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Interaction effect of phosphorus and boron on yield and quality of lettuce

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ABSTRACT

Proper nutrition is essential for satisfactory crop growth and production. A field experiment was conducted at Bangabandhu Sheikh Mujibur Rahman Agricultural University, to evaluate yield and quality of Grand Rapids lettuce using various levels of phosphorus and boron. Treatment combination of 120 kg ha^{-1} of phosphorus and 2 kg ha^{-1} of boron has significantly increased plant height, leaf number, leaf length, plant canopy, capsules $plant^{-1}$, seeds $capsule^{-1}$, seeds number $plant^{-1}$, seed yield ha^{-1}, germination (%), planting value (%), moisture (%), purity (%), dry matter (%) and 1000 seed weight. Most of the treatment combinations performed better than control treatments in all parameter. The finding could be helpful to determine the precise levels of phosphorus and boron to improve the yield and quality of lettuce.

INTRODUCTION

Lettuce (*Lactuca sativa* L.) is considered one of the most economically important leafy vegetable crops in the world and is consumed as salads (Chiesa et al. 2009; Bose et al. 1990). Recently, the worldwide demand for "Grand Rapids" lettuce has been increased because of its crisp texture and tasty. It is also considered as an important source of potentially healthy bioactive compounds and several mineral nutrients which are valuable to human health (Ahvenainen 1996; Dupont et al. 2000). In Bangladesh, lettuce getting popularity day by day but its production package is not much known to farmers.

Phosphorus (P) is an essential plant nutrient required for optimum crop production. Plants need phosphorus for growth, utilization of sugar and starch, photosynthesis, nucleus formation and cell division (Atif et al. 2014). Boron's (B) role within the plant includes cell wall synthesis, sugar transport, cell division, differentiation, membrane functioning, root elongation, regulation of plant hormone levels and generative growth of plants (Marschner 1995; Anonymous 2007). Among the various factors responsible for higher yield, the cultivar itself plays a great role. However, seed yield and quality in crop plants greatly influence by both macro and micronutrients (Jasim et al. 2014). Lettuce shows a pronounced yield and quality response to sole application of P and B fertilizer under most conditions (Buragohain and Gogoi 2010; Kano et al. 2012; Alkhader et al. 2013). Plant species vary considerably in their requirement for B and also in their capacity for uptake of this microelement (Tariq and Mott 2007). Boron availability to plants is controlled by various soil parameters such as pH, structure, moisture, temperature, organic matter, clay minerals, and sesquioxides (Tsadilas et al. 1994; Matula 2009). Apart from these factors, the interaction of B with other nutrients (N, P, K, Ca, Mg, Al, and Zn) can be synergistic or antagonistic which can influence B availability to plants (Gupta 1993). In addition, YuFan et al. (2012) observed that B application increased P uptake by plant. Many researchers reported that in combination of P and B significantly improved the growth, yield and quality of plant species (Kaya et al. 2009; YuFan et al. 2012; Jasim et al. 2014). Therefore, the present study was undertaken to see the interaction effect of P and B on the yield and quality of lettuce.

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MATERIALS AND METHODS

Experimental site

The experiment was conducted at Horticulture Research Farm as well as in the Horticulture Laboratory and Seed Technology Laboratory of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) during the period from December 2009 to April 2010 on a shallow red brown soil of Madhupur Tract. Physico-chemical properties of soil of the experimental plot is shown in Table 1.

Experimental design and treatments

The experiment was laid out in randomized complete block design with three replications. The treatments were randomly allotted in each block. The treatments comprised four levels of P (0, 40, 80 and 120 kg ha^{-1}) supplied as triple super phosphate and five levels of boron (0, 0.5, 1, 1.5 and 2kg ha^{-1}) supplied as boric acid in combination made 20 treatments. Ten tones cow dung per hectare, 250Kg ha^{-1} of urea, 200Kg ha^{-1} of MOP fertilizers were used as a basal dose. In each plot there were four rows accommodating five plants per row. Block to block and plot to plot distance were 1 m and 0.5 m, respectively. The dimension of the unit plot was 1.2 m × 2 m = 2.4 m^2. The row to row and plant to plant spacing were 40 cm and 25 cm, respectively.

Plant material and growth conditions

Lettuce (*Lactuca sativa* L., cv. Grand Rapids) was chosen as the plant material. Lettuce seeds were soaked in water for 48 hours and then the seeds were mixed with soilless mixture (1/4 perlite + 1/2 fine grade horticultural vermiculite + 1/4 peat moss) and sown in lines seedbed. Complete germination of seeds took place within 8 days of sowing. Twenty two days old seedlings were transplanted to the plot. Transplantation was done in the afternoon followed by a light irrigation around each seedling for better survival. Irrigation was given at an interval of 15 days depending on the soil and moisture condition. Four weeding were done at 10 days interval after transplanting. Staking was done in each plot using bamboo sticks to keep the plant and flower stock erect and to protect them from the damage caused by storm and high winds.

Agronomic and yield parameters

The seeds were harvested by cutting off the stalk when about 15-20% of the heads had black seeds at exposed condition. Seeds were separated by hand from the capsule after sufficiently drying. The dried seeds were sealed treatment wise in the polythene bags. All bag containing seeds were stored in refrigerator in the laboratory for evaluation of quality. Data on plant height, leaf number, leaf length and plant canopy were recorded from five randomly selected plants at 45 days after transplanting (DAT). Data on number of capsules per plant, seeds in capsule, number of seeds per plant and seed yield ha^{-1} were also calculated from five randomly selected plants.

Quality evaluations

Seed Germination Percentage (SGP)

Samples from each treatment were set to germinate at 24℃ in a Petri dish (9 cm diameter) containing a germination paper to which 5 ml water had been added. Germination, judged by the appearance of the radicle, was counted daily up to 7 days. At the final count, the number of normal and abnormal seedlings produced was assessed (ISTA 2005). The SGP was calculated as follows:

$$\text{SG (\%)} = \frac{\text{Number of germinated seed}}{\text{Total seed number}} \times 100$$

Moisture content (%)

The moisture content of the seeds was estimated by taking 4 g samples of seed from each treatment and using oven dry method at 130-133℃ for 1 h (ISTA 2013). The moisture content of seeds (wet basis) was determined by the following formula.

$$\text{Moisture content (\%)} = \frac{\text{Fresh seed wt.} - \text{Dry seed wt.}}{\text{Fresh seed wt.}} \times 100$$

Dry matter (%)

Samples from each treatment were weight (stem and leaf) and dried into oven at 70℃for 72 hours. The weight was then recorded. The total dry matter content was calculated by the following formula:

$$\text{Dry matter (\%)} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

Analytical purity (%)

As per the rules of International Seed Testing Association (ISTA 2008), purity analysis sorted out three components; inert matter, other seed and pure seed. The three components for each replicate were weighed by using the Digital Electronic Balance and expressed in percentage. The percentage by weight of each component is determined by dividing the weight of all the components. It is calculated as under:

$$\text{Purity (\%)} = \frac{\text{Weight of pure seed}}{\text{Total weight of the entire component}} \times 100$$

Planting value (%)

Pure live seed percentage represents the amount of pure seeds in a seed lot that are capable of producing seedlings. Thus the actual planting value of seed lot can determined only when the

Table1. Physico-chemical properties of soil of the experimental plot

Soil Characteristics	Analytical value
Physical Properties	
Sand	17.2 %
Silt	47.2%
Clay	35.6%
Textural class	Silty clay loam
Bulk density	1.4 g cm
Partical density	2.6 g cm
Chemical Properties	
Soil pH	5.8
Total N (%)	0.076
Organic C (%)	0.9
Exchangeable K (meq/100 g)	0.46
Exchangeable Ca (meq/100 g)	8.75
Exchangeable Mg (meq 100 g)	2.46
Exchangeable Na (meq/100g)	0.8
Available Phosphorus (ppm)	18.00
Available Sulphur (ppm)	9.25
Available Boron (ppm)	0.20

purity analysis and germination tests are consider together. It is calculated by using the formula:

$$PLS = \frac{\text{Germination \%} \times \text{Purity \%}}{100}$$

1000 seed weight

To measure the 1000 seed weight, each seed sample was divided into 3 sub-samples and 10 replicates of 100 seed from each sub sample were counted at random. Thus weights of replicates (100 × 10 × 3 replicates) were added together and the resulting mean weight was recorded at the 1000 seed weight of the seed sample.

Statistical analysis

Collected data were subjected to analysis by MSTAT and the differences among treatment means were compared by Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Phosphorus and boron interaction effect on yield parameters

The interaction effects of P and B on the yield parameters of lettuce are shown in Table 2. Treatment T_{20} ($P_{120}B_2$) produced taller plants (24.50 cm) which was significantly high than the other treatments. Minimum plant height (17.83 cm) was recorded in control treatment T1 (P_0B_0). Kabir et al. (2013) reported that the combined application of P and B increased the plant height than the control in groundnut. Alkhader et al. (2013) observed that the sole application of P fertilizers increased plant height of lettuce. The result might be due to the fact that P is involved in photosynthesis (Singh and Sale 2000), total chlorophyll concentration (Sawan et al. 2008) and thereby encourages vegetative growth resulting increase in plant height. Benjawan Chutichudet and P. Chutichudet (2009) observed that the application of boric acid to increase plant height in lettuce. In addition, B application at 2 kg ha^{-1} applied at ray floret stage resulted in recording of more plant height (Zahoor et al. 2011). Boron is important in cell elongation, cell division (Camacho-Cristobal et al. 2015); enhance plant growth, ultimately plant height increased.

The significant highest number of leaves (60.08) and leaf length (25.54 cm) were obtained from the treatment T_{20} ($P_{120}B_2$), while the lowest number of leaves (44.75) and leaf length (21.84 cm) were obtained from the T_1 (P_0B_0) treatment (Table 2). Similarly, treatment T_{20} ($P_{120}B_2$) posed a highest leaf canopy (946.7 cm^2) whereas control treatment T_1 exhibited lowest leaf canopy (645.7 cm^2) (Figure 1). Kabir et al. (2013) found that the interaction effect of P and B on number of branches $plant^{-1}$ of groundnut was significantly increased. Alkhader et al. (2013) observed that sole application of P fertilizer increased leaf number and leaf surface area in lettuce. Benjawan Chutichudet and P. Chutichudet (2009) also found that the application of boric acid to increase bush size in lettuce. Moreover, the application of B increased the leaf number, leaf length, and leaf size index of early cauliflower and broccoli (Buragohain and Gogoi 2010; Moniruzzaman et al. 2007). B deficient leaves showed decreased CO2 assimilation and stomatal conductance. Activities of ribulose-1, 5-bisphosphate carboxylase/oxygenase (Rubisco), NADP-glyceraldehyde-3-phosphate dehydrogenase (NADP-GAPDH) and stromal fructose-1,6-bisphosphatase (FBPase) were lower in B-deficient leaves than in controls (Han et al. 2008). Increase of photosynthetic activity with increased exogenously applied B concentration specifically at ray floret stage of sunflower (Zahoor et al. 2011).

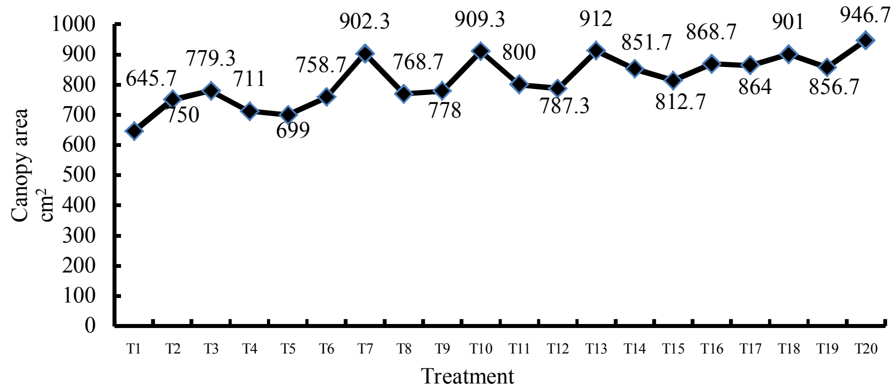


Figure 1. Interaction effect of P and B on canopy of lettuce plant

In addition, B nutrition was found increasing fresh weights of crop plants (Renukadevi *et al*., 2003).

The results showed that the highest number of capsules plant^{-1} (29.0) was obtained from the treatment T_{20}, whereas the control treatment T_1 recorded the lowest number of capsules plant^{-1} (11.0). Highest number of seeds capsule^{-1} (49.67) was linked to the treatment of T_{20}, whereas the lowest seeds capsule^{-1} (28.0) was related to control plants. Plant fertilized with treatment T_{20} produced maximum number of seeds plant^{-1}(1337) and seed yield ha^{-1} (7.28 ton). However, number of seeds plant^{-1} (389.7) and seed yield ha^{-1} (4.16 ton) were minimal for treatment T_1 (Table 2). Kano et al. (2012) reported that seed yield plant^{-1} and number of seeds plant^{-1} increased linearly with the increase of phosphorus rates in lettuce. Alkhader et al. (2013) also indicated that P fertilization has increased seed yield of lettuce. Increase of seed yield of safflower due to B foliar application has been reported by Galavi et al. (2012). These results suggested that the highest dose of P and B was better to obtain the higher seed yield of lettuce plants. Jasim et al. (2014) reported that application of macro nutrients with boron caused an enhance in increase seed yield of broad bean. The increase in yield due to P fertilizer may be attributed to the activation of metabolic processes, where its role in building phospholipids and nucleic acid is known. Moreover, P is a key constituent of ATP and plays significant role in energy transformation in plant

Table 2: Interaction effect of phosphorus and boron on the yield parameters of lettuce

Treatment	Plant height (cm)	Leaf no.	Leaf length	Capsule plant^{-1}	Seed capsule^{-1}	Seed no. plant^{-1}	Yield ha^{-1} (ton)
$T_1=P_0B_0$	17.83 e	44.75 d	21.84 bdc	11 f	28 e	389.7 h	4.16d
$T_2=P_0B_{0.5}$	17.58 e	51.33 a-d	22.04 bcd	13.33 def	31.33 de	437h	4.53 d
$T_3=P_0B_1$	18.83 cde	45.42bcd	21.42 bcd	11.66 def	30.67 de	454gh	4.34 d
$T_4=P_0B_{1.5}$	18.42 de	46.92 a-d	19.92 d	11.33 ef	31.33 de	411.7h	4.28 d
$T_5=P_0B_2$	22.71 ab	53.83 a-d	21.63 bcd	21.33 bc	42 bc	841.7bc	6.19 b
$T_6=P_{40}B_0$	19.90 b-e	50.75 a-d	22.34 bcd	12 ef	33.33 de	487.7fgh	4.22d
$T_7=P_{40}B_{0.5}$	19.08 c-e	57.17 a-d	21.44 bcd	11.67 def	34.33 de	468.3gh	4.56 d
$T_8=P_{40}B_1$	19.00 c-e	49.33 a-d	20.63 cd	22.33 b	43 b	796bcd	6.24 b
$T_9=P_{40}B_{1\cdot5}$	19.88 b-e	55.08 a-d	23.46 abc	12.33 def	30 de	432.3h	4.48 d
$T_{10}=P_{40}B_2$	21.08 b-d	49.67 a-d	22.63 bcd	16.67 cde	37.33 bcd	655de	5.32 c
$T_{11}=P_{80}B_0$	21.58 bc	51.75 a-d	22.15 bcd	15.33 def	33 de	706.7cde	5.36 c
$T_{12}=P_{80}B_{0.5}$	20.96 b-d	52.00 a-d	21.29 bcd	17 cd	32.67 de	675.3de	5.26 c
$T_{13}=P_{80}B_1$	20.06 b-e	53.83 a-d	22.46 bcd	16.33 cde	35.33 cde	662.7de	5.17 c
$T_{14}=P_{80}B_{1\cdot5}$	20.96 b-d	58.33 ab	22.71 bcd	16.67 cde	35.33 cde	600.3efg	5.27 c
$T_{15}=P_{80}B_2$	19.83 b-e	54.08 a-d	21.63 bcd	15.67 def	37.33 bcd	594efg	5.27 c
$T_{16}=P_{120}B_0$	20.63 b-e	58.83 ab	22.38 bcd	15 def	37.33 bcd	618ef	5.33 c
$T_{17}=P_{120}B_{0\cdot5}$	20.00 b-e	59.00 ab	23.67 ab	15 def	34.67 de	656de	5.22 c
$T_{18}=P_{120}B_1$	22.67ab	59.08 ab	21.96 bcd	21.33 bc	42.67 b	900.3b	6.5 b
$T_{19}=P_{120}B_{1.5}$	22.83 ab	57.92abc	24.08 ab	24.33 b	42.33 bc	882.3b	6.51 b
$T_{20}=P_{120}B_2$	24.50 a	60.08 a	25.54 a	29 a	49.67 a	1337a	7.28 a
Level of significance (5%)	*	*	*	*	*	*	*
CV %	5.79%	9.06%	6.62%	9.59%	8.02%	9.45%	3.17%

Table 3: Interaction effect of phosphorus and boron on seed quality of lettuce

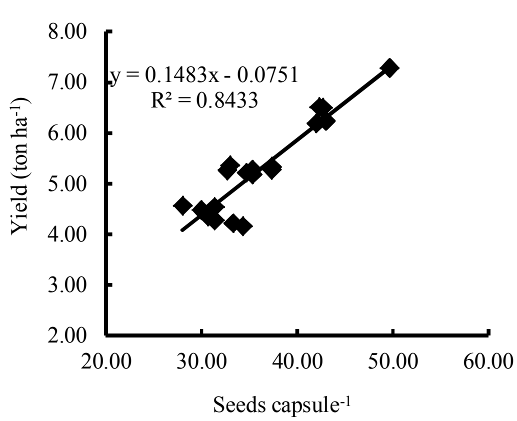
Treatment	Germination (%)	Planting value (%)	Moisture (%)	Purity (%)	Dry matter (%)	1000 seed wt (gm)
$T_1=P_0B_0$	89.03h	86.60f	28.57a	97.07e	0.0139e	2.06e
$T_2=P_0B_{0.5}$	96.78a-f	94.50a-d	26.40b	97.65a-e	0.7987bc	2.11de
$T_3=P_0B_1$	95.57b-g	93.43b-e	10.83def	97.77a-e	0.659d	2.11de
$T_4=P_0B_{1.5}$	95.63b-g	93.24b-e	8.073gh	97.50a-e	0.7607cd	2.13de
$T_5=P_0B_2$	98.33abc	95.45abc	9.52efg	97.37b-e	0.7467cd	2.75b
$T_6=P_{40}B_0$	95.33c-g	93.62b-e	10.60def	98.37ab	0.7710cd	2.11de
$T_7=P_{40}B_{0.5}$	97.20a-d	94.92abc	9.32efg	98.33ab	0.75cd	2.08e
$T_8=P_{40}B_1$	98.50ab	96.72a	12.51cd	97.87a-e	0.7503cd	2.65b
$T_9=P_{40}B_{1\cdot5}$	93.93fg	92.40cde	13.45c	98.37ab	0.7540cd	2.10de
$T_{10}=P_{40}B_2$	97.33a-e	95.78ab	11.41cde	98.40 ab	0.7677cd	2.47c
$T_{11}=P_{80}B_0$	97.60a-d	95.20abc	10.87def	97.53a-e	0.8233bc	2.24de
$T_{12}=P_{80}B_{0.5}$	94.34efg	91.77de	10.22efg	97.27cde	0.9000ab	2.20de
$T_{13}=P_{80}B_1$	96.43a-f	94.89abc	10.07efg	98.40ab	0.7973bc	2.27d
$T_{14}=P_{80}B_{1\cdot5}$	93.40g	91.52de	9.60efg	97.77a-e	O.7927bc	2.23de
$T_{15}=P_{80}B_2$	97.57a-d	94.79abc	9.41efg	97.17de	0.7457cd	2.24de
$T_{16}=P_{120}B_0$	95.80a-g	93.89a-e	9.87efg	97.93a-e	0.8190bc	2.18de
$T_{17}=P_{120}B_{0\cdot5}$	93.33g	91.43e	8.97fg	98.30abc	0.8893ab	2.2De
$T_{18}=P_{120}B_1$	94.55d-g	92.82b-e	6.17hi	98.17a-d	0.8330bc	2.69b
$T_{19}=P_{120}B_{1.5}$	96.83a-f	95.35abc	8.86fg	98.23abc	0.8503abc	2.69b
$T_{20}=P_{120}B_2$	98.83a	96.76a	5.42i	98.47a	0.9507a	3.01a
Level of significance (5%)	*	*	*	*	*	*
CV %	1.24 %	1.27%	7.93%	5.42%	6.06%	3.18%

and also roles in seed formation (El-Habbasha et. Al. 2007). On the other hand, positive role of boron in the transport of carbohydrate materials from the source to the sink (Barker and Pilbeam 2006).

Phosphorus and boron interaction effect on yield quality

The interaction effects between P and B significantly influenced the quality attributes (germination%, planting value%, moisture%, purity%, dry matter% and 1000 seed weight) of lettuce seeds were observed (Table 3). Seeds of Lettuce germinated in all treatment combinations. A significant lower germination occurred only at a treatment of T_1 (P_0B_0) (89.03%). However, treatment combination T_{20} ($P_{120}B_2$) showed highest germination rate (98.83%) followed by in T_8 ($P_{40}B_1$) (98.50%). Christos Dordas (2006) observed that foliar application of B improved seed germination of cotton. The highest moisture content (28.57%) recorded in T_1 (P_0B_0) treatment and lowest recorded in T_{20} ($P_{120}B_2$) treatment (5.42%). Moisture content decreases considerably and germination increases up to optimum moisture level (5.42%). These results indicate that the seed moisture content is the most important factor affecting seed germination. This finding is in

A



B

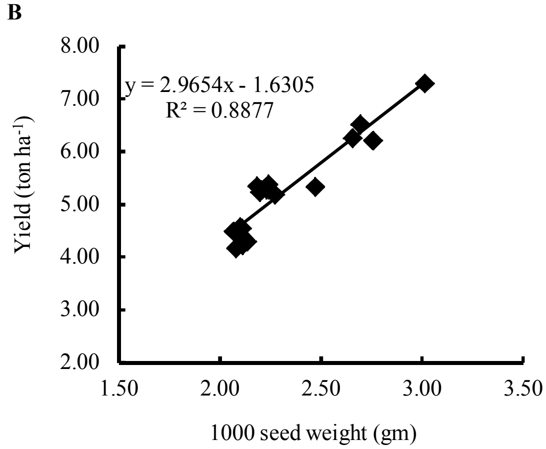


Figure 2. Relationship between seeds capsule^{-1}(A), 1000 seed weight (B) and seed yield of lettuce

accordance with Nahar et al. (2009). Previous study showed that raising soil test P from low to high increased corn yield and improved quality by decreasing grain moisture (Ohio State University 1999). The highest purity was in T_{20} ($P_{120}B_2$) treatment (98.47%) followed by T_{13} ($P_{80}B_1$) treatment (98.40%) where the lowest in T_1 (P_0B_0) treatment (97.07%). This result might be due to the effect of proper fertilizer treatment combination that helps to form better seed structure. Seed purity is an important factor, which determines the quality of seed. In fact, seed purity depends upon the immature crop seeds, amount of unwanted material such as noxious weed seed, unwanted crop seed or inert matter present in the pure seed.

In planting value maximum value (96.76%) was obtain from in T_{20} ($P_{120}B_2$) and minimum value (86.60%) was found in T_1 (P_0B_0) (Table 3). The actual planting value of seed lot can determined only when the purity analysis and germination tests are consider together. Seed moisture content is the most important factor that regulates the longevity of the seeds (Shaban 2013). Higher moisture in seeds enhances seed deterioration (Shaban 2013), which ultimately reduces the planting value of seeds in the field.

photosynthesis and gathering plant dry matter (Zahoor et al., 2011).

Interaction effect showed that maximum 1000 seed weight (3.01 g) was recorded in treatment T_{20} in plot which received 120kg P ha^{-1} and 2kg B ha^{-1}, while minimum 1000 seed weight (2.06 g) was recorded in control plot (Table 3). These results are in accordance with the findings of Amjad et al. (2001), who recorded maximum 1000 seed weight of okra when P was applied at the highest rate. Galavi et al. (2012) also found that 1000 seed weight of safflower significantly increased in response to sole application of B. Alam et al. (2010) suggests that application of P in combination with B resulted in the increase 1000seed weight of summer mungbean. The increase of yield components due to role of B in translocation of photosynthesis (Zahoor et al. 2011) and its ability to develop bold seeds.

Correlation and regression analyses of lettuce

Seeds $capsule^{-1}$ and 1000 seed weight had significantly positive correlation with seed yield of lettuce with the r values of 0.843 and 0.887, respectively (Figures 2A, B). These results indicate that the lettuce on seed yield increased with the

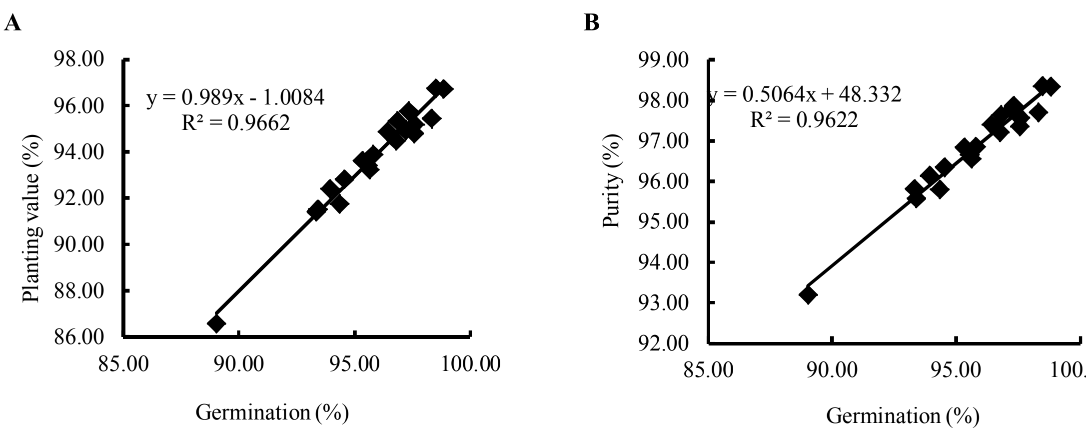


Figure 3. Relationship between planting value(%) (A),purity(%) (B) and germination (%) of lettuce

increase in seeds $capsule^{-1}$ and 1000 seed weight. The relationship between planting value (%) and purity (%) and germination (%) were found positive, linear and significant (R^2 = 0.966, R^2 = 0.962) (Figures 3A, B), suggesting that germination percentage increased with the increase in pure live seed and in purity of seed. A negative linear relationship was found between moisture content and germination percentage when the data was regressed (R^2 = 0.126) (Figure 4). It can be concluded that germination percentage decreased with the increased of moisture content, indicating that more moisture content in seed enhances respiration and biochemical activities and fungal attack of seed that results rapid seed deterioration, which reduces the quality of seed.

The highest dry matter production (0.9507%) was linked to the combination of treatment T_{20} ($P_{120}B_2$), whereas the control treatment T_1 (P_0B_0) recorded the lowest dry matter production (0.0139%) (Table 3). More and Agale (1993) indicated that application of P alone in cotton plants increased dry matter yield. Application of B alone plays an important role to increase biomass production in tobacco plants (Lopez-Lefebre et al. 2002). Adequate supply of P and B were found to interact positively to increase the biomass production of *Brassica napus* L. **(**Lei et al. 2009**).** This is due to the role of boron to encourage vegetative growth and increase the rate of

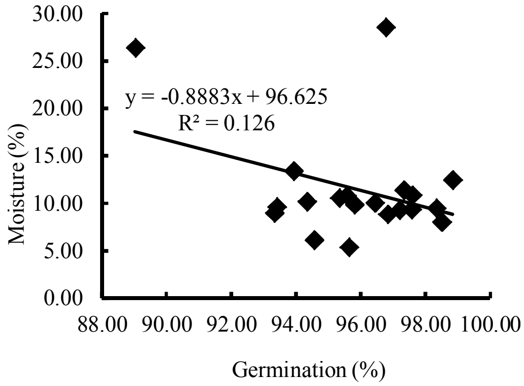


Fig.4. Relationship between moisture (%) and germination (%) of lettuce

CONCLUSION

Phosphorus and boron played an important role in increasing vegetative growth, yield and quality of lettuce seed. The fertilizer treatment combination of 120kg ha^{-1} of P and 2kg ha^{-1} of B was observed to be a suitable dose for better growth, yield and quality of lettuce in shallow red brown terrace soil of Madhupur Tract.

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