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DETERMINATION OF OPTIMUM RATE OF NITROGEN, PHOSPHORUS, POTASSIUM AND BORON FOR LEAF AND SEED YIELD OF LETTUCE

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Abstract

The experiment was conducted at Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, during October 2012 to May 2013 to determine the optimum rate of nutrients for sustainable lettuce production. Nineteen treatment combinations were considered with five levels of each elements such as nitrogen viz. 0, 50, 100, 150 and 200 kg ha^{-1}; phosphorus viz. 0, 25, 50, 75 and 100 kg ha^{-1}; potassium viz. 0, 50, 100, 150 and 200 kg ha^{-1}; boron viz. 0, 0.5, 1.0, 1.5 and 2.0 kg ha^{-1}. Results revealed that treatment T_3 ($N_{100}P_{50}K_{100}B_{1.0}$) showed the maximum leaf and seed yield of lettuce. Fertilizer doses under T_3 also showed the highest gross margin Tk. 305825 and Tk. 2816675 ha^{-1} and BCR 7.50 and 70.0 for leaf and seed yield, respectively. But, from regression analysis optimum doses of nitrogen, phosphorus, potassium and boron for maximum leaf yield (23.11 ton ha^{-1}) and seed yield (571.5 kg ha^{-1}) were $N_{143}P_{74}K_{95}B_{1.26}$ and $N_{136.4}P_{67.8}K_{118.0}B_{1.0}$, respectively that could be recommended as the best combination of nutrients for achieving higher leaf and seed yield of lettuce.

Keywords: Lettuce, fertilizer, yield, seed production, BCR.

Introduction

Lettuce (*Lactuca sativa* L.) is the most popular and important nutritious leafy salad vegetable. Lettuce is produced commercially in many countries worldwide and is also widely grown as a vegetable in home gardens (Rubatzky and Yamaguchi, 1997). Optimal fertilizer management and efficient use of N, P, K and boron (B) are necessary for improve yield and quality, and to reduce production cost of lettuce (Hoque *et al*., 2010).

Nitrogen is an essential and important determinant plant nutrient for growth and development of crop plants (Tanaka *et al*., 1984). It is the most important fertilizer nutrient for lettuce production which exhibits marked effect on the vegetative growth, leaf and seed yield, fibre and protein content of lettuce.

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Phosphorus plays a vital role in cell division, seed formation, crop maturation and also improves the quality of seed. Potassium increases water holding capacity of plant tissue, succulence of vegetables and retains good condition for longer period (Ahammed, 2009). Boron (B) is an element for the growth of new cells. Boron deficiency in soil causes reduction in number and retention of flowers, pollen germination and pollen tube growth are reduced resulting sterility in seeds (Katyal and Randhawa, 1983).

As a new crop, farmers face various problems since detailed fertilizer package of lettuce is not available. Judicious application of fertilizer has great impact on growth and yield of crop plants. Research information regarding the suitable dose of NPK and B for the satisfactory production of lettuce is meager in Bangladesh. The present investigation was therefore, undertaken with a view to determining the suitable dose of N, P, K and B in order to maximize the leaf and seed yield of lettuce in Salna soils of Bangladesh.

Materials and Methods

The experimental site and soil characters

The experiment was conducted at the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, during the period from October 2012 to May 2013. The experimental site located in the centre of the agro-ecological zone of Madhupur Tract (AEZ-28). The experimental plot was high land having silty clay loam soil. The soil was slightly acidic (pH-6.5) and low in organic matter and total-N (Table 1).

Table 1. Results of the chemical analysis of initial soil sample of the experimental plot

Soil properties	Analytical value		Optimum value
	2011-12	2012-13	
Soil pH	6.50	6.60	-
Organic matter (%)	0.95	0.95	-
Total N (%)	0.030	0.30	3.00
Available P (µg/ml)	45.00	43.00	-
Exchangeable K (meq/100ml)	0.36	0.35	1.50
B (ppm)	1.50	1.50	-
Ca (meq/100ml)	15.00	15.00	18.00
Mg (meq/100ml)	5.0	5.0	9.00
S (ppm)	15.00	14.00	60.00

Experimental design and treatment details

The experiment was laid out in a randomized complete block design (RCBD) with three replications. There were nineteen treatments containing five levels of each elements such as nitrogen viz. 0, 50, 100, 150 and 200 kg ha^{-1}; phosphorus viz. 0, 25, 50, 75 and 100 kg ha^{-1}; potassium viz. 0, 50, 100, 150 and 200 kg ha^{-1}; boron viz. 0, 0.5, 1.0, 1.5 and 2.0 kg ha^{-1}. Nineteen treatment combinations (including one control and one cow dung treatment) were selected with those levels of N, P, K and B according to the North Carolina University, USA design which were as follows:

Treatment No.	Treatment dose ($kgha^{-1}$)			
	N	P	K	B
T_1	0	50	100	1.0
T_2	50	50	100	1.0
T_3	100	50	100	1.0
T_4	150	50	100	1.0
T_5	200	50	100	1.0
T_6	100	0	100	1.0
T_7	100	25	100	1.0
T_8	100	75	100	1.0
T_9	100	100	100	1.0
T_{10}	100	50	0	1.0
T_{11}	100	50	50	1.0
T_{12}	100	50	150	1.0
T_{13}	100	50	200	1.0
T_{14}	100	50	100	0
T_{15}	100	50	100	0.5
T_{16}	100	50	100	1.5
T_{17}	100	50	100	2.0
T_{18} (Control)	0	0	0	0
T_{19}	Only Cow dung @ 10 ton/ha			

Planting/sowing

Lettuce genotype LS_{003} was used as planting material, which was a selected line for its outstanding performance. Thirty days old seedlings were transplanted on 26th November 2012, two days after final land preparation.

Fertilizer application

Cow dung was mixed up with the soil during final land preparation. The entire quantity of TSP, MoP and boric acid were applied during land preparation. Urea was applied in three equal splits at 7, 17 and 30 days after transplanting (DAT) followed by irrigation.

Intercultural operations

Irrigation was given at an interval of 8-10 days depending on the soil moisture content. Two weedings were done at 10 and 20 DAT.

Data collection

For leaf yield, 50% plants i.e. 12 plants from each plot were uprooted at 40 DAT. Out of them 5 plants were randomly selected for different data collection. Remaining 12 plants were well managed for further growth to record the seed yield data. In each unit plot 5 plants were selected randomly for recording data on different yield contributing characters for seed yield. Lettuce seed was harvested from 22 - 24 March in 2013.

Calculation of optimum dose

To determine optimum fertilizer dose for maximum yield, polynomial regression analysis was done for its calculation. The following equation used to calculate the optimum dose (Ahammed, 2009 and Paul, 2009):

$Y = -ax+bx+c$

Here, Y= yield (t ha^{-1})

x= the dose of nutrient (kg ha^{-1})

Y (max) = -b/2a.

The maximum yield is obtained when the marginal production (MP) is zero. MP is calculated by differentiating the first x derivative of y.

$MP=dy/dx=b+2ax$

$0= b+2ax$

$x=-b/2a$

Economic evaluation of different fertilizer combination was done by showing the benefit cost ratio (BCR). Gross return and variable costs were calculated considering the present market price of the materials (Islam *et al.* 2007).

Statistical analysis

The analysis of variance for various parameters was performed following ANOVA (analysis of variance) technique. When F was significant at the $P \leq 0.05$ level, treatment means were separated using DMRT. Data were analyzed following standard procedure using MSTAT-C program.

Results and discussion

The results obtained from this experiment have been presented and discussed character wise under separate headings in this chapter. The effect of N, P, K and

B on lettuce leaf and seed production have been shown in Tables 2 to 9 and Figures 1 to 10.

1. Growth, Leaf yield and yield contributing characters of lettuce

Plant height

Different levels of N, P, K and B had significant influence on plant height of lettuce at 40 days after transplanting (Table 2.). Plant height increased gradually with increase in N, P, K and B levels up to the recommended dose (T_3). The maximum plant height (23.27 cm) was recorded in T_4 ($N_{150}P_{50}K_{100}B_{1.0}$) which was statistically identical to T_{16} ($N_{100}P_{50}K_{100}B_{1.5}$), T_3 ($N_{100}P_{50}K_{100}B_{1.0}$), T_{17} ($N_{100}P_{50}K_{100}B_{2.0}$), T_5 ($N_{200}P_{50}K_{100}B_{1.0}$) and T_{15} ($N_{100}P_{50}K_{100}B_{0.50}$). The minimum plant height (13.20 cm) was recorded in the control (T_{18}) which received none of the nutrients. Application of N along with others (P, K and B) up to certain level might have favoured in increased growth of the crop and attained the maximum height of the crop. Afroz *et al.* (2009) reported that the highest plant height (21.65 cm) was recorded in 135 kg N ha^{-1} and the lowest was noted in the control (no N) which is in agreement with the present findings. Similar findings on lettuce have been reported by Hochmuth *et al.* (1994).

Leaves per plant

Regarding numbers of leaves, a significant variation was also observed as influenced by different levels of N, P, K and B. The maximum number of leaves (19.75) was found in T_3 which was statistically identical to T_4 ($N_{150}P_{50}K_{100}B_{1.0}$), T_{16} ($N_{100}P_{50}K_{100}B_{1.5}$), T_{17} ($N_{100}P_{50}K_{100}B_{2.0}$), T_5 ($N_{200}P_{50}K_{100}B_{1.0}$) and T_{15} ($N_{100}P_{50}K_{100}B_{0.50}$) (Table 2). The minimum leaves per plant (9.60) were recorded in control (T_{18}). Lower level of N, P, K and B might have reduced the efficiency of plants in uptaking the nutrients for normal growth of plant. Tejaswini *et al.* (2012) found the maximum numbers of leaves per plant (19 and 16) in lettuce with 100 kg N ha^{-1}. Afroz *et al.* (2009) reported the maximum leaves $plant^{-1}$ (25.08) with application of 135 kg N ha^{-1} and the lowest from no nitrogen. All of these findings are very close to the present results.

Leaf size

Leaf size indicates the efficiency of photosynthesis, which has an important role in crop yield. The leaf size was significantly variable among the treatments (Table 2). The leaf size was increased with increase in nutrients level up to 100-50-100-1.0 kg ha^{-1} N-P-K-B, respectively and then decreased. The maximum size of leaf (380.70 cm^2) was recorded in T_4 where the minimum (198.40 cm^2) was found in the control ($N_0P_0K_0B_0$). Moniruzzaman (2002) reported that the maximum size of leaf (488.00 cm^2) was found in $N_{100}P_{50}$ and minimum (391.64 cm^2) was found in the control (N_0P_0), which are in agreement with the findings of our result.

Table 2. Plant height and leaf characters of lettuce as influenced by N, P, K and B application

Treatments	Plant height (cm)	Leaves plant^{-1} (no)	Leaf size (cm²)
T_1 ($N_0P_{50}K_{100}B_{1.0}$)	13.92 h	11.85 h	241.40 k
T_2 ($N_{50}P_{50}K_{100}B_{1.0}$)	18.30 ef	15.56 ef	305.50 gh
T_3 ($N_{100}P_{50}K_{100}B_{1.0}$)	22.50 ab	19.75 a	373.10 b
T_4 ($N_{150}P_{50}K_{100}B_{1.0}$)	23.27 a	18.50 ab	380.70 a
T_5 ($N_{200}P_{50}K_{100}B_{1.0}$)	22.04 a-c	18.29 a-c	361.70 c
T_6 ($N_{100}P_0K_{100}B_{1.0}$)	17.95 f	14.89 fg	295.50 i
T_7 ($N_{100}P_{25}K_{100}B_{1.0}$)	21.19 b-d	17.58 b-d	347.70 d
T_8 ($N_{100}P_{75}K_{100}B_{1.0}$)	19.97 de	16.57 b-f	327.60 f
T_9 ($N_{100}P_{100}K_{100}B_{1.0}$)	19.73 de	16.37 c-f	323.80 f
T_{10} ($N_{100}P_{50}K_0B_{1.0}$)	18.37 ef	15.15 b-f	302.10 h
T_{11} ($N_{100}P_{50}K_{50}B_{1.0}$)	20.72 cd	17.00 b-e	340.10 e
T_{12} ($N_{100}P_{50}K_{150}B_{1.0}$)	18.83 ef	15.68 def	309.10 g
T_{13} ($N_{100}P_{50}K_{200}B_{1.0}$)	18.61 ef	15.60 ef	303.40 gh
T_{14} ($N_{100}P_{50}K_{100}B_0$)	21.35 b-d	17.71 bc	350.10 d
T_{15} ($N_{100}P_{50}K_{100}B_{0.5}$)	21.81 a-c	18.20 a-c	358.10 c
T_{16} ($N_{100}P_{50}K_{100}B_{1.5}$)	22.74 ab	18.42 ab	369.20 b
T_{17} ($N_{100}P_{50}K_{100}B_{2.0}$)	22.27 a-c	18.30 a-c	362.50 c
T_{18} ($N_0P_0K_0B_0$)	13.20 h	9.60 i	198.40 l
T_{19} (CD_{10})	15.78 g	13.60 gh	262.70 j
CV (%)	3.53	4.84	0.82

Means followed by same letter (s) in a column do not differ significantly at 5% level of DMRT.

Canopy spread diameter

Canopy spread at harvest was significantly influenced by different levels of N, P, K and B. The maximum canopy spread diameter (29.90 cm) was found in T_4 ($N_{150}P_{50}K_{100}B_{1.0}$), which was statistically identical to T_3 ($N_{100}P_{50}K_{100}B_{1.0}$), T_5 ($N_{200}P_{50}K_{100}B_{1.0}$) and T_{16} ($N_{100}P_{50}K_{100}B_{1.5}$) while the minimum value (14.20 cm) was recorded in the control (Table 3).

Dry matter content

The dry matter content (%) of lettuce at harvest was significantly influenced by different levels of N, P, K and B. Dry matter content of lettuce increased with increase in levels of N, P, K and B up to 200-50-100-1.0 kg N, P, K and B ha^{-1}. The highest dry matter (7.3%) was found in T_5 ($N_{200}P_{50}K_{100}B_{1.0}$) which was statistically similar with T_4 ($N_{150}P_{50}K_{100}B_{1.0}$), T_9 ($N_{100}P_{100}K_{100}B_{1.0}$), T_3 ($N_{100}P_{50}K_{100}B_{1.0}$) and T_{16} ($N_{100}P_{50}K_{100}B_{1.5}$). On the contrary, the lowest dry matter content (5.25%) was recorded in the control (Table 3). Similar finding was also reported by Nafiu *et al*. (2011) where satisfactory growth and dry matter was recorded in 200 kg NPK ha^{-1}. Afroz *et al.* (2009) also reported that the highest dry matter content was noted in 135 kg N ha^{-1} and the lowest from no nitrogen. In present study the highest dry matter content was found in $N_{100}P_{50}K_{100}B_{1.0}$, which is similar to Afroz *et al.* (2009).

Leaf yield per plant and leaf yield per hectare

The leaf yield per plant was significantly influenced by the different levels of N, P, K and B (Table 3). The highest leaf weight per plant (231.10 g) was in T_3, which was statistically different from rest of the treatments. The lowest leaf weight (96.00 g $plant^{-1}$) was recorded in the control ($N_0P_0K_0B_0$). Boroujerdnia *et al*. (2007) reported the highest leaf yield with 120 kg N ha^{-1} which corroborated our findings. Similar results were also reported by Afroz *et al.* (2009) where as the highest leaf yield was found in 135 kg N ha^{-1}. Moniruzzaman (2002) reported that $N_{100}P_{50}$ showed the maximum leaf yield (422.67 g $plant^{-1}$), that was considered to be the best combination of nitrogen and phosphorus for maximizing leaf yield in lettuce, where the lowest yield (157.33 g $plant^{-1}$) was noted in N_0P_0. The variation in results might be due to difference of genotype or the growing environment or both.

There was a significant effect of nutrients on leaf yield of lettuce (Fig. 1). Results revealed that leaf weight increased with increase in nutrients levels up to 100-50-100-1.0 kg ha^{-1} N, P, K and B respectively, after that decreased at higher dose. Yield decrease at higher levels of nutrients might be due to the detrimental effects of the nutrients. The leaf yield ranged from 9.60 to 23.11 ton ha^{-1}. The highest leaf yield (23.11 ton ha^{-1}) was found in T_3 , which was statistically identical to T_{16} ($N_{100}P_{50}K_{100}B_{1.5}$), T_4 ($N_{150}P_{50}K_{100}B_{1.0}$), T_{17} ($N_{100}P_{50}K_{100}B_{2.0}$), T_5 ($N_{200}P_{50}K_{100}B_{1.0}$), T_{15} ($N_{100}P_{50}K_{100}B_{0.50}$), T_{14} ($N_{100}P_{50}K_{100}B_{0}$) and T_7 ($N_{100}P_{25}K_{100}B_{1.0}$). The lowest leaf yield (9.60 ton ha^{-1}) was recorded in the control. Increased rates of nutrients application up to certain level might have favored the growth and development of the crop and led to increased plant height; numbers of leaves per plant, leaf size, canopy cover and ultimately resulted in increase yield of lettuce leaves. The higher doses of nutrients might have created detrimental effect to give lower yield of the crop. Afroz *et al.* (2009) reported that the highest leaf yield (28.29 ton ha^{-1}) was found in 135 kg N ha^{-1}. The leaf yield per hectare was directly contributed by the number of leaves per plant and individual weight of plant. This finding is in conformity with the result of Sajjan *et al.* (1991) in lettuce.

Table 3. Canopy spread diameter, dry matter and leaf yield per plant of lettuce is influenced by different levels of N, P, K and B

Treatment	Canopy spread diameter (cm)	Dry matter (%)	Leaf yield plant^{-1} (g)
T_1 ($N_0P_{50}K_{100}B_{1.0}$)	17.37 j	6.10 de	130.20 n
T_2 ($N_{50}P_{50}K_{100}B_{1.0}$)	23.43 gh	6.48 b-e	188.50 i
T_3 ($N_{100}P_{50}K_{100}B_{1.0}$)	28.96 a-c	7.10 a-c	231.10 a
T_4 ($N_{150}P_{50}K_{100}B_{1.0}$)	29.90 a	7.20 ab	224.20 bc
T_5 ($N_{200}P_{50}K_{100}B_{1.0}$)	29.50 ab	7.30 a	219.60 de
T_6 ($N_{100}P_0K_{100}B_{1.0}$)	22.40 h	6.20 de	178.80 l
T_7 ($N_{100}P_{25}K_{100}B_{1.0}$)	26.45 def	6.50 b-e	211.10 f
T_8 ($N_{100}P_{75}K_{100}B_{1.0}$)	24.92 fg	7.00 b	198.90 h
T_9 ($N_{100}P_{100}K_{100}B_{1.0}$)	24.63 fg	7.20 ab	196.60 h
T_{10} ($N_{100}P_{50}K_0B_{1.0}$)	22.95 gh	6.60 b-e	183.00 k
T_{11} ($N_{100}P_{50}K_{50}B_{1.0}$)	25.56 ef	6.70 b-e	206.40 g
T_{12} ($N_{100}P_{50}K_{150}B_{1.0}$)	23.51 gh	6.55 b-e	187.60 ij
T_{13} ($N_{100}P_{50}K_{200}B_{1.0}$)	23.08 gh	6.01 e	184.20 jk
T_{14} ($N_{100}P_{50}K_{100}B_0$)	26.64 d-f	6.48 b-e	212.60 f
T_{15} ($N_{100}P_{50}K_{100}B_{0.5}$)	27.22 c-e	6.40 c-e	217.20 e
T_{16} ($N_{100}P_{50}K_{100}B_{1.5}$)	28.00 a-d	7.05 a-c	226.50 b
T_{17} ($N_{100}P_{50}K_{100}B_{2.0}$)	27.50 b-e	6.80 bc	221.90 cd
T_{18} ($N_0P_0K_0B_0$)	14.20 k	5.25 f	96.00 o
T_{19} (CD_{10})	19.98 i	6.72 b-e	156.00 m
C.V (%)	3.49	4.53	0.96

Means followed by same letter (s) in a column do not differ significantly at 5% level of DMRT.

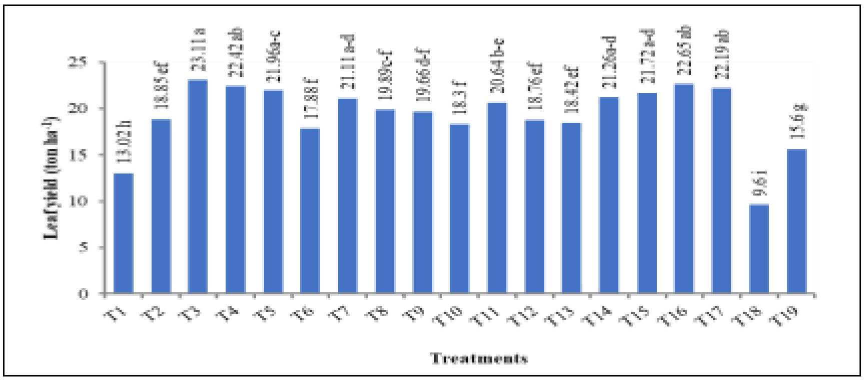

Fig. 1. Effect of N, P, K and B on leaf yield of lettuce.

Means placed on top of the bass followed by same letter(s) do not different significantly at 5% level of significance.

T_1 $=N_0P_{50}K_{100}B_{1.0}$; T_2 $=N_{50}P_{50}K_{100}B_{1.0}$; T_3 $=N_{100}P_{50}K_{100}B_{1.0}$; T_4 $=N_{150}P_{50}K_{100}B_{1.0}$; T_5 $=N_{200}P_{50}K_{100}B_{1.0}$; T_6 $=N_{100}P_0K_{100}B_{1.0}$; T_7 $=N_{100}P_{25}K_{100}B_{1.0}$; T_8 $=N_{100}P_{75}K_{100}B_{1.0}$; T_9 $=N_{100}P_{100}K_{100}B_{1.0}$; T_{10} $=N_{100}P_{50}K_0B_{1.0}$; T_{11} $=N_{100}P_{50}K_{50}B_{1.0}$; T_{12} $=N_{100}P_{50}K_{150}B_{1.0}$; T_{13} $=N_{100}P_{50}K_{200}B_{1.0}$; T_{14} $=N_{100}P_{50}K_{100}B_0$; $T_{15}$$=N_{100}P_{50}K_{100}B_{0.50}$; T_{16} $=N_{100}P_{50}K_{100}B_{1.50}$; T_{17} $=N_{100}P_{50}K_{100}B_{2.0}$; T_{18} $=N_0P_0K_0B_0$; T_{19} $=CD_{10}$

2. Seed yield of lettuce

Days to 50% flowering

Days to 50% flowering of lettuce plants were significantly influenced by different levels of N, P, K and B application. The plants took minimum days (117.30) for 50% flowering in T_3, which was statistically identical to T_7 and T_{16} (Table 4). The maximum period (121.50 days) was taken to 50% flowering in T_{18} followed by T_{11} ($N_{100}P_{50}K_{50}B_{1.0}$) and T_{10} ($N_{100}P_{50}K_0B_{1.0}$). Similar result was also reported by Paul (2009) where control ($N_0P_0K_0$) showed the highest period for 50% flowering and the lowest period was noted in $N_{100}P_{50}K_{100}$ kg ha^{-1} in sweet pepper. The result is in agreement with the findings of our study. This might be due to optimum doses of fertilizer that enhances metabolic and physiological activities and promoted the vegetative and reproductive growth.

Table 4. Effect of N, P, K and B on days to 50% flowering, days to seed maturity and branches per plant of lettuce

Treatments	Days to 50% Flowering	Days to seed maturity	Branches per plant (no.)
T_1 ($N_0P_{50}K_{100}B_{1.0}$)	120.10 b-e	142.40 b-e	24.36 e
T_2 ($N_{50}P_{50}K_{100}B_{1.0}$)	120.20 b-e	141.50 b-e	30.00 d
T_3 ($N_{100}P_{50}K_{100}B_{1.0}$)	117.30 j	139.50 f	40.66 a
T_4 ($N_{150}P_{50}K_{100}B_{1.0}$)	119.50 d-g	143.00 b-d	41.50 a
T_5 ($N_{200}P_{50}K_{100}B_{1.0}$)	120.50 a-d	143.50 a-c	41.60 a
T_6 ($N_{100}P_0K_{100}B_{1.0}$)	118.50 g-i	141.40 c-e	35.50 bc
T_7 ($N_{100}P_{25}K_{100}B_{1.0}$)	117.60 i-j	139.70 f	37.50 bc
T_8 ($N_{100}P_{75}K_{100}B_{1.0}$)	119.50 d-g	141.30 c-e	36.38 bc
T_9 ($N_{100}P_{100}K_{100}B_{1.0}$)	120.50 a-d	143.50 a-c	35.60 bc
T_{10} ($N_{100}P_{50}K_0B_{1.0}$)	120.80 ab	143.80 ab	34.50 c
T_{11} ($N_{100}P_{50}K_{50}B_{1.0}$)	121.00 ab	143.00 b-d	36.50 bc
T_{12} ($N_{100}P_{50}K_{150}B_{1.0}$)	119.20 e-g	142.50 b-d	34.42 c
T_{13} ($N_{100}P_{50}K_{200}B_{1.0}$)	120.60 a-c	143.80 ab	35.66 bc
T_{14} ($N_{100}P_{50}K_{100}B_0$)	118.60 fg	140.90 de	38.60 ab
T_{15} ($N_{100}P_{50}K_{100}B_{0.5}$)	119.50 d-g	141.80 b-e	37.00 bc
T_{16} ($N_{100}P_{50}K_{100}B_{1.5}$)	117.90 h-j	140.10 e	37.50 bc
T_{17} ($N_{100}P_{50}K_{100}B_{2.0}$)	119.50 d-g	142.80 b-d	36.50 bc
T_{18} ($N_0P_0K_0B_0$)	121.50 a	144.20 a	15.20 f
T_{19} (CD_{10})	119.60 e-f	141.50 b-e	28.14 d
C.V (%)	0.35	0.65	3.73

Means followed by same letter (s) in a column do not differ significantly at 5% level of DMRT.

Days to seed maturity

Days to seed maturity of lettuce were significantly variable among different levels of N, P, K and B. The maximum period for seed maturity (144.20 days) was found in T_{18} closely followed by T_{13} ($N_{100}P_{50}K_{200}B_{1.0}$), T_{10} ($N_{100}P_{50}K_0B_{1.0}$), T_5 and T_9 ($N_{100}P_{100}K_{100}B_{1.0}$) while it was minimum (139.50 days) in T_3 followed by T_7 (Table 4). Moniruzzaman (2002) reported that the maximum period for days to seed maturity was observed in $N_{150}P_0$ and the minimum was found in $N_{150}P_{50}$, which is in agreement with the present findings. This might be also due to optimum doses of fertilizer that enhance the vegetative and reproductive growth.

Branches per plant

The number of branches per plant was also varied significantly due to the application of N, P, K and B (Table 4). T_5 ($N_{200}P_{50}K_{100}B_{1.0}$) showed the highest number of branches per plant (41.60) followed by T_4, T_3 and T_{14}. The lowest number of branches per plant (15.20) was recorded in the control. Number of branches increased up to 200 kg N ha^{-1} application. But application of P, K and B at the rate of 50, 100 and 1.00 kg ha^{-1}, respectively also significantly increased number of branches per plant beyond which it decreased significantly. Similar results were also reported by Ahammed (2009), where the maximum branches $plant^{-1}$ was recorded in N, P, K and S at the rate of 150, 25, 50 and 4.00 kg ha^{-1}, respectively in stem amaranth. Faiza *et al.* (2002) also reported maximum branches per plant with the application of 150 kg N ha^{-1}. Sharma (1995) also reported that the maximum branches per plant were noted at 75 kg P_2O_5 and 100 kg K_2O ha^{-1}.

Capsules per plant

The capsules per plant were significantly influenced by different levels of N, P, K and B. The number of capsules per plant ranged from 324.50 to 582.20, having the highest number (582.20) in T_3 closely followed by T_8 ($N_{100}P_{75}K_{100}B_{1.0}$). The minimum number of capsules per plant (324.50) was recorded in the control (Table 5). Capsules per plant increased significantly up to 100, 50, 100 and 1.00 kg ha^{-1} of N, P, K and B application respectively, beyond that capsules per plant decreased significantly. Similar results were also found by Sajjan *et al*. (1992) in lettuce.

Seeds per capsule and 1000 seed weight

Seeds per capsule were significantly influenced by the different levels of N, P, K and B (Table 5). The highest average seeds $capsule^{-1}$ (11.96) was recorded from the plants of T_3 ($N_{100}P_{50}K_{100}B_{1.0}$) which was statistically similar with T_8 ($N_{100}P_{75}K_{100}B_{1.0}$) and T_9 ($N_{100}P_{100}K_{100}B_{1.0}$). On the other hand, the lowest seeds $capsule^{-1}$ (9.20) was noticed in T_{18} ($N_0P_0K_0B_0$). The above results clearly indicated that application of N, P, K and B dose up to $N_{100}P_{50}K_{100}B_{1.0}$ increased seed formation of lettuce and further increment in the dose of N, P, K and B in lettuce seed production declined the seed formation. Similar results also reported by Moniruzamman (2002). But no significant differences were found in 1000 seed weight although it ranged from 1.01 to 1.08 g.

Table 5. Effect of N, P, K and B on capsules per plant, seeds per capsule and 1000 seed weight (g) of lettuce

Treatments	Capsules per plant (no.)	Seeds per capsules (no.)	1000 seeds weight (g)
T_1 ($N_0P_{50}K_{100}B_{1.0}$)	328.70 g	9.50 de	1.03
T_2 ($N_{50}P_{50}K_{100}B_{1.0}$)	460.30 e	9.80 cde	1.01
T_3 ($N_{100}P_{50}K_{100}B_{1.0}$)	582.20 a	11.96 a	1.07
T_4 ($N_{150}P_{50}K_{100}B_{1.0}$)	548.10 b	11.01 b	1.01
T_5 ($N_{200}P_{50}K_{100}B_{1.0}$)	545.60 b	10.78 bc	1.07
T_6 ($N_{100}P_0K_{100}B_{1.0}$)	448.30 e	10.25 bcd	1.07
T_7 ($N_{100}P_{25}K_{100}B_{1.0}$)	533.70 bc	10.27 bcd	1.07
T_8 ($N_{100}P_{75}K_{100}B_{1.0}$)	553.60 ab	11.20 ab	1.06
T_9 ($N_{100}P_{100}K_{100}B_{1.0}$)	536.70 bc	11.08 ab	1.08
T_{10} ($N_{100}P_{50}K_0B_{1.0}$)	494.60 d	10.20 bcd	1.04
T_{11} ($N_{100}P_{50}K_{50}B_{1.0}$)	520.60 b-d	10.53 bc	1.05
T_{12} ($N_{100}P_{50}K_{150}B_{1.0}$)	525.10 b-d	10.80 bc	1.04
T_{13} ($N_{100}P_{50}K_{200}B_{1.0}$)	510.00 cd	10.75 bc	1.05
T_{14} ($N_{100}P_{50}K_{100}B_0$)	529.80 bc	10.50 bc	1.05
T_{15} ($N_{100}P_{50}K_{100}B_{0.5}$)	541.40 bc	10.91 b	1.05
T_{16} ($N_{100}P_{50}K_{100}B_{1.5}$)	546.20 b	10.80 bc	1.05
T_{17} ($N_{100}P_{50}K_{100}B_{2.0}$)	532.10 bc	10.60 bc	1.03
T_{18} ($N_0P_0K_0B_0$)	324.50 g	9.20 e	1.05
T_{19} (CD_{10})	395.60 f	9.30 de	1.08
C.V (%)	2.71	3.75	2.78

Means followed by same letter (s) in a column do not differ significantly at 5% level of DMRT.

Seed yield

The seed yield was significantly variable among different treatments. The seed yield of lettuce ranged from 240.5 to 57.5 kg ha^{-1}. The highest seed yield (571.50 kg ha^{-1}) was found in $T_{3,}$ which was statistically identical to T_8, T_9, T_4 and T_{16}

($N_{100}P_{50}K_{100}B_{1.50}$). The lowest seed yield (240.50 kg ha^{-1}) was recorded in the control. It was observed that the seed yield of lettuce increased with increase in nutrient levels upto 100-50-100-1.0 kg ha^{-1} of N, P, K and B, respectively beyond that seed yield was decreased (Figure 2). Sajjan *et al.*, (1992) and Ahammed (2009) reported that significant increase in number of branches per plant, number of capsules per plant, number of seeds per capsules and 1000 seeds weight contributed to high seed yield per hectare. The seed yield per hectare in different treatments varied possibly due to the effects of different nutrients.

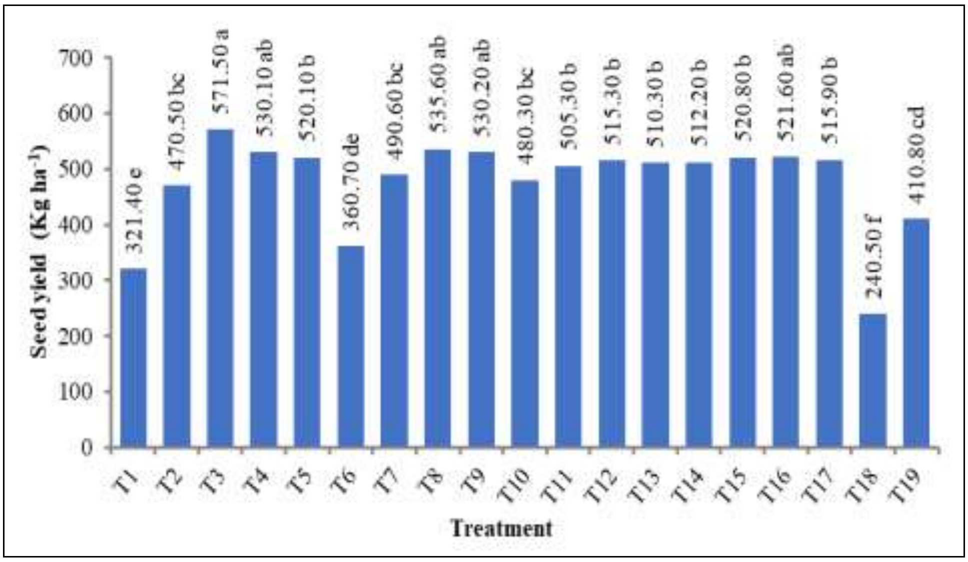

Fig. 2. Effect of NPK and B on seed yield of lettuce.

Means placed on top of the bass followed by same letter(s) do not different significantly at 5% level of significance.

T_1 =$N_0P_{50}K_{100}B_{1.0}$; T_2 =$N_{50}P_{50}K_{100}B_{1.0}$; T_3 =$N_{100}P_{50}K_{100}B_{1.0}$; T_4 =$N_{150}P_{50}K_{100}B_{1.0}$; T_5 =$N_{200}P_{50}K_{100}B_{1.0}$; T_6 =$N_{100}P_0K_{100}B_{1.0}$; T_7 =$N_{100}P_{25}K_{100}B_{1.0}$; T_8 =$N_{100}P_{75}K_{100}B_{1.0}$; T_9 =$N_{100}P_{100}K_{100}B_{1.0}$; T_{10} =$N_{100}P_{50}K_0B_{1.0}$; T_{11} =$N_{100}P_{50}K_{50}B_{1.0}$; T_{12} =$N_{100}P_{50}K_{150}B_{1.0}$; T_{13} =$N_{100}P_{50}K_{200}B_{1.0}$; T_{14} =$N_{100}P_{50}K_{100}B_0$; T_{15}=$N_{100}P_{50}K_{100}B_{0.5}$; T_{16} =$N_{100}P_{50}K_{100}B_{1.5}$; T_{17} =$N_{100}P_{50}K_{100}B_{2.0}$; T_{18} =$N_0P_0K_0B_0$; T_{19} =CD_{10}.

Relationship between nutrient levels and leaf yield of lettuce

The quadratic relationship was found between the leaf yield of lettuce and applied nutrients (N, P, K and B). From the regression equation y= 0.0005x^2 + 0.1431x + 13.0777; y= 0.013x2 + 3.546x + 325.5; y= 0.001x2 + 0.148x + 18.12; y= 0.044x2 + 5.963x + 365.5 the optimum dose of N, P, K and B calculated to be 143, 74, 95 and 1.3 k ha^{-1}, respectively (Table 6). The maximum yield for optimum dose of N, P, K and B was 23.1, 23.0, 23.1 and 23.1 ton ha^{-1}, respectively.

Table 6. Response function of leaf yield of lettuce to N, P, K and B application

Nutrient	Regression equation	R^2 value	Optimum dose (kg ha^{-1})	Obtainable maximum yield (ton ha^{-1})
N	$y= 0.0005x^2 + 0.1431x + 13.0777$	$R^2= 0.9802$	143	23.1
P	$y= 0.001x^2 + 0.148x + 18.12$	$R^2= 0.739$	74	23.0
K	$y= 0.0004x^2 + 0.0663x + 18.434$	$R^2= 0.643$	95	23.1
B	$y= 1.054x^2 + 2.666x + 21.10$	$R^2= 0.816$	1.3	23.1

Relationship between nutrient levels and seed yield of lettuce

Similarly, the quadratic relationship was found between the seed yield of lettuce and applied nutrients (N, P, K and B). From the regression equation $y= 0.013x^2 + 3.546x + 325.5$; $y= 0.044x^2 + 5.963x + 365.5$; $y= 0.005x^2 + 1.182x + 476.4$; $y= 36.91x^2 + 75.46x + 508.3$ the optimum dose of N, P, K and B calculated to be 136.4, 67.8, 188.0 and 1.0 kg ha^{-1}, respectively (Table 7). The maximum seed yield for optimum dose of N, P, K and B was 571.5, 571.5, 571.5 and 571.5 kg ha^{-1}, respectively.

Table 7. Response function of seed yield of lettuce to N, P, K and B application

Nutrient	Regression equation	R^2 value	Optimum dose (kg ha^{-1})	Obtainable maximum yield (kg ha^{-1})
N	$y= 0.013x^2 + 3.546x + 325.5$	$R^2= 0.956$	136.4	571.5
P	$y= 0.044x^2 + 5.963x + 365.5$	$R^2= 0.951$	67.8	571.5
K	$y= 0.005x^2 + 1.182x + 476.4$	$R^2= 0.636$	118.0	571.5
B	$y= 36.91x^2 + 75.46x + 508.3$	$R^2= 0.503$	1.0	571.5

3. Economic evaluation of fertilizer use

Leaf yield

The economic evaluation based on different treatment combination of N, P, K, B and cow dung in relation to the leaf yield of lettuce is presented in Table 8. It was observed that the highest production cost (Tk. 47810 ha^{-1}) was found in T_9 and this is due to higher cost for TSP fertilizer. The highest benefit cost ratio (BCR) (7.50) was noted in T_3 (100-50-100-1.00 kg NPKB ha^{-1}) and this might be due to lower cost of fertilizer and highest gross margin (Tk. 305825 ha^{-1}). The lowest BCR (4.35) was found in T_1 (0-50-100-1.00 kg NPKB ha^{-1}) due to higher cost of fertilizer and lower gross return. A similar finding was found by Islam *et al.* (2007).

Table 8. Economic evaluation based on different levels of NPKB in relation to leaf yield of lettuce

N-P-K-B Kg ha^{-1}	Leaf yield (ton ha^{-1})	Total cost of production (Tk ha^{-1})	Gross return (Tk ha^{-1})	Gross margin (Tk ha^{-1})	BCR
T_1 ($N_0P_{50}K_{100}B_{1.0}$)	13.02	36845	195300	158810	4.35
T_2 ($N_{50}P_{50}K_{100}B_{1.0}$)	18.85	38655	282750	244095	6.34
T_3 ($N_{100}P_{50}K_{100}B_{1.0}$)	23.11	40825	346650	305825	7.50
T_4 ($N_{150}P_{50}K_{100}B_{1.0}$)	22.42	42995	336300	293305	6.82
T_5 ($N_{200}P_{50}K_{100}B_{1.0}$)	21.96	45162	329400	284235	6.29
T_6 ($N_{100}P_0K_{100}B_{1.0}$)	17.88	33840	268200	234360	6.93
T_7 ($N_{100}P_{25}K_{100}B_{1.0}$)	21.11	37332.50	316650	279000	7.47
T_8 ($N_{100}P_{75}K_{100}B_{1.0}$)	19.89	44317.50	298350	253080	5.71
T_9 ($N_{100}P_{100}K_{100}B_{1.0}$)	19.66	47810	294900	245820	5.14
T_{10} ($N_{100}P_{50}K_0B_{1.0}$)	18.30	35825	274500	238040	6.64
T_{11} ($N_{100}P_{50}K_{50}B_{1.0}$)	20.64	38325	309600	270640	7.06
T_{12} ($N_{100}P_{50}K_{150}B_{1.0}$)	18.76	43325	281400	237440	5.48
T_{13} ($N_{100}P_{50}K_{200}B_{1.0}$)	18.42	45825	276300	229840	5.02
T_{14} ($N_{100}P_{50}K_{100}B_0$)	21.26	38325	318900	279940	7.30
T_{15} ($N_{100}P_{50}K_{100}B_{0.5}$)	21.72	39575	325800	285590	7.21
T_{16} ($N_{100}P_{50}K_{100}B_{1.5}$)	22.65	42075	339750	297040	7.06
T_{17} ($N_{100}P_{50}K_{100}B_{2.0}$)	22.19	43325	332850	288890	6.67
T_{18} ($N_0P_0K_0B_0$)	9.60	22000	144000	122000	5.55
T_{19} (CD_{10})	15.60	32000	234000	202000	6.31

Price of input: Urea: Tk. 20 kg^{-1}; TSP: Tk. 27.50 kg^{-1}; MoP: Tk. 25 kg^{-1}; Boric acid: Tk. 500 kg^{-1} and Cow dung: Tk. 1.00 kg^{-1}. **price of output:** Lettuce: Tk. 15.00 kg^{-1}

Seed yield

The economic evaluation based on different treatment combination of N, P, K, B and cow dung in relation to the seed yield of lettuce is presented in Table 9. Treatment T_9 showed the highest production cost (Tk. 47810 ha^{-1}) followed by T_{13} and T_5. The highest benefit cost ratio (BCR) (70.0) was recorded in T_3 (100-50-100-1 kg NPKB ha^{-1}), because of lower cost of fertilizer and highest gross margin (Tk. 2857500 ha^{-1}). The lowest benefit cost ratio (43.6) also recorded in

100-50-100-1 kg NPKB ha^{-1} and this is due to higher fertilizer cost and lower gross return. Similar finding was found by Islam *et al.* (2007).

Table 9. Economic evaluation based on different levels of NPKB in relation to seed yield of lettuce

N-P-K-B Kg ha^{-1}	Seed yield (kg ha^{-1})	Total cost of production (Tk. ha^{-1})	Gross return (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	BCR
T_1 ($N_0P_{50}K_{100}B_{1.0}$)	321.40	36845	1607000	1570155	43.6
T_2 ($N_{50}P_{50}K_{100}B_{1.0}$)	470.50	38655	2352500	2313845	60.9
T_3 ($N_{100}P_{50}K_{100}B_{1.0}$)	571.50	40825	2857500	2816675	70.0
T_4 ($N_{150}P_{50}K_{100}B_{1.0}$)	530.10	42995	2650500	2607505	61.6
T_5 ($N_{200}P_{50}K_{100}B_{1.0}$)	520.10	45162	2600500	2555338	57.6
T_6 ($N_{100}P_0K_{100}B_{1.0}$)	360.70	33840	1803500	1769660	53.3
T_7 ($N_{100}P_{25}K_{100}B_{1.0}$)	490.60	37332.5	2453000	2415667.5	65.7
T_8 ($N_{100}P_{75}K_{100}B_{1.0}$)	535.60	44317.5	2678000	2633682.5	60.4
T_9 ($N_{100}P_{100}K_{100}B_{1.0}$)	530.20	47810	2651000	2603190	55.4
T_{10} ($N_{100}P_{50}K_0B_{1.0}$)	480.30	35825	2401500	2365675	67.0
T_{11} ($N_{100}P_{50}K_{50}B_{1.0}$)	505.30	38325	2526500	2488175	65.9
T_{12} ($N_{100}P_{50}K_{150}B_{1.0}$)	515.30	43325	2576500	2533175	59.5
T_{13} ($N_{100}P_{50}K_{200}B_{1.0}$)	510.30	45825	2551500	2505675	55.7
T_{14} ($N_{100}P_{50}K_{100}B_0$)	512.20	38325	2561000	2522675	66.8
T_{15} ($N_{100}P_{50}K_{100}B_{0.5}$)	520.80	39575	2604000	2564425	65.8
T_{16} ($N_{100}P_{50}K_{100}B_{1.5}$)	521.60	42075	2608000	2565925	62.0
T_{17} ($N_{100}P_{50}K_{100}B_{2.0}$)	515.90	43325	2579500	2536175	59.5
T_{18} ($N_0P_0K_0B_0$)	240.50	22000	1202500	1180500	54.7
T_{19} (CD_{10})	410.80	32000	2054000	2022000	64.2

Price of input: Urea: Tk. 20 kg^{-1}; TSP: Tk. 27.50 kg^{-1}; MoP: Tk. 25 kg^{-1}; Boric acid: Tk. 500 kg^{-1} and Cow dung: Tk. 1.00 kg^{-1}. **price of output:** Lettuce seed: Tk. 5000.00 kg^{-1}

3. Conclusion

The different levels of N, P, K and B showed significant effect on the leaf and seed yield of lettuce. Treatment T_3 ($N_{100}P_{50}K_{100}B_{1.0}$) was considered as the best combination of N, P, K and B application producing the maximum leaf and seed yield of lettuce in respect of economic profitability with the highest gross margin and BCR both for leaf (Tk. 305825 ha^{-1} and 7.50) and seed (Tk. 2816675 ha^{-1} and 70.0). But, from regression equation, the calculated optimum nutrient doses for maximum leaf and seed yield are $N_{143}P_{74}K_{95}B_{1.3}$ and $N_{136.4}P_{67.8}K_{188.0}B_{1.0}$ kg ha^{-1}

respectively that could be recommended as the optimum doses of N, P, K and B to achieve higher leaf and seed production of lettuce in Salna soils of Bangladesh.

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