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Combined effect of potassium and boron on low-temperature tolerance in mungbean under late sowing condition

Mohshina Mustare Liza[1], **Swarna Shome**[1*], **Alak Barman**[2], **Polly**[3], **Md. Eliyachur Rahman**[4]

[1]*Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh*

[2]*Soil Science Division, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh*

[3]*Department of Horticulture, First Capital University of Bangladesh, Chuadanga, Bangladesh*

[4]*Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh*

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Abstract

An experiment was conducted at the research field of Sher-e-Bangla Agricultural University to study the effect of potassium and boron on low-temperature tolerance in mungbean under late sowing conditions. Two levels of potassium (10 kg and 20 kg ha^{-1}) and 2 levels of boron (1 kg and 2 kg ha^{-1}) were applied with recommended fertilizer dose in case of mungbean sown on 24 September and 25 October. The experiment was laid out in randomized complete block design with three replications. Results revealed that mungbean sown on 24 September performed better than those sown on 25 October but the addition of potassium and boron with recommended dose improved the performance of late sown mungbean. Mungbean sown on 24 September produced the highest seed yield with the addition of 10 kg K and 2 kg B while mungbean sown on 25 October provided maximum yield due to the addition of 10 kg K and 1 kg B. So, 10 kg K + 2 kg B and 10 kg K + 1 kg B with recommended dose may be suggested for mungbean sown on 24 September and 25 October, respectively.

* **Corresponding Author:** Swarna Shome ✉ swarnashome.sau@gmail.com

Introduction

Mungbean (*Vigna radiata* L.) is an important pulse crop of Bangladesh, which contains high-graded vegetable proteins and a satisfactory level of minerals and vitamins. Mungbean seeds contain 51% carbohydrate, 26% protein, 3% minerals and 3% vitamins. Mungbean is cultivated in late rabi (last week of January to the first week of February), kharif-I (second week of February to the first week of March) and kharif- II (first week of August to the 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 the winter season in most of the regions of our country especially in the northern region due to low-temperature injury. 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) (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). 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 the 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 (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 protect 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*)*. On the other hand, boron can increase the antioxidant activities of plants and thereby alleviate ROS damage induced by temperature stress. 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 cell damage (Waraich *et al.,* 2011). Therefore, K and B might have a positive effect on the late sowing induced low-temperature stress tolerance in mungbean. As for ensuring food and nutritional security of enormous population of Bangladesh, we are focusing on intensive cropping system, we cannot sow all the crop in optimum time as field is occupied with other crops. However, being a short duration and year-round crop, mungbean can be fit easily at any time of the calendar year. But when mungbean cannot be sown in optimum time that is September and has to be sown in October as field is occupied with other crops, it can cause a yield reduction due to low temperature stress. But addition of potassium and boron with recommended dose may help to overcome the yield loss and increase seed yield of late sown mungbean. In Bangladesh, many studies have been executed to explore the nutrient requirement and optimum sowing time of mungbean, but reports are very few on nutrient management to overcome the yield loss of late sown mungbean. Considering the above situations, the study has been conducted to scrutinize the combined effect of potassium and boron on low-temperature tolerance in mungbean under late sowing conditions.

Materials and methods

Experimental site

The experiment was conducted at Sher-e-Bangla Agricultural University Farm (23°74/ latitude and 95°35/ longitude) during the period between September 2013 and January 2014. The climate of the experimental site is sub-tropical, the land of the selected experimental plot is medium-high under the Tejgaon series (FAO, 1988).

Experimental design and treatments

BARI Mung-6 was used as a test crop. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. There were ten different treatment combinations *viz.* T_1=

Recommended dose of chemical fertilizer (FRG, 2012) + sowing time 24 September, T_2= Recommended fertilizer dose + sowing time 25 October, T_3= T_1 + 10 kg K + 1 kg B, T_4= T_1 + 20 kg K + 1 kg B, T_5= T_1 + 10 kg K + 2 kg B, T_6= T_1 + 20 kg K + 2 kg B, T_7= T_2 + 10 kg K + 1 kg B, T_8= T_2 + 20 kg K + 1 kg B, T_9= T_2 + 10 kg K + 2 kg B and T_{10}= T_2 + 20 kg K + 2 kg B.

Crop management

The land of the experimental plot was prepared with a power tiller on 23 September 2013. The full amount of N, P, K and B was applied at the time of final land preparation in the forms of urea, triple superphosphate, muriate of potash and boric acid, respectively. The experimental plots were fertilized as per treatment. Crop management activities were done when needed. Mungbean (var. BARI Mung-6) was sown apart rows maintaining row to row distance of 30 cm. Seed to seed distance was 10 cm. The sowing date was maintained as per treatment.

Data collection

Data on plant height, days to flowering, pod length (cm), no. of pods plant^{-1}, no. of seeds pod^{-1} were recorded from ten pre-selected plants. Dry matter of leaves and stem was measured by uprooting three plants from each plot and drying them in the oven. Thousand seed weight, seed yield, stover yield, biological yield and harvest index were recorded after harvesting, threshing and drying. Seed yield was determined at 12% moisture content.

Data analysis

The collected data was 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 the Least Significance Difference (LSD) test at 5% probability level (Gomez and Gomez, 1984).

Results and discussion

Plant height

Significant variation was observed for the combined effect of different levels of potassium and boron fertilizer doses and sowing time throughout the growing period for the plant height of mungbean (Table 1). Seeds sown on 24 September produced taller plants than those sown on 25 October when combined with different doses of potassium and boron. At 20 and 30 DAS, T_6 treatment gave the highest plant (39.33 cm and 43.89 cm, respectively) while T_5 produced the tallest plant at 40, 50 and 60 DAS (51.1 cm, 51.44 cm, 55.72 cm, respectively) At 20 DAS, the shortest plant (13.56 cm) was recorded form T_9 treatment which was statistically similar with T_2, T_7, T_8 and T_{10} treatments. At 30, 40 and 60 DAS, T_2 produced the shortest plant (15.92 cm, 18.32 cm and 21.55 cm, respectively) while T_{10} provided the shortest plant (20.30 cm) at 50 DAS. Extra potassium and boron with recommended fertilizer doses produced significantly taller plants when sown on 24 September. On the contrary, adding more K and B with recommended dose produced a taller plant than recommended dose alone but that was not statistically significant representing little effect of extra K and B on plant height in low temperature. Xu *et al.* (2008) opined that low-temperature stress inhibits the growth and development of plants. But potassium and boron are directly or indirectly involved in several physiological and biochemical processes during plant growth such as cell elongation, cell division, cell wall bio-synthesis, membrane function (Zhao *et al.*, 2007).

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 a dry matter of leaf in mungbean.

In general, mungbean sown on 24 September combined with different fertilizer doses gave the highest dry matter of leaf compared to those sown on 25 October (Table 2).

At 20 and 60 DAS, the highest dry matter of leaf (1.10 g and 1.02 g, respectively) was found from the T_1 treatment combination (24 September with

Recommended dose) which was statistically similar T_3, T_4, T_5 and T_6. At 30, 40, 50 DAS, T_5 (24 September with Recommended fertilizer dose and additional 10 kg K ha^{-1} + 2 kg B ha^{-1}) gave the highest (0.78 g, 2.38 g, 1.63 g, respectively) dry matter of leaf. At 20 and 30 DAS, the lowest (0.02 g and 0.04 g, respectively) dry matter of leaf was observed in T_{10} which was statistically similar with T_2 at 20 DAS and T_8 at 30 DAS. At 40, 50 and 60 DAS, the lowest dry matter of leaf (0.23 g, 0.12 g and 0.31 g, respectively) was recorded from T_2 (25 October with Recommended dose).

Table 1. Combined effect of different levels of potassium and boron fertilizer doses and sowing time on plant height at different days after sowing of mungbean

Treatment	Plant height (cm)				
	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
T_1	36.56 a	40.00 b	44.44 c	50.78 a	51.67 b
T_2	15.14 b	15.92 c	18.32 e	21.63 d	21.55 f
T_3	38.00 a	41.22 ab	45.88 bc	45.89 b	47.11 c
T_4	36.63 a	41.99 ab	45.05 c	46.44 b	46.58 c
T_5	37.81 a	39.22 b	51.11 a	51.44 a	55.72 a
T_6	39.33 a	43.89 a	49.66 ab	50.89 a	51.80 b
T_7	15.04 b	17.68 c	23.11 d	26.78 c	28.83 d
T_8	14.55 b	17.17 c	20.35 de	21.33 d	23.88 e
T_9	13.56 b	17.12 c	20.43 de	20.65 d	24.33 e
T_{10}	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

T_1= Recommended dose of chemical fertilizer (FRG, 2012) + sowing time 24 September, T_2= Recommended fertilizer dose + sowing time 25 October, T_3= T_1 + 10 kg K + 1 Kg B, T_4= T_1 + 20 kg K + 1 kg B, T_5= T_1 + 10 kg K + 2 kg B, T_6= T_1 + 20 kg K + 2 Kg B, T_7= T_2 + 10 kg K + 1 Kg B, T_8= T_2 + 20 kg K + 1 kg B, T_9= T_2 + 10 kg K + 2 kg B and T_{10}= T_2 + 20 kg K + 2 kg B.

The addition of extra potassium and boron with recommended dose slightly improved the dry matter content of the leaf. The reason might be such low temperature affected photosynthetic electron transport, stomatal conductance, rubisco activity, and CO_2 fixation in leaf due to conversion of O_2 to ROS (Foyer *et al.,* 2002). High K^+ concentration strengthened the plant's antioxidant system and ameliorated levels of ginsenoside-related secondary metabolite transcripts, which are associated with cold tolerance (Devi *et al.,* 2012).

Table 2. Combined effect of different levels of potassium and boron fertilizer doses and sowing time on dry matter of leaf at different days after sowing of mungbean.

Treatment	Dry matter of leaf (g)				
	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
T_1	1.1 a	0.43 c	1.24 e	0.67 c	1.02 a
T_2	0.11 c	0.12 e	0.23 g	0.12 e	0.31 c
T_3	0.78 a	0.47 c	2.17 b	0.96 b	0.83 a
T_4	0.68 ab	0.69 b	1.57 d	0.77 c	0.84 a
T_5	0.98 a	0.78 a	2.38 a	1.63 a	0.87 a
T_6	0.93 a	0.66 b	1.78 c	1.1 b	0.55 b
T_7	0.17 bc	0.05 f	0.27 g	0.24 de	0.45 bc
T_8	0.17 bc	0.05 f	0.24 g	0.32 d	0.38 bc
T_9	0.15 c	0.18 d	0.47 f	0.15 e	0.38 bc
T_{10}	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

T_1= Recommended dose of chemical fertilizer (FRG, 2012) + sowing time 24 September, T_2= Recommended fertilizer dose + sowing time 25 October, T_3= T_1 + 10 kg K + 1 kg B, T_4= T_1 + 20 kg K + 1 kg B, T_5= T_1 + 10 kg K + 2 kg B, T_6= T_1 + 20 kg K + 2 kg B, T_7= T_2 + 10 kg K + 1 kg B, T_8= T_2 + 20 kg K + 1 kg B, T_9= T_2 + 10 kg K + 2 kg B and T_{10}= T_2 + 20 kg K + 2 kg B.

Dry matter of stem

Significant variation was observed in the case of the effect of different levels of potassium and boron Fertilizer doses along with sowing time throughout the growing period for dry matter of stem of mungbean (Table 3). The sowing date of 24 September combined with different fertilizer doses gave the highest dry matter of stem compared to the sowing date of 25 October. At 20 and 30 DAS, T_5 (24 September with Recommended fertilizer dose and additional 10 kg K ha^{-1} + 2 kg B ha^{-1}) gave the highest dry matter of stem (0.27 g and 0.35 g, respectively) which was statistically similar with T_4 and T_1. At 40 DAS, the highest dry matter of stem (1.75 g) was obtained from T_3. At 50 DAS, the highest dry matter of stem (1.22 g) was obtained from T_1 which was statistically similar to T_3. At 60 DAS, the highest dry matter of stem (1.22 g) was recorded from T_1 which was statistically similar with T_3, T_4, T_5 and T_6. At 20, 30, 40 and 60 DAS, the lowest dry matter of stem (0.04 g, 0.05 g, 0.13 g and 0.19 g, respectively) was found in T_{10} (25 October with recommended fertilizer dose and additional 20 kg K ha^{-1} + 2 kg B ha^{-1}) which was statistically similar with T_2. At 50 DAS the lowest dry matter (0.06 g) of the stem was recorded from T_8 (25 October with recommended fertilizer dose and additional 20 kg K ha^{-1} + 1 kg B ha^{-1}) which was statistically similar with T_2. This result is supported by Paul *et al.* (2011) who stated that late planting reduces biomass production.

Table 3. Combined effect of different levels of potassium and boron fertilizer doses and sowing time on dry matter of stem at different days after sowing of moonbeam.

Treatment	Dry matter of stem (g)				
	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
T_1	0.24 ab	0.34 a	0.79 c	1.22 a	1.20 a
T_2	0.07 c	0.07 c	0.17 d	0.15 c	0.20 b
T_3	0.20 b	0.32 a	1.75 a	1.1 a	1.10 a
T_4	0.24 ab	0.26 b	0.30 d	0.67 b	1.11 a
T_5	0.27 a	0.35 a	1.17 b	0.74 b	1.18 a
T_6	0.19 b	0.23 b	0.96 c	0.67 b	1.12 a
T_7	0.09 c	0.06 c	0.18 d	0.07 c	0.28 b
T_8	0.05 c	0.08 c	0.17 d	0.06 c	0.12 b
T_9	0.05 c	0.10 c	0.15 d	0.19 c	0.19 b
T_{10}	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

T_1= Recommended dose of chemical fertilizer (FRG, 2012) + sowing time 24 September, T_2= Recommended fertilizer dose + sowing time 25 October, T_3= T_1 + 10 kg K + 1 kg B, T_4= T_1 + 20 kg K + 1 kg B, T_5= T_1 + 10 kg K + 2 kg B, T_6= T_1 + 20 kg K + 2 kg B, T_7= T_2 + 10 kg K + 1 kg B, T_8= T_2 + 20 kg K + 1 kg B, T_9= T_2 + 10 kg K + 2 kg B and T_{10}= T_2 + 20 kg K + 2 kg B.

Pod length

From the value of pod length, it was found that the combined effect of different levels of potassium and boron fertilizer doses and sowing time showed significant differences (Table 4). The longest pod (7.33 cm) was observed fromT_1 (24 September with recommended dose) which was statistically at par with T_3, T_4, T_5 and T_6. The shortest pod (3.89 cm) was obtained from the combination of 25 October with recommended dose (T_2) which was statistically similar with T_7, T_8, T_9 and T_{10}.

No. of pods plant^{-1}

The combined effect of different levels of potassium and boron fertilizer doses and sowing time was significantly influenced the no. of pods plant $^{-1}$ (Table 4). Results showed that the maximum no. of pods plant $^{-1}$ (14.89) was observed with the treatment combination T_5 (24 September with the recommended dose and an additional 10 kg K ha^{-1} + 2 kg B ha^{-1}) which was statistically similar with T_3, T_4 and T_6. On the other hand, the minimum no. of pods $plant^{-1}$ (6.33) was found with T_2 (25 October with recommended dose). Variation in sowing time beyond optimum decreasing the no. of pods $plant^{-1}$ also reported earlier by Kabir *et al.* (2009). Low-temperature stress during reproductive development induces flower abscission, pollen sterility, pollen tube distortion, ovule abortion and reduced fruit set, which ultimately lowers yield (Waraich *et al.*, 2012).

Table 4. Combined effect of different levels of potassium and boron fertilizer and sowing time on yield contributing character of mungbean.

Treatment	Pod length (cm)	No. of pods $plant^{-1}$	No. of seeds pod^{-1}	1000-seed weight (g)	Days to flowering
T_1	7.33 a	13.77 a	8.60 ab	31.55 cd	34.00 d
T_2	3.89 b	6.33 c	3.68 d	29.22 de	40.33 a
T_3	7.30 a	13.39 a	8.75 a	38.09 b	31.33 e
T_4	7.05 a	13.77 a	6.53 abc	43.06 a	28.00 e
T_5	6.73 a	14.89 a	8.80 a	43.21 a	24.00 g
T_6	7.08 a	12.89 ab	8.43 ab	35.83 b	31.00 e
T_7	4.22 b	9.66 bc	5.45 cd	35.72 b	38.00 b
T_8	4.00 b	6.33 c	3.91 cd	26.90 e	36.00 c
T_9	3.96 b	8.00 c	4.89 cd	31.86 c	35.67 cd
T_{10}	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

T_1= Recommended dose of chemical fertilizer (FRG, 2012) + sowing time 24 September, T_2= Recommended fertilizer dose + sowing time 25 October, T_3= T_1 + 10 kg K + 1 kg B, T_4= T_1 + 20 kg K + 1 kg B, T_5= T_1 + 10 kg K + 2 kg B, T_6= T_1 + 20 kg K + 2 kg B, T_7= T_2 + 10 kg K + 1 kg B, T_8= T_2 + 20 kg K + 1 kg B, T_9= T_2 + 10 kg K + 2 kg B and T_{10}= T_2 + 20 kg K + 2 kg B.

No. of seeds pod^{-1}

No. of seeds pod^{-1} was significantly influenced by the integrated effect of different levels of potassium and boron fertilizer doses and sowing time (Table 4). Results showed that the maximum no. of seeds pod^{-1} (8.8) was found with the treatment combination T_5 (24 September with the recommended dose and additional 10 kg K ha^{-1} + 2 kg B ha^{-1}) which was statistically similar with T_3, T_4 and T_6. On the other hand, the minimum no. of seeds pod^{-1} (3.68) was observed with T_2 (25 October with recommended dose). The temperature has a profound effect on pollen development and fertilization during flowering (Prasad *et al.*, 1999; (Boote *et al.*, 2005). Hall (2004) opined that the loss of pollen or stigma viability under temperature stress might be the major reason for the lowered number of seeds produced in the legume. Application of potassium and boron help to develop tolerance in plants against low temperature (Zhao *et al.*, 2007). The increase in phospholipids, membrane permeability and improvement in the biophysical and biochemical properties of cell due to addition of K might be the reason for increasing plant's low temperature resistance (Hakerlerler *et al.*, 1997).

1000-seed weight

1000-seed weight was significantly influenced by the effect of different levels of potassium and boron fertilizer doses and sowing time (Table 4). Results showed that the highest 1000-seed weight (43.21 g) was found with the treatment combination T_5 (24 September with the recommended dose and an additional 10 kg K ha^{-1} + 2 kg B ha^{-1}) which was statistically at par with T_4. On the other hand, the lowest 1000 seed weight (26.90 g) was observed with T_8 which was statistically similar with T_2 and T_{10}. This result is an agreement with Uddin *et al.* (2013) that September sowing showed the highest 1000 seed weight than 15 October. But the addition of potassium and boron helped to increase 1000-seed weight under both sowing times.

Days to flower

The combined effect of different levels of potassium and boron fertilizer doses and sowing time in case of days to flower was significantly varied (Table 4). The highest days to flower initiation (40.33 days) were found with the treatment combination T_2 (25 October with recommended dose). On the other hand, the lowest days to flower (24 days) was observed with T_5 (24 September with the recommended dose and an additional 10 kg K ha^{-1} + 2 kg B ha^{-1}). Supplementation of potassium and boron significantly reduced the days required for flowering both under optimum and late sowing conditions.

Seed yield

The combined effect of different levels of potassium and boron fertilizer doses and sowing time was significantly influenced the seed yield (Table 5).

Table 5. The combined effect of different levels of potassium and boron fertilizer and sowing date on seed yield, stover yield, biological yield and harvest index of mungbean.

Treatment	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
T_1	0.94 d	1.27 b	2.21 b	42.61 cd
T_2	0.67 f	0.35 e	1.03 d	65.75 a
T_3	1.13 b	1.74 a	2.87 a	39.41 de
T_4	1.27 a	0.93 c	2.20 b	57.86 b
T_5	1.29 a	0.95 c	2.24 b	57.41 b
T_6	1.07 c	1.20 b	2.27 b	47.14 c
T_7	1.06 c	1.89 a	2.96 a	36.05 e
T_8	0.83 e	0.50 de	1.33 c	62.59 a
T_9	0.95 d	0.58 d	1.53 c	62.02 ab
T_{10}	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

T_1= Recommended dose of chemical fertilizer (FRG, 2012) + sowing time 24 September, T_2= Recommended fertilizer dose + sowing time 25 October, T_3= T_1 + 10 kg K + 1 kg B, T_4= T_1 + 20 kg K + 1 kg B, T_5= T_1 + 10 kg K + 2 kg B, T_6= T_1 + 20 kg K + 2 kg B, T_7= T_2 + 10 kg K + 1 kg B, T_8= T_2 + 20 kg K + 1 kg B, T_9= T_2 + 10 kg K + 2 kg B and T_{10}= T_2 + 20 kg K + 2 kg B.

The highest seed yield (1.29 t ha^{-1}) was found with the treatment combination T_5 (24 September with the recommended dose and additional 10 kg K ha^{-1} + 2 kg B ha^{-1}) which was statistically at par with T_4 (24 September with the recommended dose and additional 20 kg K ha^{-1} + 1 kg B ha^{-1}). The lowest seed yield (0.67 t ha^{-1}) was observed with T_2 (25 October with recommended dose). Seed yield of late sown mungbean was significantly increased when 10 kg K and 1 kg B ha^{-1} was added to the recommended fertilizer dose which showed that additional K and B increased low-temperature tolerance in mungbean. This might be because K helps in photosynthesis, translocation of photosynthates into sink organs, maintenance of turgidity and activation of enzymes under stress conditions and potassium supply in high amounts can protect against oxidative damage caused by chilling or frost (Mengel and Kirkby, 2001).

On the other hand, boron nutrition improves sugar transport in the plant body which helps to improve seed germination and seed grain formation which in turn improves the yield by improving the temperature stress (Waraich *et al.*, 2011).

Stover yield

Stover yield was significantly influenced by the interaction effect of different levels of potassium and boron fertilizer doses and sowing time (Table 5). The highest stover yield (1.89 t ha^{-1}) was found with the treatment combination from T_3 (24 September with the recommended dose and additional 10 kg K ha^{-1} + 1 kg B ha^{-1}) which was statistically at par with T_7 and the lowest stover yield (0.35 t ha^{-1}) was obtained from T_2 (25 October with recommended dose) which was statistically at par with T_8. A similar result was found by Uddin *et al.* (2013) who observed that September sowing showed the highest straw yield than October sowing.

Biological yield

Significant variation was observed due to the integrated effect of different levels of potassium and boron fertilizer doses and sowing time for the biological yield of mungbean (Table 5). T_7 (25 October with recommended dose and 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 T_3 (2.87 t ha^{-1}) and the lowest (1.03 t ha^{-1}) was found from T_2 (25 October with recommended dose). The biological yield of late sown mungbean was significantly increased when additional potassium and boron were added to the recommended dose of fertilizer. This might be due to that potassium and boron application separately and in combination reduced harmful effects caused by the delay in planting on the traits leaf chlorophyll content, flag leaf relative water content, cell membrane stability index, and photosynthetic activity (Eisvand *et al.*, 2018).

Harvest index

Significant variation was found due to the interaction effect of different levels of potassium and boron fertilizer doses and sowing time for harvest index of mungbean (Table 5). The highest harvest index (65.75%) was found from T_2 (25 October with recommended dose) which is statistically at par (62.59%, 62.02%) with T_8, T_9 and the lowest (36.05%) was found in T_7 (25 October with the recommended dose and additional 10 kg K ha^{-1} + 1 kg B ha^{-1}) which is statistically at par with T_3 (39.41%). 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.

Conclusion

Based on the above result, it was observed that yield of BARI Mung-6 can be significantly increased by adding 10 kg K ha^{-1} + 2 kg B ha^{-1} when sown on 24 September and by supplementing 10 kg K ha^{-1} + 1 kg B ha^{-1} with recommended fertilizer dose when sown on 25 October. Further experimentation will be required with other combinations of sowing time along with the different levels of potassium and boron fertilizer to find out the best potassium and boron supplementation dose to tolerate different levels of temperature stress.

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