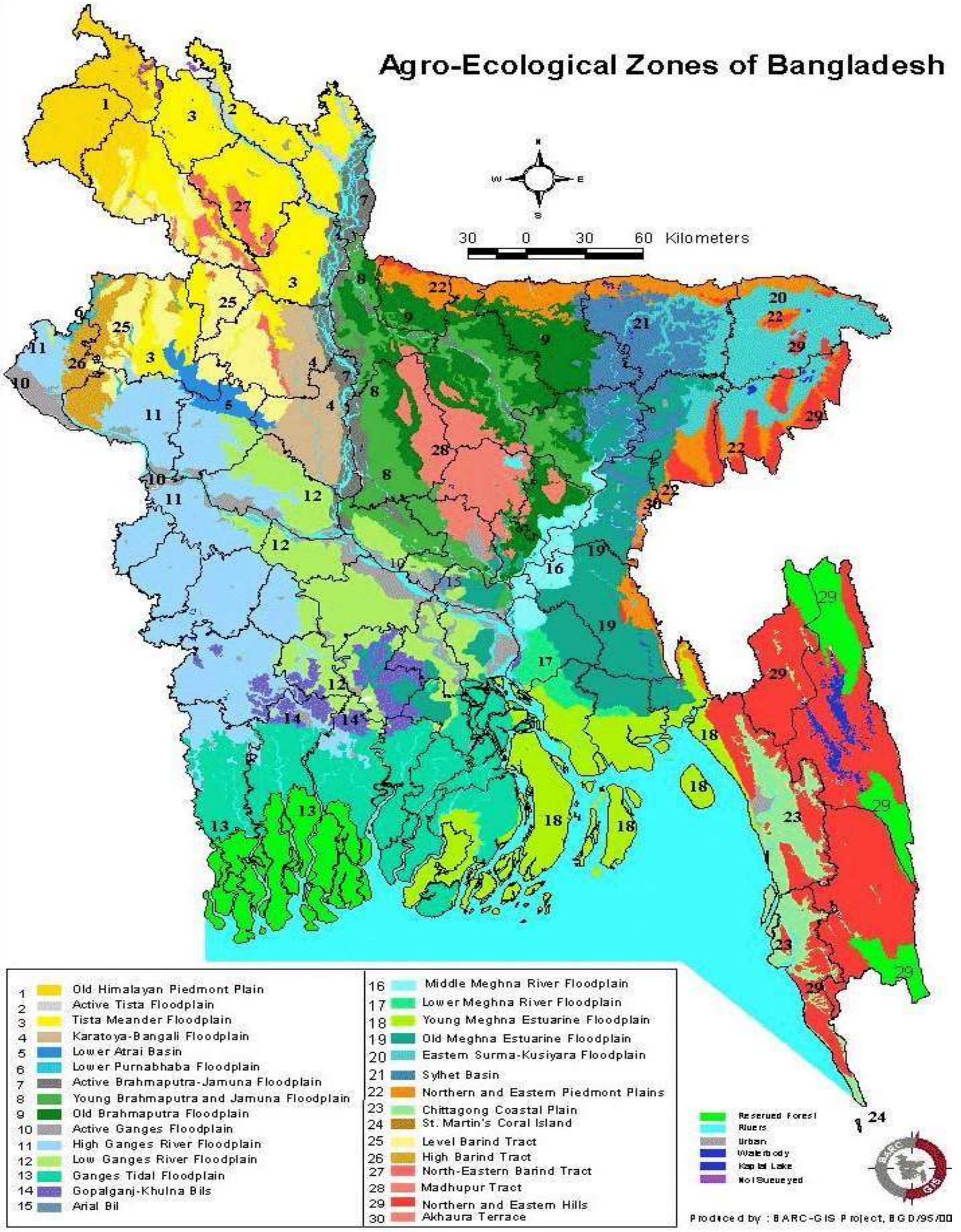
Source 1: https://www.ebay.co.uk/itm/green-gram-powder-Mung-Bean-Powder-For-Natural-sking-care-Helth-100-Organic-/282509154323

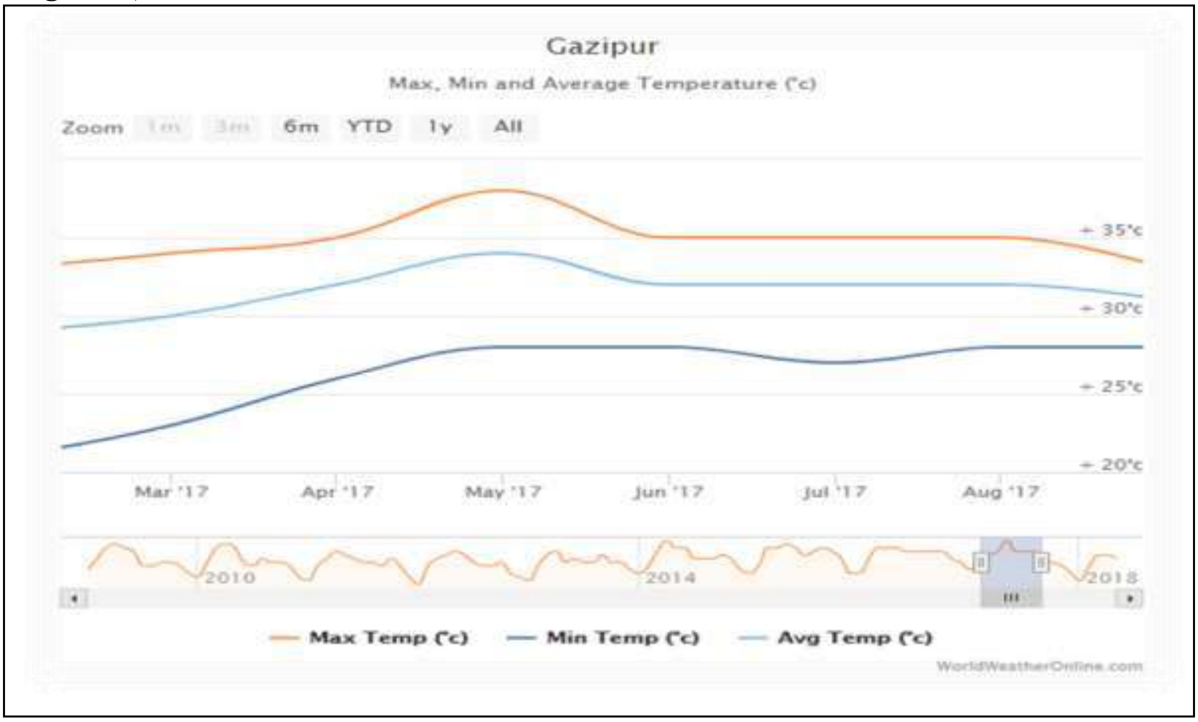
Appendix 1

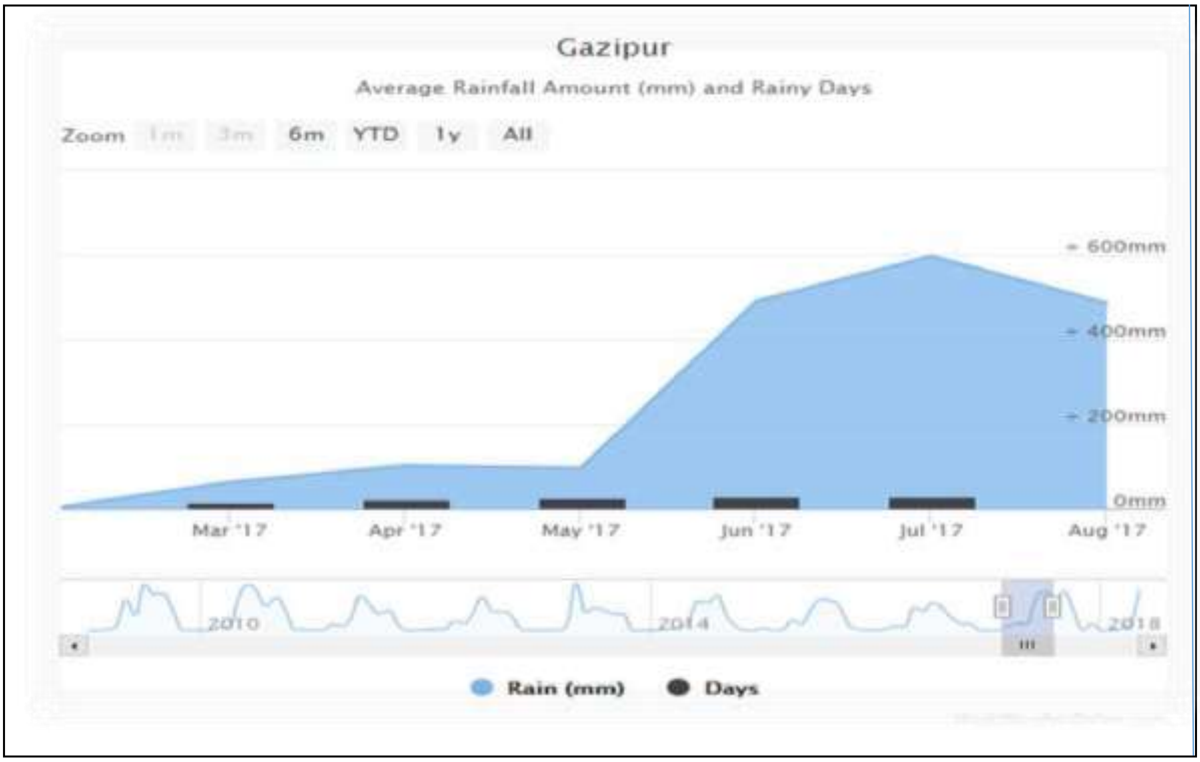
Experimental location at BARI, Gazipur (28) on the map of Agro-ecological Zones of Bangladesh



Appendix 2

Monthly weather data of Gazipur during experiment (from Mar'2017 to Aug'2017)

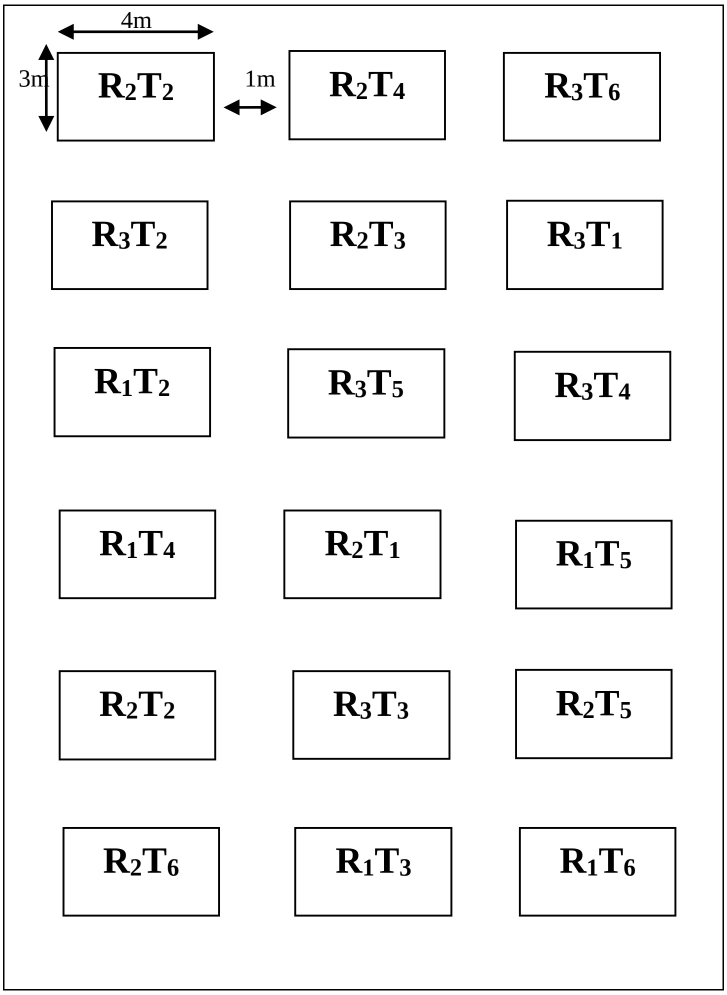


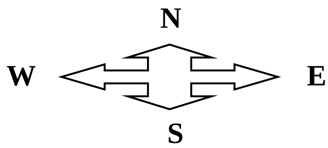


(Source- WWW.WorldWeatherOnline.com)

Appendix 3

Layout of the experiment field





Single plot area = 12 m^2

Column to column distance=1m

Row to row distance= 0.75 m

Treatments:

T_1= 0 kg K ha^{-1}

T_2= 30 kg K ha^{-1}

T_3= 40 kg K ha^{-1}

T_4= 50 kg K ha^{-1}

T_5= 60 kg K ha^{-1}

T_6= 70 kg K ha^{-1}

Replication:

R_1= Replication 1

R_2= Replication 2

R_3= Replication 3

Appendix 4

Appendix 4.1.1

Effect of potassium on the plant height of mungbean during Kharif-I, 2017 at BARI farm, Gazipur

Treatments	Potassium (kg ha^{-1})	Plant height (cm)
T_1	Control	30.2 e
T_2	30	31.2 d
T_3	40	32.7 c
T_4	50	33.4 b
T_5	60	34 ab
T_6	70	34.2 a
CV (%)		1.17
LSD (5%)		0.690

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability.

Appendix 4.1.2

Effect of different levels of potassium on number of pods $plant^{-1}$ in mungbean during Kharif-I, 2017 at BARI farm, Gazipur

Treatments	Potassium (kg ha^{-1})	Number of pods $plant^{-1}$
T_1	Control	10.65 e
T_2	30	12.39 d
T_3	40	13.52 c
T_4	50	14.27 bc
T_5	60	15.09 a
T_6	70	14.88 ab
CV (%)		6.22
LSD (5%)		0.7841

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability.

Appendix 4.1.3

Effect of different levels of potassium on pods length in mungbean during Kharif-I, 2017 at BARI farm, Gazipur

Treatments	Potassium (kg ha^{-1})	Pod length (cm)
T_1	Control	8.30 e
T_2	30	8.43 d
T_3	40	8.70 c
T_4	50	8.90 b
T_5	60	9.06 a
T_6	70	8.94 b
CV (%)		1.03
LSD (5%)		0.0835

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability.

Appendix 4.1.4:

Effect of different levels of potassium on number of seeds pod^{-1} in mungbean during Kharif-I, 2017 at BARI farm, Gazipur

Treatments	Potassium (kg ha^{-1})	Number of seeds pod^{-1}
T_1	Control	8.90 d
T_2	30	9.03 c
T_3	40	9.21 b
T_4	50	9.26 b
T_5	60	9.37 a
T_6	70	9.34 a
CV (%)		1.18
LSD (5%)		0.0642

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability.

Appendix 4.1.5

Effect of different levels of potassium on thousand seed weight in mungbean during Kharif-I, 2017 at BARI farm, Gazipur

Treatments	Potassium (kg ha^{-1})	Thousand seed weight (g)
T_1	Control	44.09 e
T_2	30	45.37 d
T_3	40	46.48 c
T_4	50	47.89 b
T_5	60	49.24 a
T_6	70	48.71 a
CV %		1.72
LSD (5%)		0.6184

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability.

Appendix 4.1.6

Effect of different levels of potassium on seed yield in mungbean during Kharif-I, 2017 at BARI farm, Gazipur

Treatments	Potassium (kg ha^{-1})	Seed yield (kg ha^{-1})
T_1	Control	875 c
T_2	30	1063 b
T_3	40	1083 b
T_4	50	1131 ab
T_5	60	1209 a
T_6	70	1190 a
CV (%)		6.35
LSD (5%)		86.454

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability.

Appendix 4.1.7

Effect of different levels of potassium on stover yield in mungbean during Kharif-I, 2017 at BARI farm, Gazipur

Treatments	Potassium (kg ha^{-1})	Stover yield (kg ha^{-1})
T_1	Control	2313 c
T_2	30	2592 b
T_3	40	2533 b
T_4	50	2592 ab
T_5	60	2736 a
T_6	70	2742 a
CV (%)		7.43
LSD (5%)		160.15

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability.

Appendix 4.1.8

Effect of different levels of potassium on number of nodules $plant^{-1}$ during Kharif-I, 2017 at BARI farm, Gazipur

Treatments	Nodules Days After Sowing			
	25 DAS	35 DAS	45 DAS	55 DAS
T_1	5.67 c	15.57 d	18.27 e	16.63 e
T_2	5.81 bc	18.70 c	20.70 d	17.47 d
T_3	5.88 b	19.97 b	21.57 cd	18.10 c
T_4	5.96 ab	20.80 ab	22.0 bc	19.23 b
T_5	6.08 a	21.43 a	23.37 a	19.97 a
T_6	6.08 a	20.93 a	22.83 ab	20.13 a
CV (%)	1.58	2.35	3.21	4.83
LSD (5%)	0.170	0.834	1.255	0.279

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability. Here, Treatment T_1 = control, T_2 = potassium 30 kg $ha^{-1,}$ T_3 = potassium 40 kg ha^{-1}, T_4 = potassium 50 kg ha^{-1}, T_5 = potassium 60 kg ha^{-1}, T_6 = potassium 70 kg ha^{-1}.

Appendix 4.2.1

Effect of different levels of potassium on nitrogen contents in mungbean seed during Kharif-I season, 2017 at BARI, Gazipur

Treatments	Potassium (kg ha^{-1})	Nitrogen (%)
T_1	Control	3.22 f
T_2	30	3.27 e
T_3	40	3.40 d
T_4	50	3.50 c
T_5	60	3.56 a
T_6	70	3.53 b
CV (%)		0.30
LSD (5%)		0.0187

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability.

Appendix 4.2.2

Effect of different levels of potassium on phosphorus contents in mungbean seed during Kharif-I season, 2017 at BARI, Gazipur

Treatments	Potassium (kg ha^{-1})	Phosphorus (%)
T_1	Control	0.42 d
T_2	30	0.48 c
T_3	40	0.49 c
T_4	50	0.52 b
T_5	60	0.54 a
T_6	70	0.53 ab
CV (%)		1.43
LSD (5%)		0.0129

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability.

Appendix 4.2.3

Effect of different levels of potassium on potassium contents in mungbean seed during Kharif-I season, 2017 at BARI, Gazipur

Treatments	Potassium (kg ha^{-1})	Potassium (%)
T_1	Control	0.77 f
T_2	30	1.00 e
T_3	40	1.17 d
T_4	50	1.35 c
T_5	60	1.49 b
T_6	70	1.51 a
CV (%)		1.02
LSD (5%)		0.0224

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability.

Appendix 4.2.4

Effect of different levels of potassium on sulphur contents in mungbean seed during Kharif-I season, 2017 at BARI, Gazipur

Treatments	Potassium (kg ha^{-1})	Sulphur (%)
T_1	Control	0.131 e
T_2	30	0.148 d
T_3	40	0.157 c
T_4	50	0.170 b
T_5	60	0.196 a
T_6	70	0.199 a
CV (%)		2.62
LSD (5%)		7.937E-03

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability.

Appendix 4.2.5

Effect of different levels of potassium on zinc contents in mungbean seed during Kharif-I season, 2017 at BARI, Gazipur

Treatments	Potassium (kg ha^{-1})	Zinc (ppm)
T_1	Control	27.60 e
T_2	30	32.87 d
T_3	40	35.67 c
T_4	50	37.00 b
T_5	60	37.93 a
T_6	70	38.13 a
CV (%)		1.40
LSD (5%)		0.887

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

Appendix 4.2.6

Effect of different levels of potassium on boron contents in mungbean seed during Kharif-I season, 2017 at BARI, Gazipur

Treatments	Potassium (kg ha^{-1})	Boron (ppm)
T_1	Control	21.53 d
T_2	30	23.63 c
T_3	40	24.73 c
T_4	50	26.17 b
T_5	60	29.70 a
T_6	70	28.86 a
CV (%)		2.67
LSD (5%)		1.2522

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability.

Appendix 4.3.1

Effect of different levels of potassium on nitrogen contents in mungbean stover during Kharif-I season, 2017 at BARI, Gazipur

Treatments	Potassium (kg ha^{-1})	Nitrogen (%)
T_1	Control	1.48 e
T_2	30	1.61 d
T_3	40	1.67 c
T_4	50	1.70 b
T_5	60	1.78 a
T_6	70	1.77 a
CV (%)		1.09
LSD (5%)		0.0332

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability.

Appendix 4.3.2

Effect of different levels of potassium on phosphorus content in mungbean stover during Kharif-I season, 2017 at BARI, Gazipur

Treatments	Potassium (kg ha^{-1})	Phosphorus (%)
T_1	Control	0.23 c
T_2	30	0.28 b
T_3	40	0.31 a
T_4	50	0.33 a
T_5	60	0.34 a
T_6	70	0.33 a
CV (%)		4.47
LSD (5%)		0.0261

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability.

Appendix 4.3.3

Effect of different levels of potassium on potassium contents in mungbean stover during Kharif-I season, 2017 at BARI, Gazipur

Treatments	Potassium (kg ha^{-1})	Potassium (%)
T_1	Control	1.11 e
T_2	30	1.36 d
T_3	40	1.48 c
T_4	50	1.61 b
T_5	60	1.68 a
T_6	70	1.69 a
CV (%)		1.19
LSD (5%)		0.0321

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability.

Appendix 4.3.4

Effect of different levels of potassium on sulphur contents in mungbean stover during Kharif-I season, 2017 at BARI, Gazipur

Treatments	Potassium (kg ha^{-1})	Sulphur (%)
T_1	Control	0.21 d
T_2	30	0.22 c
T_3	40	0.23 c
T_4	50	0.24 b
T_5	60	0.25 a
T_6	70	0.25 a
CV (%)		2.15
LSD (5%)		9.070E-03

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability.

Appendix 4.3.5

Effect of different levels of potassium on zinc contents in mungbean stover during Kharif-I season, 2017 at BARI, Gazipur

Treatments	Potassium (kg ha^{-1})	Zinc (ppm)
T_1	Control	27.50 e
T_2	30	30.44 d
T_3	40	33.59 c
T_4	50	35.38 b
T_5	60	37.33 a
T_6	70	36.99 a
CV (%)		2.36
LSD (5%)		1.4373

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability.

Appendix 4.3.6

Effect of different levels of potassium on boron contents in mungbean stover during Kharif-I season, 2017 at BARI, Gazipur

Treatments	Potassium (kg ha^{-1})	Boron (ppm)
T_1	Control	21.25 c
T_2	30	23.25 c
T_3	40	25.45 b
T_4	50	27.26 ab
T_5	60	28.54 a
T_6	70	28.55 a
CV (%)		4.36
LSD (5%)		2.0534

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability.

PLATES

Plate 1: Seed sowing

Plate 2: Treatment wise plot arrangement

Plate 3: Counting number of pods $plant^{-1}$

Plate 4: Washing of mungbean root

Plate 5: Plant roots with nodule

Plate 6: Mature mungbean plot

Plate 7: Weighing of mungbean plants after harvest