EFFECT OF POTASSIUM AND BORON ON LOW TEMPERATURE TOLERANCE IN MUNGBEAN UNDER LATE SOWING CONDITION

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MY PARENTS & TEACHERS

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CERTIFICATE

This is to certify that the thesis entitled **"Effect of Potassium and Boron on LowTemperature Tolerance in Mungbean Under Late Sowing condition"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **Master of Science (MS)** in **Agronomy**, embodies the result of a piece of bonafide research work carried out by **Mohshina Mustare Liza**, Registration number: **08-2752** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated:
Dhaka, Bangladesh

(**Prof. Dr. Md. Shahidul Islam)**
Supervisor

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ABSTRACT

The experiment was conducted at the research field of the Department of Agronomy, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207 during the period from September 2013 to January 2014 to study the effect of potassium and boron on low temperature tolerance in mungbean under late sowing condition. The experiment consisted of two factors: Factor A: Fertilizer doses (5 level)- F_0 = Recommended dose (R), F_1 = R+ Additional 10kg K ha^{-1} +1kg B ha^{-1}, F_2 = R+ Additional 20 kg K ha^{-1} +1kg B ha^{-1}, F_3 = R+ Additional 10 kg K ha^{-1} +2 kg B ha^{-1}, F_4 = R+ Additional 20 kg K ha^{-1} +2 kg B ha^{-1} and Factor B: Sowing time (2)- S_1 = 24 September, S_2 =25 October. The experiment was laid out in a split plot design with three replications where different level potassium and boron were placed on main plot and sowing time was in sub plots. Result showed that the tallest plant (40.03 cm), highest 1000-seed weight (37.53 g) and seed yield (1.12 t ha^{-1}) were found at F_3 fertilizer dose and those of the lowest were obtained from F_0. Mungbean sown on 24 September (S_1) recorded the highest values in case of plant height (50.57 cm), dry matter of leaf and stem (0.824 g and 1.147 g) at 60 DAS, pod length (7.09 cm), no. of pods $plant^{-1}$ (13.74), no. of seeds pod^{-1} (8.22), 1000-seed weight (38.34 g), seed yield (1.14 t ha^{-1}), stover yield (1.22 t ha^{-1}) and biological yield (2.36 t ha^{-1}). It was also observed that F_3 gave the highest seed yield (1.29 t ha^{-1}) which was statistically similar (1.27 t ha^{-1}) with F_2 when sown on 24 September, and F_1 gave the highest seed yield (1.06 t ha^{-1}) and significantly different from all other treatments when sown on 25 October. Results suggested that F_2 & F_1 may be recommended when sown respectively on 24 September and 25 October.

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LIST OF ACRONYMS

Abbreviation	Full meaning
AEZ	Agroecological zone
Agric.	Agriculture
Agril.	Agricultural
ANOVA	Analysis of variance
B	Boron
BARI	Bangladesh Agricultural Research Institute
cm	Centimeter
^0C	Degree Centigrade
CV	Coefficient of variation
DAS	Days after sowing
EC	Emulsifible concentrate
et al.	And others
etc.	Etcetera
g	Gram
K	Potassium
kg	Kilogram
LSD	Least significant difference
m	Meter
m^2	Meter squares
NS	Non significant
SRDI	Soil Resources Development Institute
SAU	Sher-e-Bangla Agricultural University
t ha^{-1}	Ton per hectare
var.	Variety
WHO	World Health Organization
%	Percent
@	At the rate of

CHAPTER 1
INTRODUCTION

Mungbean (*Vigna radiata L.*) is an important pulse crop of Bangladesh, which contains high graded vegetable proteins and satisfactory level of minerals and vitamins. Among the pulses area, only 8.10% lands are used for the cultivation of mungbean (Kabir, 2001). According to World Health Organization (WHO), per capita per day requirement of pulse is 45g. But in Bangladesh, only 12 g pulse is available per capita per day. About 6.01 million tons of pulse is required to meet the present per capita requirement of our country. It is generally used as 'Dhal' or summer mungbean. Only 8-10 percent of protein intake from animal sources, the rest can be met from plant sources by increasing the consumption of pulses. Besides, being a source of protein for human, mungbean has the ability to provide nitrogen fixation to soil perhaps the best of all other pulses. In mungbean increase the nitrogen fertility of soils through biological nitrogen fixation it increase soil fertility. Mungbean seed contain 51% carbohydrate, 26% protein, 3% minerals and 3% vitamins.

Mungbean is cultivated in late rabi (last week of January to first week of February), kharif-I (second week of February to first week of March) and kharif- II (first week of August to first week of September) seasons, respectively in the southern, the north & north- western and the south-western regions in Bangladesh though it is cultivated in both summer and winter seasons in many countries of the world. Mungbean cannot be cultivated in winter season most of the regions of our country specially in the northern region due to low temperature injury although its cultivated in some districts of southern region like Barisal, Barguna, Patuakhali etc. At present, the mungbean growing areas are gradually decreasing due to industrialization, housing and expansion of urban areas. Beside, its production is also decreased for not bringing large area under mungbean cultivation, specially northern regions due to low temperature problem. The present population 145 million will increase to 233 million by 2030 requiring 48 million tons of extra food grain by that year. Low temperature affects photosynthetic electron transport, stomatal conductance, rubisco activity, and CO_2 fixation in plants due to conversion of O_2 to ROS (reactive oxygen species) (Huner *et al.*, 1998; Foyer *et al.*, 2002). Low temperature stress inhibits the growth and development of plants (Xu *et al.*, 2008). The accumulation of ROS damages membrane lipids and can lead to the death of plant cells (Molassiotis *et al.*, 2006). Plants possess enzymatic and non-enzymatic antioxidants in order to scavenge ROS. The enzyme antioxidants are superoxide dismutase (SOD), catalase (CAT), guaiacol per oxidase (GPX), glutathione peroxidase (GSH-Px), ascorbate peroxidase (APX), glutathione reductase (GR), dehydroascorbate reductase (DHAR) and mono-dehydroascorbate reductase (MDHAR), while non-enzymatic antioxidants include reduced glutathione (GSH) and ascorbate (AsA) (Asada, 1992). Therefore, hampers antioxidants mechanisms in plant, there by inhibit photosynthesis as well as growth and development in mungbean. Mineral nutrition of plants plays a critical role in increasing plant resistance to environmental stresses (Marschner, 1995). Among the mineral nutrients, Potassium (K) plays a crucial role in survival of crop plants under environmental stress conditions. K is essential for many physiological processes, such as photosynthesis, translocation of photosynthates into sink organs, maintenance of turgidity and activation of enzymes under stress conditions (Marschner, 1995;Mengel and Kirkby, 2001). Under low supply of K, chilling or frost induced photo-oxidative damage can be exacerbated causing more decreases in plant growth and yield. Potassium supply in high amounts can provide protection against oxidative damage caused by chilling or frost. A high K^+ concentration activated the plant's antioxidant systems which are associated with cold tolerance (Devi *et al*, 2012). Higher K tissue concentrations reduced chilling damage and increased cold resistance, ultimately increasing yield production. Frost damage was inversely related to K concentration and was significantly reduced by K fertilization.

Boron can increase the antioxidant activities of plants and thereby alleviate ROS damage induced by temperature stress. Boron nutrition improves sugar transport in the plant body which helps to improve seed germination and seed grain formation. This in turn improves the yield by improving the temperature stress (Waraich *et al.,* 2011). B application also improves the CHO metabolism and decreases the phenolic compounds in leaves. This in turn reduces the production of ROS species and enhances the photosynthetic rate and reduces the cell damage (Waraich *et al.,* 2011). With the increasing demand of protein and to meet the challenge of 21^{st} century mungbean are needed with higher yield potential as well as management practices to impose multiple resistances to diseases, insects and resistance to a biotic stresses like low temperature. Therefore, it might have the positive effect of K and B on the late sowing induced low temperature stress tolerance in mungbean.

Objective of the research work:

The study has the following specific objectives:

- To observe the effect of late sowing on growth and yield of mungbean in kharif- II season.

- To findout the effect of K and B on low temperature tolerance in mungbean under late sowing condition.

CHAPTER 2

REVIEW OF LITERATURE

Mungbean is one of the important pulse crops in Bangladesh as well as many countries of the world. The crop has conventional less concentration by the researcher on various aspects because normally it grows without less care or management practices. For that a very few studies regarding growth, development and yield of mungbean have been carried out in our country as well as many other countries of the world. So the research work so far done in Bangladesh is not adequate and conclusive. Nevertheless, some of the important and informative works regarding the fertilizer and sowing time so far been done at home and abroad on some other fertilizer and sowing time of this crop along with their findings have been reviewed in this chapter under following heading:

2.1. Effect of Potassium and Boron on growth and yield

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.

An experiment was conducted by Pandey and Gupta (2013) to study the effect of foliar application of B on reproductive biology and seed quality of blackgram grown under controlled sand culture condition at deficient and sufficient B levels. After 32 days of sowing B deficient plants were sprayed with three concentrations of B (0.05%, 0.1% and 0.2% borax) at three different stages of reproductive development. Foliar spray at all the three concentrations and at all stages increased the yield parameters like number of pods, pod size and number of seeds formed plant^{-1}. Foliar B application also improved the seed yield of black gram.

Haque (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 experiment. The results revealed that grain and stover yield of mungbean increased with increasing levels of K and S. The maximum significant grain and stover yield were obtained with the treatment combinations K_2S_2 (25 kg K ha^{-1} + 6 kg S ha^{-1}) and The same treatments combinations gave the highest plant height, number of branch plant^{-1}, yield attributes like number of pods plant^{-1}, number of grains pod^{-1}, weight of 1000 seeds.

A field experiment was conducted by Quddus *et al*. (2012) on *Mungbean–Chickpea–T. Aman* cropping pattern at Pulses Research Sub–Station, Madaripur under Low Ganges River Floodplain Soils (AEZ–12) during 2007–08 and 2008–09 to find out the suitable fertilizer doses for this pattern. Four treatments were set up for Chickpea and Mungbean *viz.* T_1 = Recommended fertilizer dose as per FRG, 2005 BARC ($N_{15}P_{18}K_{10}S_5Zn_{0.5}B_{0.5}$); T_2 = $N_{21}P_{23}K_{30}S_{18}Zn_2B_{1.5}$; T_3 = $N_{23}P_{15}K_8$ and T_4 = Control (without fertilizer). Average of two years, the plant height of cheakpea ranged from 36.95 to 44.15 cm. The highest plant height of Chickpea was recorded in T_2, which was statistically identical to T_1 and T_3 during 2008–09 and significantly higher over the other treatments during 2007–08. Average of two years, the highest plant height (45.38 cm) of mungbean was recorded in the treatment T_2, which was statistically identical to T_1. The lowest value (39.50 cm) was being noted in the treatment T_4.

A field experiment was conducted by Quddus *et al*. (2012) on chickpea – *Mungbean–T. Aman* cropping pattern at Pulses Research Sub–Station, Madaripur under Low Ganges River Floodplain Soils (AEZ–12) during 2007–08 and 2008–09 to find out the suitable fertilizer doses for this pattern. Four treatments were set up for chickpea and Mungbean *viz.* T_1 = Recommended fertilizer dose as per FRG, 2005 BARC ($N_{15}P_{18}K_{10}S_5Zn_{0.5}B_{0.5}$); T_2 = $N_{21}P_{23}K_{30}S_{18}Zn_2B_{1.5}$; T_3 = $N_{23}P_{15}K_8$ and T_4 = Control (without fertilizer). The maximum average number of pods plant^{-1} (46.15) of chickpea was recorded in the treatment T_2 and the minimum value (36.55) was noted in the treatment T_4. The maximum and minimum number of seeds pod^{-1} was recorded in the treatment T_2 and T_4, respectively, in both the years. The average highest 100–seed weight (11.88 g) was also recorded in the treatment T_2. Similar treatment also observed the highest average seed yield (1524 kg ha^{-1}) and stover yield (4049 kg ha^{-1}). Similar results were also obtained for Mungbean. The highest mean number of pods plant^{-1} (23.10), seeds pod^{-1} (9.01), 100–seed weight (5.76 g) was recorded in the treatment T_2. The highest average seed yield (2208 kg ha^{-1}) and Stover yield (5121 kg ha^{-1}) were also found in the treatment T_2. The highest seed and Stover yield in both the years were recorded in T_2 which were significantly higher than all other treatments.

Quddus *et al.* (2011) studied to evaluate the effect of Zn and B on the yield and yield contributing characters of mungbean (*Vigna radiata* L. Wilczek) and to find out the optimum dose of Zn and B for yield maximization. There were four levels of Zn (0, 0.75, 1.5, and 3.0 kg ha^{-1} and B (0, 0.5, 1.0, and 2 kg ha^{-1}) along with a blanket dose of N_{20} P_{25} K_{35} S_{20} kg ha^{-1}. The experiment was laid out in RCBD with three replications. Results showed that the combination of $Zn_{1.5}B_{1.0}$ produced significantly higher yield (3058 kg ha^{-1}) and (2631 kg ha^{-1}, in the year 2008 and 2009, respectively. The lowest yield (2173 kg ha^{-1}) and (1573 kg ha^{-1}) were found in control (Zn_0B_0) for in the year 2008 and 2009, respectively. The combined application of Zn and B were observed superior to their single application in both the years.

Hussain *et al.* (2011) conducted an experiment to study the growth and yield responses of two cultivars of Mungbean (*Vigna radiata* L.) to different potassium levels. 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. Increased potassium levels significantly affected the plant height, growth and yield contributing parameters.

Valenciano *et al*. (2011) reported that the Spain and Europe's leading chickpea (*Cicer arietinum*) producing country and chickpea is mainly cultivated on non–irrigated soils with low native fertility. The study was carried out from 2006 to 2008 in the province of Leo´ n, Spain, under acid soil field conditions, with the aim of determining whether the application of Zn, B and molybdenum (Mo) improved chickpea growth and yield on acid soils. The main factor was Mo application, with two levels of Mo, i.e. 0 and 241 g Mo ha^{-1}. The secondary factor was B application, with two levels of B, i.e., 0 and 241 g B ha^{-1}. The tertiary factor was Zn application, with five levels of Zn, i.e., 0, 120.5, 241.0, 482.0 and 964.0 g Zn ha^{-1}. Among the fertilizer application, Zn @ 241.0 g ha^{-1} produces the maximum weight of dry leaf–stem (0.56 g plant^{-1}), pod dry weight (8.82 g plant^{-1}) and total dry matter weight (14.97 g plant^{-1}), but dry weight of root had higher (0.62 g plant^{-1}) in higher application of Zn (482.0 g ha^{-1}). In contrast, B_1 (241.0 g ha^{-1}) and Mo_1 (241.0 g ha^{-1}) had also showed greater performance on root (0.57 and 0.59 g plant^{-1}), leaf–stem (5.26 and 5.40 g plant^{-1}), pod dry weight (8.17 and 8.75 g plant^{-1}) and total dry matter weight (14.01 and 14.74 g plant^{-1}).

An experiment was conducted 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 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.

Valenciano *et al*. (2010) reported that Spain is the main chickpea (*Cicer arietinum*) producing country in Europe, despite there are few studies on micronutrient application to chickpea. The response of chickpea to the applications of Zn, B and Mo was studied in pot experiments with natural conditions and acidic soils in northwest Spain from 2006 to 2008 following a factorial statistical pattern (5×2×2) with three replications. Five concentrations of Zn (0, 1, 2, 4 and 8 mg Zn pot^{-1}), two concentrations of B (0 and 2 mg B pot^{-1}), and two concentrations of Mo (0 and 2 mg Mo pot^{-1}) were added to the pots. Chickpea responded to the Zn, B and Mo applications. There were differences between soils. The mature plants fertilized with Zn, with B and with Mo had a greater total dry matter production.

A field experiment was conducted by Sharma *et al*. (2010) for three years during *Kharif* 2001, 2002 and 2003 at Agricultural Research station, Gulbarga (Karnataka) on shallow black soil. The experiment was laid out in RCBD with three replications. There were fourteen treatment combinations comprising of control, recommended dose of fertilizer (RDF), RDF+$ZnSo_4$ (15 and 25 kg ha^{-1}), RDF + Borax (5 and 10 kg ha^{-1}), RDF + sodium molybdate (1 kg and 2 kg ha^{-1}), RDF + chelated iron (1kg and 2 kg ha^{-1}), RDF + seed treatment ($ZnSo_4$

4 g ha^{-1} seeds, Borax 4 g ha^{-1} seeds, sodium molybdate 4 gm kg^{-1} seeds and chelated iron 4 g kg^{-1} of seeds). Among the soil application, the treatment with RDF+$ZnSo_4$ 15 kg ha^{-1} recoded significantly higher plant height (196.1 cm), number of primary branches (14.3) and secondary branches (10.1) followed by the treatments RDF + $ZnSo_4$ @ 25kg ha^{-1} and RDF + Borax @ 10kg ha^{-1}. Among the seed treatments, RDF + seed treatment with sodium molybdate @ 4 g kg^{-1} seeds recorded significantly higher plant height (183.3cm), primary branches (13) and secondary branches (9.8) as compared to control.

Valenciano *et al*. (2010) studied to response of mungbean to the applications of Zn, B and Mo in pot experiments. Five concentrations of Zn (0, 1, 2, 4 and 8 mg Zn pot^{-1}), two concentrations of B (0 and 2 mg B pot^{-1}) and two concentrations of Mo (0 and 2 mg Mo pot^{-1}) were added to the pots. Harvest Index (HI) improved with the Zn application and with the Mo application. The highest HI was obtained with the $Zn_4B_2Mo_2$ treatment (60.30%) while the smallest HI was obtained with the Zn_0 B_0Mo_0 treatment (47.65%). The Zn, B and Mo applications improved seed yield, mainly due to the number of pods $plant^{-1}$. This was the yield component that had the most influence on, and the most correlation with seed yield. The highest seed yield was obtained from the $Zn_4B_2Mo_2$ treatment (4.00 g $plant^{-1}$) while the lowest was obtained from the $Zn_0B_0Mo_0$ treatment (2.31 g $plant^{-1}$). There was a low interaction between the three micronutrients. The Zn application was more efficient when it was applied with both B and Mo.

Tekale *et al*. (2009) studied to examine the impact of B, Zn and IAA singly and in different treatments combinations at flowering and pod initiation stages of pigeon pea variety Asha and ICPL81–119. Seven treatment combinations consisting of T_1 (control), T_2 (IAA+B+Zn at flower initiation, FL), T_3 (IAA+B+Zn at pod initiation, PI), T_4 (IAA+B+Zn at both FL and PI stages), T_5 (IAA only at FL and PI stages), T_6 (B+Zn at FL and PI stages) and T_7 (IAA at FL and B+Zn at PI) were tested in RBD with three replications. The data revealed that plant height increased vigorously up to 90 days and then slowed up to maturity. The differences amongst treatments were significant at all the stages except S_1 stage. The treatment T_4 was at par with other treatments. Increase in plant height was mainly attributed due to higher shoot growth through cell elongation, cell differentiation and apical dominance promoted by IAA in addition with Zn and B. The data related to number of branches plant^{-1} revealed that treatment T_4 (18.32 and 21.27 at 50% podding and maturity stages respectively) gave the maximum value as compared to other treatments. These might be due to promotion of bud and branch development by the auxins whereas B and Zn application ultimately increased the availability of other nutrients. The leaf, stem, root and total dry matter plant^{-1} varied significantly at 125 and 180 DAS. Dry matter accumulation in leaf, stem, root and total dry matter was maximum in treatment T_4 followed by T_2 at all crop growth stages.

Tekale *et al*. (2009) studied to examine the impact of B, Zn and IAA singly and in different treatments combinations at flowering and pod initiation stages of pigeon pea variety Asha and ICPL81–119. Seven treatment combinations consisting of T_1 (control), T_2 (IAA + B + Zn at flower initiation, FL), T_3 (IAA + B + Zn at pod initiation, PI), T_4 (IAA + B + Zn at both FL and PI stages), T_5 (IAA only at FL and PI stages), T_6 (B + Zn at FL and PI stages) and T_7 (IAA at FL and B + Zn at PI) were tested in RCBD with three replications. It was interesting to notice that application of T_4 (IAA + B + Zn at FL and PI stages) showed remarkable improvement in yield attributing traits as compared to T_2 (IAA + B + Zn at FL). The data related to seed yield shows that the treatments differed significantly. Highest value was noted in T_4 (24.52 g plant^{-1}) whereas T_6 was less effective with value 19.49 g plant^{-1}. Data on harvest index exhibited that all the treatments differed statistically. The maximum value was obtained with T_4 (35.78 %) and the least effect was seen in T_6 (29.18 %). These might be due to the fact that IAA promotes the prevention of pod abscission and cell elongation at suppression of abscission of pod was the major determining factor of the seed yield.

Kumar and Singh (2009) reported that balanced application of N, P, K, S, and Zn significantly increased the yield (2154 kg ha^{-1}) of Mungbean.

Parth and Bhattacharya (2009) conducted an experiment on the Effect of different levels of boron and molybdenum on growth and yield of mungbean. Boron and Molebdenum and their combined application significantly improved all growth and yield contributing characters of mungbean.

A pot experiment was 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.

Sumdanee (2009**)** conducted an experiment to evaluate the influence of Boron and Molybdenum on the growth and yield of Mungbean (*vigna radiata*) .The experiment was consist of two factors: factor A: Boron 4 levels ;0 (B_0), 1(B_1), 1.5(B_2), 2(B_3). factor B: Molybdenum 4 levels 0 (M_0), 1(M_1), 1.5(M_2), 2(M_3). The experiment was laid out in a split-plot design with three replications. Result showed that B_3 (2kg B ha^{-1}) gave the highest plant height, dry matter of plant, no. of pod $plant^{-1}$, pod length, 1000 seed weight, seed yield.

Vishwakarma *et al*. (2008) revealed that in Mungbean maximum plant height (60.33 cm) and number of branches (5.83 $plant^{-1}$) were recorded with application of borax as soil application.

Ved-Ram *et al.* (2008) found positive effects of N, P, K, S and Zn application on the plant height in mungbean.

The highest number of pods plant^{-1} (26.66), pod and kernel yield (25.46 and 16.34 tha^{-1}, respectively) were recorded with application of borax as soil application in groundnut. (Vishwakarma *et al*., 2008).

Ved-Ram *et al.* (2008) found positive effects of N, P, K, S and Zn application on the pods plant^{-1}. They also observed that the application of N, P, K, S, and Zn nutrients favoured the seeds pod^{-1} and 1000–seed weight.

Dixit and Elamathi (2007) reported that foliar application of B (0.2%) in greengram increased the number of pods plant^{-1} (181), 1000–seeds weight (28.7 g), grain yield (7.53 t ha^{-1}) .

A field experiments was conducted by Shil *et al*. (2007) on chickpea (cv. BARI Chola–5) in Calcareous Dark Grey Floodplain Soil under AEZ-11 at Jessore and Non Calcareous Grey Floodplain Soil under AEZ-13 at Rahmatpur during the rabi season of 2001–2002 and 2002–2003. The objective was to find out the optimum dose of B and Mo for yield maximization. Four levels each of B (0, 1, 2 and 2.5 kg ha^{-1}) and Mo (0, 1, 1.5 and 2 kg ha^{-1}) along with a blanket dose of $N_{20}P_{25}K_{35}S_{20}Zn_2$ kg ha^{-1} & cowdung 5 t ha^{-1} were applied in this study. The combination of $B_{2.5}$ $Mo_{1.5}$ kg ha^{-1} and $B_{2.5}$ Mo_1 kg ha^{-1} produced significantly higher yield in both the years of study at Jessore and Rahmatpur, respectively.

A field experiment was conducted by Gupta *et al*. (2007) at the Fertilizer Research Station of Chandra Sekhar Azad University of Agriculture and Technology in Pura, Uttar Pradesh, during the summer season (March to June) of 2005. A maximum seed yield of 1254 kg ha^{-1} was obtained under T_9 ($N_{22}P_{60}K_{60}S_{20}Zn_{15}B_5$). Yield under T_9 was 123% above the control. Treatments supplying less N (T_8: $N_{15}P_{60}K_{60}S_{20}Zn_{15}B_5$) or no Zn ($T_{11}$: $N_{22}P_{60}K_{60}S_{20}Zn_0B_5$) provided yields that were statistically equivalent to T_9. Stover yield followed a similar trend and varied between 1068 kg ha^{-1} in the control to 2006 kg ha^{-1} under T_9.

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).

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.

Niranjana (2005) studied to investigate the effect of B (1.0 g kg^{-1} seed), Zn (2 and 4 g kg^{-1} seed) and Mo (2 and 4 g kg^{-1} seed) as seed treatments on the growth and yield of mungbean. He observed that the micronutrient showed significant effect on growth parameters. The Zn at 4 g + Mo at 2 g kg^{-1} seed treatment recorded the highest root length (13.66 cm) and its dry weight (887.0 mg) over the control.

Garg *et al*. (2005) reported that adequate supply of K increase the photosynthesis capacity of mungbean.

Niranjana *et al*. (2005) conducted a field experiment to investigate the effect of B (1.0 g kg^{-1} seed), Zn (2 and 4 g kg^{-1} seed) and Mo (2 and 4 kg^{-1} seed) as seed treatments on the growth and yield of groundnut cv. KRG^{-1} on Alfisol, which was deficient in Zn (0.46 mg kg^{-1}) and Mo (0.032 mg kg^{-1}). He observed that the micronutrient showed significant effect on yield, oil content and growth parameters. The Zn at 4 g + Mo at 2 g kg^{-1} seed treatment recorded the highest pod yield of 24.99 t ha^{-1} over the control.

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 Mo in addition to essential major elements along with a maintenance dose of cowdung has gaining practical significance for boosting up the yield of chickpea.

Salam (2004) reported that B increased the plant growth, leaf dry matter , and root length and root nodules of bean.

An on–farm field experiment was conducted by Bhattacharya *et al*. (2004) to assess the effect of balanced fertilization on the performance of green gram (*Vigna radiate L.*) and black gram (*Vigna mungo*). Seven treatments included:

a zero fertilizer control ($N_0P_0K_0$), recommended rates of 20 kg N, 40 kg P_2O_5, and 40 kg K_2O ha^{-1} applied as N, NP, NPK, NPK plus 10 kg borax ha^{-1}, NPK plus 1 kg ammonium molybdate ha^{-1}, and the complete N P K B Mo treatment. Green gram variety, the data on plant height, dry matter production, and crop growth rate (CGR) of the two crops were recorded. The complete N P K B Mo treatment produced significantly higher plants than any other treatment at 60 days after seeding (DAS). They also reported that the complete NPK+ B+ Mo treatment produced significantly higher dry matter production in green gram and black gram than any other treatment at 60 days after seeding (DAS). This treatment also enhanced the CGR values of the both crops.

Kumar *et al.* (2004) conducted an experiment to study the effect of different potassium levels on Mungbean under custard apple based agri-horti system at Agricultural Research Farm of Rajiv Gandhi South Campus, Barkachha, Mirzapur. The experiment was conducted in a completely by randomized block design with seven treatments which were replicated thrice. These treatments were different doses of potassium, that is, 0 kg ha^{-1} (T1), 20 kg ha^{-1} (T2), 40 kg ha^{-1} (T3), 60 kg ha^{-1} (T4), 80 kg ha^{-1} (T5), 100 kg ha^{-1} (T6) and 120 kg ha^{-1} (T7). Results showed that application of different potassium levels gave varying yield. Highest yield (1096 kg ha^{-1}) was obtained with the application of 120 kg ha^{-1} potassium.

Sahai (2004) reported that Potassium application increased the availability of nitrogen and phosphorus which resulted in better plant growth.

Janakiraman *et al.* (2004) conducted a field experiments to determine that groundnut growth and yield were significantly higher when Fe, Zn and B were applied with recommended doses of NPK fertilizers. Combined application of 50 kg N ha^{-1}, 25 kg P_2O_5 ha^{-1}, 25 kg K_2O ha^{-1} along with $FeSO_4$ @10.0 kg ha^{-1}, $ZnSO_4$ @ 5.0 kg ha^{-1} and borax @ 1.0 kg ha^{-1} maximized the groundnut yield and net return.

Bhattacharya *et al*. (2004) studied to assess the effect of balanced fertilization on the performance of greengram (*Vigna radiate L.*) and blackgram (*Vigna mungo*). Seven treatments included: recommended fertilizer as control ($N_0P_0K_0$) as N, NP, NPK, NPK plus 10 kg borax ha^{-1}, NPK plus 1 kg ammonium molybdate ha^{-1}, and the complete N P K B Mo treatment. In both crops, plots receiving no fertilizer or N only exhibited similarly poor yields. Plots treated with the complete NPKBMo treatment returned the highest green gram yield (1,398 kg ha^{-1}). A similar yield response was observed in black gram although the response to micronutrients appeared less prominent. Balanced application of NPK along with B and Mo will be an effective solution for higher grain yield of pulses in red and lateritic soils. Adequate NPK fertilization increased green and black gram yields by 13% and 38% over the control. Further, inclusion of B and Mo improved yield by 38% for green gram and 50% for black gram over the control.

Application of 0.25 to 0.50 kg B ha^{-1} significantly increased pod yield of groundnut (Kumar, 2004).

Samiullah and Khan (2003) reported that Potassium application not only enhanced the availability of other nutrient but also increased the photosynthetic activity (and transportation of photosynthates from source to sink might be the main reason for increase in number of seed per pod.

Bharti *et al*. (2002) carried out a field experiment in Bihar, India during the winter of 1997–98 to observe the effects of B (0, 1.5 and 2.5 kg ha^{-1}) application on the yield and nutrition of chickpea (cv. BG 256). They reported that the mean seed yield, and stover yield , N and B content increased, whereas stover yield decreased with increasing B rates.

A field experiments were conducted by Singh *et al*. (2002) in sandy loam calcareous soil in Uttar Pradesh, India during 1995–96 to study the effect of B application on yield of pea (cv. Rachna) and blackgram (cv. PV–19). Boron was applied as borax at the rates of 1, 2, 3 and 4 kg borax ha^{-1}, with a control. Application of borax up to 4 kg ha^{-1} significantly increased the grain yield of black gram. The maximum yield was 15.4 t ha^{-1} and minimum grain yield of 1.65 t ha^{-1} was found in the control. The additional grain yield over the control was 280, 431, 899 and 1377 kg ha^{-1} at 1.0, 2.0, 3.0 and 4.0 kg borax ha^{-1}, respectively. Application of B progressively increased the grain yield of pea from 510 to 1843 kg ha^{-1} up to 4 kg borax ha^{-1}.

Chowdhury *et al.* (1998) observed that the tallest plant was found in mungbean plant receiving inoculams alone with mo and B (both 1kg ha^{-1}) as compared to all other treatments. They also reported that plant height increased 123% higher in plants B (1kg ha^{-1}) over control.

Zaman *et al*. (1996) conducted an experiment on Mungbean and observed that the application of mo (1 kg ha^{-1}) with B (2 kg ha^{-1}) produced maximum plant height compared to control.

Zaman *et al*. (1996) observed that application of B (2kg ha^{-1}) significantly increased higher plant height of Mungbean over control.

Mahajan *et al.* (1994) found that soil application of B (0.5 kg ha^{-1}) increased pod yield.

Sakal *et al*. (1988) reported increased mungbean yields with increasing levels of B from 0 to 2.5 kg ha^{-1}. Similar result also observed that by Rerkasm *et al.* (1987) in blackgram.

2.2. Effect of sowing time on growth and yield

Uddin *et al*. (2013) conducted an experiment to findout the level of phosphorous and varietal effect with different planting date on the yield and yield contributing characters of Mungbean. Among the dates of planting, September showed the highest tallest plant at harvest (62.37 cm), number of pods $plant^{-1}$ (14.70), pod length (9.267 cm), seed pod^{-1} (12.63), number of seeds $plant^{-1}$ (188.3), seed weight $plant^{-1}$ (6.965 g), seed yield (1.17 t ha^{-1}), straw yield (2.46 t ha^{-1}), 1000-seed weight (52.3 g) and the lowest on 15 October planting.

Husnain *et al*. (2013) conducted experiment at the Agronomy research field of Sher-e-Bangla Agricultural University, Dhaka, during the period from November 2013 to March 2014 to study the effect of sowing time and seed treatment on growth and yield of mungbean. The maximum weight of 1000 seed, highest grain yield, harvest index and also found maximum germination percentage and vigour index were found when mungbean was sown on 29th November and ensure the best performance.

Jahan *et al.* (2012) conducted experiment to study the effect of time of sowing on the growth and yield of BARI mung-5. Crop responded significantly to sowing time and 15 April sowing seeds produced plants having maximum plant height (68.4 cm), leaves plant^{-1} (29.33), total dry matter plant^{-1} (17.99), branches plant^{-1} (8.17), pods plant^{-1} (11.33), pod length (8.78 cm), seeds pod^{-1} (11.17), 1000 seed weight (46.52 g), seed yield plant $^{-1}$ (5.33 g), yield ha^{-1} (1.77 t) and harvest index (29.58 %) at harvest. The seed yield decreased by 36.8 and 49.9% when seed sown early (15 March) or late (15 May) due to production of lower yield component. Rehman *et al*. (2009) reported higher number of seeds pod^{-1} in mungbean plant sown in April. However, the results is contradictory to the findings of Miah *et al.* (2009) reported lower number of seeds pod^{-1} and lower number of pods plant^{-1} when mungbean sown on April. They agreed that time of sowing had greater influence on plant to grow well coupled with favourable environment condition producing maximum yield contributing characters in mungbean plants.

Paul *et al*. (2011) conducted an experiment on effect of sowing time of blackgram on its yield and plant growth in North –Western part of India. It was observed that 30th November was better date of sowing. Due to comparatively low temperature experienced by the crop in which growth of flowers, pod formation and seed development were better in perforamance. Late planting reduces the biomass production but increases harvest index. In early planting due to low temperature at flowering stage flowers and pods dropping was more resulting in poor yield.

Rashid (2011) conducted an experiment to study the **e**ffect of dates of sowing on incidence and severity of Mungbean Yellow Mosaic Virus and Cercospora Leaf spot of mungbean. Results revealed that the disease incidence of Mungbean Yellow Mosaic Virus (MYMV) of six varieties or lines, BMXK2 03000, BMXK2 03005-4 and BARI mung-6 showed highly resistance (HR), resistant (R) and resistant to moderately resistant reaction, at the sowing time of January 15, February 01- 15 and April 01 respectively. In, sowing BMXK2 03005-4 and BARI mung-6 showed moderately resistance (MR). But in MYMV disease severity BMXK2 03005-4 and BARImung-6 showed 1 scoring scale starting from January 15 to March 15 sowing. In April 01, sowing disease severity of BMXK2 03005-4 and BAR Imung-6 showed 3 scoring scale.

A field experiment was conducted by Kayan (2010) with lentil where three different sowing dates (1st, 15th and 30th October) were located into the main plots. Plant height, first pod height, biological yield per plant, number of pods per plant, number of seeds per plant, grain yield per plant, biological yield, grain yield and harvest index were recorded. Sowing date had a significant effect on yield and yield components. The most suitable period for winter lentil sowing date is between 1st and 15th of October.

Kabir *et al*. (2009) conducted an experiment to observe the effect of sowing time and cultivars on the growth and yield performance of Mungbean under rain fed condition. The study revealed that seed yield was reduced consequently as the date of sowing was delayed. The 100-seed weight was not influenced by the variation in sowing dates, which was supported by Nawaz *et al.* (1995) .Variation in sowing time beyond optimum was found to decrease the number of pods per plant and it was also reported earlier by Dixit *et al.* (1993). Bahal (1984) also found significant differences in plant height between sowing time and genotype interactions in mungbean. Gurag *et al*. (1996) conducted an experiment found that seed yield was greatly increased in 25 September to 10 October sowing and reduced if sowing delayed from 10 October.

Kawsar *et al.* (2009) conducted an experiment to identify the suitable variety and optimum sowing date for getting maximum yield of summer mungbean . The highest seed yield (969.62 kg ha^{-1}) was obtained from 2 March sowing followed by 20 February (917.54 kg ha^{-1}) and 12 March sowing (869.52 kg ha^{-1}). Sowing after 2 March gradually decreased the seed yield producing the lowest value (388.87 kg ha^{-1}) at 11 April sowing. In general, delayed sowing enhanced the maturity. BINA moog 7 yielded the highest (1201.32 kg ha^{-1}) when sown on 2 March, which was statistically similar to 20 February and 12 March sowing. Therefore, summer mungbean variety BINA moog 7 may be sown during the period from 20 February to 12 March for higher seed yield and for late sowing, BINA moog 6 may be considered as it matures earlier than others.

Sadeghipour (2008) observed the effect of sowing dates on yield and yield components of mungbean varieties in a two years field experiment was conducted during 2005 and 2006 in Iran. Results of combined analysis showed that seed yield was significantly affected by sowing dates. The maximum seed yield (102.9 gm) was obtained in June 29 sowing date because the number of pods per plant and 1000-seeds weight were also increase.

Soomro *et al.* (2003) conducted an experiment to study the effect of different sowing dates on grain yield and yield attributing components on mungbean genotypes sown during kharif under rainfed conditions. It was observed that delay in sowing caused a substaintial decrease in all the growth and development and also yield parameters. Genotypes responded significantly towards the grain yield. Maximum grain yield of 1668 kg ha^{-1} was produced by advanced breeding line (NCM-209) when sown early in the season (5th July). It was concluded that first week of July was found to be ideal time of sowing for mungbean and NCM-209 performs better than other genotypes.

Mishra *et al.* (1996) reported that seed yield decreased with delay in sowing date after 23 October and the weed free control gave the highest yield.

Ramzan *et al*. (1992) conducted an experiment to study the effect of sowing date on mungbean seed yield under rainfed conditions. Two mungbean cultivars (M28 and V6601) was planted on 4, 14 and 24th of July and August (six sowings) on a sandy loam soil during 1986 and 1987. Both the varieties planted between 4-14 July gave significantly greater seed yield and yield components. Sowing there after reduced seed yield massively. Maximum seed yield (430 kg ha^{-1}) was obtained from both varieties planted on 4 July. This sowing also produced taller plant with better yield components. The data concluded that 4-14 July is the optimum planting time for mungbean in rainfed condition of Chakwal.

Bukhtiar *et al.* (1991) observed that in lentil the higher hervest index (HI) of 42.3% in AARIL344 and 41.4% in AARIL337 was obtained from 23 November sowing. The lower HI (25.1%) was recorded in AARIL355 sown on 26 September. The last week of October was found better with an optimum range from the end of September to 2^{nd} week of November. Yeild of lentil varied significantly for different sowing date.

In Sudan, El-Sanag and Nourai (1983), found that delaying sowing from 1 October until 21 October increased seed yield by 217 %, while sowing after the first week in November generally significantly reduced yield.

After studying the above information and literature related to the effect of potassium and boron and sowing time, it can be concluded that potassium and boron and sowing time have significant effect on the growth and yield of mungbean under late sowing condition.

CHAPTER 3
MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University Farm during the period between September 2013 and January 2014 to study the effect of potassium and boron on low temperature tolerance in Mungbean under late sowing condition. The details of the materials and methods used in this experiment are presented under the following headings:

3.1. Experimental site

The experiment was conducted at the farm field of Sher-e-Bangla Agricultural University, Dhaka. The experimental site is located between $23^0 74^/$ latitude and $95^0 35^/$ longitude (Anon, 1989).

3.2. Climate

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 and presented in Appendix II.

3.3. Soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) corresponding AEZ No. 28 and is shallow red brown terrace soil. The land of the selected experimental plot is medium high under the Tejgaon series (FAO, 1988).

3.4. Planting materials / crop

In this research work the experimental material consisted of BARImung-6 and one macro (K) and one micro (B) nutrient fertilizer.

3.5. Description of BARImung-6

BARIMung-6

This variety was introduced from AVRDC (NM- 94). Medium plant stature, Plant height is 60-65 cm. Resistant to yellow mosaic virus (YMV) and Cercospora leaf spot (CLS). Photo - insensitive, bold seed size with green seed coat. Protein 21.2%; CHO 46.8 %. Head dhal Yield 67.2% .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: 55-60 days.

3.6. Seed collection

Seed of BARImung-6 was collected from Pulse Division of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Dhaka-1207.

3.7. Preparation of experimental plot

The land of the experimental plot was prepared with a power tiller on 23 September 2013. All kind of weeds and residues of previous crops was removed from the field. The field layout was made on 24 September, 2013 according to split plot design.

3.8. Fertilizer management

The full amount of N, P, K and B was applied at the time of final land preparation in the forms of urea, triple super phosphate, muriate of Potash and boric acid, respectively. Mungbean is recommended to be applied urea, TSP, MP and boric acid @ 45, 100, 58 kg ha^{-1}, respectively (BARI, 1998) during final land preparation. The experimental plots were fertilized as per treatment.

3.9. Experimental Treatment

Two sets of treatments included in the experiment were as follow:

Factor A: Fertilizer dose- 5

F_0 = Recommended dose (R) [BARI, 1998]

F_1 = R+ Additional 10 kg K ha^{-1} + 1 kg B ha^{-1}

F_2 = R+ Additional 20 kg K ha^{-1} + 1 kg B ha^{-1}

F_3 = R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}

F_4= R+ Additional 20 kg K ha^{-1}+ 2 kg B ha^{-1}

Factor B: Sowing time - 2

S_1: 24 September

S_2: 25 October

3.10. Experimental design

The experiment was conducted following split plot design with three replications assigning fertilizer in the main plot and sowing time in the sub-plot. Total no. of experimental plot was 30. The size of experimental plot was $3m^2$ (2m x1.5 m). Spacing between two main plot was 30 cm. Spacing between the two unit plot was 25 cm respectively.

3.11. Sowing method

Mungbean (var. BARI Mung-6) seed was sown apart rows maintaining. Row to row distance was 30cm. Seed to seed distance was 10 cm. The sowing date was maintained as per treatment.

3.12. Intercultural operation

Thinning was done at 7 days after emergence of seed for every sowing time . Weeding was done at 20-25 days after emergence of seed. Mulching was done at 30-35 days after emergence of seedlings. The crop plants were attacked by *Cercospora* leaf spot at early stage and by pod borer at later stage. Bavistin 50

EC and Diazinon 60 EC were sprayed at the rate of 10 gm liter^{-1}, respectively to control that pest.

3.13. Harvesting

Harvesting was done when 90% of the pod became blackish in color. Before harvesting 3 sampling plant from each plot was marked and harvested for recording the data on different yield contributing characters. The crop was harvested from prefixed 1.0 m^2 area. The pods from the rest of the plants of prefixed 1 m^2 area were collected at each harvest in time plot wise and were bagged separately, tagged and brought to the threshing floor for yield data. The stover yield was taken from the plants of the same area by sun–drying.

3.14. Threshing

The Pods were sun dried for three days by placing them on the open threshing floor. Seeds were separated from the pods by beating with bamboo sticks.

3.15. Drying, cleaning and weighing

The seeds collected by threshing were dried in the sun to reduce the seed moisture at safe moisture content level. The dried seeds were cleaned and weighed. The stover was also sun dried and weighed.

3.16. Recording of Data

A. Crop growth data

Data regarding crop growth parameters were recorded on plant height and dry matter of leaves, stem at 10 days interval starting from 20 DAS and continued up to 60 DAS.

B. Yield contributing data

Days to flowering

Pod length (cm)

No. of pods plant^{-1}

No. of seeds pod^{-1}

Thousands seed weight

C. Yield and harvest index

Seed yield

Stover yield

Biological yield

Harvest index

3.17. Experimental measurements

i) Plant height (cm) at 10 days interval up to 60 DAS

The height of the 3 selected plants were measured by a meter scale from the ground level to the tip of the plant from 20 to 60 DAS at 10 days interval and the mean height was expressed in cm.

ii) Dry matter of leaves (g) at 10 days interval up to harvest

Dry matter of leaves (g) data were collected by uprooting 3 plants from the field and plucking the leaf from the plant .Collected leaves were sun dried for 24 hours then packed on paper made packages and oven dried the sample for 72 hours at 70°C. The oven dried samples were weighed (g) and counted for dry matter of leaf.

iii) Dry matter of stem at 10 days interval up to harvest

Dry matter of stems data were collected by uprooting 3 plant from the field and after plucking the leaf from the plant, stems were sun dried for 24 hours then packed on paper made packages and oven dried the sample for 72 hours at 70°C. The oven dried samples were weighed (g) for dry matter of stem and counted for dry matter of stem.

iv) Days to flowering

Days to 1st flowering was measured by counting the number of the days required to start flower initiation in each plot.

v) Pod length

Pod length was measured in centimeter (cm) scale from randomly selected 10 pods. Mean value of these pod lengths were recorded as treatment wise.

vi) No. of pods plant^{-1}

Number of total pods of 3 randomly selected plants from each plot was counted and the mean no. was expressed as plant^{-1} basis. Plants were selected from the inner row of each plot.

vii) No. of seeds pod^{-1}

The number of seeds pod^{-1} was recorded from randomly selected ten pods at harvest. Data were recorded as the average of 10 pods selected at random from each plot.

viii) 1000-seed weight

One thousand cleaned, dried seeds were counted randomly from each harvest sample and weighed by using a digital electric balance and weight was expressed in gram (g).

ix) Seed yield

Pods collected from plants of pre-demarkated central 1m^2 area, were considered for taking yield data. Pods were collected thrice from that plants and the seeds collected from that pods were adjusted at 12 % moisture content by sun-drying. The weights of that seeds were taken and yield was expressed in ton per hectare.

x) Stover yield

The stover collected from the central 1 m^2 area of each plot was sun dried properly. The weight of stover was taken and converted the yield ton per hectare.

xi) Biological yield

The summation of economic yield (grain yield) and biomass yield (stover yield) was considered as biological yield. Biological yield was calculated by using the following formula:

Biological yield = Grain yield + Stover yield (dry weight basis)

xii) Harvest index

It is the ratio of economic yield to biological yield and was calculated with the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

3. 18. Data Analysis

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 at 5% probability level (Gomez and Gomez, 1984).

CHAPTER 4
RESULTS AND DISCUSSION

The present study was conducted to determine the effect of potassium and boron on low temperature tolerance in mungbean under late sowing condition. Data on different growth, yield contributing characters and yield were recorded to find out the suitable dose of fertilizer to alleviate the low temperature stress. The analyses of variance (ANOVA) of the data on different growth and yield parameters are presented in Appendices. The results have been presented with the help of table and graphs and possible interpretations given under the following headings:

4.1. Effect of different levels of Potassium and Boron fertilizer dose

4.1.1. Plant height

Plant height varied significantly by different levels of Potassium and Boron fertilizer doses (Figure 1 and Appendix III) throughout the growing period except 20, 40 and 50 DAS. At 30 DAS F_4 (R+ Additional 20 kg K ha^{-1} + 2 kg B ha^{-1}) gave the tallest plant (30.96 cm) which was statistically similar with F_3 (28.1 cm) and at 60 DAS F_3 (R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}) gave the tallest plant (40.03 cm). At 30 DAS F_0 (Recommended dose) gave the shortest plant (27.96 cm). At 60 DAS F_2 gave the shortest (35.23 cm) plant which was statistically similar with F_0. 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 over control. Significant increase in plant height induced by different doses of B was observed in mungbean (Quddus *et al*., 2011). They reported that B significantly influenced on plant height where 1.0 kg ha^{-1} B noticed the highest plant height. Kaisher *et al*. (2010) also found significant variation in plant height where the tallest plant was in 5 kg B ha^{-1} and the shortest from control. Similarly, Vishwakarma *et al*. (2008) and Singaravel *et al*. (2006) also found significant variation in plant height of groundnut with application of borax as soil application. Hussain *et al* .(2011) stated that increased amount of potassium levels significantly affected the plant height. Gowthmia (2013) stated that application of potassium nitrate and boric acid increased the plant height.

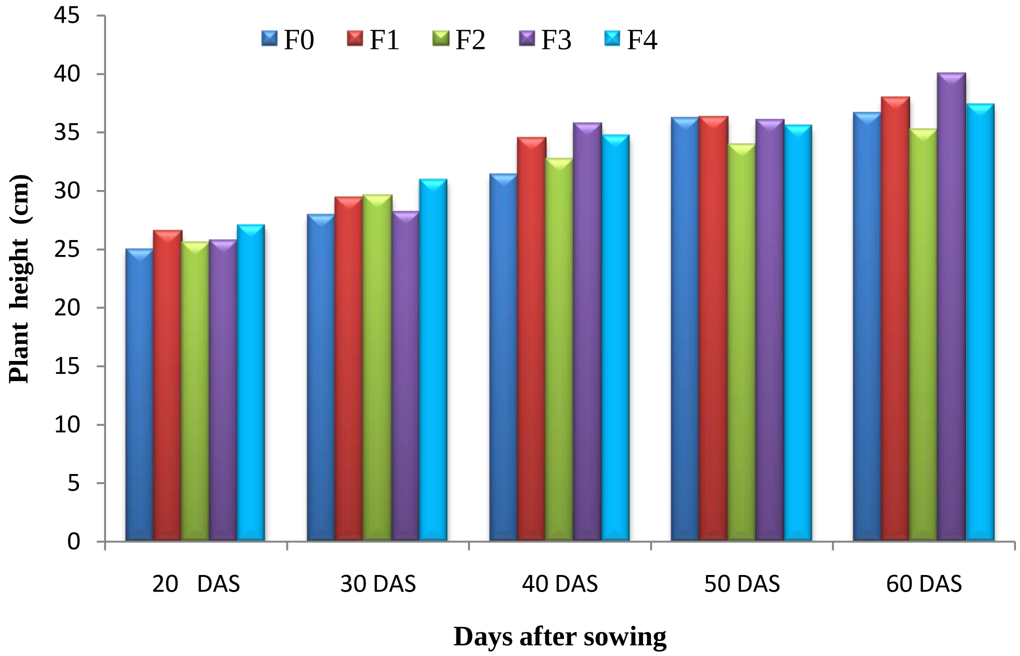

Figure 1. Plant height of mungbean at different DAS as influence by different level of Potassium and Boron fertilizer dose (LSD value = 3.90, 2.88, 5.78, 3.25 and 1.75 at 20, 30, 40, 50 and 60 DAS, respectively)

F_0 = Recommended dose (R), F_1 = R+ Additional 10 kg K ha^{-1} + 1 kg B ha^{-1}, F_2 = R+ Additional 20 kg K ha^{-1} + 1 kg B ha^{-1} , F_3 = R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}, F_4= R+ Additional 20 kg K ha^{-1} + 2 kg B ha^{-1}

4.1.2. Dry matter of leaf

Dry matter of leaf was significantly varied by different levels of Potassium and Boron fertilizer doses (Figure 2 and Appendix IV) throughout the growing period except 20, 60 DAS. At 30, 40, 50 DAS highest dry matter of leaf (0.48, 1.42, 0.89 g respectively) was found from F_3 (R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}) fertilizer dose. At 30 DAS lowest dry matter of leaf (0.26 g) was recorded from F_1 which is statistically similar with F_0. The lowest dry matter of leaf (0.74, 0.40 g) was obtained from F_0 (Recommended dose) at 40, 50 DAS. Salam (2004) reported that B increased the plant growth, leaf dry matter of mugbean. This result is in agreement with Valenciano *et al.* (2011) who reported that B (241.0 g ha^{-1}) showed greater performance to leaf–stem, total dry matter weight of plant. Gowthmia (2013) stated that application of potassium nitrate and boric acid increased the total dry matter of plant.

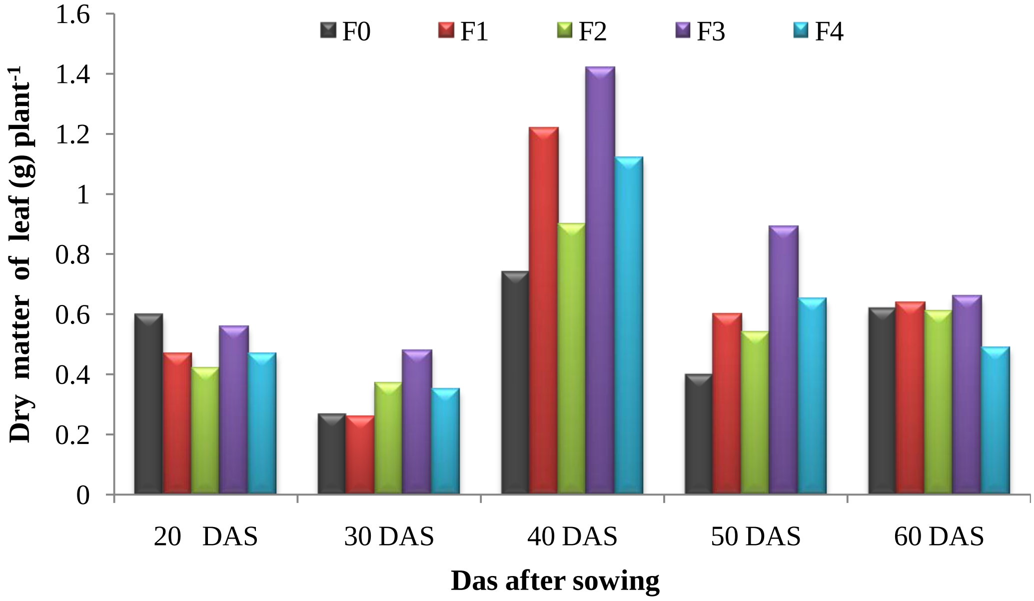

Figure 2. Effect of different levels Potassium and Boron fertilizer dose on dry matter of leaf of mungbean plant at different DAS
(LSD = 0.19, 0.05, 0.16, 0.17, 0.18 at 20, 30, 40, 50 and 60 DAS, respectively)

F_0 = Recommended dose (R), F_1 = R+ Additional 10 kg K ha^{-1} + 1 kg B ha^{-1}, F_2 = R+ Additional 20 kg K ha^{-1} + 1 kg B ha^{-1}, F_3 = R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}, F_4= R+ Additional 20 kg K ha^{-1} + 2 kg B ha^{-1}

4.1.3. Dry matter of stem

Significant variation was observed by different levels of Potassium and Boron fertilizer doses for dry matter production of stem throughout the growing period except 20, 30, 60 DAS (Figure 3 and Appendix V). At 40 DAS the highest dry matter of stem (0.97 g) was recorded from F_1 (R + Additional 10 kg K ha^{-1} + 1 kg B ha^{-1}). At 50 DAS the highest dry matter of stem (.68 g) was recorded from F_0 which was statistically similar with F_1, F_3. At 40 and 50 DAS the lowest (0.23 and 0.37 g) was found from F_2.

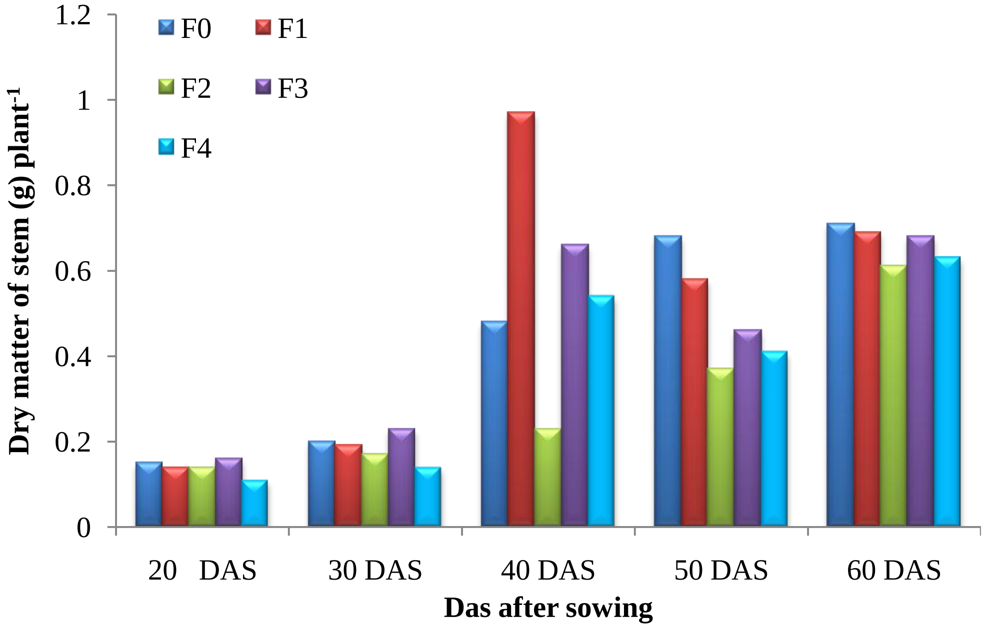

Figure 3. Effect of different levels Potassium and Boron fertilizer dose on dry matter of stem mungbean plant at different DAS (LSD = 0.05, 0.11, 0.13, 0.23 and 0.33 at 20, 30, 40, 50 and 60 DAS, respectively)

F_0 = Recommended dose (R), F_1 = R+ Additional 10 kg K ha^{-1} + 1 kg B ha^{-1}, F_2 = R+ Additional 20 kg K ha^{-1} + 1 kg B ha^{-1}, F_3 = R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}, F_4= R+ Additional 20 kg K ha^{-1} + 2 kg B ha^{-1}

4.1.4. Pod length

Due to different levels of Potassium and Boron fertilizer dose pod length of mungbean did not vary significantly (Table 1). But numerically, the longest pod (5.76 cm) was obtained from F_1 (R+ Additional 10 kg K ha^{-1} + 1 kg B ha^{-1}) and shortest (5.35 cm) was found in F_3 (R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}).

Table 1. Yield contributing character of Mungbean influenced by different levels of Potassium and Boron fertilizer dose

Treatment	Pod length (cm)	No. of pods plant^{-1}	No. of seeds pod^{-1}	1000-seed weight (g)	Days to flower
F_0	5.61	10.05	6.14 ab	30.38 c	37.17 a
F_1	5.76	11.53	7.10 a	36.90 ab	34.67 ab
F_2	5.52	10.05	5.22 b	34.98 b	32.00 cd
F_3	5.34	11.44	6.84 ab	37.53 a	29.83 d
F_4	5.63	9.72	7.16 a	32.43 c	34.00 bc
$LSD_{(0.05)}$	**NS**	**NS**	**1.85**	**2.15**	**2.62**
CV(%)	**12.64**	**22.74**	**15.19**	**3.32**	**4.16**

In a colum means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05 level of significance
F_0 = Recommended dose (R), F_1 = R+ Additional 10 kg K ha^{-1} + 1 kg B ha^{-1}, F_2 = R+ Additional 20 kg K ha $^{-1}$ + 1 kg B ha^{-1}, F_3 = R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}, F_4 = R+ Additional 20 kg K ha^{-1} + 2 kg B ha^{-1}

4.1.5. No. of pods plant^{-1}

Statistically non significant variations in no. of pods plant $^{-1}$ was observed at different levels of potassium and Boron fertilizer dose (Table 1). But Numerically, the treatment F_1 (R+ Additional 10 kg K ha^{-1} + 1 kg B ha^{-1}) gave the highest no. of pods plant $^{-1}$ (11.53) and the treatment F_4 (R+ Additional 20 kg K ha^{-1} + 2 kg B ha^{-1}) gave the lowest no. of pods plant $^{-1}$ (9.72).

4.1.6. No. of seeds pod^{-1}

No. of seeds pod^{-1} was significantly influenced by different levels of Potassium and Boron fertilizer dose (Table 1). Results showed that the maximum no. of seeds pod^{-1} (7.16) was recorded from F_4 (R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}) fertilizer dose which was statistically similar with F_3 , F_1. The minimum no. of seeds pod^{-1} (5.22) was obtained with F_2 which was statistically at par with F_0 (Recommended dose). This result was supported by Valenciano *et al.* (2011) who reported that B_1 (241.0g ha^{-1}) produced th**e** 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 no. of seeds pod^{-1}. Haque *et al.* (2013**)** reported that number of grains pod^{-1} increased with increasing levels of K.

4.1.7. 1000- seed weight

Weight of 1000-seed was significantly influenced by different levels of Potassium and Boron fertilizer dose (Table 1). Result showed that the highest 1000-seed weight (37.53 g) was observed from F_3 (R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}) fertilizer dose and the lowest (30.38 g) from F_0 (Recommended dose). Valenciano *et al.* (2011) reported that $\mathbf{B_1}$ (241.0 g ha^{-1}) produced th**e** 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 seeds increased with increasing levels of K.

4.1.8. Days to flower

Significant variation was observed in days to flower due to different levels of Potassium and Boron fertilizer dose (Table 1). Results showed that the highest days to flower (37.17 days) was recorded with F_0 (Recommended dose) fertilizer dose which was statistically at par with F_1 (R+ Additional 10 kg K ha^{-1} + 1 kg B ha^{-1}) and the lowest days to flower (29.83 days) with F_3 (R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}) which was statistically similar with F_2 (R+ Additional 20 kg K ha^{-1} + 1 kg B ha^{-1}) fertilizer dose.

4.1.9. Seed yield

Seed yield showed significant difference due to application of different levels of Potassium and Boron fertilizer dose on Mungbean (Figure 4 and Appendix VII). All other doses showed highest seed yield than recommended doses. The highest seed yield (1.12 t ha^{-1}) was recorded with F_3 (R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}) fertilizer dose which was statistically similar with F_1, F_2 and the lowest seed yield (0.80 t ha^{-1}) was with F_0 (Recommended dose). Kaisher *et al*. (2010) found that B at 5 kg ha^{-1} significantly increased the yield of mungbean. Similarly, Quddus *et al.* (2011) also found that the highest seed yield 1040 kg ha^{-1} was recorded with B level 1.5 kg ha^{-1} which was statistically identical with B level 1.0 kg ha^{-1} but significantly higher than that of others. The yield increased 13.8% with boron level 1.5 kg ha^{-1} over control. Gowthmia (2013) stated that application of potassium nitrate and boric acid increase the seed yield.

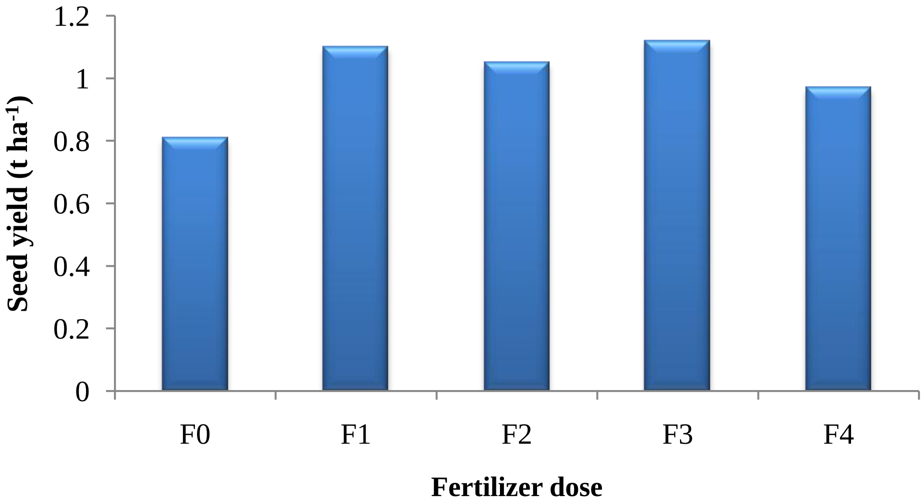

Figure 4. Seed yield of mungbean plant influenced by different levels of Potassium and Boron fertilizer doses (LSD=0.08)

F_0 = Recommended dose (R), F_1 = R+ Additional 10 kg K ha^{-1} + 1 kg B ha^{-1}, F_2 = R+ Additional 20 kg K ha^{-1} + 1 kg B ha^{-1}, F_3 = R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}, F_4 = R+ Additional 20 kg K ha^{-1} + 2 kg B ha^{-1}

4.1.10. Stover yield

Application of different levels of Potassium and Boron fertilizer showed significant variation in term of stover yield (Figure 5 and Appendix VII). Results showed that the highest stover yield (1.81 t ha^{-1}) was recorded from F_1 (R+ Additional 10 kg K ha^{-1} + 1 kg B ha^{-1}) and the lowest was observed from (0.71 t ha^{-1}) F_2 (R+ Additional 20 kg K ha^{-1}+ 1 kg B ha^{-1}) which was significantly at par with F_0 (Recommended dose). Similarly, Quddus *et al*., (2011) also found that the treatment combination of $N_{21}P_{23}K_{30}S_{18}Zn_2B_{1.5}$ produced significantly the highest average stover yield (4049 kg ha^{-1}). Haque *et al.* (2013**)** stated that stover yield of mungbean increased with increasing levels of K .

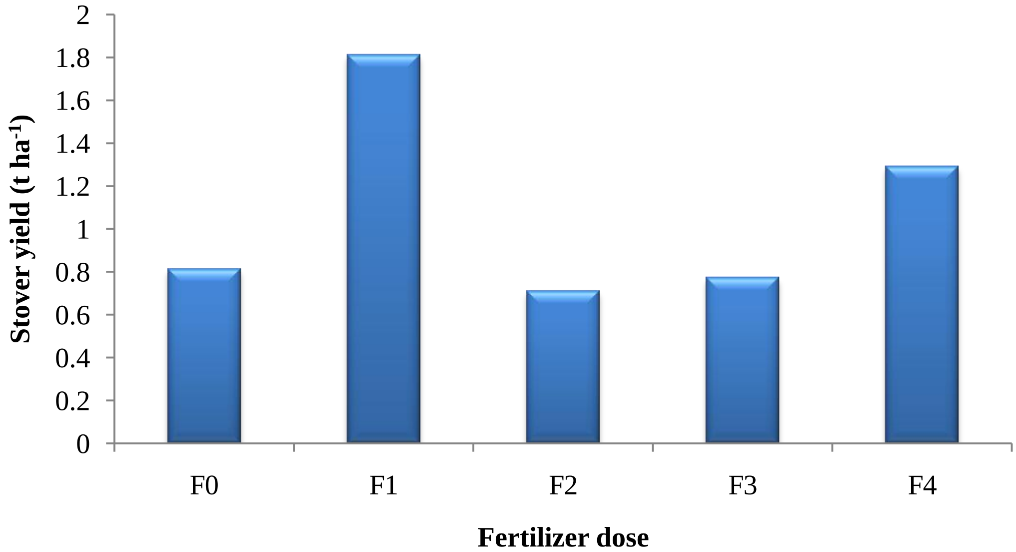

Figure 5. Stover yield of mungbean plant influenced by different levels of Potassium and Boron fertilizer doses (LSD=0.18)

F_0 = Recommended dose (R), F_1 = R+ Additional 10 kg K ha^{-1} + 1 kg B ha^{-1}, F_2 = R+ Additional 20 kg K ha^{-1} + 1 kg B ha^{-1}, F_3 = R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}, F_4 = R+ Additional 20 kg K ha^{-1} + 2 kg B ha^{-1}

4.1.11. Biological yield

Different levels of Potassium and Boron fertilizer application significantly influenced the biological yield of mungbean in the present study (Figure 6 and Appendix VII). Application of F_1 (R+ Additional 10 kg K ha^{-1} + 1 kg B ha^{-1}) fertilizer dose showed the highest biological yield due to higher grain and Stover yield and F_0 (Recommended dose) showed the lowest biological yield due to poorer grain and stover yield.

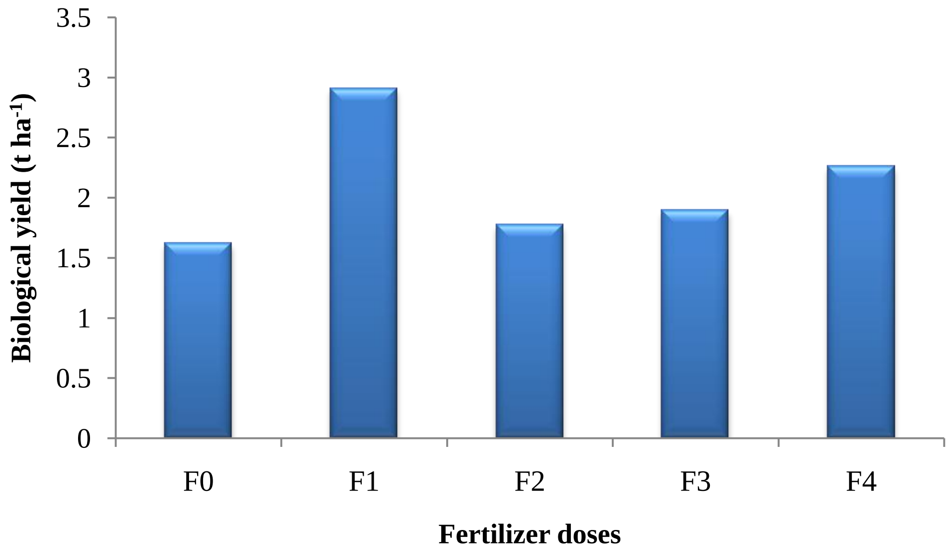

Figure 6. Effect of different levels Potassium and Boron fertilizer doses on biological yield of mungbean (LSD value= 0.1)

F_0 = Recommended dose (R), F_1 = R+ Additional 10 kg K ha^{-1} + 1 kg B ha^{-1}, F_2 = R+ Additional 20 kg K ha^{-1} + 1 kg B ha^{-1}, F_3 = R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}, F_4 = R+ Additional 20 kg K ha^{-1} + 2 kg B ha^{-1}

4.1.12. Harvest index

Harvest index was significantly varied by different levels of Potassium and Boron fertilizer (Figure 7 and Appendix VII). The Highest harvest index (60.2 %) was recorded from F_2 (R+ Additional 20 kg K ha^{-1} + 1 kg B ha^{-1}) which was statistically similar with F_3 (R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}) due to higher grain yield and poorer stover yield. The lowest (37.73 %) was found from F_1 (R+ Additional 10 kg K ha^{-1} + 1 kg B ha^{-1}) due to poorer grain yield and higher stover yield.

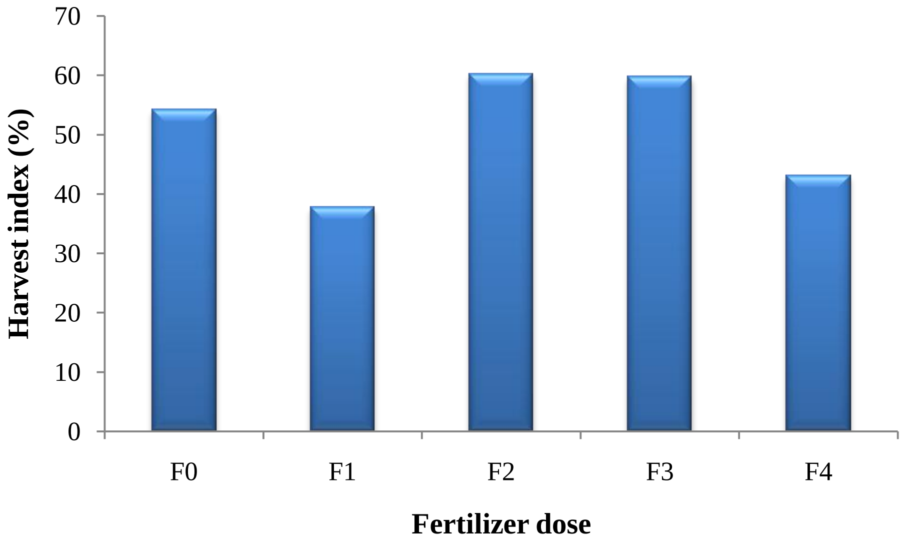

Figure 7. Effect of different levels Potassium and Boron fertilizer doses on harvest index (LSD value= 4.53)

F_0 = Recommended dose (R), F_1 = R+ Additional 10 kg K ha^{-1} + 1 kg B ha^{-1}, F_2 = R+ Additional 20 kg K ha^{-1} + 1 kg B ha^{-1}, F_3 = R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}, F_4 = R+ Additional 20 kg K ha^{-1} + 2 kg B ha^{-1}

4.2. Effect of sowing time

4.2.1. Plant height

Sowing time significantly influenced plant height of mungbean in the present study (Figure 7 and Appendix III). The tallest plant (37.66, 41.26, 47.23, 49.08 and 50.57 cm) was recorded from S_1 (24 September) at 20, 30, 40, 50 and 60 DAS, respectively and the shortest plant (14.62, 17.18, 20.40, 22.13 and 24.30 cm) was observed in S_2 (25 October) at 20, 30, 40, 50 and 60 DAS, respectively. This result is supported by Soomro *et al.* (2003) who reported that delay in sowing caused a substaintial decrease in all the growth parameter of mungbean.

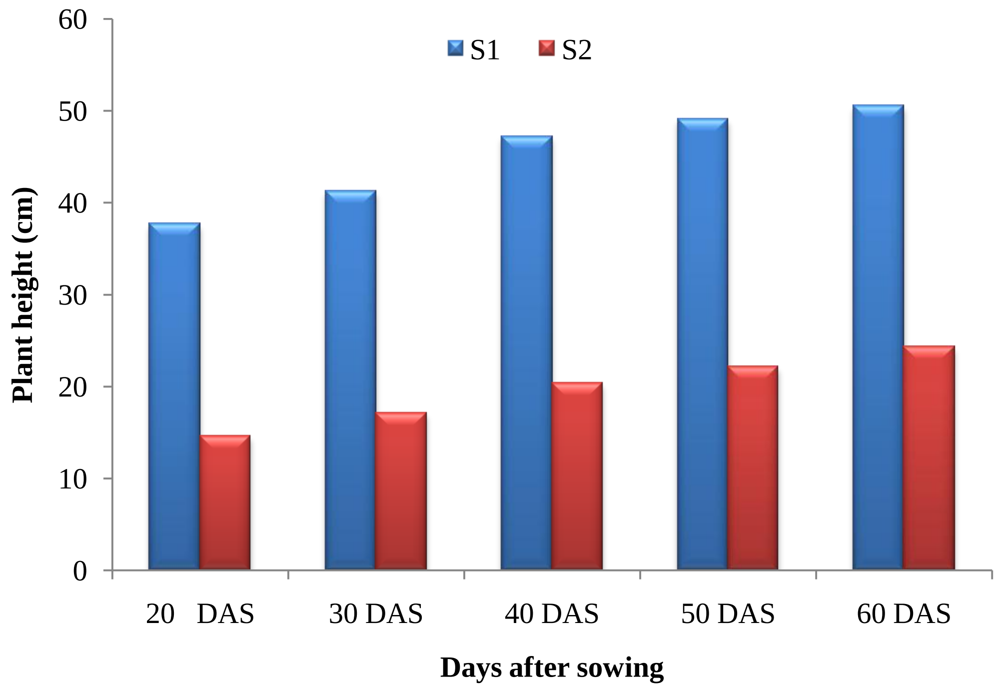

Figure 8. Effect of sowing time on plant height of mungbean plant at different days after sowing (LSD= 1.27, 1.70, 1.78, 1.46 and 0.81 at 20, 30, 40, 50 and 60 DAS, respectively)

S_1 = First sowing (24 September), S_2 = Second sowing (25 October)

4.2.2. Dry matter of leaf

Dry matter of leaf was significantly varied by sowing time throughout the growing period (Figure 8 and Appendix IV). The highest dry matter of leaf (0.89, 0.60, 1.83, 1.02 and 0.82 g) was found from S_1 (24 September) at 20, 30, 40, 50 and 60 DAS, respectively and the lowest was (0.12, 0.09, 0.34, 0.21and 0.39g) recorded in S_2 (25october) at 20, 30, 40, 50 and 60 DAS, respectively.

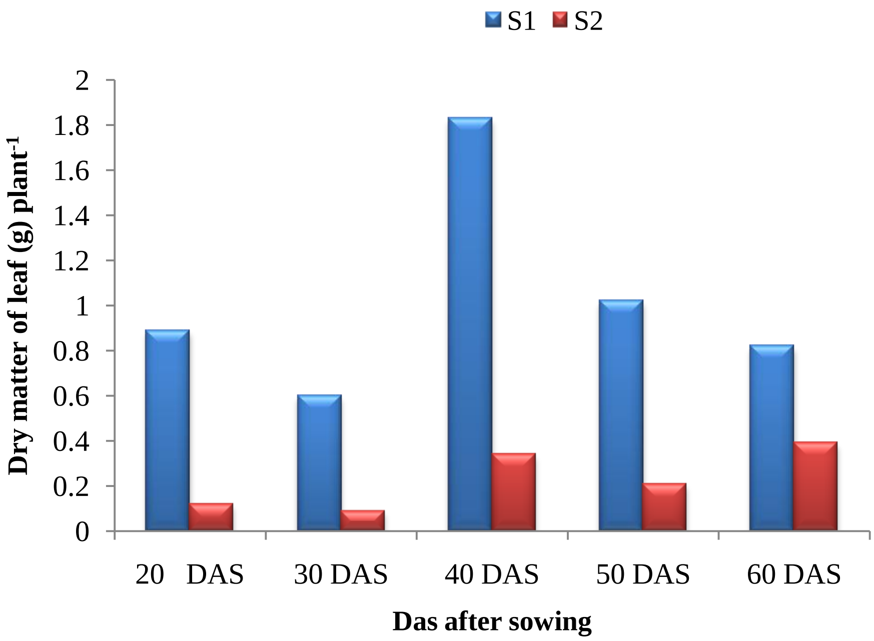

Figure 9. Effect of sowing time on dry matter of leaf of mungbean plant at different days after sowing (LSD = 0.07, 0.01, 0.07, 0.06 and 0.08 at 20, 30, 40, 50 and 60 DAS respectively)

S_1 = First sowing (24 September), S_2 = Second sowing (25 October)

4.2.3. Dry matter of stem

Statistically significant variation was recorded for dry matter of stem (Figure 9 and Appendix V). The highest dry matter of stem (0.23, 0.30, 0.9, 0.88 and 1.14 g) was obtained from S_1 (24 September) at 20, 30, 40, 50 and 60 DAS and the lowest dry matter of stem (0.06, 0.07, 0.16, 0.12 and 0.18 g) was obtained in S_2 (25 October) at 20, 30, 40, 50 and 60 DAS respectively.

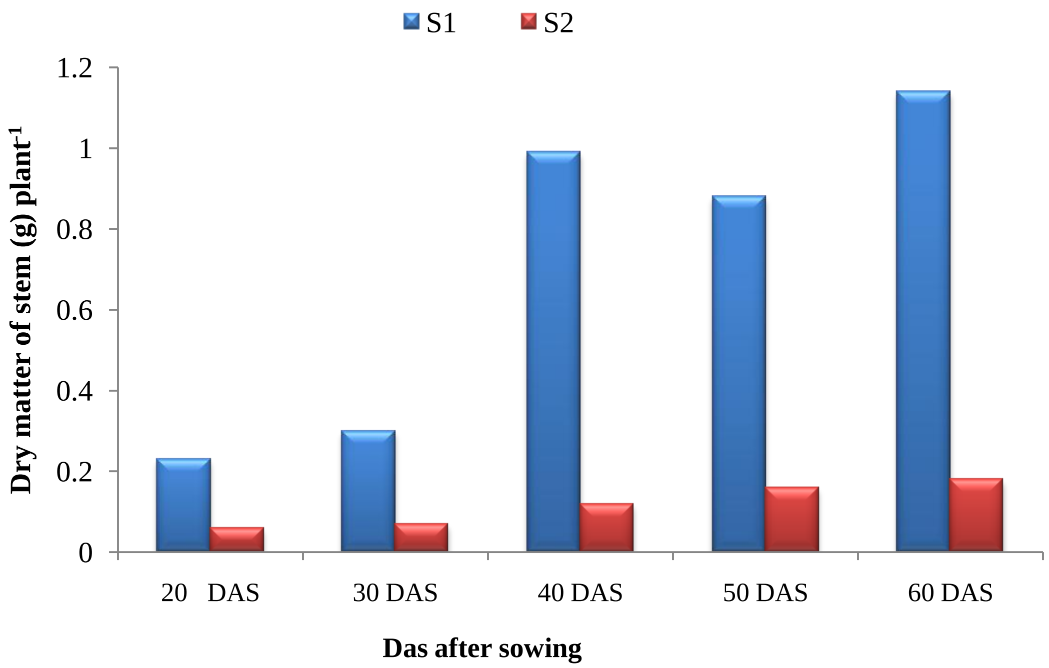

Figure 10. Effect of sowing time on dry matter of stem of mungbean plant at different days after sowing (LSD = 0.02, 0.02, 0.08, 0.08 and 0.14 at 20, 30, 40, 50 and 60 DAS, respectively)

S_1 = First sowing (24 September), S_2 = Second sowing (25 October)

4.2.4. Pod length

Different sowing time showed significant differences in pod length of mungbean (Table 2). Results showed that the longest pod (7.09 cm) was found from S_1 (24 September) and the shortest pod (4.05 cm) was found in S_2 (25 October).

Table 2. Yield contributing character of mungbean as influenced by sowing time

Treatment	Pod length (cm)	No. of pods plant^{-1}	No. of seeds pod^{-1}	1000 - seed weight (g)	Days to flower
Sowing time					
S_1	7.09 a	13.74 a	8.22 a	38.35 a	29.66 b
S_2	4.05 b	7.37 b	4.76 b	30.54 b	37.40 a
$LSD_{(0.05)}$	**0.57**	**1.64**	**1.21**	**1.12**	**0.89**
CV(%)	**12.65**	**19.1**	**22.9**	**4.02**	**3.27**

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly at 0.05 level of significance

S_1 = First sowing (24 September), S_2 = Second sowing (25 October)

4.2.5. No. of pods plant^{-1}

No. of pods plant $^{-1}$ was significantly influenced by different sowing time in the present study (Table 2). Results showed that the maximum no. of pods plant^{-1} (13.74) was found in S_1 (24 September) and the minimum no. of pods plant^{-1} (7.37) was observed from S_2 (25 October). Kabir *et al*. (2009) stated that decrease the no. of pods plant^{-1} beyond optimum sowing time. Variation in sowing time beyond optimum was found to decrease the no. of pods plant^{-1} also reported earlier by Dixit *et al.* (1993).

4.2.6. No. of seeds pod^{-1}

Different sowing time showed significant variation in no. of seeds pod^{-1} (Table 2). The maximum no. of seeds pod^{-1} (8.22) was found from S_1 (24 September) and the minimum no. of seeds pod^{-1} (4.76) was obtained from S_2 (25 October).

4.2.7. 1000- seed weight

Weight of 1000-seed was varied significantly due to different sowing time (Table 2). The highest 1000 seed weight (38.34 g) was recorded from S_1 (24 September) and the lowest 1000 seed weight (30.54 g) was obtained from S_2 (25 October). This result is an agree with Uddin *et al*. (2013) that September sowing showed highest 1000 seed weight than 15 0ctober.

4.2.8. Days to flower

Days to flower was significantly influenced by different sowing time in the present study (Table 2). Results showed that maximum days to flowering (37.40 days) was recorded from S_2 (25 October) and the minimum days to flowering (29.66 days) was obtained in S_1 (24 September).

4.2.9. Seed yield

Due to different sowing time significant variation was found on seed yield of mungbean (Figure 11 and Appendix VII). The highest seed yield (1.14 t ha^{-1}) was recorded from S_1 (24 September) while the lowest seed yield (0.88 t ha^{-1}) was found in S_2 (25 October). This result agrees with Kabir *et al*. (2009) who revealed that seed yield was reduced consequently as the date of sowing was delayed. Ramzan *et al*. (1992) also revealed that delay in sowing reduced seed yield massively. Jahan *et al.* (2012) stated that seed yield decreased by 36.8 and 49.9% when seed sown early (15March) or late (15 May) due to production of lower yield component. Kawsar *et al.* (2009) observed that sowing after 2 March gradually decreased the seed yield producing the lowest value (388.87 kg ha^{-1}) at 11 April sowing.

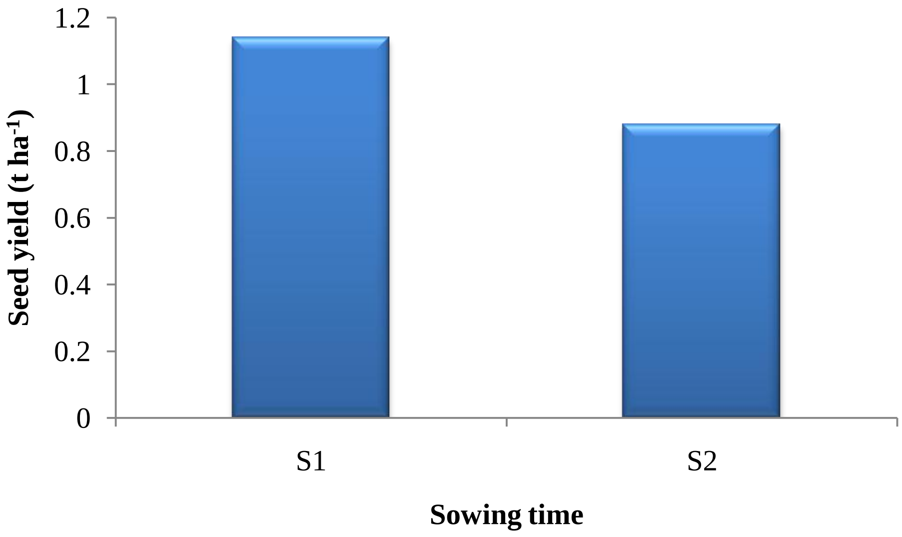

Figure 11. Effect of sowing time on seed yield of mungbean
(LSD value= 1.21)

S_1 = First sowing (24 September), S_2 = Second sowing (25 October)

4.2.10. Stover yield

Stover yield was significantly influenced by different sowing time (Figure 12 and Appendix VII). The highest stover yield (1.22 t ha^{-1}) was obtained from S_1 (24 September) while the lowest stover yield (0.94 t ha^{-1}) was recorded from S_2 (25 October). Similar result was found by Uddin *et al*. (2013) who observed that September sowing showed highest straw yield than October sowing.

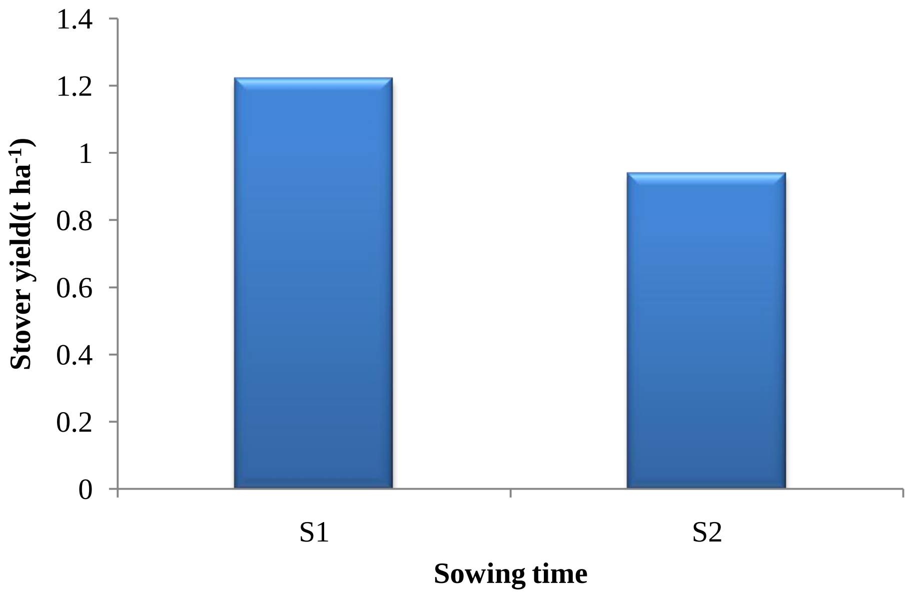

Figure 12. Effect of sowing time on stover yield of mungbean (LSD value= 0.09)

S_1 = First sowing (24 September), S_2 = Second sowing (25 October)

4.2.11. Biological yield

Sowing date significantly influenced the biological yield (Figure 13 and Appendix VII) of Mungbean. S_1 (24 September) showed highest (2.36 t ha^{-1}) biological yield and the lowest (1.82 t ha^{-1}) biological yield was found from S_2 (25 October). This result is supported by Paul *et al*. (2011) who stated that late planting reduces the biomass production.

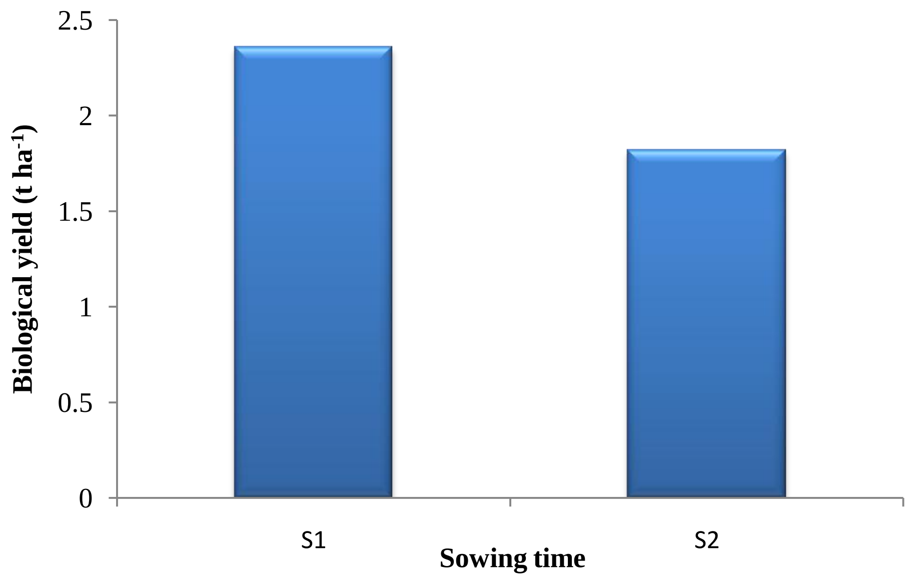

Figure 13. Effect of sowing time on biological yield of mungbean (LSD value=0.22)

S_1 = First sowing (24 September), S_2 = Second sowing (25 October)

4.2.12. Harvest index

A significant variation was observed in respect of harvest index due to the different sowing time (Figure 14 and Appendix VII). The highest harvest index (53.08 %) was found from S_2 (25 October) and the lowest (48.88 %) was obtained from S_1 (24 September). This result is agreed with Paul *et al*. (2011) who observed that late planting reduces the biomass production but increases harvest index. Seijoon *et al.* (2000) also found similar results and suggested that the increased harvest index with late sowing could be related to high assimilate use efficiency due to increased sink capacity.

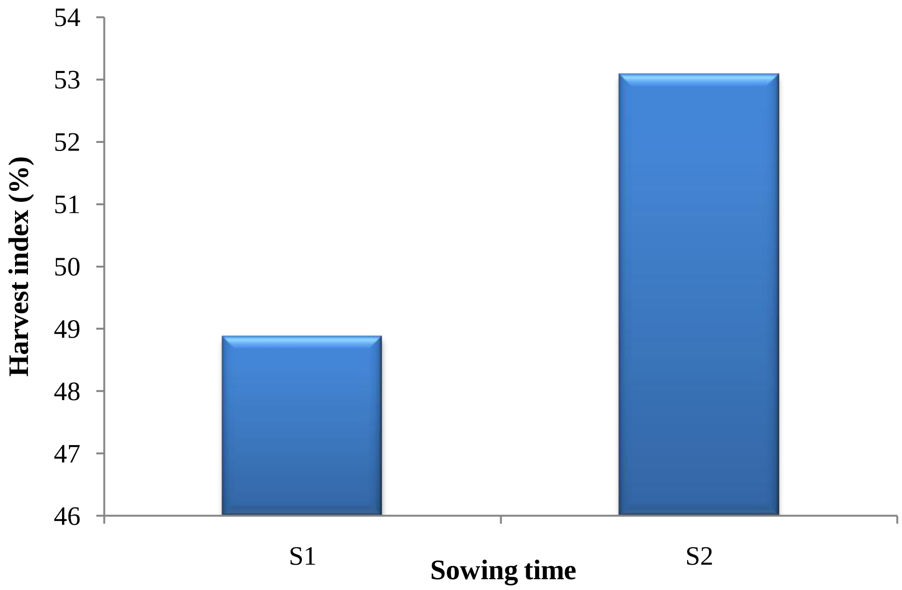

Figure 14. Effect of sowing time on harvest index of mungbean (LSD value=2.13)

S_1 = First sowing (24 September), S_2 = Second sowing (25 October)

4.3. Interaction effect of different levels Potassium and Boron Fertilizer doses and sowing time

4.3.1. Plant height

Significant variation was observed in case of interaction effect of different levels Potassium and Boron fertilizer doses and sowing time throughout the growing period for plant height of mungbean (Table 3). Sowing date S_1 combined with different fertilizer doses gave tallest plant compared to S_2. At 20 and 30 DAS, tallest plant (39.33 and 43.89 cm) was recorded from S_1F_4 (24 September with R+ Additional 20 kg K ha^{-1} + 2 kg B ha^{-1}) which was statistically similar with S_1F_3, S_1F_2, S_1F_3 at 20 DAS and S_1F_2, S_1F_1 at 30 DAS later period (At 40, 50, 60 DAS), the tallest plant (51.1, 51.44, 55.72 cm) was recorded from S_1F_3 (24 September with R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}). At 20 and 50 DAS, shortest plant (14.81, 20.30 cm) was observed from S_2F_4 (25 October with R+ Additional 20 kg K ha^{-1} + 2 kg B ha $^{-1}$) which was statistically similar with S_2F_3, $S_2F_{2,}$ $S_2F_{1,}$ S_2F_0 at 20 DAS and S_2F_3, $S_2F_{2,}$ S_2F_0 at

50 DAS. At 30, 40 and 60 DAS, shortest plant (15.92, 18.32 and 21.55 cm) was obtained from S_2F_0 (25 October with Recommended fertilizer dose).

Table 3. Interaction effect of different levels of Potassium and Boron fertilizer dose and sowing time on plant height (cm) at different days after sowing of mungbean plant

Treatment	Plant height (cm) at per plant				
	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
S_1F_0	36.56 a	40.00 b	44.44 c	50.78 a	51.67 b
S_1F_1	38.00 a	41.22 ab	45.88 bc	45.89 b	47.11 c
S_1F_2	36.63 a	41.99 ab	45.05 c	46.44 b	46.58 c
S_1F_3	37.81 a	39.22 b	51.11 a	51.44 a	55.72 a
S_1F_4	39.33 a	43.89 a	49.66 ab	50.89 a	51.80 b
S_2F_0	15.14 b	15.92 c	18.32 e	21.63 d	21.55 f
S_2F_1	15.04 b	17.68 c	23.11 d	26.78 c	28.83 d
S_2F_2	14.55 b	17.17 c	20.35 de	21.33 d	23.88 e
S_2F_3	13.56 b	17.12 c	20.43 de	20.65 d	24.33 e
S_2F_4	14.81 b	18.03 c	19.82 de	20.30 d	22.93 ef
$LSD_{(0.05)}$	**2.85**	**3.8**	**3.99**	**3.27**	**1.83**
CV(%)	**5.99**	**7.16**	**4.00**	**5.05**	**2.69**

In a column means having similar letter(s) are statistically identical and those having dissimilar letter (s) differ significantly at 0.05 level of significance

F_0 = Recommended dose (R), F_1 = R+ Additional 10 kg K ha^{-1} + 1 kg B ha^{-1}, F_2 = R+ Additional 20 kg K ha^{-1} + 1 kg B ha^{-1}, F_3 = R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}, F_4= R+ Additional 20 kg K ha^{-1} + 2 kg B ha^{-1}
S_1 = First sowing (24 September), S_2 =Second sowing (25 October)

4.3.2. Dry matter of leaf

Interaction effect of different levels of Potassium and Boron fertilizer doses and sowing time showed significant variation throughout the growing period for dry matter of leaf in Mungbean. In general, sowing date S_1 (24 September) combined with different fertilizer doses gave highest dry matter of leaf compared to S_2 (25 October) (Table 4). The highest dry matter of leaf (1.10, 1.02 g) was found from S_1F_0 (24 September with Recommended dose) which was statistically similar S_1F_3, S_1F_4, S_1F_2, S_1F_1 and S_1F_3, S_1F_2, S_1F_1 at 20 and 60 DAS, respectively. At 30, 40, 50 DAS, S_1F_3 (24 September with R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}) gave the highest (0.78, 2.38, 1.63 g) dry matter of leaf. At 20 and 30 DAS, the lowest (0.02 and 0.04 g) dry matter of leaf was observed in S_2F_4 which was statistically similar with S_2F_0 at 20 DAS and S_2F_2 at 30 DAS. At 40, 50 and 60 DAS the lowest dry matter of leaf (0.23, 0.12 and .31g) was recorded from S_2F_0 (25 October with Recommended dose).

Table 4. Interaction effect of different levels of Potassium and Boron fertilizer doses and sowing time on dry matter of leaf (g) at different days after sowing of mungbean plant

Treatment	Dry matter of leaf (g) at per plant				
	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
S_1F_0	1.1 a	0.43 c	1.24 e	0.67 c	1.02 a
S_1F_1	0.78 a	0.47 c	2.17 b	0.96 b	0.83 a
S_1F_2	0.68 ab	0.69 b	1.57 d	0.77 c	0.84 a
S_1F_3	0.98 a	0.78 a	2.38 a	1.63 a	0.87 a
S_1F_4	0.93 a	0.66 b	1.78 c	1.1 b	0.55 b
S_2F_0	0.11 c	0.12 e	0.23 g	0.12 e	0.31 c
S_2F_1	0.17 bc	0.05 f	0.27 g	0.24 de	0.45 bc
S_2F_2	0.17 bc	0.05 f	0.24 g	0.32 d	0.38 bc
S_2F_3	0.15 c	0.18 d	0.47 f	0.15 e	0.38 bc
S_2F_4	0.03 c	0.04 f	0.47 f	0.21 de	0.44 bc
$LSD_{(0.05)}$	**0.51**	**0.05**	**0.17**	**0.15**	**0.19**
CV (%)	**17.45**	**10.42**	**8.61**	**13.05**	**16.85**

In a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly at 0.05 level of significance

F_0 = Recommended dose (R), F_1 = R+ Additional 10 kg K ha^{-1} + 1 kg B ha^{-1}, F_2 = R+ Additional 20 kg K ha^{-1} + 1 kg B ha^{-1}, F_3 = R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}, F_4= R+ Additional 20 kg K ha^{-1} + 2 kg B ha^{-1}
S_1 = First sowing (24 September), S_2 = Second sowing (25 October)

4.3.3. Dry matter of stem

Significant variation was observed in case of interaction effect of different levels of Potassium and Boron Fertilizer doses and sowing time throughout the growing period for dry matter of stem of mungbean (Table 5). Sowing date S_1 combined with different fertilizer doses gave highest dry matter of stem compared to S_2. At 20 and 30 DAS, S_1F_3 (24 September with R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}) gave the highest dry matter of stem (0.27, .35 g) which was statistically similar with S_1F_2 and S_1F_0. At 40 DAS, the highest dry matter of stem (1.75 g) was obtained from S_1F_1. At 50 DAS , the highest dry matter of stem (1.22 g) was obtained from S_1F_0 which was statistically similar with S_1F_1. At 60 DAS, the highest dry matter of stem (1.22 g) was recorded from S_1F_0 which was statistically similar with S_1F_1, S_1F_2, S_1F_3, S_1F_4. At 20, 30, 40 and 60 DAS the lowest dry matter of stem (0.04, 0.05, 0.13, 0.19 g) was found in S_2F_4 (25 October with R+ Additional 20 kg K ha^{-1} + 2 kg B ha^{-1}) which was statistically similar with S_2F_0. At 50 DAS the lowest dry matter (0.06 g) of stem was recorded from S_2F_2 (25 October with R+ Additional 20 kg K ha^{-1} + 1 kg B ha^{-1}) which was statistically similar with $S_2F_{0.}$

Table 5. Interaction effect of different levels of Potassium and Boron fertilizer dose and sowing time on dry matter of stem (g) at different days after sowing of mungbean plant

Treatment	Dry matter of stem (g) at per plant				
	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
S_1F_0	0.24 ab	0.34 a	0.79 c	1.22 a	1.20 a
S_1F_1	0.20 b	0.32 a	1.75 a	1.1 a	1.10 a
S_1F_2	0.24 ab	0.26 b	0.30 d	0.67 b	1.11 a
S_1F_3	0.27 a	0.35 a	1.17 b	0.74 b	1.18 a
S_1F_4	0.19 b	0.23 b	0.96 c	0.67 b	1.12 a
S_2F_0	0.07 c	0.07 c	0.17 d	0.15 c	0.20 b
S_2F_1	0.09 c	0.06 c	0.18 d	0.07 c	0.28 b
S_2F_2	0.05 c	0.08 c	0.17 d	0.06 c	0.12 b
S_2F_3	0.05 c	0.10 c	0.15 d	0.19 c	0.19 b
S_2F_4	0.04c	0.05 c	0.13 d	0.15 c	0.15 b
$LSD_{(0.05)}$	**0.05**	**0.05**	**0.18**	**0.19**	**0.33**
CV(%)	**22.14**	**14.57**	**17.31**	**20.56**	**27.42**

In a column means having similar letter(s) are statistically identical and those having dissimilar letter (s) differ significantly at 0.05 level of significance

F_0 = Recommended dose (R), F_1 = R+ Additional 10 kg K ha^{-1} + 1 kg B ha^{-1}, F_2 = R+ Additional 20 kg K ha^{-1} + 1 kg B ha^{-1}, F_3 = R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}, F_4= R+ Additional 20 kg K ha^{-1} + 2 kg B ha^{-1}
S_1 = First sowing (24 September), S_2 = Second sowing (25 October)

4.3.4. Pod length

From the value of pod length it was found that interaction effect of different levels of Potassium and Boron fertilizer doses and sowing time showed significant differences (Table 6). The longest pod (7.33 cm) was observed from S_1F_0 (24 September with Recommended dose) which was statistically at par with S_1F_1, S_1F_2, S_1F_3, S_1F_4. The shortest pod (3.89 cm) was obtained from the combination of S_2F_0 (25 October with Recommended dose) which was statistically similar with S_2F_1, S_2F_2, S_2F_3, S_2F_4.

Table 6. Interaction effect of different levels of Potassium and Boron Fertilizer and sowing time on yield contributing character of mungbean plant

Treatment	Pod length (cm)	No. of pods plant^{-1}	No. of seeds pod^{-1}	1000-seed weight (g)	Days to flowering
S_1F_0	7.33 a	13.77 a	8.60 ab	31.55 cd	34.00 d
S_1F_1	7.30 a	13.39 a	8.75 a	38.09 b	31.33 e
S_1F_2	7.05 a	13.77 a	6.53 abc	43.06 a	28.00 e
S_1F_3	6.73 a	14.89 a	8.80 a	43.21 a	24.00 g
S_1F_4	7.08 a	12.89 ab	8.43 ab	35.83 b	31.00 e
S_2F_0	3.89 b	6.33 c	3.68 d	29.22 de	40.33 a
S_2F_1	4.22 b	9.66 bc	5.45 cd	35.72 b	38.00 b
S_2F_2	4.00 b	6.33 c	3.91 cd	26.90 e	36.00 c
S_2F_3	3.96 b	8.00 c	4.89 cd	31.86 c	35.67 cd
S_2F_4	4.18 b	6.56 c	5.90 bcd	29.03 de	37.00 bc
$LSD_{(0.05)}$	**1.28**	**3.66**	**2.7**	**2.51**	**1.99**
CV(%)	**12.65**	**19.10**	**22.90**	**4.02**	**3.27**

In a column means having similar letter(s) are statistically identical and those having dissimilar letter (s) differ significantly at 0.05 level of significance

F_0 = Recommended dose (R), F_1 = R+ Additional 10 kg K ha^{-1} + 1 kg B ha^{-1}, F_2 = R+ Additional 20 kg K ha^{-1} + 1 kg B ha^{-1}, F_3 = R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}, F_4= R+ Additional 20 kg K ha^{-1} + 2 kg B ha^{-1}
S_1 = First sowing (24 September), S_2 = Second sowing (25 October)

4.3.5. No. of pods plant^{-1}

Interaction effect of different levels of Potassium and Boron fertilizer doses and sowing time was significantly influenced the no. of pods plant $^{-1}$ (Table 6). Results showed that the maximum no. of pods plant $^{-1}$ (14.89) was observed with the treatment combination S_1F_3 (24 September with R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}) which was statistically similar with S_1F_1, S_1F_2 , S_1F_4. On the other hand the minimum no. of pods plant $^{-1}$ (6.33) was found with S_2F_0 (25 October with Recommended dose).

4.3.6. No. of seeds pod^{-1}

No. of seeds pod^{-1} was significantly influenced by interaction effect of different levels of Potassium and Boron fertilizer doses and sowing time (Table 6). Results showed that the maximum no. of seeds pod^{-1} (8.8) was found with the treatment combination S_1F_3 (24 September with R+ Additional 10 kg K ha^{-1} + 2 kg B ha $^{-1}$) which was statistically similar with S_1F_1, $S_1F_{2,}$ S_1F_4. On the other hand the minimum no. of seeds pod^{-1} (3.68) was observed with S_2F_0 (25 October with Recommended dose).

4.3.7. 1000- seed weight

1000- seed weight was significantly influenced by interaction effect of different levels of Potassium and Boron fertilizer doses and sowing time (Table 6). Results showed that the highest 1000- seed weight (43.21 g) was found with the treatment combination S_1F_3 (24 September with R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}) which was statistically at par with $S_1F_{2.}$ On the other hand the lowest 1000 seed weight (26.90 g) was observed with S_2F_2 which was statistically similar with S_2F_0, $S_2F_{4.}$

4.3.8. Days to flower

The combine effect of different levels of Potassium and Boron fertilizer doses and sowing time in case of days to flower was significantly varied (Table 6). The highest days to flower initiation (40.33 days) was found with the treatment combination S_2F_0 (25 October with Recommended dose). On the other hand the lowest days to flower (24 days) was observed with S_1F_3 (24 September with R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}).

4.3.9. Seed yield

Interaction effect of different levels of Potassium and Boron fertilizer doses and sowing time was significantly influenced the seed yield (Table 7). The highest seed yield (1.29 t ha^{-1}) was found with the treatment combination S_1F_3 (24 September with R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}) which was statistically at par with S_1F_2 (24 September with R+ Additional 20 kg K ha^{-1} + 1 kg B ha^{-1}. The lowest seed yield (0.67 t ha^{-1}) was observed with S_2F_0 (25 October with Recommended dose). It was also observed that considering interactions of S_2 with all other fertilizer levels S_2F_1 gave significantly highest yield compared to S_2F_0, S_2F_2, S_2F_3, S_2F_4.

4.3.10. Stover yield

Stover yield was significantly influenced by interaction effect of different levels of Potassium and Boron fertilizer doses and sowing time (Table 7). The highest stover yield (1.89 t ha^{-1}) was found with the treatment combination from S_1F_1 (24 September with R+ Additional 10 kg K ha^{-1} + 1 kg B ha^{-1}) which was statistically at par with S_2F_1 and the lowest stover yield (0.35 t ha^{-1}) was obtained from S_2F_0 (25 October with Recommended dose) which was statistically at par with S_2F_2.

Table 7. Interaction effect of different levels of Potassium and Boron fertilizer and sowing date on seed yield, stover yield, biological yield and harvest index of mungbean plant

Treatment	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index(%)
S_1F_0	0.94 d	1.27 b	2.21 b	42.61 cd
S_1F_1	1.13 b	1.74 a	2.87 a	39.41 de
S_1F_2	1.27 a	0.93 c	2.20 b	57.86 b
S_1F_3	1.29 a	0.95 c	2.24 b	57.41 b
S_1F_4	1.07 c	1.20 b	2.27 b	47.14 c
S_2F_0	0.67 f	0.35 e	1.03 d	65.75 a
S_2F_1	1.06 c	1.89 a	2.96 a	36.05 e
S_2F_2	0.83 e	0.50 de	1.33 c	62.59 a
S_2F_3	0.95 d	0.58 d	1.53 c	62.02 ab
S_2F_4	0.87 e	1.38 b	2.25 b	39.04 de
$LSD_{(0.05)}$	**0.05**	**0.20**	**0.22**	**4.61**
CV (%)	**3.44**	**10.49**	**5.77**	**4.98**

In a column means having similar letter (s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05 level of significance

F_0 = Recommended dose (R), F_1 = R+ Additional 10 kg K ha^{-1} + 1 kg B ha^{-1}, F_2 = R+ Additional 20 kg K ha^{-1} + 1 kg B ha^{-1}, F_3 = R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}, F_4 = R+ Additional 20 kg K ha^{-1} + 2 kg B ha^{-1}
S_1 = First sowing (24 September), S_2 = Second sowing (25 October)

4.3.11. Biological yield

Significant variation was observed due to interaction effect of different levels of Potassium and Boron fertilizer doses and sowing time for biological yield of mungbean (Table 7). S_2F_1 (25 October with R+ Additional 10 kg K ha $^{-1}$+ 1 kg B ha^{-1}) showed the highest biological yield (2.96 t ha^{-1}) which was statistically similar with S_1F_1 (2.87 t ha^{-1}) and the lowest (1.03 t ha^{-1}) was found from S_2F_0 (25 October with Recommended dose).

4.3.12. Harvest index

Significant variation was found due to interaction effect of different levels of Potassium and Boron fertilizer doses and sowing time for harvest index of mungbean (Table 7). The highest harvest index (65.75 %) was found from S_2F_0 (25 October with Recommended dose) which is statistically at par (62.59, 62.02 %) with S_2F_2, S_2F_3 and the lowest (36.05 %) was found in S_2F_1 **(**25october with R+ Additional 10 kg K ha^{-1} + 1 kg B ha^{-1}) which is statistically at par with (39.41 %) S_1F_1.

CHAPTER 5

SUMMARY AND CONCLUSION

The experiment was conducted at the research field of the Department of Agronomy, Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka 1207 during the period from September 2013 to January 2014 to investigate the effect of Potassium and Boron on low temperature tolerance in mungbean under late sowing condition. BARI Mung-6 was used as a planting material for the present study. The experiment consisted of two factors: Factor A: Fertilizer dose (5 level) – F_0 = Recommended dose (R), F_1 = R+ Additional 10 kg K ha^{-1} + 1 kg B ha^{-1}, F_2 = R+ Additional 20 kg K ha^{-1} + 1 kg B ha^{-1} , F_3 = R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}, F_4= R+ Additional 20 kg K ha^{-1} + 2 kg B ha^{-1} and Factor B: 2 sowing time- S_1: 24 September, S_2: 25 October. The experiment was laid out in a split plot design with three replications. Data analysis was done by MSTAT-C package program whereas mean separation was done by LSD test at 5% level of probability. Data were recorded on plant height, dry matter of leaf, dry matter of stem as growth parameter; pod length, pods $plant^{-1}$, no. of seeds pod^{-1}, days to flower, 1000-seed weight, seed yield, stover yield, biological yield and harvest index as yield and yield contributing character. As a result of different levels of potassium and boron fertilizer, the tallest (40.03 cm) plant was obtained from F_3 (R+ Additional 10 kg K ha^{-1}+ 2 kg B ha^{-1}) and F_2 (R + Additional 20 kg K ha^{-1}+ 1 kg B ha^{-1}) gave the shortest (35.23 cm) plant at 60 DAS. The highest leaf dry matter (0.48, 1.42, 0.89 g) was recorded from F_3 (R+ Additional 10 kg K ha^{-1}+ 2 kg B ha^{-1}) and the lowest (0. 27, 0.74, 0.40 g) from F_0 at 30, 40 and 50 DAS except 20 and 60 DAS. The highest dry matter of stem (0.97, 0.68 g) was recorded from F_1 (R+ Additional 10 kg K ha^{-1}+ 1 kg B ha^{-1}) and F_0 (recommend dose) at 40 and 50 DAS while the lowest (0.23, 0.37 g) was recorded with F_2 (R+ Additional 20 kg K ha^{-1}+ 1 kg B ha^{-1}) at 40 and 50 DAS except 20, 30, 60 DAS . The highest No. of seeds pod^{-1} (7.16) was recorded with F_4 (R+ Additional 10 kg K ha^{-1}+ 2 kg B ha^{-1}) fertilizer dose and the lowest No. of seeds pod^{-1} (5.22) was obtained from F_2 (R+ Additional 20 kg K ha^{-1}+ 1 kg B ha^{-1}). The highest 1000-seed weight

(37.53 g) and seed yield (1.12 t ha^{-1}) was recorded from F_3 (R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}) and F_0 (Recommended dose) gave the lowest 1000-seed weight (30.38 g) which finally attributed to lowest seed yield (0.80 t ha^{-1}). The highest stover yield and biological yield (1.81 t ha^{-1} and 2.91 t ha^{-1}) was recorded from F_1 while F_2 and F_0 (Recommended dose) produced the lowest (0.71 t ha^{-1} and 1.62 t ha^{-1}). F_2 (R+ Additional 20 kg K ha $^{-1}$+1 kg B ha^{-1}) gave the highest (60.23 %) harvest index and the lowest was observed from (37.73 %) F_1 (R + Additional 10 kg K ha^{-1} + 1 kg B ha^{-1}).

Results showed that sowing time had significant influence on all growth, yield contributing character and yield parameters of mungbean. Mungbean seeds sown in 24 September (S_1) produced the tallest plant (50.57 cm) at 60 DAS, maximum dry matter of leaf (0.89, 0.60, 1.83, 1.02, 0.82 g respectively) and stem (0.23, 0.30, 0.9, 0.88, 1.14g); whereas the lowest value for leaf (0.12, 0.09, 0.34, 0.21, 0.39g) and stem (0.06, 0.07, 0.16, 0.12, 0.18 g) were recorded from S_2 (25 October) throughout the growing season. The tallest pod (7.09 cm), maximum No. of pods plant^{-1} (13.74), No. of seeds pod^{-1} (8.22), 1000-seed weight (38.34 g), seed yield (1.14 t ha^{-1}), Stover yield (1.22 t ha^{-1}), biological yield (2.36 t ha^{-1}) were recorded from S_1 (24 September) compared to the plots sown in S_2 (25 October) (4.05 cm, 7.37, 63.71, 4.76, 30.54 g , 0.88 t ha^{-1}, 0.94 t ha^{-1}, 1.82 t ha^{-1}) while days to flowering (37.40 days) and harvest index (53.08 %) was highest in case of S_2 (25 October) because of poor vegetative growth.

Results also revealed that interaction of different levels of fertilizer doses and sowing time had significant effect on all growth, yield contributing and yield parameters of BARI mung-6. S_1F_3 (24 September with R+ Additional 10kg K ha^{-1} + 2kg B ha^{-1}) produced the tallest plant (55.72 cm) and S_2F_0 (25 October with Recommended dose) gave the shortest (21.55 cm) at 60 DAS. The highest dry matter of leaf (2.38, 1.63, .87 g) was recorded from S_1F_3 (24 September with R+ Additional 10kg K ha^{-1} + 2kg B ha^{-1}) at 30, 40, 50 DAS, respectively and S_1F_0 (1.10, 1.02 g) at 20, 60 DAS while lowest (0.23, 0.12 and .31 g) was recorded from S_2F_0 (25 October with Recommended dose) at 40, 50 and 60 DAS and from S_2F_4 (0.02 and 0.04 g) at 20, 30 DAS. At 20 and 30 DAS, S_1F_3 (24 September with R+ Additional 10 kg K ha^{-1}+ 2 kg B ha^{-1}) gave highest dry matter of stem (0.27, 0.35 g) and from S_1F_0 (24 September with Recommended dose) (1.22 and 1.22 g) at 50 and 60 DAS. At 40 DAS, the highest dry matter of stem (1.75 g) was obtained from S_1F_1. At 20, 30, 40 and 60 das the lowest dry matter of stem (0.04, 0.05, 0.13, 0.19 g) was found in S_2F_4 and from S_2F_2 (0.06 g) at 50 DAS. The maximum No. of pods plant $^{-1}$ (14.89), No. of seeds pod^{-1} (8.8), 1000- seed weight (43.21 g) and Seed yield (1.29 t ha^{-1}) was observed from S_1F_3 (24 September with R+ Additional 10 kg K ha^{-1} + 2 kg B ha^{-1}) which was statistically similar with S_1F_2 and lowest was (6.33, 3.68, 29.22 g, 0.67 t ha^{-1}) recorded from S_2F_0 (25 October with Recommended dose). S_2F_1 gave the highest seed yield considering interactions of S_2 with all other fertilizer levels. The tallest pod (7.33 cm) was observed from S_1F_0 (24 September with Recommended dose) and shortest (3.89 cm) from S_2F_0. Maximum Stover yield (1.89 t ha^{-1}) and biological yield (2.96 t ha^{-1}) was observed from the treatment combinations of S_2F_1 (25 October with R+ Additional 10 kg K ha^{-1} +1 kg B ha^{-1}) and the lowest Stover yield, biological yield (0.35 t ha^{-1}, 1.03 t ha^{-1}) from S_1F_0 (24 September with Recommended dose). The highest harvest index (65.75 %) was recorded from S_2F_0 (25 October with Recommended dose) and lowest from (36.05 %) S_2F_1 (25 October with R+ Additional 10 kg K ha^{-1} + 1 kg B ha^{-1}).

Based on the above result, it was observed that yield of BARI mung-6 can be significantly increased by applying (R+ Additional 20 kg K ha^{-1} + 1 kg B ha^{-1}) F_2 when sown on 24 September and by applying F_1 (R+ Additional 10 kg K ha^{-1} + 1 kg B ha^{-1}) when sown on 25 0ctober.

Considering the situation of the present experiment, further studies in the following areas may be suggested:

1. Such study need to be conducted under different levels of low temperature stress condition.
2. Other combination of sowing time along with different level of potassium and boron fertilizer may be used for further study to specify the actual time of sowing for the specific potassium and boron fertilizer dose.

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APPENDICES

Appendix I. Characteristics of the soil of experimental field analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Expeimental Field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% Clay	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: SRDI (Soil Resources Development Institute), 2013.

Appendix II. Monthly record of air temperature, relative humidity rainfall and sunshine hour of the experimental site during the period from September 2013 to January 2014

Month	*Air temperature (^{0}C)		*Relative humidity (%)	*Rainfall (mm) (total)	*Sunshine hour
	Maximum	Minimum			
September ,2013	31.46	14.82	73.5 %	2.1	4.15
October,2013	30.18	14.85	67.82 %	1.4	7.48
November, 2013	28.10	6.88	58.18 %	0.52	7.85
December ,2013	25.36	5.21	54.3 %	0.21	5.85
January ,2014	21.17	15.46	64.02 %	00	5.98

*monthly average
Source: Bangladesh Meteorological Department (Climate & weather division), Agargoan, Dhaka – 1207

Appendix III. Analysis of variance of the data on plant height of mungbean as influenced by different levels of potassium and boron on fertilizer dose and sowing time .

Source of variation	Degrees of freedom	Mean Square at different days after sowing				
		20DAS	30DAS	40DAS	50DAS	60DAS
Replication	2	0.41	2.19	1.46	13.87	1.86
Factor A	4	2.40NS	8.84*	18.48NS	6.06NS	18.81*
Error	8	4.29	2.34	9.43	2.98	0.86
Factor B	1	3982.92*	4349.49*	5396.72*	5446.73*	5176.37*
AB	4	2.70*	2.96 *	17.00*	36.62*	46.65*
Error	10	2.45	4.38	4.82	3.23	1.01

***** Significant at 5% level
NS =Non Significant

Appendix IV. Analysis of variance of the data on dry matter of leaf (g) of mungbean as influenced by different levels of potassium and boron on fertilizer dose and sowing time

Source of variation	Degrees of freedom	Mean Square at different days after sowing				
		20DAS	30DAS	40DAS	50DAS	60DAS
Replication	2	0.00	0.00	0.01	0.00	0.00
Factor A	4	0.03NS	0.04 *	0.43*	0.19*	0.02NS
Error	8	0.01	0.00	0.00	0.00	0.01
Factor B	1	4.43*	2.01 *	16.65*	5.03*	1.37*
AB	4	0.06*	0.03*	0.23*	0.25*	0.07*
Error	10	0.00	0.00	0.00	0.00	0.01

***** Significant at 5% level
NS =Non significant

Appendix V. Analysis of variance of the data on dry matter of stem (g) of mungbean as influenced by different levels of potassium and boron on fertilizer dose and sowing time.

Source of variation	Degrees of freedom	Mean Square				
		20DAS	30DAS	40DAS	50DAS	60DAS
Replication	2	0.00	0.00	0.00	0.00	0.04
Factor A	4	0.00NS	0.00 *	0.43 *	0.09 *	0.00NS
Error	8	0.00	0.00	0.00	0.01	0.03
Factor B	1	0.21*	0.39 *	5.20*	4.31*	6.88*
AB	4	0.00 *	0.00*	0.42*	0.10*	0.01 *
Error	10	0.00	0.00	0.01	0.01	0.03

***** Significant at 5% level
NS =Non significant

Appendix VI. Analysis of variance of the data on yield contributing character on mungbean as influenced by different levels of potassium and boron on fertilizer dose and sowing time.

Source of variation	Degrees of freedom	Mean square			
		Pod length	No.of pods plant^{-1}	1000-seed weight	Days to flower
Replication	2	0.31	4.32	2.12	0.23
Factor A	4	0.14NS	4.40NS	4.02*	46.11*
Error	8	0.49	5.76	0.97	1.94
Factor B	1	69.52*	303.69*	89.58*	448.53*
AB	4	0.09*	3.58 *	1.47*	8.11*
Error	10	0.49	4.06	2.21	1.20

* Significant at 5% level
NS =Non significant

Appendix VII. Analysis of variance of the data on yield, stover yield, biological yield and Harvest index on mungbean influenced by different levels of potassium and boron on fertilizer dose and sowing time.

Source of variation	Degrees of freedom	Mean Square			
		Seed yield	Stover yield	Biological yield	Harvest Index
Replication	2	0.00	0.01	0.006	6.56
Factor A	4	0.09*	1.33*	1.61*	614.56*
Error	8	0.002	0.01	0.01	5.80
Factor B	1	0.51*	0.57*	2.17 *	132.42*
AB	4	0.03*	0.31*	0.45*	212.76*
Error	10	0.00	0.01	0.01	6.43

***** Significant at 5% level
NS =Non significant