COMBINED EFFECTS OF POTASSIUM AND BORON ON THE GROWTH, YIELD AND NUTRIENT CONTENTS OF MUNGBEAN

BY

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CERTIFICATE

This is to certify that the thesis entitled, "**Combined Effects of Potassium and Boron on the Growth, Yield and Nutrient Contents of Mungbean**" submitted to the Faculty of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURAL CHEMISTRY,** embodies the result of a piece of bona fide research work carried out by **MD. FORHAD HOSSEN** bearing Registration No. 10-04024 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has been duly acknowledged.

Dated:

Place: Dhaka, Bangladesh

Prof. Dr. Rokeya Begum,

Research Supervisor

Dedicated To

My Beloved Parents

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ABSTRACT

The experiment was conducted at the research plot of the central farm of Sher-e-Bangla Agricultural University, Dhaka during the period from February, 2016 to June, 2016 to study the combined effects of potassium and boron on growth, yield and nutrient contents of mungbean. The experiment was laid out in a two factors randomized complete block design (RCBD) with three replications. The experiment was designed with nine different treatment level viz. K_0B_0 (0 kg K ha^{-1} and 0 kg B ha^{-1}), K_0B_1(0 kg K ha^{-1} and 1.5 kg B ha^{-1}), K_0B_2 (0 kg K ha^{-1} and 2.5 kg B ha^{-1}), K_1B_0(15 kg K ha^{-1} and 0 kg B ha^{-1}), K_1B_1(15 kg K ha^{-1} and 1.5 kg B ha^{-1}) , K_1B_2(15 kg K ha^{-1} and 2.5 kg B ha^{-1}), K_2B_0(25 kg K ha^{-1} and 0 kg B ha^{-1}), K_2B_1(25 kg K $ha^{-1}$and 1.5 kg B ha^{-1}) and K_2B_2(25 kg K $ha^{-1}$and 2.5 kg B ha^{-1}). The results indicate that tallest plant(68.47cm), highest number of leaves(23.73), maximum dry matter content(7.75gm), branches per plant(5.37), highest nodule per plant(44), number of pods per plant(21.47), number of seeds per pod(9.833), tallest pod(10.10cm), 1000 seed weight(46.97gm), maximum seed yield(1.87 t ha^{-1}) and harvest index(46.31) obtained from K_2B_2 treatment except days to 1st flowering(35.67 days) and stover yield(2.66 t ha^{-1}). Lowest values for all of the growth and yield parameters obtained from the treatment K_0B_0 Results showed that different potassium and boron levels significantly influenced the nutrients contributing characters of mungbean. The uptake of nutrient N, P, K and B by seed was significantly influenced with the K_2B_2 treatment. The maximum protein and β-carotene content in seed was recorded in 25 kg K/ha with 2.5 kg B/ha treatment combination. Mungbean growth yield and nutrient contents was increased with increasing the K and B levels.

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
B	=	Boron
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	MiliLitre
M.S.	=	Master of Science
MoA	=	Ministry of Agriculture
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
µg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

Chapter I
Introduction

CHAPTER I

INTRODUCTION

In Bangladesh farmers grow various types of pulse crops among them lentil, chickpea, cowpea, blackgram, mungbean, fieldpea and grasspea are pre dominant. Pulses constitute the main source of protein for the poor people. Pulse protein is rich in lysine which is deficient in rice. Mungbean (*Vigna radiata* L.) belongs to family Leguminosae and sub-family Papilionaceae, is one of the important pulse crop of Bangladesh which contains high graded vegetable proteins and satisfactory level of minerals and vitamins. It has an edge over other pulses because of its high nutritive value, digestibility and non-flatulent behavior. Mungbean is an important pulse crop that can be grown twice in a year. Besides being a rich source of protein, it maintains soil fertility through biological nitrogen fixation in soil and thus plays a vital role in sustainable agriculture. It ranks fourth position considering both acreage and production in Bangladesh (MoA, 2014). In 2014-15, the area under pulse crop is 0.409 million hectare with a production of 0.726 million tons, where mungbean is cultivated in the area of 0.039 million ha with production of 0.033 million tons (BBS, 2015). Pulse plays an important role in human nutrition and it is called "poor man's meat" because it is the cheapest source of protein for the poor people. Mungbean seed contains 1-3% fat, 5.4% carbohydrates, 25.67% protein, 3.5-4.5% fibers and 4.5-5.5% ash, while calcium and phosphorus are 132 and 367 mg per 100 grams of seed, respectively (Faruque *et al.*, 2000). It also contains 75 mg calcium, 8.5 mg iron and 49 mg β-carotene per 100 g of split dal (Choudhury and Hassan 2013). It contains almost double amount of protein as compared to cereals and capable of supplying major source of protein. According to FAO (2013) recommendation, a minimum intake of pulse by a human should be 80 gm day^{-1} but in Bangladesh per capita consumption of pulses is only 14.72 g (BBS, 2012). To meet the suggested requirement, the production to be increased more than two folds.

The average yield of mungbean in Bangladesh is 842 kg ha^{-1} (BBS, 2015) which are much lower than in India (1320 kg ha^{-1}) and some other countries. Average low yield of mungbean in Bangladesh is due to substandard methods of cultivation, imbalanced plant nutrition, poor plant protection and lack of high yielding varieties. Lack of attention on fertilizer use is also instrumental in lowering mungbean yields (Mansoor, 2007). Mungbean yield and quality can be improved by balanced use of fertilizer. Potassium (K) is the third macronutrient required for plant growth, after nitrogen (N) and phosphorus (P). Pulse crop attains yield benefits from potassium (K) application. It is evident from the literature that application of NPK fertilizer improved mungbean yield (Ali *et al.*, 2010). Among other macro nutrients potash (K) plays a vital role in photosynthesis, enzyme activation, protein synthesis and resistance against the pest attack and diseases (Arif *et al.*, 2008). Potassium also plays a vital role as macronutrient in plant growth and sustainable crop production (Baligar, 2001). It helps in osmo-regulation of plant cell, assists in opening and closing of stomata (Yang *et al.*, 2004). It plays a key role in activation of more than 60 enzymes (Bushkh *et al.*, 2011). Improved K supply also enhances biological nitrogen fixation and protein content of pulse grains (Srinivasarao *et al.*, 2003).

K has an important osmotic role in plants. It exerts significant effects on disease management through specific metabolic functions that alter compatibility relationships of the host-parasite environment (Kafkafi *et al.*, 2001). The intricate relationships between K nutrition and metabolic functions as well as its interrelationships with various other nutrients within the plant and the soil enable K to modify disease resistance or susceptibility. It maintains turgor pressure of cell which is necessary for cell expansion. The supply of phosphorus and K to leguminous crops is necessary especially all the flowering and pod setting stages (Zahran *et al.*, 1998).

Boron ranks third among the micronutrient and has a chief role in plant cell wall and membrane constancy (Bassil *et al.*, 2004). It increases the yield and growth of plants by increasing the leaf area expansion, 1000 seed weight, nodule formation, seed yield and biological yield. It influences the major cellular functions and metabolic activities in plants and required for cell differentiation at all growing tips of plants (meristems) where cell division is active (El-Hamdaoui *et al.*, 2003). Boron is important for protein synthesis and improved protein content Kaisher *et al.* (2010). Low concentration of boron bounds the nitrogen fixation in legumes by restricting the nodule formation and nitrogen fixation increased with higher boron concentration (Yakubu *et al*, 2010). Nabi *et al*. (2006) observed the effect of boron on the growth and plant height, leaf area and biomass production of mungbean by the application of boron. Boron plays a positive role on the activity of urease, de-hydrogenase and phosphatase enzyme showed a significant and positive correlation with boron application. Boron is essential micronutrient for cell division especially in the process of nodule formation in legumes. When boron supply was limited poorer calcium content is observed in shoot, whereas boron supplied, the calcium content in plant was increased. The deficiency of B affects some grain legume (Rerkasem *et al*.,1987).The soil of different parts of Bangladesh is more or less deficient in B as well as nitrogen fixing bacteria (*Rhizobium* spp.) which causes poor yield of pulse (Bhuiyan *et al*., 1999).Regarding the situation, the aim of the research is to evaluate the effect of K and B on growth, yield and nutrient content of mungbean.

Objectives:

Considering the above facts, the following objectives are taken to perform our goals:

1. To screen out the performance of K and B on mungbean growth and yield

2. To observe the effectiveness of K and B on mungbean nutrient contents, protein and β-carotene content

Chapter II

Review of literature

CHAPTER II

REVIEW OF LITERATURE

Mungbean is an important pulse crop not only in Bangladesh but also many countries of the world. The crop has conventional less concentration by the researcher on various aspects because normally it grows with less care and management practices. Although potassium and boron and variety of mungbean play an important role in improving yield but research works related to potassium and boron on mungbean are limited and not conclusive in context of Bangladesh. However, some of the important and informative works and research findings related to potassium and boron on mungbean so far been done at home and abroad have been reviewed in this chapter under the following headings-

2.1 Effect of potassium on the growth yield and nutrient contents of mungbean

A field experiment in factorial layout in RCBD in three replications in order to study the effect of potassium and iron on growth and productivity of this crop. The results showed that potassium significantly enhanced all growth and yield characters while the effect of Iron (Fe) was less significant than K but it has accumulative effect which was significant and clear in plant yield. It can be concluded that nutrients must be added as a foliar application as they have progressive effect on growth as well as yield of mung bean. The high concentrations of those two elements were superior to low concentrations. (Al-Issawi and Mahdi2016)

An experiment on growth and yield response of two mungbean (Mung-06 and NM-92) varieties to different application rates of potassium was evaluated under field condition. Plants were fertilized with five K (0, 50, 75, 100 and 125 kg ha^{-1}) levels. The data obtained from the study indicated that there was significant effect of potassium levels on growth, yield and yield components of both varieties. Compared to Mung-06, n the variety NM-92 performed well by displaying maximum seed germination, taller plants with more branches, pods, seeds and biological yield. In addition to the recommended rates of nitrogen and phosphorus, the K applied @ 125 kg ha^{-1} significantly increased seed germination, plant height, number of branches per plant, number of pods, seed index and biological yield (kg ha^{-1}) as well. The difference between 125 and 100 kg K ha^{-1} rates for mjority of the growth and yield parameters under study remained non-significant. However, the plants given 75, 50 and 00 kg K ha^{-1} ranked 3rd, 4th and 5th, respectively for all the recorded yield parameters. It is, therefore, concluded that 100 kg K ha^{-1}can be the effective rate for achieving economically higher mungbean yield (Buriro *et. al.*, 2015).

A field experiment carried out by Biswash *et al.* (2014) from February to April, 2013 in the field of the farm of Sher-e-Bangla Agricultural University to study the effect of potassium fertilizer and vermicompost on growth, yield and nutrient contents of mungbean (BARI Mung 5). The two-factorial experiment was conducted by using RCBD (Randomized Completely Block Design) with three replications. During the experiment, following treatments were included: K0 -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}. Potassium and vermicompost doses as well as their interactions showed significant effect on growth and yield parameters. At harvest highest plant height, number of leaves and branches $plant^{-1}$, average 11 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}). N, 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 potassium 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).

Fooladivanda *et al*. (2014) conducted an experiment to evaluate the impact of water stress and levels of potassium on yield and yield components of two varieties of mung bean (*Vigna radiata)* (promising lines VC6172 and Indian), an experiment in the form of split factorial, based on randomized complete block design with three replicates was conducted in 2011, at the research farm of Safi-Abad Dezfool, Iran (latitude 32016' N, longitude 48026' E and altitude 82.9 m above sea level) .Water stress in three levels: irrigation at 120 (no stress), 180 (moderate stress) and 240 (severe stress) mm evaporation from pan, were allocated to the main 12 plots and potassium fertilizer at three levels (0, 90, 180 kg ha^{-1}) and two varieties of mung bean (promising line VC6172 and Indian) were allotted to the sub-plots. Results showed that water stress and potassium fertilizer significantly affect all traits. The highest grain yield (2093 kg ha^{-1}) was obtained from no stress treatment in the case of 180 kg ha^{-1} potassium. Total dry matter, number of pods and grain yield, were significantly different between the two varieties. The interaction between fertilizer and variety, on dry matter and grain yield and the interaction between irrigation and variety, on dry matter were significant. We conclude that use of potassium fertilizer can reduce the adverse effects of water stress.

Kumar *et al.* (2014) carried out a 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. The experiment was conducted in a complete randomized block design with seven treatments which were replicated thrice. 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). Potassium application is directly related to growth, plant biomass and yield in crops. 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.

An experiment carried out by Deep and mittal (2014) where they indicated that , the cosmos in atmosphere exerts variable force depending upon the relative positions of moon, sun and earth (lunar phase) and affects the plants/crops. Here, a lunar activity on sprouting of mung beans in terms of their potassium contents and sprout lengths has been tested. Under the similar mung processing in different moon phases, a rhythmic character of sprout lengths and potassium contents was observed. The statistical analysis of observations rules out the effect of moon phases on sprout lengths and predicts just randomness of the length variations. While the potassium content variations are prominent; Near New Moon, First Quarter and after Full Moon (Super Moon) phases there is rise in the contents. All this has been explained in terms of Earth's magnetic field variations with moonphases, thereby affecting the contents of minerals in sprouts.

Mazed *et al.* (2013) conducted an experiment at the experimental farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh during the period from April, 2013 to July, 2013 to study the growth and yield of Mungbean as influenced by potassium (K) and sulphur (S). Four levels of K (0, 15, 25 and 35 kg ha^{-1}) and three levels of S (0, 3 and 6 kg ha^{-1}) were used in the study. The results revealed that grain and stover yield of mungbean increased with increasing levels of K and S.

Beg and Ahmed (2012) carried out an experiment and found that foliar application of Potassium on moong bean at the time of flowering at half and full basal fertilizer doses in different concentrations was applied and it was found that the treatment T where 1.00 kg. Potassium / ha was applied as foliar spray showed best result. It enhanced almost all the vegetative and yield characteristics of moongbean at both the basam fertilizer doses. In this way a little amount of Potassium used as foliar spray at the time of flowering when the plant required maximum nutrients can enhanced the productivity and save a large amount of fertilizers.

An experiment carried out by Hussain *et al.* (2011) at experimental area of Department of Agronomy, University of Agriculture, Faisalabad during summer 2005. The objective was to find out the best level of potash fertilizer on growth and yield response of two mungbean (*Vigna radiata* L.) cultivars (Niab Mung-92 and Chakwal Mung-06) to different levels of potassium. The experiment was laid out in Randomized Complete Block Design with factorial arrangements and replicated thrice. Treatments were comprised of five levels of potash fertilizer (0, 30, 60, 90,120 Kg ha^{-1}). Different potassium 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 potash per hectare. Genotype M-06 produced higher seed yield than that of NM-92. The interactive effect of Mungbean varieties and Potassium level was found significant in parameter of protein contents (%). Maximum protein contents were observed in case of Mung-06 with application of 90 Kg potash per hectare. It is concluded that the application of Potash fertilizer gave higher yield of mungbean cultivars under agro-climatic conditions of Faisalabad.

Amin *et. al*.(2015) conducted an experiment with mungbean genotype IPSA-13 in the field of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh to study the root growth, nutrient concentration and seed yield of mungbean as influenced by N and K under waterlogged conditions. Nutrient supply in the soil had significant impact on better recovery in root development of 4-day waterlogged plants. Development of adventitious roots was one of the adaptive responses of IPSA-13 mungbean genotype. Root length was decreased due to the anaerobic condition. Plants waterlogged for 4-days allocated more dry matter in adventitious root development and hence root volume was higher in waterlogged plants. Root volume in flooded plants increased due to the development of adventitious roots. Root dry weight increased with combined application of N and K fertilizers. Flooded plants treated with 14 kg N ha^{-1} + 25 kg K ha^{-1} produced the highest TDM and seed yield, though the yield was statistically similar to that obtained when the levels of N and K were applied separately, as well as with that of 1% urea + 25 kg K ha^{-1}.

Al-Shaheen *et. al* (2016) was conducted a field experiment in summer season in the fields of one of the farmers on the banks of the Euphrates River in Ramadi City on the Mungbean harvest, to study the effect of two Irrigation period (7-14) days, and three intensities of potassium (0, 50, 100) Kg/h on some of the characteristics of this harvest and the class of the used harvest is the local kind. Results showed superiority the plants were irrigated every 7 days in the highest rate of all the characteristics of study. The results also showed surpass the plants were fertilized by a higher concentration of potassium (100) kg \ ha of all the characteristics of study. The search results showed the superiority of irrigated every 7 days and fertilized by the high level of potassium (100) kg \ ha in the highest rate for all characteristics of study in a significant difference from other interventions.

2.2 Effect of boron on the growth yield and nutrient contents of mungbean

Qamar *et. al.* (2016) conducted an experiment an found that Pulses have significant role in the profitability of agriculture because of major proportion of our population depends on it due to its higher nutritional value, rich source of protein and low price. Pulses are also important component of animal feed and their dried straw is used as hay. In pulses, mungbean (*Vigna radiata* L.) is a vital crop. Boron has positive effect on growth and development, nitrogen assimilation and root growth. Low level of boron causes negative impact on growth, narrow leave expansion, restricted root elongation and morphological features of mungbean plant.

An experiment carried out by Hamza *et. al.*(2016) at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, during the period from February 2012 to May 2012 to investigate the effect of levels of phosphorus (0, 20, 40 and 60 kg ha^{-1}) and boron (0, 1.0, 1.5 and 2.0 kg ha^{-1}) on growth and yield of summer mungbean cv. BINAmung-8. The experiment was laid out in a Randomized Complete Block Design (RCBD) with sixteen treatment combinations having three replications. The results indicated that the crop responded significantly to phosphorus and boron in respect of growth and yield such as plant height, number of branches $plant^{-1}$, pods $plant^{-1}$, pod length, number of seeds pod^{-1}, 1000 seed weight, seed yield, stover yield, biological yield and harvest index. In the combination of phosphorus and boron, all the parameters were significant by influence. The highest seed yield (1.19 t ha^{-1}) was obtained from 40 kg P ha^{-1} followed by 60 kg P ha^{-1} (1.13 t ha^{-1}) and 20 kg P ha^{-1} (1.10 t ha^{-1}) while the lowest seed yield (1.01 t ha^{-1}) was obtained from the control plot. In case of boron application, the highest seed yield (1.16 t ha^{-1}) was obtained from 1.5 kg B ha^{-1} followed by 2.0 kg B ha^{-1} (1.14 t ha^{-1}) and 1.0 kg B ha^{-1} (1.09 t ha^{-1}) whereas the lowest seed yield (1.04 t ha^{-1}) was obtained from the control plot. The highest seed yield (1.25 t ha^{-1}) was obtained from the combination of 40 kg P ha^{-1} × 1.5 kg B ha^{-1} while the lowest seed yield (0.95 t ha^{-1}) was obtained from the control plot. The results suggest that mungbean crop may preferably be fertilized with a combination of 40 kg P ha^{-1} × 1.5 kg B ha^{-1} to obtain maximum seed yield in the agroclimatic condition of the study area.

A study conducted by Tahir *et al.* (2013) at Agronomic Research Area, University of Agriculture, Faisalabad to evaluate the production potential of mungbean (*Vigna radiata* L.) in response to sulphur and boron on the genotype NIAB Mung-2006. The treatments were comprised of four sulphur levels i.e. 0, 12, 24 and 36 kg ha^{-1} and three boron levels i.e. 0, 4 and 8 kg ha^{-1}. Gypsum was used as sulphur source and boric acid for boron. It appeared that sulphur at 24 kg ha^{-1} and boron at 4 kg ha^{-1} significantly increased plant height (58.30 cm), number of pods $plant^{-1}$ (21.33), 1000-seed weight (35 g), number of nodules $plant^{-1}$ (13.33), biological yield (7688 kg ha^{-1}) and seed yield (1200 kg ha^{-1}).

An experiment was carried out by Quddus *et al.* (2011) in Calcareous Low Ganges River Floodplain Soil (AEZ 12) at Pulses Research Sub-Station (PRSS), Madaripur during Kharif I to evaluate the effect of zinc (Zn) and boron (B) on the yield and yield contributing characters of mungbean (*Vigna radiata* L.) and to find out the optimum dose of Zn and B for yield maximization. There were four levels of zinc (0, 0.75, 1.5, and 3.0 kg ha^{-1} and boron (0, 0.5, 1.0, and 2 kg ha^{-1}) along with a blanket dose of N20 P25 K35 S20 kg ha^{-1}. Results showed that the combination of Zn1.5B1.0 produced significantly higher yield (3058 kg ha^{-1}) and (2631 kg ha^{-1}). The lowest yield (2173 kg ha^{-1}) and (1573 kg ha^{-1}, were found in control (Zn_0B_0) combination.

Hasnain et. al.(2011) conducted an experiment and found that Boron (B) toxicity has been recognized as a serious problem in arid and semi arid regions of the world. This study was aimed to determine critical levels of B by studying phenotypic variation for B-tolerance/ toxicity at the germination and seedling stage in three mung bean (*Vigna radiata*) cultivars; M-6, M-8 & 96009. Boron levels ranging from 0-20 ppm were applied using Boric acid. Germination, growth and photosynthetic attributes were significantly ($p<0.001$) influenced by varying B levels. However, the cultivars were significantly invariable for germination, seedling height and leaf number. B levels (5-10 ppm) appeared to be nutritionally critical whereas, 15-20 ppm induced B toxicity. The toxicity was expressed in terms of reduction in plant's growth as well as by visible symptoms which included chlorosis and necrosis of the foliage. The present study also demonstrated variation in B tolerance at the seedling stage in these cultivars. Among the tested cultivars, M-6 and M-8 exhibited better growth responses as compared with 96009. Fresh biomass and shoot: root ratio appeared to serve as selection criteria for B tolerance. The study further suggested screening of cultivars/ accessions on a large scale to explore more diversity of traits as well as the use of biochemical markers for mechanistic understanding of B tolerance.

A field experiment carried out by Patra and Bhattacharya (2009) in kharif (rainy) season in a sandy loam soil (mixed hyperthermic paleudalfs) at Jhargram, Paschim Medinipur in the Red and Laterite zone of West Bengal to investigate the effect of four levels of boron and three levels of molybdenum on growth and yield of Mungbean [*Vigna radiata* (L.) Wilczek (cv. Baisakhi Mung)]. Boron, molybdenum and their combined application significantly improved all the growth and yield attributing characters of Mungbean. The synergistic influence of these two micronutrients helped augmenting growth and yield of the crop.

An experiment carried out by Kaisher *et al.* (2010) to investigate the effect of sulphur (S) and B on yield and protein content of Mungbean, variety BARI Mung–5. The plant height was significantly influenced by S and its application. The tallest plant was found with 30 kg S ha^{-1} whereas the shortest was found in control. The result showed that plant height increase up to 30 Kg S ha^{-1} and after that it decreases. The result might be due to the fact that S is involved in the formation of chlorophyll and thereby encourages vegetative growth resulting increase in plant height. The plant height varied significantly due to B level. The 25 tallest plant was found with 5 kg B ha^{-1} and the shortest from control. Boron level more than 5 kg ha^{-1} the plant height was decreased. It might be due to B, which plays on important role in the development and differentiation of tissue, cell division and nitrogen absorption from the soil, enhance plant growth, ultimately plant height increased. The result indicates that S and B levels influenced the plant height individually and by their combination. Similar results were also obtained by the application of S and B in respect of branches production $plant^{-1}$. The result might be due to S encourages the vegetative growth, so it increases the branches $plant^{-1}$. They stated that application of B increases number of branches $plant^{-1}$. The branch $plant^{-1}$ was maximum with 30 kg S and 5 kg B ha^{-1}. Above result in could be concluded that S and B level individually affect branches plant but not by their interaction.

Dixit and Elamathi (2007) reported that foliar application of B (0.5%) in green gram increased the plant height (32.26 cm) and dry weight $plant^{-1}$ (12.90 g). 30 Singaravel *et al*. (2006) found that the recommended NPK in combination with 25 kg $ZnSO_4$ ha^{-1}, 10 kg borax ha^{-1} and 10 t composted coir pith ha^{-1} gave the highest number of pods $plant^{-1}$, crop yield, and N, P, K, Zn and B uptake of the groundnuts also increased.

A pot experiment conducted by Paul (2009) to study the effect of N, Mo, B and *Bradyrhizobium* inoculant on growth, nodulation, yield and yield contributing characters and nitrogen uptake of black gram. *Bradyrhizobium* inoculation in presence of Mo and B recorded the highest root and shoot length, seed and stover yield, yield attributes, N and protein content of black gram compared to non–inoculated control. Molybdenum and B performed better results. This result indicated that the use of *Bradyrhizobium* inoculation with Mo and B appeared to be an effective method for successful black gram production.

Islam (2005) observed that seed yield of chickpea increased significantly due to application of 1 to 1.5 kg B ha^{-1}. In these contexts, application of B and addition to essential major elements along with a maintenance dose of cowdung has gaining practical significance for boosting up the yield of chickpea.

Chapter III

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The experiment was carried out at Sher-e-Bangla Agricultural University research farm Dhaka, during the period from February, 2016 to June, 2016 to the study influence of K and B on growth, yield and nutrient contents of mungbean. Materials used and methodologies followed in the present investigation have been described in this chapter.

3.1 Description of the experimental site

3.1.1 Site and soil

The site of the research farm is located in 24.09^{0}N latitude and 90.26^{0}E longitudes. As per the Bangladesh Meteorological Department, Agargaon, Dhaka-1207 the altitude of the location was 8 m from the sea level. The land topography was medium high and soil texture was silt clay with pH 6.50.

3.1.2 Climate and weather

The climate of the experimental site is sub-tropical, characterized by three distinct seasons, the winter from November to February, the pre-monsoon period or hot season from march to April and the monsoon period from august to January (Edris *et al*., 1979). Meteorological data related to the temperature, relative humidity and rainfalls during the period of the experiment was collected from Bangladesh Meteorological Department (Climate Division), Sher-e-Bangla Nagar, Dhaka 1207and presented in Appendix

3.2 Planting materials

BARI mung-6:

Seed of BARI mung-6 is used as the planting material. BARI mung-6 is released and developed by Bangladesh Agricultural Research Institute, Joydebur, Gazipur in 2003. Medium plant stacture, Plant height is 55-68 cm. Resistant to yellow mosaic virus (YMV) and Cercospora leaf spot (CLS). Photo - insensitive, bold seed size with green seed coat. Protein 21.2- 24.5%; CHO 46.8%. Cooking Time 18 min. Synchrony in maturity and late potentiality. Recommended for cultivation in Jessore, Khulna, Faridpur, Pabna, Rajshahi and Dinajpur. 1000-seed weight: 40.0 g. seed yield: 1.5 –1.6 t ha $^{-1}$. Duration: 55-65 days. The seeds of BARI mung-6 for the experiment were collected from BARI, Joydepur, Gazipur. The seeds were large shaped, deep green and free from mixture of other seeds, weed seeds and extraneous materials.

3.3 Treatments under investigation

There was two factors in the experiment namely phosphorus and potassium levels as mentioned below:

Factor-A: 3 level of Potassium

K_0 = 0 kg K ha^{-1}

K_1 = 15 kg K ha^{-1}

K_2 = 25 kg K ha^{-1}

Factor-B: 3 levels of Boron

B_0 = 0 kg B ha^{-1}

B_1 = 1.5 kg B ha^{-1}

B_2 = 2.5 kg B ha^{-1}

3.4 Experimental design and layout

The experiment was laid out in a two factors randomized complete block design (RCBD) design having three replications. Each replication had 9 unit plots to which the treatment combinations were assigned randomly. The unit plot size was 6 m^2 (3m ×2m). The blocks and unit plots were separated by 1.0 m and 0.50 m spacing respectively.

3.5 Land preparation

The experimental land was opened with a power tiller on 8 February, 2016. Ploughing and cross ploughing were done with country plough followed by laddering. Land preparation was completed on 15 February, 2016 and was ready for sowing of seeds.

3.6 Fertilizer application

The full amount of N and P was applied at the time of final land preparation in the forms of urea, triplesuperphosphate(TSP) respectively. Mungbean urea is to be applied 20 kg ha^{-1} which is half of recommended dose and TSP @ 100 kg ha^{-1}, respectively (BARI, 1998) during final land preparation. The experimental plots were fertilized as per treatment. Potassium and boron were applied as per treatment. All fertilizers were applied by broadcasting and mixed thoroughly with soil.

3.7 Sowing of seeds

Seeds were sown at the rate of 40 kg ha^{-1} in the furrow on February 16, 2016 and the furrows were covered with the soils soon after seeding. Mungbean (var. BARI Mung-6) seed was sown apart rows maintaining. Row to row spacing was 30cm. Seed to seed spacing was 10 cm. The sowing date was maintained as per treatment.

3.8 Intercultural operations

3.8.1 Weed control

Weeding was done twice in all the unit plots with care so as to maintain a uniform plant population as per treatment in each plot at 15 DAS and 30 DAS respectively.

3.8.2 Thinning

Thinning was done at 10 days after sowing (DAS) and 30 DAS. Plant to plant distance was maintained at 10 cm.

3.8.3 Irrigation and drainage

Pre sowing irrigation was given to ensure the maximum germination percentage. During the whole experimental period, there was a shortage of rainfall in earlier part; however, it was heavier in later one. So it was essential to remove the excess water from the field at later period.

3.8.4 Insect and pest control

At early stage of growth few worms (*Agrotis ipsilon*) infested the young plants and at later stage of growth pod borer (*Maruca testulalis*) attacked the plant. Ripcord 20 EC was sprayed at the rate of 1.5 ml with 1 litre water to 5 decimal lands for two times at 15 days interval after seedlings germination to control the insects. Before sowing seeds were treated with Bavistin 200 WP to protect seed borne disease. Hairy caterpillar was successfully controlled by the application of Malathion 57 EC @ 1 L ha^{-1} on the time of 50% pod formation stage (55-57 DAS).

3.9 Determination of maturity

At the time when 80% of the pods turned brown colour, the crop was considered to attain physiological maturity.

3.10 Harvesting and sampling

The crop was harvested from prefixed one m^2 areas. Before harvesting ten plants were selected randomly from each plot and were uprooted for data recording. The rest of the plants of prefixed one m^2 area were harvested plot wise and were bundled separately, tagged and brought to the threshing floor.

3.11 Threshing

The crop was sun dried for three days by placing them on the open threshing floor. Seeds were separated from the plants following conventional methods.

3.12 Drying, cleaning and weighing

The seeds thus collected were dried in the sun for reducing the moisture in the seeds to a constant level. The dried seeds and straw were cleaned and weighed.

3.13 Recording of characters

3.13.1 Plant height (cm)

The height of the selected plant was measured from the ground level to the tip of the plant at 20, 30, 40, 50, and harvest after sowing.

3.13.2 Number of leaves per plant

Number of leaves per plant was counted from each selected plant sample and then averaged at 20, 30, 40, 50, and harvest after sowing.

3.13.3 Dry matter content per plant

Five plants were collected randomly from each plot at harvest. Fresh plant samples from each plot were put into envelop and placed in oven maintained at 70^0C for 72 hours. The sample was then transferred into desiccators and allowed to cool down at room temperature. The final dry weight of the sample was taken and recorded in gram.

3.13.4 Number of branches per plant

Number of branches per plant was counted from each selected plant sample and then averaged.

3.13.5 Number of nodules per plant

Five plants from each plot was uprooted carefully with soil at 50 DAS then washed out with water and make clean. The number of nodules per plant was observed.

3.13.6 Days to 1st flowering stage

Days to 1st flowering were recorded by counting the number of days required to start flower initiation of mungbean plant in each plot.

3.13.7 No. of pods per plant

Number of total pods of 3 randomly selected plants from each plot was counted and the mean number was expressed as plant^{-1} basis. Plants were selected from the different inner row of each plot randomly.

3.13.8 No. of seeds per pod

The number of seeds per pod was recorded from randomly selected ten pods at harvest. Data were recorded as the average of 10 pods selected at random from each plot.

3.13.9 Pod length (cm)

Pod length was measured in centimeter (cm) scale from randomly selected ten pods. Mean value of them was recorded treatment wise.

3.13.10 1000-seed weight (g)

A composite sample was taken from the yield of ten plants. The 1000-seeds of each plot were counted and weighed with a digital electric balance. The 1000-seed weight was recorded.

3.13.11 Seed yield (t ha^{-1})

Seed yield was recorded on the basis of total harvested seeds per 1 m^2 and was expressed in terms of yield (g). Seed yield was adjusted to 12% moisture content. Seed yield was recorded on the basis of total harvested seeds per 1m^2 and was expressed in terms of yield (t ha^{-1}). Seed yield was adjusted to 12% moisture counted from each plot and average number of nodules per plant was recorded as per treatment.

3.13.12 Stover yield

The stover collected from 6 (3 m ×2 m) square meter of each plot was sun dried properly. The weight of stover was taken and converted the yield in t ha^{-1}.

3.13.13 Harvest index (%)

Harvest index was calculated from the ratio of grain yield to biological yield and expressed in percentage. It was calculated by using the following formula.

$$\text{HI (\%)} = \frac{\text{Economic yield (Grain yield)}}{\text{Biological yield(Grain yield +Stover yield)}} \times 100$$

3.14 Chemical analysis of plant samples

3.14.1 Collection and preparation of seed samples

Seeds of mungbean were collected after threshing for N, P and K analyses. The plant samples were dried in an oven at 70^0C for 72 hours and then ground by a grinding machine (wiley-mill) to pass through a 20-mesh sieve. The samples were stored in plastic vial for analyses of N, P and K. The seed samples were analyzed for the determination of N, P and K concentrations.

3.14.2 Digestion of seed of mungbean with sulphuric acid for N

For the determination of nitrogen an amount of 0.5 g oven dry, ground sample were taken in a micro kjeldahl flask. 1.1 g catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100: 10: 1), and 7 ml conc. H_2SO_4 were added. The flasks were heated at 160^0 C and added 2 ml 30% H_2O_2 then heating was continued at 360^0 C until the digests become clear and colorless. After cooling, the content was taken into a 50 mL volumetric flask and the volume was made up to the mark with de-ionized water. A reagent blank was prepared in a similar way. 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.

3.14.3 Digestion of seed of mungbean with nitric-perchloric acid for P and K

A seed sample weighing 0.5 g was transferred into a dry, clean 100 ml digestion vessel. Ten ml of di-acid (HNO_3: $HClO_4$ in the ratio 2:1) mixture was added to the flask. After leaving for a while, the flask was heated at a temperature slowly raised to 200^0C. Heating was stopped when the dense white fumes of $HClO_4$ occurred. The content of the flask were boiled until it became clean and colorless. After cooling, the content was taken into a 50 mL volumetric flask and the volume was made up to the mark with de-ionized water.

3.14.4 Nitrogen content in seed

Total N content of seed is determined followed by the Micro Kjeldahl method. One gram of oven dry ground seed sample was taken into micro kjeldahl flask to which 1.1 gm catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100: 10: 1), and 7 mL H_2SO_4 were added. The flasks were swirled and heated 65 ^0C and added 2 ml H_2O_2 and then heating was continued until the digest was clear and colorless. After cooling, the content was taken into 50 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent 23 blank was prepared in a similar manner. These digests were used for nitrogen determination (Page *et al.*, 1982).

Then 20 mL digest solution was transferred into the distillation flask, Then 10 mL of H_3BO_3 indicator solution was taken into a 250 ml conical flask which is marked to indicate a volume of 50 mL and placed the flask under the condenser outlet of the distillation apparatus so that the delivery end dipped in the acid. Add sufficient amount of 10N-NaOH solutions in the container connecting with distillation apparatus. Water runs through the condenser of distillation apparatus was checked. Operating switch of the distillation apparatus collected the distillate. The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water.

Finally the distillates were titrated with standard 0.01 N H_2SO_4 until the color changes from green to pink.

The amount of N was calculated using the following formula:

$$\% N = \frac{(T-B) \times N \times 1.4}{S}$$

Where,

T = Sample titration (ml) value of standard H_2SO_4

B = Blank titration (ml) value of standard H_2SO_4

N = Strength of H_2SO_4

S = Sample weight in gram

3.14.5 Phosphorus content in seed

Phosphorus in the digest was determined by using 5 ml for seed sample from 50 ml digest by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated with the standard P curve (Page *et al.*, 1982).

3.14.6 Potassium content in seed

Potassium content in seed was determined with the help of flame emission spectrophotometer. One milli-liter of digest seed sample was taken and diluted 20 ml volume to make desired concentration so that the flame photometer reading of samples. This samples aspirated into a gas flame. The air pressure was fixed at 10 PSI. percent emission was recorded following the method described by Ghosh, *et al.*(1983).

3.14.7 Boron content in seed

Boron (B) content in the seed sample was determined. The extracting agent monocalcium phosphate $Ca(H_2PO_4)_2$. H_2O solution added to seed for extraction was used and color was developed by adding curcumin solution. Then absorbance was read on spectrophotometer at 555 nm wavelengths.

3.14.8 Calcium content in seed

Calcium content in the seed was determined by complexometric method of titration using Na_2EDTA as a complexing agent at ph 12 where calcon was used as indicator (Page *et al.* 1982). Exactly 5 ml of sample was taken followed by 30 ml water, 2 ml 10% NAOH solution , 10 drops of hydroxyl amine hydrochloride ($NH_2OH.HCL$) potassium ferocyanide [$K_2Fe(CN)6.\ 3H_2O$] and triethanol amine(TEA),($C_6H_{15}NO_3$) as masking agent. After the addition of calcon indicator solution, the test sample was tritrated against Na_2EDTA (0.01) solution from a burette until the pink color turned into blue.

Calcium was estimated by the following reaction

1 mL 1M Na_2EDTA = I mL 1M Ca= 40.08 mg Ca

3.14.9 Protein content in seed

The percentage of Protein content in the seed sample was calculated by multiplying the percentage of nitrogen content in the seed sample with 6.25.

3.14.10 β-carotene content in seed

Extraction and estimation of carotene in seed of mungbean were done by chromatographic method as outlined in the Association of Official Agricultural Chemist (1965). 20 g of well meshed seed was taken in a conical flax containing about 100mL of n-hexane and acetone mixture in the ratio of 60:40 and mixed them for 5 minutes in presence of 0.1 g magnesium carbonate in regular interval. Mixed material then filtered with suction. The residue was washed with 25 mL of acetone followed by 25 mL n-haxene and the washing was added to the orginal extract. Acetone was removed from the extract by washing with 100mL of distilled water in a separators funnel. The upper n-haxene layer was treated with anhydrous Na_2SO_4 and transferred to 100ml volumetric flax containing 9 mL acetone which was ready for chromatographic analysis. The β-carotene content in seed then determined spectrophotometrically at 436 nm by a standard curve.

3.15 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program MSTAT-C and the mean differences were adjusted by Least Significance Difference (LSD) test (Gomez & Gomez, 1986).

Chapter IV
Results and Discussion

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 three levels of potassium and three levels of boron and their interaction effects on vegetative growth yield and nutrient contents of mungbean. The growth and yield components such as plant height, leaf number, pod length, and yield of mungbean as influenced by potassium and boron are presented in Table and Figures. The results of each parameter have been adequately described and discussed. Possible interpretations whenever necessary have been given under the following headlines:

4.1 Plant height (cm)

Plant height varied significantly by different levels of potassium fertilizer doses (Figure 1) throughout the growing period 20, 30, 40, 50 DAS and harvest. Significant variation of plant height was found due to potassium in all the stages of plant growth (Appendix V and Table 2).The tallest plant at the 5 stages (24.27, 38.18, 55.80, 63.83 and 65.38 cm respectively) was recorded from K_2(25 kg K ha^{-1}) which followed (19.54 32.79 50.50 58.64 58.98 cm, respectively) by K_1(15 kg K ha^{-1}), while the shortest plant (14.50 29.53 45.30 52.97 54.30cm, respectively) was observed from K_0(0 kg K ha^{-1}) treatment. Hussain *et al.* (2011) stated that increased amount of potassium levels significantly affected the plant height of mungbean.

Significant variation of plant height was found due to boron in all the studied in all the stages of plant growth (Figure 2).The tallest plant at the 5 stages (21.33, 35.50, 52.67, 60.97 and 62.19 cm respectively) was recorded from B_2(2.5 kg ha^{-1}) which followed (19.71 33.94 51.53 59.21 59.70 cm, respectively) by B_1(1.5 kg P ha^{-1}), while the shortest plant(17.27 31.06 47.40 55.27 56.77 cm, respectively) was observed from B_0(0 kg B ha^{-1}) treatment. This result is in agreement with Zaman *et al.* (1996) who observed that application of B @ 2kg ha-1 significantly increased plant height of mungbean.

Significant interaction effects of potassium and boron on plant height was observed at harvesting time (Table 1). Plant height increased with advancing growing period irrespective of K and B fertilization. The tallest plant (25.27, 40.17, 57.20, 66.17 and 68.47 cm) was obtained from K_2B_2(25 kg K ha^{-1}and 2.5 kg Bha^{-1}) treatment, which was statistically (24.00, 38.17, 55.90, 63.40 and 64.67 cm) similar with K_2B_1(25 kg K ha^{-1} and 1.5 kg ha^{-1}) and which (23.53, 36.20, 54.30, 61.93and 63.00 cm) followed by K_2B_0 (25 kg K ha^{-1} and 0 kg B ha^{-1}). On the other hand, the shortest plant (11.17, 25.93, 39.63, 48.70 and 51.27 cm) was obtained fromK_0B_0 (control) treatment. Gowthami (2013) stated that the application of potassium nitrate and boric acid increased the plant height.

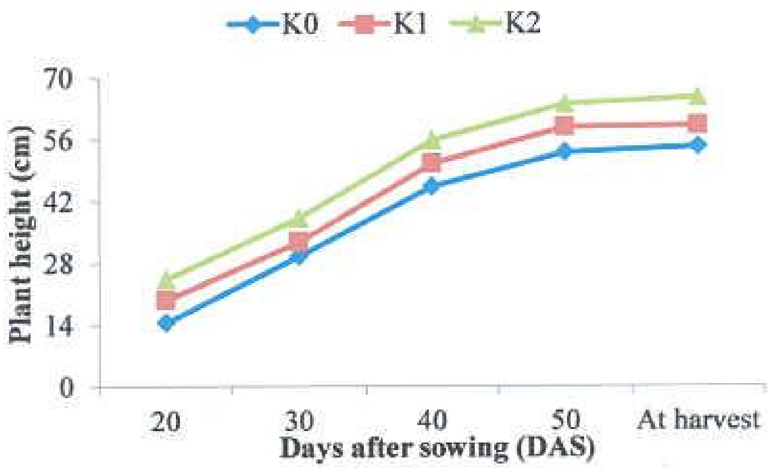

Figure 1. Effects of potassium on the plant height of mungbean at different days after sowing (LSD $_{(0.05)}$ = 1.28, 2.24, 3.54, 3.78 and 4.64 at 20, 30, 40, 50 DAS and at harvest, respectively)

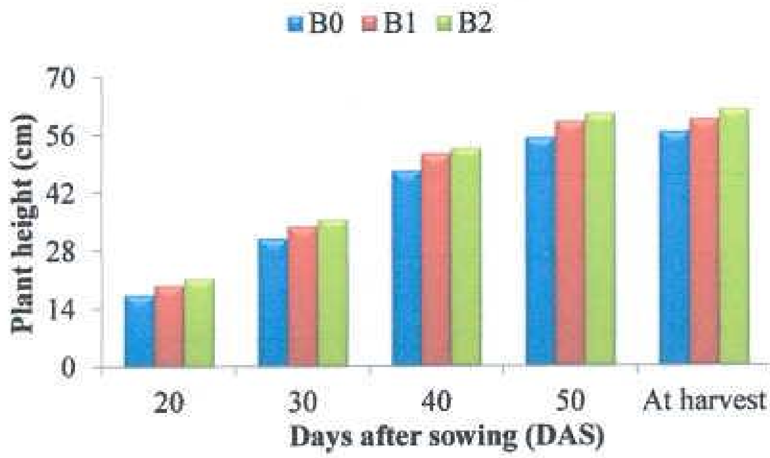

Figure 2. Effects of boron on the plant height of mungbean at different days after sowing (LSD $_{(0.05)}$ = 1.28, 2.24, 3.54, 3.78 and 4.64 at 20, 30, 40, 50 DAS and at harvest, respectively)

Table 1. Interaction effects of potassium and boron on the plant height of mungbean at different days after sowing

Treatment	Plant height (cm) at different days after sowing (DAS)				
combinations	20	30	40	50	At harvest
K_0B_0	11.17 f	25.93 e	39.63 d	48.70 d	51.27 e
K_0B_1	15.00 e	30.53 d	46.97 c	54.07 c	54.87 de
K_0B_2	17.33 d	32.13 d	49.30 bc	56.13 bc	56.77 b-e
K_1B_0	17.10 de	31.03 d	48.27 bc	55.17 cd	56.03 c-e
K_1B_1	20.13 c	33.13 cd	51.73 a-c	60.17 a-c	59.57 b-d
K_1B_2	21.40 bc	34.20 cd	51.50 a-c	60.60 a-c	61.33 a-d
K_2B_0	23.53 ab	36.20 bc	54.30 ab	61.93 ab	63.00 a-c
K_2B_1	24.00 a	38.17 ab	55.90 a	63.40 a	64.67 ab
K_2B_2	25.27 a	40.17 a	57.20 a	66.17 a	68.47 a
LSD $_{(0.05)}$	**2.22**	**3.87**	**6.12**	**6.54**	**8.04**
CV (%)	**6.59**	**6.68**	**7.00**	**6.46**	**7.79**

4.2 Number of leaves per plant

Number of leaves per plant varied significantly by different levels of K and B fertilizer doses (Figure 3) throughout the growing period at 20, 30, 40, 50 DAS and harvest plant. Significant variation on number of leaves per plant was found due to potassium in all the studied durations (Appendix V and Table 2). The maximum leaves number per plant at the 5 stages (5.856, 9.356, 13.57, 21.86 and 20.16 respectively) was recorded from K_2(25 kg K ha^{-1}) which followed (5.144, 8.144, 11.72, 19.18 and 17.47 respectively) by K_1(15 kg K ha^{-1}), while the shortest plant (4.233, 7.233, 11.33,17.59 and 16.11 respectively) was observed from K_0(0 kg K ha^{-1}) treatment.

Significant variation on number of leaves per plant was found due to boron in all the studied durations (Figure 4). The maximum number of leaves per plant at the 5 stages (5.578, 8.800, 12.89, 20.67 and 18.96 respectively) was recorded from B_2(2.5 kg ha^{-1}) which and was followed (5.244, 8.122, 11.89, 19.36 and 17.62 respectively) by B_1(1.5 kg B ha^{-1}), while the shortest plant (4.411 7.811 11.84 18.60 17.16 respectively) was observed from B_0(0 kg B ha^{-1}) treatment.

Significant interaction effects of potassium and boron number of leaves per plant on was observed at harvesting time (Table 2). Plant height increased with advancing growing period irrespective of potassium and boron fertilization. The maximum leaves per plant (6.60, 10.53, 14.60, 23.73 and 24.00 cm) was obtained from K_2B_2(25 kg K $ha^{-1}$and 2.5 kg B ha^{-1}) treatment, which was statistically similar (6.23, 9.07, 13.33, 21.40 and 19.60) with K_2B_1 (25 kg K ha^{-1} and 2.5 kg ha^{-1}) and which is (5.80, 8.20, 12.20, 19.63 and 17.93) followed by K_1B_2 (15 kg K ha^{-1} and 2.5 kg ha^{-1}). On the other hand, the shortest plant (4.07, 6.83, 10.70, 16.23 and 15.20) was obtained from K_0B_0 (control) treatment. Rerkasem *et al.* (1987) observed that 10 kg borax ha^{-1} increased the number of leaves $plant^{-1}$ in greengram. Dutta *et al.* (1984) stated that application of B (1 kg ha^{-1}) in mungbean increased the number of leaves $plant^{-1}$.

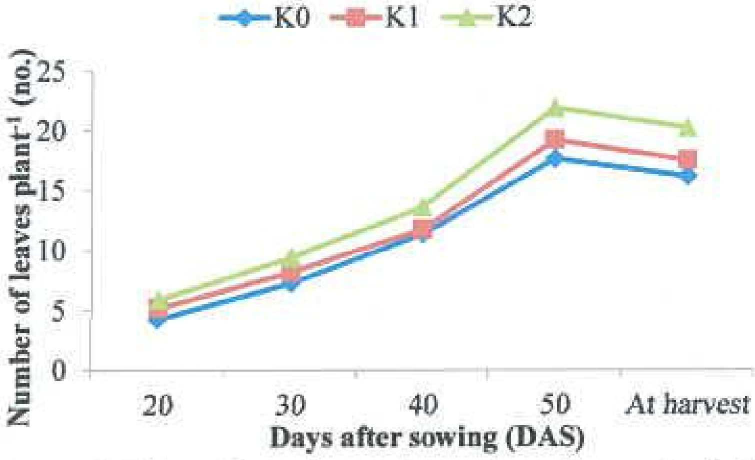

Figure 3. Effects of potassium on the number of leaves plant^{-1} of mungbean at different days after sowing (LSD $_{(0.05)}$ = 0.35, 0.46, 0.94, 1.59 and 1.20 at 20, 30, 40, 50 DAS and at harvest, respectively)

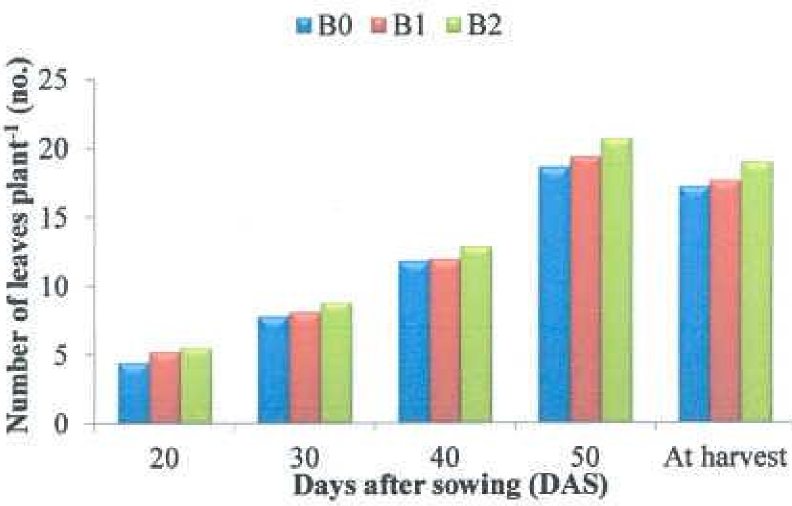

Figure 4. Effects of boron on the number of leaves plant^{-1} of mungbean at different days after sowing (LSD $_{(0.05)}$ = 0.35, 0.46, 0.94, 1.59 and 1.20 at 20, 30, 40, 50 DAS and at harvest, respectively)

Table 2. Interaction effects of potassium and boron on the number of leaves plant^{-1} of mungbean at different days after sowing

Treatment combinations	Number of leaves plant^{-1} (no.) at different days after sowing (DAS)				
	20	30	40	50	At harvest
K_0B_0	4.07 f	6.83 f	10.70 d	16.23 d	15.20 e
K_0B_1	4.30 ef	7.20 ef	11.43 cd	17.90 cd	16.20 de
K_0B_2	4.33 ef	7.67 de	11.87 b-d	18.63 cd	16.93 c-e
K_1B_0	4.43 ef	8.13 cd	12.07 b-d	19.13 bc	17.40 cd
K_1B_1	5.20 cd	8.10 cd	10.90 d	18.77 b-d	17.07 c-e
K_1B_2	5.80 bc	8.20 cd	12.20 b-d	19.63 bc	17.93 b-d
K_2B_0	4.73 de	8.47 bc	12.77 bc	20.43 bc	18.87 bc
K_2B_1	6.23 ab	9.07 b	13.33 ab	21.40 ab	19.60 b
K_2B_2	6.60 a	10.53 a	14.60 a	23.73 a	22.00 a
LSD $_{(0.05)}$	0.60	0.80	1.62	2.75	2.08
CV (%)	6.87	5.58	7.69	8.13	6.72

4.4 Dry matter content per plant

Dry matter content per plant of mungbean differed significantly due to different levels of potassium (Figure 5). The highest dry matter content per plant (7.393g) was recorded from K_2 treatment which is almost similar to (7.046g) by K_1. In comparatively the lowest dry matter content per plant (6.446 g) was found K_0 treatment. Statistically significant differences were found for dry matter content per plant of mungbean due to different level of boron (Figure 6). The maximum dry matter content per plant (7.291 g) was recorded from B_2 treatment and the minimum (6.559g) was observed from B_0 treatment. The combined effect of different doses of potassium and boron fertilizer on dry matter content per plant f of mungbean was significant at different days after sowing (Table 3). The maximum dry matter content per plant (7.75g) was recorded from the combination of K_2B_2Treatment which is followed by whereas, the minimum (8.50g) was observed from the combination(7.51g) and (7.28 g) recorded from the combination of K_2B_1 and K_1B_2

treatment respectively. Where the minimum (6.05) result observed from K_0B_0 treatment. Salam (2004) reported that B increased the plant growth, leaf dry matter of mugbean. Gowthmia (2013) stated that application of potassium nitrate and boric acid increased the total dry matter of plant.

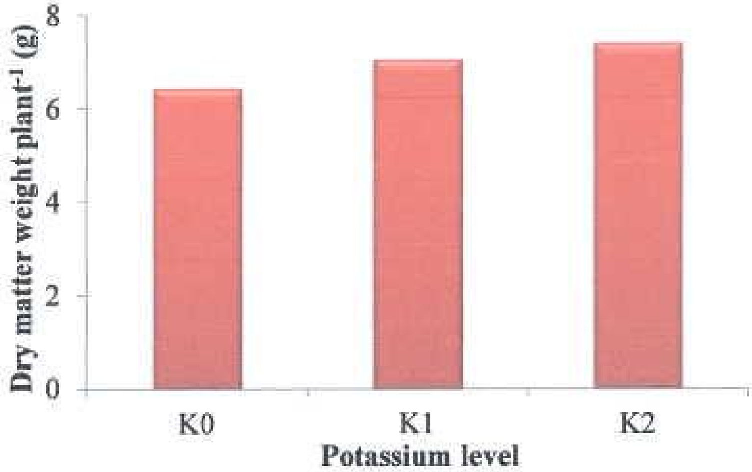

Figure 5. Effects of potassium on the dry matter weight plant^{-1} of mungbean (LSD $_{(0.05)}$ = 0.08)

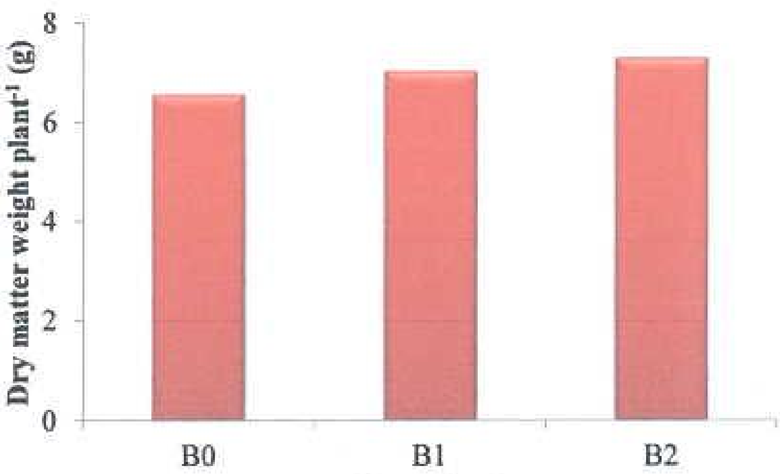

Figure 6. Effects of boron on the dry matter weight plant^{-1} of mungbean (LSD $_{(0.05)}$ = 0.08)

4.4 Number of branches per plant

Effect of potassium at different doses showed significant variation on the number of branch per plant of mungbean (Figure 7). K_2 treatment, showed the highest number of branch per plant (4.67). On the other hand, the lowest number of branch per plant (3.26) was recorded with K_0 treatment. Application of optimum level fertilizer doses might be increased the vegetative growth of mungbean that lead to the highest number of branch per plant.

The number of branch per plant as affected by different doses of boron showed a statistically significant variation (Figure 8). Among the different doses of boron the highest number of branch per plant (4.59) was observed in B_2 which was statistically followed (4.09) with B_2. On the other hand, the lowest number of branch per plant (3.42) was recorded in the B_0 treatment.

Combined effects of different doses of potassium and boron fertilizers on number of branch per plant showed a statistically significant variation (Table 3). The highest number of branch per plant (5.37) was recorded in K_2B_2, the lowest number of branch per plant (2.27) was found in K_0B_0 treatment.

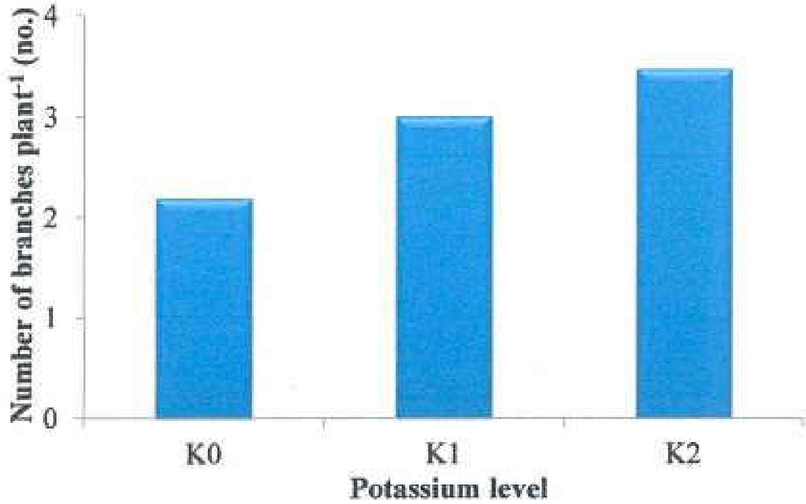

Figure 7. Effects of potassium on the number of branches plant^{-1} of mungbean (LSD $_{(0.05)}$ = 0.21)

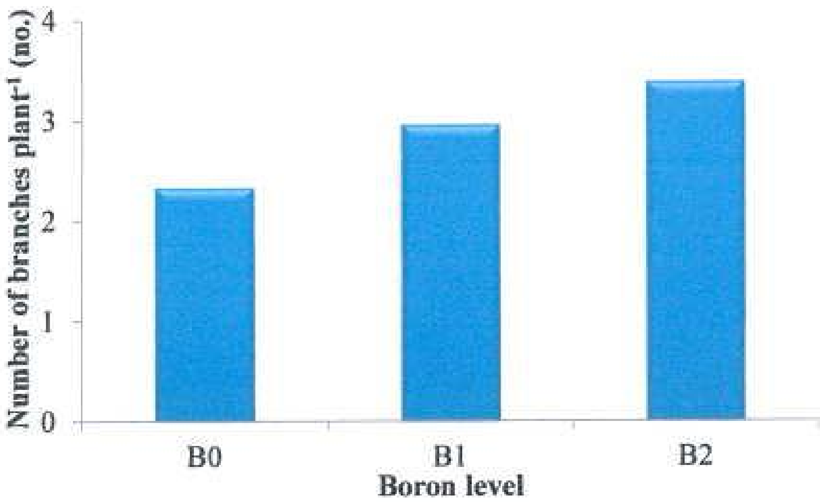

Figure 8. Effects of boron on the number of branches plant^{-1} of mungbean (LSD $_{(0.05)}$ = 0.21)

4.5 Number of nodules per plant

Number of nodules per plant of mungbean at 45 DAS showed statistically significant variation due to supplemental application of potassium (Figure 9). The highest number of nodules per plant (34.78) was recorded from K_2which was followed (31.22) by K_1, whereas the lowest number was (22.56) observed from K_0 at 45 DAS. Different level of boron application significantly affected the number of nodules per plant of mungbean at 45 DAS (Figure 10). The highest number of nodules per plant (36.44) was found from B, while the lowest (22.56) was observed from B_0 at 45 DAS. Combined effect of potassium and boron significantly influenced the number of Number of nodules per plant at 45DAS (Table 3). The highest number of nodules per plant (44.00) was recorded from the combination of K_2B_2 treatment which was statistically (37.0) followed by K_1B_2, while the minimum number (15.33) of nodules was recorded from the combination of no potassium and boron (K_0B_0) treatment at 45DAS. Results indicated that potassium and boron favored the mungbean plant to have better growth and produced the maximum number of nodules per plant.

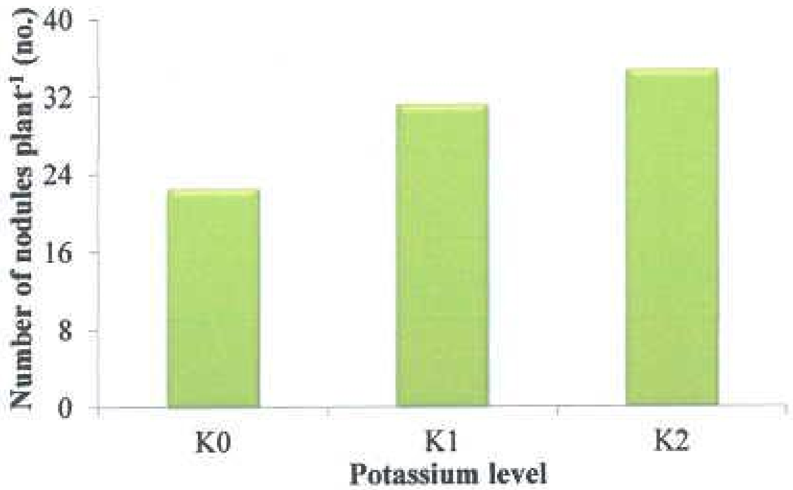

Figure 9. Effects of potassium on the number of nodules plant^{-1} of mungbean (LSD $_{(0.05)}$ = 2.85)

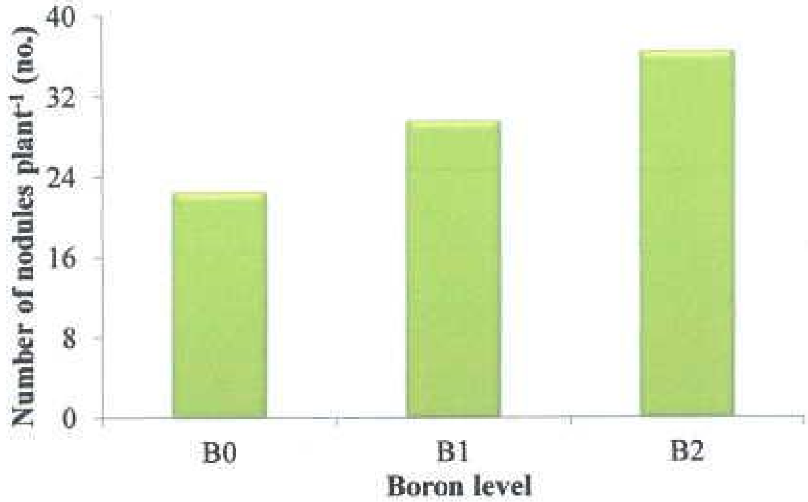

Figure 10. Effects of boron on the number of nodules plant^{-1} of mungbean (LSD $_{(0.05)}$ = 2.85)

4.6 Days to 1st flowering

Application of potassium fertilizer at different doses showed significant variation on (Figure 11). The maximum days to flowering (40.67) was observed from K_0 which was statistically followed 38.89) by $K_1$and the minimum days to flowering (36.89) was observed from K_2 (Table 8).

Significant variation of flowering time was found due to boron (Figure 12). The maximum days to flowering (39.89 d) was found from B_0. On the other hand, the minimum days to flowering (37.67d) was observed from B_2.

Combind effect of potassium and boron and mungbean varieties showed significant differences on (Table 3). The delayed date of flowering (42.00 d) was recorded from the treatment combination of K_0B_0, whereas the earliest flowering time(35.67 d) was found from K_2B_2 (Table 9). Saha *et al.* (1996) also reported same finding.

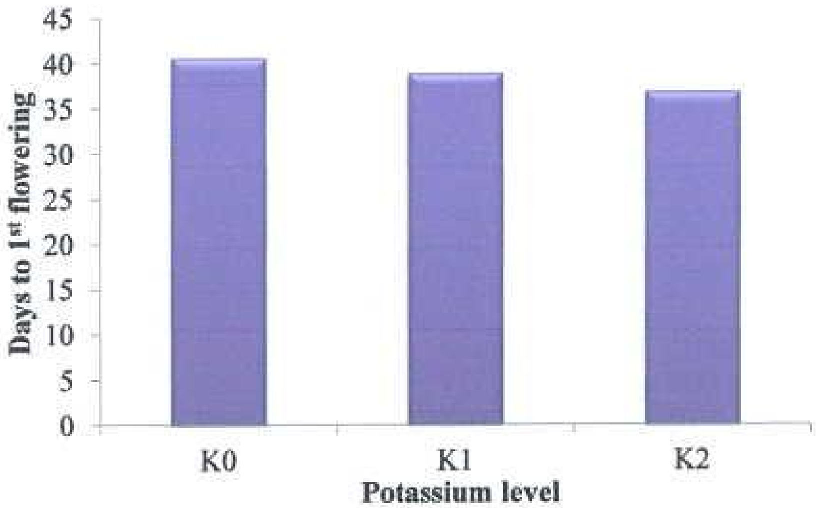

Figure 11. Effects of potassium on the days to 1st flowering of mungbean ($LSD_{(0.05)} = 0.63$)

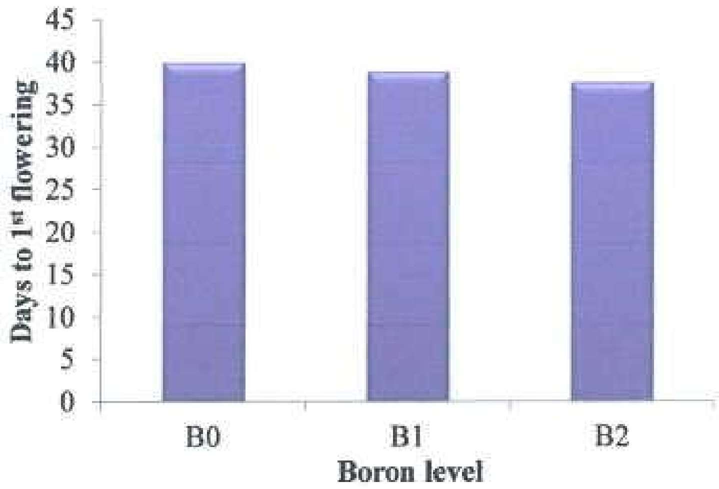

Figure 12. Effects of boron on the days to 1st flowering of mungbean (LSD $_{(0.05)}$ = 0.63)

4.7 Number of pods per plant

The variations in respect of number of pod per plant due to the effects of different levels of potassium were statistically significant (Figure 13). The maximum pods per plant (19.48) was observed in K_2. The control plants produced the minimum (15.88).

Pod per plant showed significant variation due to the effects of different levels of boron (Figure 14).The highest number of pod per plant (20.07) was obtained from the grown with the dose of B_2. The lowest (15.92) was found when the plants were raised without boron.

The combined effect of different doses of potassium and boron fertilizers showed a statistically significant effect on number of pods per plant of mungbean (Table 3). The highest number of pods per plant (21.47) was recorded with the treatment combination of K_2B_2 which is statistically similar with (20.37) and (19.53) was observed K_2B_1 and K_1B_2 respectively. The minimum number of pod per plant (12.47) was observed from K_0B_0 treatment. Tahir *et al*. (2013) reported that boron at 4 kg ha^{-1} significantly increased number of pods plant^{-1} (21.33).

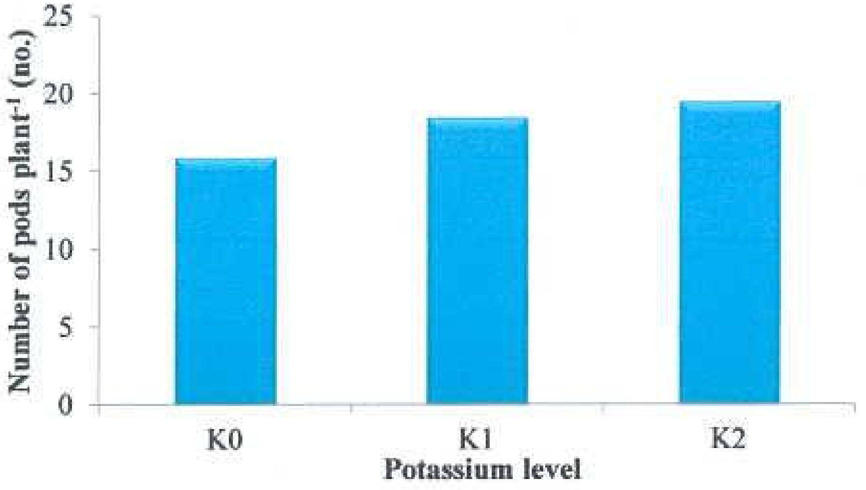

Figure 13. Effects of potassium on the number of pods plant^{-1} of mungbean (LSD $_{(0.05)}$ = 1.28)

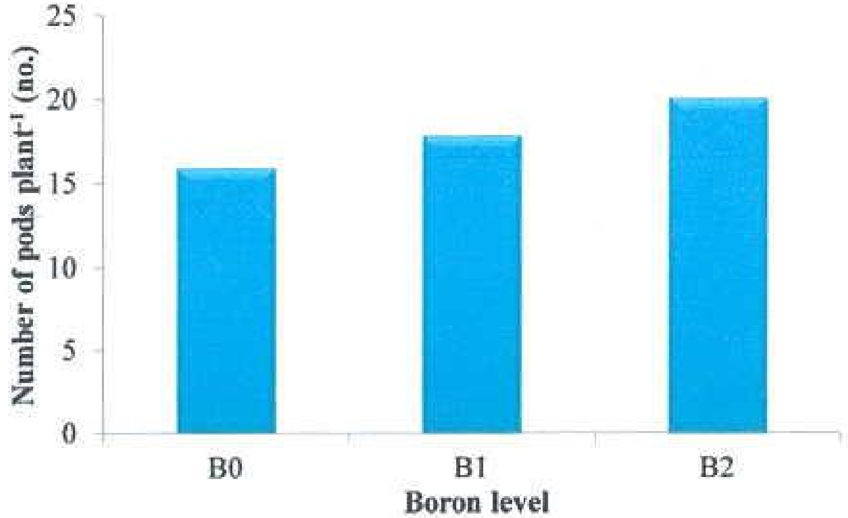

Figure 14. Effects of boron on the number of pods plant^{-1} of mungbean (LSD $_{(0.05)}$ = 1.28)

Table 3. Interaction effects of potassium and boron on the dry matter weight plant^{-1}, number of branches plant^{-1}, nodules pant^{-1}, Days to 1st flowering, pods plant^{-1} and seeds pod^{-1} of mungbean

Treatment combinations	Dry matter weight plant^{-1} (g)	No. of branches plant^{-1} (No.)	No. of nodules pant^{-1} (No.)	Days to 1st flowering	No. of pods plant^{-1} (No.)	No. of seeds pod^{-1} (No.)
K_0B_0	6.05 g	2.27 f	15.33 f	42.00 a	13.17 f	6.20 g
K_0B_1	6.44 f	3.50 e	24.00 e	39.67 b	16.10 e	7.20 ef
K_0B_2	6.84 de	4.00 cd	28.33 de	40.33 b	18.37 b-d	8.03 d
K_1B_0	6.71 e	3.93 d	25.33 e	39.67 b	17.17 de	6.67 fg
K_1B_1	7.15 c	4.20 b-d	31.33 cd	40.00 b	17.83 c-e	8.13 cd
K_1B_2	7.28 c	4.40 bc	37.00 b	37.00 c	20.37 ab	9.13 ab
K_2B_0	6.91 d	4.07 cd	27.00 de	38.00 c	17.43 c-e	7.47 de
K_2B_1	7.51 b	4.57 b	33.33 bc	37.00 c	19.53 a-c	8.90 bc
K_2B_2	7.75 a	5.37 a	44.00 a	35.67 d	21.47 a	9.83 a
LSD $_{(0.05)}$	**0.14**	**0.40**	**4.93**	**1.09**	**2.22**	**0.80**
CV (%)	**1.23**	**5.79**	**9.65**	**1.63**	**7.14**	**5.8**

4.8 Number of seeds per pod

There was significant variation in the number of seed per pod in mungbean when different doses of potassium fertilizer were applied (Figure 15). The highest number of seed per pod (8.733) was recorded in K_2 treatment. The lowest number of seed per pod (7.144) was recorded in the K_0 treatment. Application of boron fertilizer at different doses showed significant variation on number of seed per pod (Figure 16). Among the different fertilizer doses B_2 treatment showed the highest number of seed per pod (9.000). The lowest number of seed per pod (6.778) was recorded with B_0 treatment where no boron was applied. The combined effect of different doses of potassium and boron fertilizer on the number of seed per pod was significant (Table 3). However, the highest number of seed per pod (9.83) was recorded with the treatment combination of K_2B_2

which was statistically similar to (9.133) by K_2B_0. On the other hand, the lowest number of seed per pod (6.20) was found in K_0B_0 treatment. This result was supported by Valenciano *et al.* (2011) who reported that B_1 (241.0g ha^{-1}) produced the higher the no. of Seeds pod^{-1} result regarding to kaisher *et al.* (2010) and Dixit and elamathi (2007) also found that the B at 5 kg ha^{-1} and B (0.2%) significantly increased the number of seeds pod-1. Haque *et al.* (2013) reported that number of grains pod^{-1} increased with increasing levels of K.

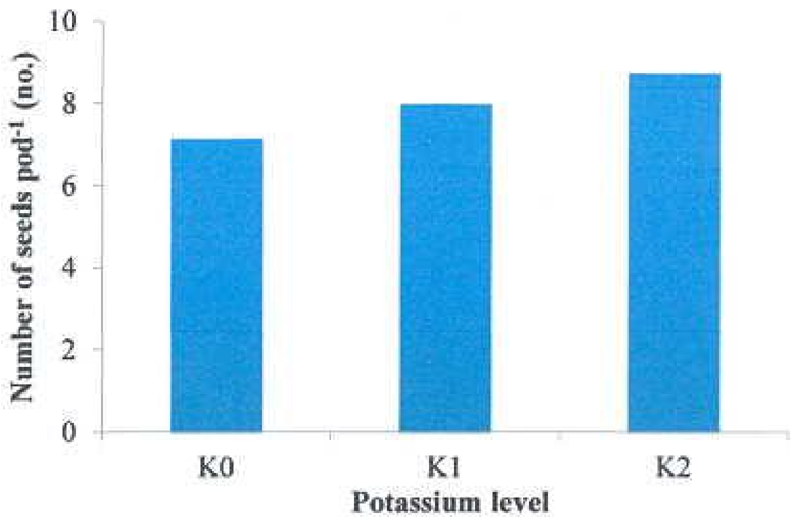

Figure 15. Effects of potassium on the number of seeds pod^{-1} of mungbean (LSD $_{(0.05)}$ = 0.46)

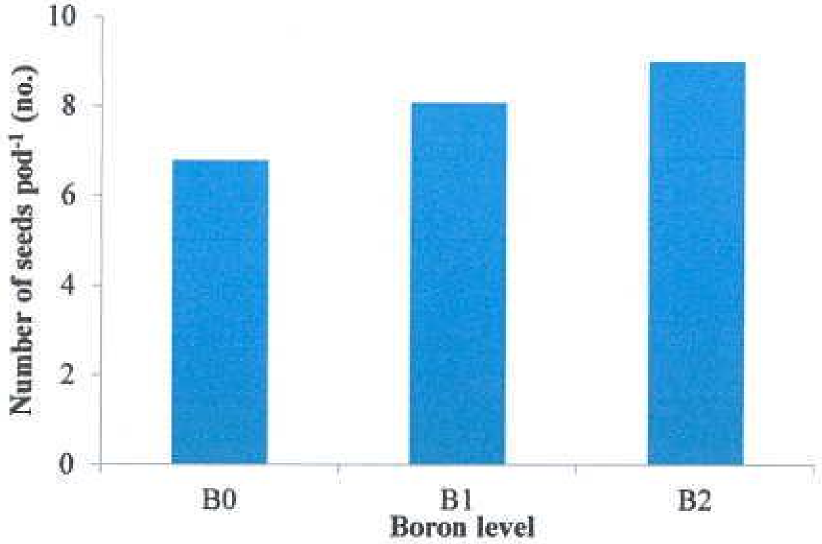

Figure 16. Effect of boron on the number of seeds pod^{-1} of mungbean ($LSD_{(0.05)} = 0.46$)

4.9 Pod length (cm)

Application of potassium fertilizer at different doses showed no significant variation on pod length (Figure 17). Among the different fertilizer doses K_2 treatment showed the highest pod length (8.80 cm). The lowest pod length (6.95) was recorded with K_0 treatment where no potash was applied.

There was significant variation in pod length in mungbean when different doses of boron fertilizer were applied (Figure 18). The highest pod length (9.456 cm) was recorded in B2 treatment. The lowest pod length (7.556 cm) was recorded in the B_0 treatment where no phosphorus fertilizer was applied.

Combind effect of potassium and boron and mungbean varieties showed significant differences on pod length (Table 4). The longest pod (10.10 cm) was found from K_2B_2, which was statistically similar (9.70 cm) to K_1B_2, whereas the shortest pod (7.07cm) was observed from K_0B_0 which was closely followed (7.60 cm) by K_0B_1 (Table 8). Kaisher *et al.* (2010) and Dixit and elamathi (2007) also found similar findings.

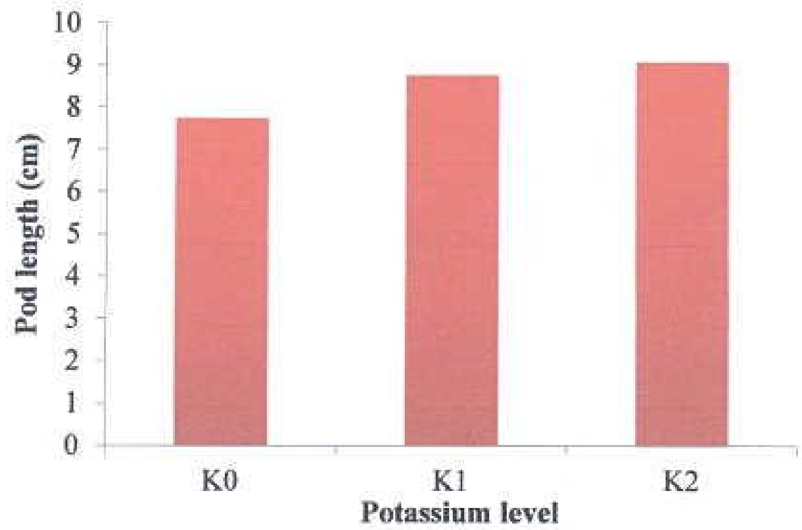

Figure 17. Effects of potassium on the pod length of mungbean (LSD $_{(0.05)}$ = 0.65)

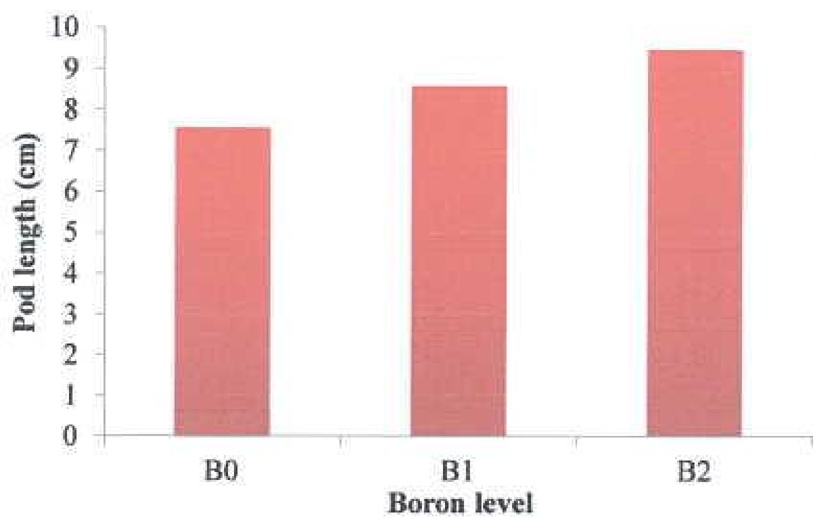

Figure 18. Effects of boron on the pod length of mungbean (LSD $_{(0.05)}$ = 0.65)

4.10 1000-Seed weight (g)

There was significant variation in 1000-seed weight in mungbean when different doses of potassium fertilizer were applied (Figure 19). The highest 1000-seed weight (43.57 g) was recorded in K_2 treatment. The lowest 1000-seed weight (37.01g) was recorded in the K_0 treatment. Application of boron fertilizer at different doses showed significant variation on 1000-seed weight (Figure 20). Among the different fertilizer doses B_2 treatment showed the highest 1000-seed weight (44.21 g). The lowest 1000-seed weight (37.72) was recorded with B_0 treatment where no potash was applied.

The combined effect of different doses of phosphorus and potassium fertilizer on the 1000-seed weight was significant (Table 4). However, the highest 1000-seed weight (46.97 g) was recorded with the treatment combination of K_2B_2 which was statistically similar (45.33 g) to K_1B_2. The lowest 1000-seed weight (34.40 g) was found in K_0B_0 treatment which was closely followed (36.30 g) by K_0B_1.Valenciano *et al.* (2011) reported that B1 (241.0 g ha^{-1}) produced the higher result regarding to 1000 seed weight. Kaisher *et al.* (2010) and Dixit and Elamathi (2007) found that the B at 5 kg ha^{-1} and B (0.2 %) significantly increased the 1000-seed weight. Haque *et al.* (2013) stated that weight of 1000-seed increased with increasing levels of K.

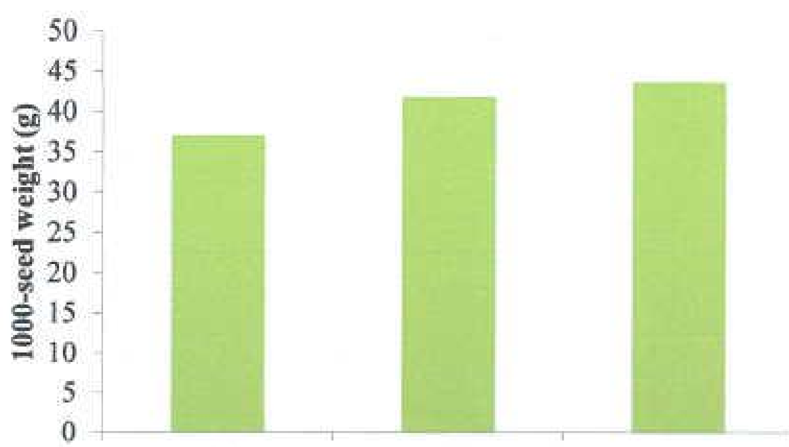

Figure 19. Effects of potassium on the 1000-seed weight of mungbean (LSD $_{(0.05)}$ = 2.32)

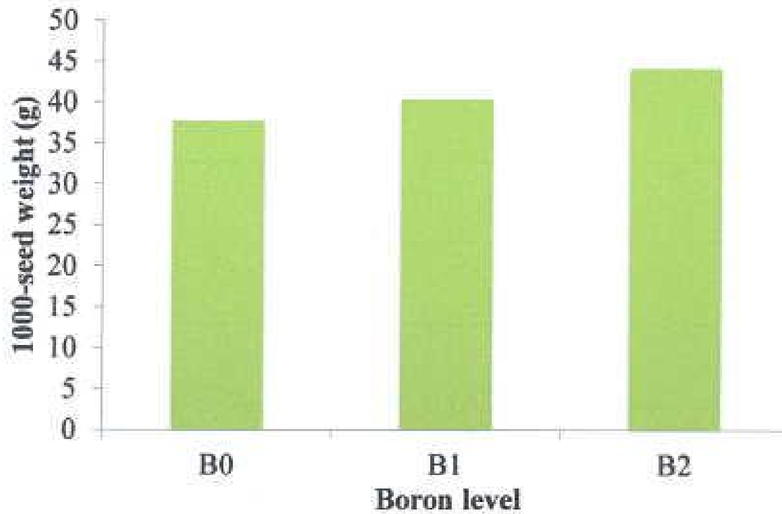

Figure 20. Effects of boron on the 1000-seed weight of mungbean (LSD $_{(0.05)}$ = 2.32)

4.11 Seed yield (t ha^{-1})

The results of the single effects of different levels of potassium have been shown in (Figure 21). From the table it was apparent that K_2 treatment recorded the highest yield (1.65 t ha^{-1}). On the contrary, the lowest seed yield (1.172 t ha^{-1}) was observed with K_0, where no potash was applied.

Significant variation was observed on the seed yield when different doses of boron fertilizer were applied (Figure 22). The highest seed yield (1.699 t ha^{-1}) was recorded in B_2 treatment. The lowest (1.204 t ha^{-1}) was in the B_0 treatment.

The combined effect of different doses of potassium and boron fertilizer on the seed yield of mungbean was significant (Table 4). The highest seed yield (1.87 t ha^{-1}) was recorded with the treatment combination of K_2B_2 which was statistically similar (1.76 t ha^{-1}) to K_1B_2 which is followed (1.64 t ha^{-1}) by K_2B_1. The lowest seed yield (0.81 t ha^{-1}) was found in K_0B_0 treatment. Seed yield increases because here K play important role in mungbean plant like it increases disease resistance, activate more than 60 enzymes, helps in formation of protein, prevent from lodging, encourages cell division, enhances biological nitrogen fixation ultimately results higher yield. On the other hand B plays inportent roles in mungbean plant such as viable pollen formation, pod and seed formation, increases cell division, calcium metabolism increases, synthesis of amino acid and protein, nodule formation and nitrogen fixation increases and results higher yield. Similar results were reported by Channaveerswami (2005) in groundnut and Rajkhowa *et al.* (2002) in green gram. Tahir *et al.* (2013) reported that boron at 4 kg ha^{-1} significantly increased seed yield (1200 kg ha^{-1}). The mean seed yield increased when K and B content increased in soil reported by Bharti *et al.* (2002) . Tripathi *et al.* (2012) reported that application of 45 kg S ha^{-1} recorded higher grain yield as compared to control. Mandal *et al.* (1998) reported that the application of B fertilizer thus increasing the yield of pulse crops. Yang *et al.* (1989) also indicated that combined application of N, K, Zn and B increased seed yield in rapeseed.

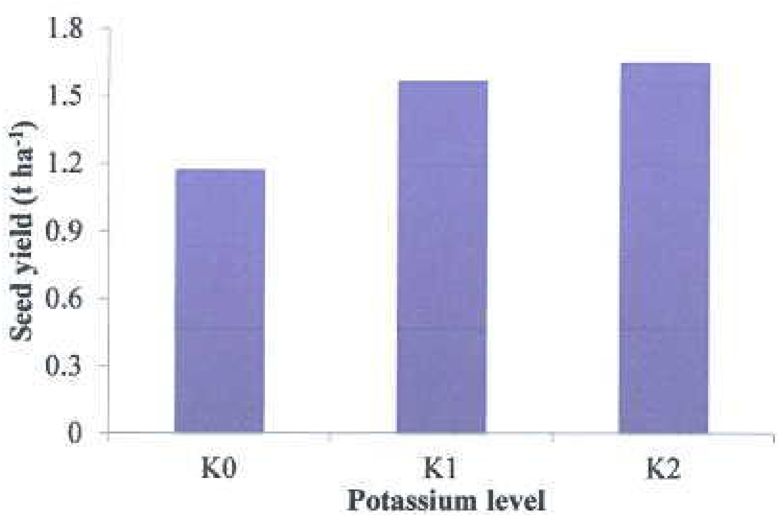

Figure 21. Effects of potassium on the seed yield of mungbean (LSD $_{(0.05)}$ = 0.09)

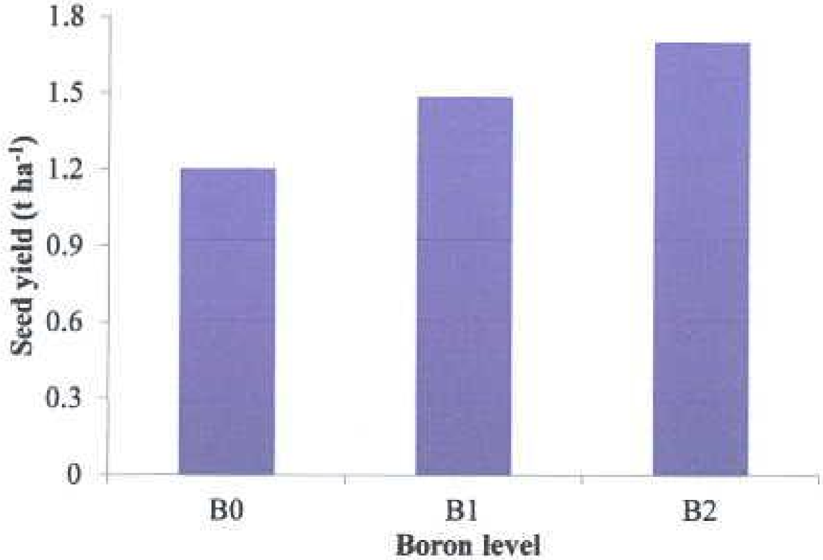

Figure 22. Effects of boron on the seed yield of mungbean (LSD $_{(0.05)}$ = 0.09)

4.12 Stover yield

Stover yield of mungbean were significantly influenced by potassium fertilizer (Figure 23). The maximum stover yield (2.472 t ha^{-1}) was recorded from the K_1 treatment whereas, the minimum (2.302 t ha^{-1}) was found in the K_2 treatment. Stover yield were significantly influenced by boron fertilizer (Figure 24). The maximum stover yield (2.516 t ha^{-1}) was recorded from the B_1treatment whereas, the minimum (2.308 t ha^{-1}) was found in the B_2 treatment.

The interaction effect of nitrogen and boron fertilizer on stover yield of mungbean was significant (Table 4). The height yield (2.66 t ha^{-1}) was recordved from the combination of K_2B_1 treatment which was statistically identical K_1B_1 (2.58 t ha^{-1}). The lowest stover yield (2.18 t ha^{-1}) was found in the combination of K_2B_2 treatment which is similar (2.19 t ha^{-1}) With the combination K_0B_0 treatment. Haque *et al.* (2013) stated that stover yield of mungbean increased with increasing levels of K.

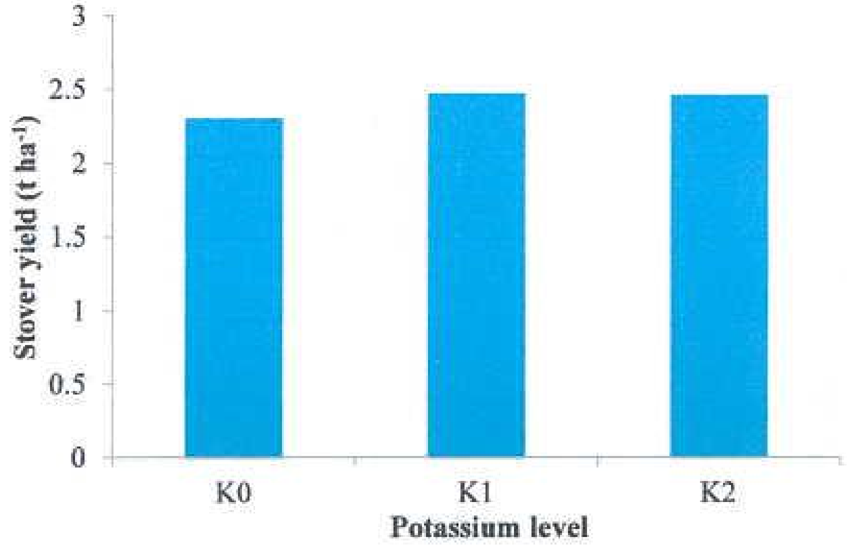

Figure 23. Effects of boron on the stover yield of mungbean (LSD $_{(0.05)}$ = 0.16)

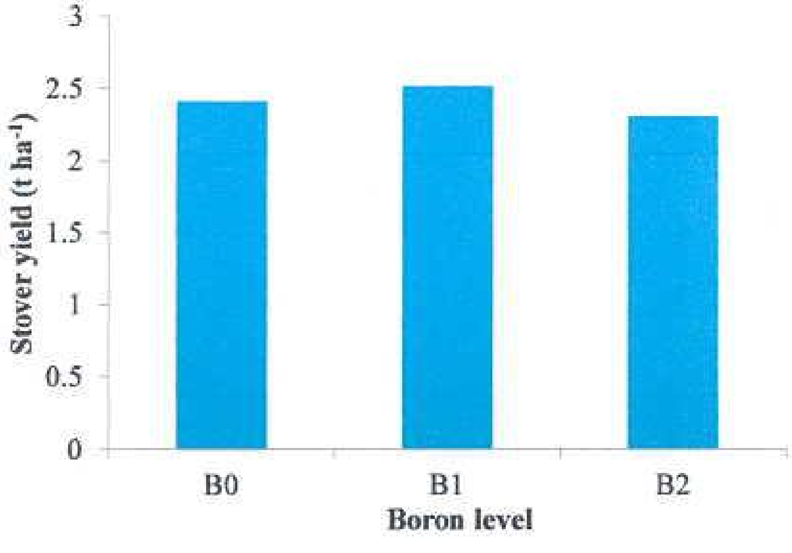

Figure 24. Effects of boron on the stover yield of mungbean (LSD $_{(0.05)}$ = 0.16)

Table 4. Interaction effects of potassium and boron on the pod length, 1000-seed weight, seed yield, stover yield and harvest index of mungbean

Treatment combinations	Pod length (cm)	1000 seed weight (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index (%)
K_0B_0	7.07 e	34.40 f	0.81 g	2.19 c	27.08 c
K_0B_1	7.60 de	36.30 ef	1.24 f	2.31 bc	34.96 b
K_0B_2	8.57 b-d	40.33 cd	1.46 de	2.41 a-c	37.78 b
K_1B_0	7.67 de	38.50 de	1.36 ef	2.51 ab	35.19 b
K_1B_1	8.93 bc	41.43 b-d	1.57 cd	2.58 ab	37.91 b
K_1B_2	9.70 ab	45.33 ab	1.76 ab	2.33 bc	43.27 a
K_2B_0	7.93 c-e	40.27 c-e	1.44 de	2.53 ab	36.19 b
K_2B_1	9.20 ab	43.47 a-c	1.64 bc	2.66 a	38.16 b
K_2B_2	10.10 a	46.97 a	1.87 a	2.18 c	46.31 a
LSD $_{(0.05)}$	**1.13**	**4.01**	**0.15**	**0.28**	**4.81**
CV (%)	**7.67**	**5.68**	**6.15**	**6.78**	**7.42**

4.13 Harvest Index

A significant difference was found in harvest index due to potassium application (Figure 25). The maximum harvest index (40.22%) was recorded from K_2 treatment whereas, the minimum (33.27 %) was found from control (K_0) treatment. A significant difference was found in harvest index due to boron (Figure 26). The maximum harvest index (42.45 %) was recorded from B_1 treatment whereas, the minimum (32.82%) was found in control (B_0) treatment. The interaction effect of potassium and boron fertilizer application was significant on harvest index (Table 4). The highest harvest index (46.31 %) was recorded from the combination of K_2B_2 treatment which, was statistically similar (43.27%) to the combination K_1B_2 and which was followed by (38.16%) to the combination K_2B_1. The lowest (27.08 %) were found in the combination of control K_0B_0. Present study revealed that 25kg N ha^{-1} and 2.5 kg B ha^{-1} produced best harvest index (%)

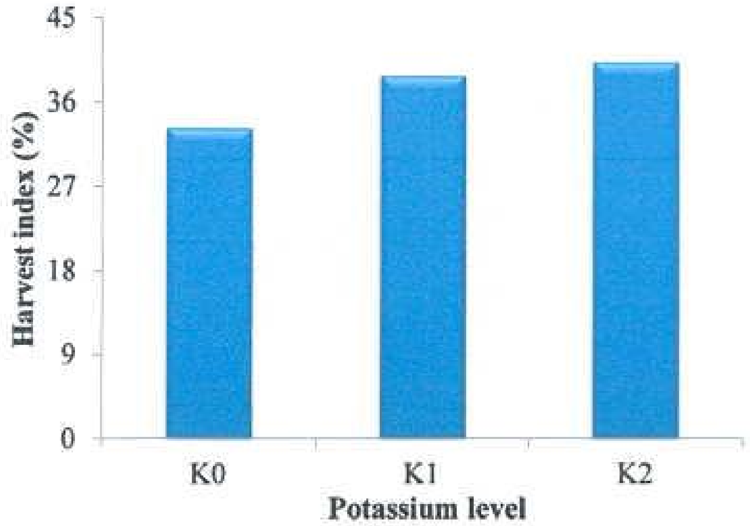

Figure 25. Effects of potassium on the harvest index of mungbean ($LSD_{(0.05)} = 2.78$)

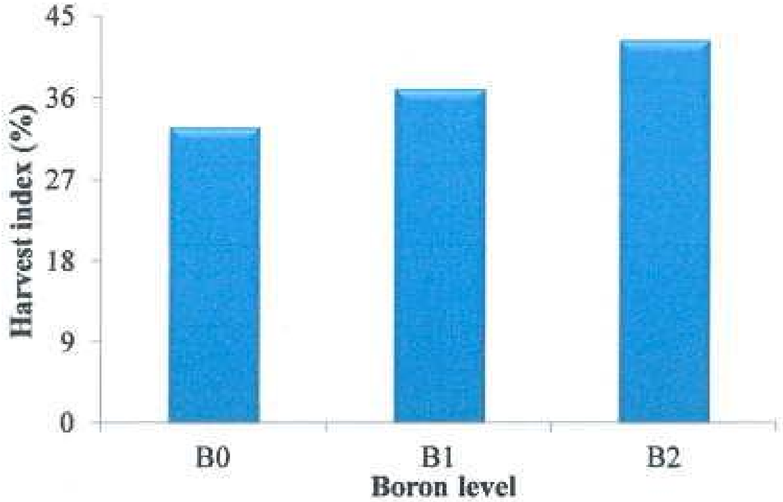

Figure 26. Effects of boron on the harvest index of mungbean ($LSD_{(0.05)} = 2.78$)

4.14 Nitrogen content in seed of mungbean

N content of seed was significantly influenced by application of different levels of potassium (Table 5).The highest N content in mungbean seed (4.376 %) was recorded in K_2 (25 kg ha^{-1}) and the lowest (3.882%) was in K_0 treatment where no potassium was applied.

N content of seed was not significantly influenced by the application of different levels of boron (Table 5). The highest N content in mungbean seed (4.194%) was recorded in B_2 (2.5 kg ha^{-1}), which showed similar (4.154%) result with B_1 (1.5 kg ha^{-1}) treatment. The lowest Nitrogen content in mungbean seed (4.099%) was recorded in B_0 treatment where no boron was applied.

Significant effects were observed dew to combined application of different doses of potassium and boron fertilizer on the nitrogen content in seed (Table 6). The highest concentration of N in the seed (4.45%) was recorded in the treatment K_2B_2 which showed similar (4.36% and 4.32%) result with K_2B_1 and K_2B_0 treatments respectively. The lowest N content (3.84%) in seed was found in K_0B_0. Singh et al. (1993) found significant increase of nitrogen content in mungbean due to the application of increasing level of K fertilizer.

Table 5. EffectS of potassium and boron on the chemical compositions of mungbean

Effect of potassium						
Treatment	**Nitrogen content (%)**	**Phosphorous content (%)**	**Potassium content (%)**	**Boron content ($\mu g\ g^{-1}$)**	**Calcium content (mg)**	**Protein content (%)**
K_0	3.88 c	0.30 c	1.34 c	17.53 c	0.04 c	24.26 c
K_1	4.19 b	0.33 b	1.69 b	18.82 b	0.08 a	26.08 b
K_2	4.38 a	0.36 a	2.03 a	19.39 a	0.07 b	27.36 a
LSD (0.05)	**0.08**	**0.01**	**0.03**	**0.51**	**0.01**	**1.14**
CV (%)	**1.82**	**3.95**	**2.06**	**2.77**	**5.61**	**4.39**
Effect of boron						
Treatment	**Nitrogen content (%)**	**Phosphorous content (%)**	**Potassium content (%)**	**Boron content (%)**	**Calcium content (%)**	**Protein content (%)**
B_0	4.10 b	0.32 b	1.63 c	13.59 c	0.05 b	25.63
B_1	4.15 ab	0.33 b	1.69 b	18.74 b	0.06 a	25.85
B_2	4.19 a	0.34 a	1.75 a	23.40 a	0.07 a	26.22
LSD (0.05)	**0.08**	**0.01**	**0.03**	**0.51**	**0.01**	**NS**
CV (%)	**1.82**	**3.95**	**2.06**	**2.77**	**5.61**	**5.61**

4.15 Phosphorus content in seed of mungbean

The effect of different doses of potassium fertilizer showed a statistically significant variation in the phosphorus content in seed (Table 5). The highest P content in mungbean seed (00.3556) was recorded in K_2 (25 kg ha^{-1}) which was followed (0.3289%) by K_1. On the other hand, the lowest P content in seed (0.3000%) was recorded in K_0 treatment where no potassium was applied.

The effect of different doses of boron fertilizer showed a statistically significant variation in the phosphorus content in seed (Table 5). The highest P content in seed (0.3378%) was recorded in B_2 (2.5 kg ha^{-1}) treatment. On the other hand, the lowest (0.3211%) was in B_0 treatment where no boron was applied.

The effect of different doses of potassium fertilizer showed a statistically significant variation in the phosphorus content seed (Table 6) of mungbean. The highest content of P in the seed (0.37%) was recorded in the treatment combination of K_2B_2 which showed similar (0.35%) result with K_2B_0 and followed by K_2B_1 and K_1B_2 treatment (0.35% and 0.34%) respectively. On the other hand, the lowest P content (0.29%) in seed was found in K_0B_0. Increased P content in mungbean seed was also reported by Kaushik et al. (1996) due to the application of K fertilizer.

4.16 Potassium content in seed of mungbean

K content of seed was significantly influenced by application of different levels of potassium (Table 5). The highest K content in mungbean seed (2.034%) was recorded in K_2 (25 kg ha^{-1}) which was followed (1.692%) by K_1 treatment. The lowest K content in mungbean seed (1.343%) was recorded in K_0 treatment where no potassium was applied.K content of seed was significant influenced by the application of different levels of boron (Table 5). The highest K content in mungbean seed (1.747%) was recorded in B_2 (2.5kg ha^{-1}) treatment. On the other hand, the lowest K content in mungbean seed (1.630%) was recorded in B_0 treatment where no boron was applied.

Significant effect was observed in combined application of different doses of potassium and boron fertilizer on the K content in seed of mungbean (Table 6). The highest content of K in the seed (2.12%) was recorded in the treatment combination of K_2B_2 which was followed (2.02%) result with K_2B_1 treatment. The lowest K content (1.26%) was found in K_0B_0. Singh *et al.* found that singnificant increase of potassium content in mungbean due to application of K.

4.17 Boron content in seed of mungbean

The effect of different doses of potassium fertilizer showed a statistically significant variation in the boron content seed of mungbean(Table 5). The highest B content in mungbean seed (19.39µg gm^{-1}) was recorded in K_2 which was followed (18.82µg gm^{-1}) by K_1. The lowest B content in seed (17.53µg gm^{-1}) was recorded in K_0 treatment where no potassium was applied. The effect of different doses of boron fertilizer showed a statistically significant variation in the phosphorus content in seed (Table 5). The highest B content in seed (23.40µg gm^{-1}) was recorded in B_2 treatment. On the other hand, the lowest B content in mungbean seed (13.59µg gm^{-1}) was recorded in B_0 treatment where no boron was applied (Table 6).

The highest content of B in the seed (24.43µg gm^{-1}) was recorded in the treatment combination of K_2B_2 which followed (23.15µg gm^{-1} and 22.62µg gm^{-1}) by K_1B_2 and K_0B_2 treatment respespectively. Lowest (11.65 µg gm^{-1}) was found in K_0B_0. Results indicated that potassium and boron favored the available boron in seeds mungbean.

4.18 Calcium content in seed of mungbean

Ca content of seed was significantly influenced by application of different levels of potassium (Table 5). The highest Ca content (0.07889gm) was recorded in K_1 (15 kg ha^{-1}). The lowest Ca content (0.03889gm) was recorded in K_0 treatment where no potassium was applied.

Ca content of seed was not significant influenced by the application of different levels of boron (Table 5). The highest Ca content in mungbean seed (0.07000gm) was recorded in B_2 (2.5 kg ha^{-1}), which showed similar (0.06333 gm) result with B_1 (1.5 kg ha^{-1}) treatment. On the other hand, the lowest Ca (0.05222gm) content in seed was recorded in B_0 treatment.

Significant effect was observed in combined application of different doses of potassium and boron fertilizer on the Ca content in seed of mungbean (Table 6). The highest content of Ca in the seed (0.087gm) was recorded in the treatment combination of K_1B_2 which showed similar (0.080gm) result with K_1B_1 treatment. On the other hand, the lowest Ca content (0.027gm) in seed was found in K_0B_0. Results indicated that potassium and boron favored the Ca content in seeds because boron increases the solubility of Ca ion to the plant.

Table 6. Interaction effect of potassium and boron on the chemical compositions of mungbean

Treatment combination	Nitrogen content (%)	Phosphorous content (%)	Potassium content (%)	Boron content (μg gm^{-1})	Calcium content (gm)	Protein content (%)
K_0B_0	3.84 e	0.29 g	1.26 f	11.65 e	0.03 e	24.00 d
K_0B_1	3.88 e	0.30 fg	1.37 e	18.32 c	0.04 de	24.25 cd
K_0B_2	3.93 e	0.31 ef	1.40 e	22.62 b	0.05 cd	24.54 b-d
K_1B_0	4.13 d	0.32 de	1.67 d	14.49 d	0.07 ab	25.83 a-d
K_1B_1	4.23 b-d	0.33 cd	1.69 d	18.80 c	0.08 a	26.08 a-c
K_1B_2	4.21 cd	0.34 b-d	1.72 d	23.15 b	0.09 a	26.31 ab
K_2B_0	4.32 abc	0.35 ab	1.96 c	14.62 d	0.06 bc	27.06 a
K_2B_1	4.36 ab	0.35 bc	2.02 b	19.10 c	0.07 ab	27.23 a
K_2B_2	4.45 a	0.37 a	2.12 a	24.43 a	0.07 ab	27.79 a
$LSD_{(0.05)}$	**0.13**	**0.02**	**0.05**	**0.89**	**0.02**	**1.97**
CV (%)	**1.82**	**3.95**	**2.06**	**2.77**	**5.61**	**4.39**

4.19 Protein content in seed

Protein content of seed was significantly influenced by application of different levels of potassium (Table 5). The highest protein content in mungbean seed (27.36%) was recorded in K_2 (25 kg ha^{-1}) which was followed (26.08%) result by K_1 treatment. On the other hand, the lowest protein content in mungbean seed (24.26%) was recorded in K_0 treatment where no potassium was applied.

Protein content of seed was not significantly influenced by the application of different levels of boron (Table 5). The highest protein content in mungbean seed (26.22%) was recorded in B_2 (2.5 kg ha^{-1}) treatment. The lowest (25.63%) was recorded in B_0 treatment.

Significant effect was observed in combined application of different doses of potassium and boron fertilizer on the seed protein content in seed of mungbean (Table 6). The highest protein (27.79%) was recorded in the treatment combination of K_2B_2 which was statistically similar (27.23%, 27.06% and 26.31%) to K_2B_1, K_2B_0 and K_1B_2 treatments and followed (24.54%) by K_2B_1 treatment. The lowest protein content (24.00%) was found in K_0B_0. Chanda *et al.* (2002) concluded that the application of higher levels of K increased the protein content in mungbean.

4.11 β-carotene content in seed of mungbean

β-carotene t in seed was significantly influenced by the application of different levels of potassium (Table 10). The highest β-carotene in seed (51.97mg) was recorded in K_1 (15 kg ha^{-1}). The lowest β-carotene (47.56mg) was recorded in K_0 treatment. β-carotene content was significantly influenced by different levels of boron (Table 9). The highest β-carotene (50.67mg) was recorded in B_2 (2.5 kg ha^{-1}), which showed similar (0.06333 mg) result with B_0 (1.5 kg ha^{-1}) treatment. The lowest β-carotene content in mungbean seed (48.96mg) was found in B_1 treatment.

Significant effect was observed in combined application of different doses of potassium and boron fertilizer on the β-carotene content in seed of mungbean (Table 7). The highest β-carotene content in the seed (53mg) was recorded in the treatment combination of K_2B_2 which showed similar (52.07mg) result with K_2B_0 treatment. The lowest β-carotene content (46.77mg) in seed was found in K_0B_1 which was statistically similar with K_0B_0.

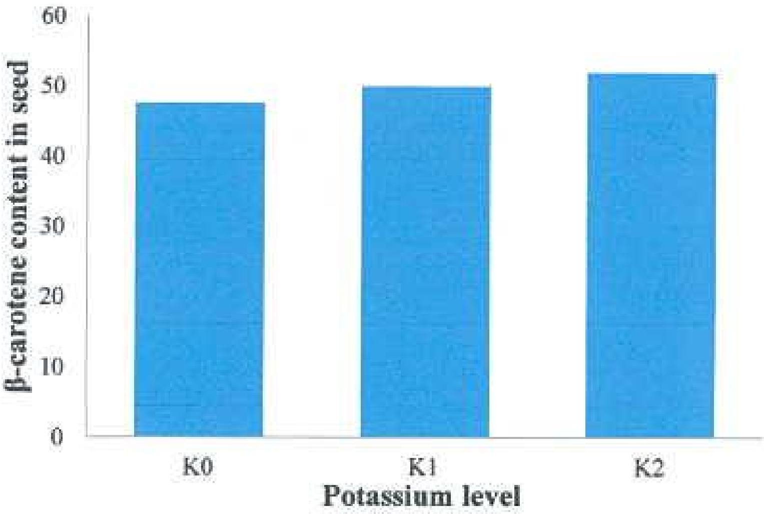

Figure 28. Effect of boron on the harvest index of mungbean (LSD $_{(0.05)}$ = 0.7963)

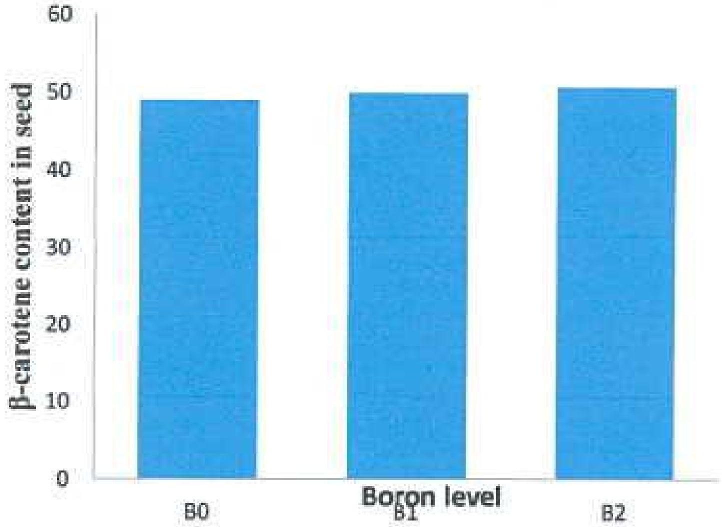

Figure 28. Effects of boron on the harvest index of mungbean (LSD $_{(0.05)}$ = 0.796)

Table 7. Interaction effect of potassium and boron on β-carotene content in seed of mungbean

Treatment combination	β-carotene content in seed (mg/100gm)
K_0B_0	46.77g
K_0B_1	47.57fg
K_0B_2	48.33ef
K_1B_0	50.10cd
K_1B_1	49.27de
K_1B_2	50.67c
K_2B_0	52.07ab
K_2B_1	50.83bc
K_2B_2	53.00 a
$LSD_{(0.05)}$	**1.379**
CV (%)	**1.60**

Chapter V
Summary and conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the central research farm of Sher-e-Bangla Agricultural University, Dhaka during the period from February, 2016 to June, 2016 to study influence of potassium and boron on growth and yield of mungbean. The treatment consisted of three different potassium level viz. K_0 (0 kg K ha^{-1}), K_1 (15 kg K ha^{-1}) and K_2 (25 kg K ha^{-1}). Three boron levels viz. B_0 (0 kg B ha^{-1}), B_1 (1.5 kg P ha^{-1}), B_2 (2.5 kg P ha^{-1}). The experiment was laid out in a two factors randomized complete block design (RCBD) with three replications. The seeds of BARI mung-6 variety were sown. Seeds were sown at the rate of 40 kg ha^{-1}. Necessary intercultural operations were done as and when necessary. The size of each unit plot 3m × 2 m. The spacing between blocks and plots were 0.5 m and 0.25 m. Chemical fertilizers were applied as per its recommended dose. The crop was harvested at full maturity and harvesting was done manually from each plot.

Results showed that a significant variation was observed among the treatments in respect to majority of the observed parameters. The collected data were statistically analyzed for evaluation of the treatment effect.

The plant height was significantly affected due to the different level of potassium. The tallest plant (24.27, 38.18, 55.80, 63.83 and 65.38 cm at 20, 30, 40, 50 DAS and harvest respectively) was obtained from K_2 (25 kg K/ha) treatment. It was observed that the plant height was significantly affected due to the different level of boron. The tallest plant height the highest plant height (21.33, 35.50, 52.67, 60.97 and 62.19 cm at 20, 30, 40, 50 DAS and harvest respectively) was obtained from level of boron B_2 (2.5 kg ha^{-1}).

Interaction effect of different level of potassium and level of boron had a significant variation on plant height. The highest plant height (25.27, 40.17, 57.20, 66.17 and 68.47cm at 20, 30, 40, 50 DAS and harvest, respectively) was recorded with K_2B_2 treatment.

Number of leaves per plant was significantly influenced by level of potassium. Among the different doses of K_2 showed the highest number of leaf per plant (10.07, 18.56 and

22.96 at 20, 30, 40, 50 DAS and harvest, respectively). Number of leaves was significantly influenced by level of boron. The highest number of leaf plant^{-1} (10.33, 19.16, 29.78 at 20, 30, 40, 50 DAS and harvest, respectively) was recorded in B_2 (2.5 kg ha^{-1}). Interaction effect of different level of potassium and level of boron had a significant variation on number of leaves per plant. The highest leaf per plant (11.33, 21.33, and 33.67 at 20, 30, 40, 50 DAS and harvest, respectively) was recorded with the treatment combination of K_2B_2.

The number of branch per plant as affected by different doses of potassium showed a statistically significant variation. The highest number of branch per plant (4.67) was observed in K_2 (25 kg ha^{-1}). The doses B_2 treatment, showed the highest number of branch per plant (4.59). The highest number of branch per plant (5.37) was recorded in the treatment combination of K_2B_2.

The number of nodule per plant and days to 1st flowering as affected by different doses of potassium showed a statistically significant variation. Among the different doses of potassium the highest number of nodule per plant (34.78) and minimum days to 1st flowering (36.89) was observed in K_2 (25 kg ha^{-1}). The doses B_2 treatment, showed the highest number of nodule per plant (36.44) and minimum days to 1st flowering (37.64). The highest number of nodule per plant (44.00) and minimum days to 1st flowering (35.67) was recorded in the treatment combination of K_2B_2.

Number of pod per plant showed significant variation due to the effects of different levels of potassium (Fig. 8).The highest number of pod per plant(19.48) was obtained from the grown with the dose of K_2 (25 kg ha^{-1}).Number of pods per plant was significantly influenced by level of boron. The highest number of pods per plant (20.07) was observed from B_2 (2.5 kg ha^{-1}).

Interaction effect of different row level of potassium and boron had a significant variation on number of pods per plant. The highest number of pods per plant (21.47) was recorded with the treatment combination of K_2B_2.

The number of seeds per pod, pod length and thousand seed weight of mungbean (BARI mung-6) were significantly influenced by levels of potassium. K_2 treatment showed the highest number of seed per pod (8.733), pod length (9.078 cm) and thousand seed weight (43.57g). The number of seeds per pod, thousand seed weight and pod length were significantly influenced by levels of boron. The highest number of seed per pod (9.00), pod length (9.456 cm) and thousand seed weight (44.21 gm) were recorded in B_2 treatment. Interaction effects of different row levels of potassium and boron had a significant variation on number of seeds per pod, pod length and thousand seed weight. The highest number of seed per pod (9.833), pod length (10.10 cm) and thousand seed weight (46.97 gm) were obtained from K_2B_2 treatment.

There was significant variation in the seed yield and stover yield per hectare due to the different levels of potassium. The maximum seed yield (1.650 t ha^{-1}) and stover yield (2.460 t ha^{-1}) was obtained from K_2 (25 kg ha^{-1}).The seed yield and stover yield per hectare were also significantly increased by levels of boron. The highest yield of seed (1.699 t ha^{-1}) and stover (2.516 t ha^{-1}) was recorded in B_2 (2.5 kg ha^{-1}) and B_1 (1.5 kg ha^{-1}) treatment respectively. Combined effects of different row levels of potassium and leves of boron had a significant variation on seed yield and stover yield per hectare. The highest yield of seed (1.89 t ha^{-1}) and yield of stover (2.66 t ha^{-1}) was recorded with the treatment combination of K_2B_2 and K_2B_1 respectively. The lowest yield of seed (0.81 t ha^{-1}) and stover yield (2.18 t ha^{-1}) was found in K_0B_0 and K_2B_2 treatment respectively.

N, P, K content of seed was significantly influenced by the application levels of potassium. The highest N content in mungbean seed (4.376%), P content (0.3556%) and K (2.034%) were recorded in K_2 (25 kg ha^{-1}). Effect of boron on N, P and K content of seed was significantly influenced by the application levels of boron. The highest N content in mungbean seed (4.194%), P content (0.3378%) and potassium content (1.747%) was recorded in B_2 (2.5 kg ha^{-1}).

Significant effecs was observed in combined application of different doses of potassium and boron fertilizer on the N, P and K concentration in seed of mungbean. The highest content of N in the seed (4.45%), phosphorus in seed (.3378%) and potassium in the seed (2.12%), was recorded in the treatment combination of K_2B_2.

There was significant variation in B and Ca contents of seed due to the different levels of potassium. The highest B content in mungbean seed (19.39μg gm^{-1}) and Ca (0.07889gm) were recorded in K_2 (25 kg ha^{-1}) and K_1 (15 kg ha^{-1}) respectively. Effect of boron on B and Ca contents of seed were significantly influenced by levels of boron. The highest B content in mungbean seed (23.40μg gm^{-1}) and Ca content (0.070gm) was recorded in B_2 (2.5 kg ha^{-1}).

Combined effect of different levels of potassium and level of boron had a significant variation on the B and Ca content in seed of mungbean. The highest content of B in the seed (24.43μg gm^{-1}) and Ca in the seed (0.087gm) was recorded in the treatment combination of K_2B_2 and K_1B_2 respectively.

Protein content of seed influenced by different doses of potassium showed a statistically significant variation. Among the different doses of potassium the highest protein content (27.36) was observed in K_2 (25 kg ha^{-1}) and (26.22%)was in B_2 treatment . The highest protein (27.79%) was recorded in the treatment combination of K_2B_2.

It may be concluded that the performance of mungbean cv. BARI mung-6 was better in respect of growth, yield and nutrient contents when application of potassium @ 25 kg ha^{-1} and boron @ 2.5 kg ha^{-1}. However, to reach a specific conclusion and recommendation more research work on mungbean should be done in farmer field of different agro ecological zones of Bangladesh.

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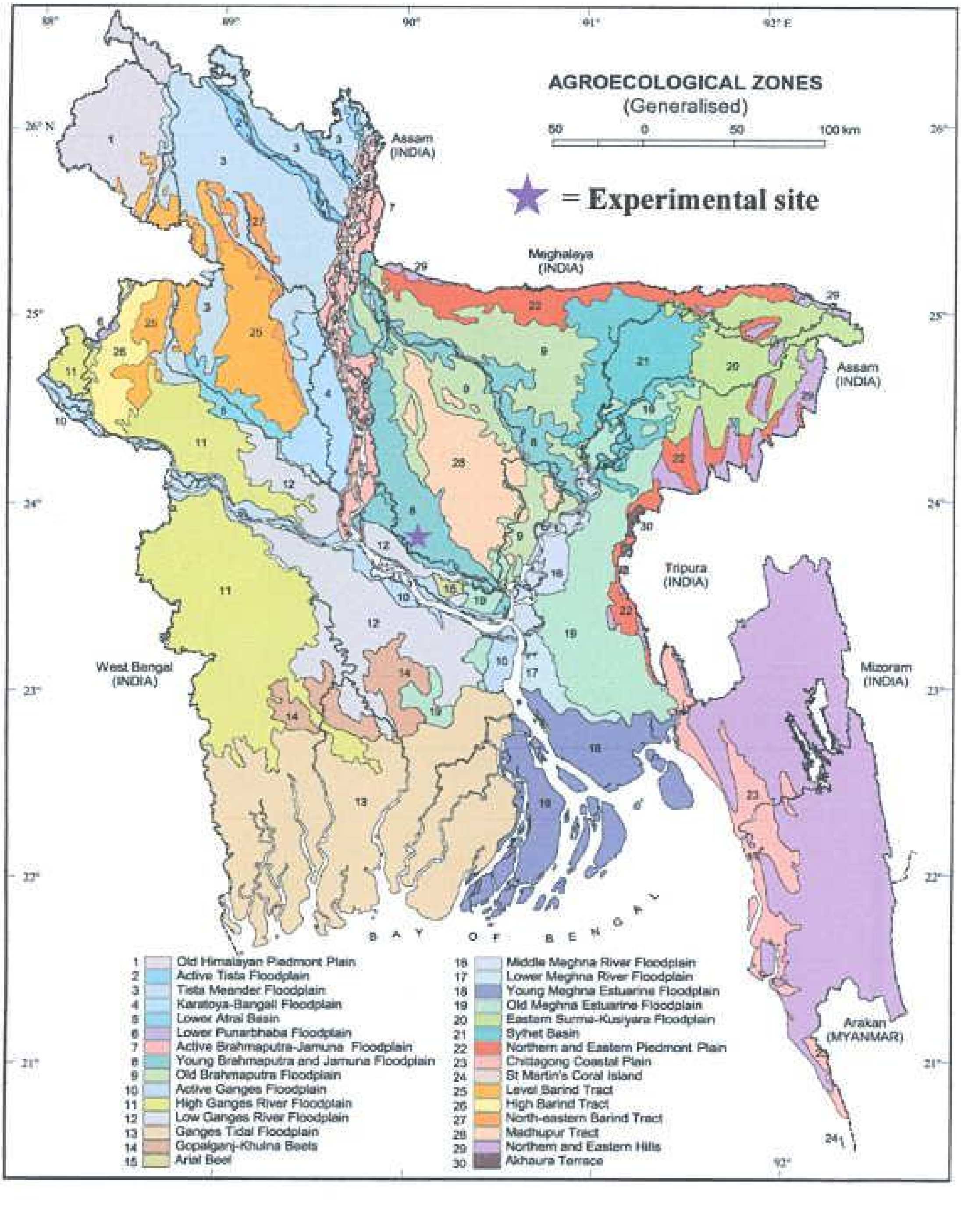
Appendices

APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Research Farm, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Deep Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)

Physical characteristics	
Constituents	**Percent**
Sand	25
Silt	47
Clay	28
Textural class	Silty clay
Chemical characteristics	
Soil characters	**Value**
pH	6.5
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (me/100 g soil)	0.10
Available B($\mu g\ gm^{-1}$)	Negligible

Source: Soil Resource and Development Institute (SRDI), Farmgate, Dhaka

Appendix III. Monthly meteorological information during the period from February, 2016 to June, 2016

Year	Month	Air temperature (^{0}C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2015	November	28.10	11.83	58.18	47
	December	25.00	9.46	69.53	0
2016	January	25.20	12.80	69	00
	February	27.30	16.90	66	39
	March	31.70	19.20	57	23
	April				

Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix IV. Analysis of variance of the data on plant height of mungbean as influenced by combined effect of potassium and boron

Source of variation	df	Mean square of plant height at different days after sowing (DAS)				
		20	30	40	50	At harvest
Replication	2	0.38	2.75	25.74	5.66	4.36
Potassium (A)	2	214.70*	171.55*	248.07*	265.87*	278.34*
Boron (B)	2	37.72*	45.78*	69.16*	76.70*	66.30*
Potassium (A) Boron (B)	4	4.21*	2.45*	12.38*	4.34*	1.26*
Error	16	1.64	5.00	12.52	14.29	21.55

*Significant at 5% level of significance

^{NS} Non significant

Appendix V. Analysis of variance of the data on plant leaves no. of mungbean as influenced by combined effect of potassium and boron

Source of variation	df	Mean square of plant leave no. at different days after sowing (DAS)				
		20	30	40	50	At harvest
Replication	2	0.20	0.45	0.07	4.06	2.46
Potassium (A)	2	5.95*	10.20*	12.81*	41.85*	38.14*
Boron (B)	2	3.25*	2.30*	3.14*	9.84*	7.85*
Potassium (A) Boron (B)	4	0.58*	0.81*	1.04*	1.95*	1.52*
Error	16	0.12	0.21	0.88	2.52	1.45

*Significant at 5% level of significance

NS Non significant

Appendix VI. Analysis of variance of the data on plant branch no. nodule no. 1st flowering pod no. and seed per pod of mungbean as influenced by combined effect of potassium and boron

Source of variation	df	Mean square of plant				
		Branch no.	Nodule no.	1st flowering	Pod no.	Seed per pod
Replication	2	0.05	0.70	7.15	2.41	0.89
Potassium (A)	2	3.77*	355.70*	32.15*	30.98*	5.69*
Boron (B)	2	2.48*	434.03*	11.15*	38.74*	11.21*
Potassium (A) Boron (B)	4	0.17*	10.48*	2.70*	1.20*	0.10*
Error	16	0.05	8.12	0.40	1.64	0.21

*Significant at 5% level of significance

NS Non significant

Appendix VII. Analysis of variance of the data on plant pod length 1000 seed weight seed yield stover yield harvest index dry matter mungbean as influenced by combined effect of potassium and boron

Source of variation	Df	Mean square of plant					
		Pod length	1000 seed weight	Seed yield	Stover yield	Harvest index	Dry matter
Replication	2	0.18	24.37	0.002	0.14	1.60	0.08
Potassium (A)	2	4.38*	103.15*	0.59*	0.08*	121.27*	2.07*
Boron (B)	2	8.14*	95.70*	0.55*	0.10*	209.93*	1.24*
Potassium (A) Boron (B)	4	0.16*	0.39*	0.017*	0.09*	9.69*	0.03*
Error	16	0.43	5.37	0.008	0.03	7.72	0.007

*Significant at 5% level of significance

NS Non significant

Appendix VIII. Analysis of variance of the data on N%, P%, K%, available B, available Ca and protein%of mungbean as influenced by combined effect of potassium and boron

Source of variation	Df	Mean square of					
		N%	P%	K%	Available B	Available Ca	Protein %
Replication	2	0.008 0.28	0.00	0.01	0.33	0.00	0.44
Potassium (A)	2	0.56*	0.007*	1.08*	8.14*	0.004*	21.80*
Boron (B)	2	0.02*	0.001	0.03*	216.96*	0.001*	0.78 NS
Potassium (A) Boron (B)	4	0.002*	0.00	0.004*	1.70*	0.00*	0.03*
Error	16	0.006	0.00	0.001	0.26	0.00	1.29

*Significant at 5% level of significance

NS Non significant