



## **Effect of Nitrogen and Phosphorus on the Growth and Seed Yield of Spinach**

**Md. Rafiqul Islam<sup>1</sup>, Khaleda Khatun<sup>2</sup>, Tahmina Mostarin<sup>2</sup>, Md. Ehsanul Haq<sup>3\*</sup>,  
Md. Nahidul Islam<sup>2</sup>, Bithi Rani Biswas<sup>2</sup> and Jinia Afsun<sup>2</sup>**

<sup>1</sup>*Institute of Seed Technology, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.*

<sup>2</sup>*Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.*

<sup>3</sup>*Plant Breeding Division, Bangladesh Rice Research Institute, Gazipur, Bangladesh.*

### **Authors' contributions**

*This work was carried out in collaboration among all authors. Authors KK and TM planned the experiment and lead the research. Authors TM, KK and MRI designed and carried out the research. Authors MEH and MRI performed the statistical analysis. Author MRI carried out the research on the field. Authors MNI, BRB and JA collected the data. Authors MRI and MEH wrote the manuscript.*

*Authors MRI, MNI, BRB and JA managed the literature searches. All authors provided critical feedback and helped shape the research, analysis and manuscript. All authors read and approved the final manuscript.*

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### **ABSTRACT**

The experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during Rabi (November 2017 to March 2018) season to find out the growth, yield and economic benefit of spinach seed as influenced by nitrogen and phosphorus. The research involved two factors. Factor A: Four levels of nitrogen; N<sub>0</sub>= 0 kg/ha N<sub>1</sub>= 27.6 kg/ha, N<sub>2</sub>=55.2 kg/ha, N<sub>3</sub>= 82.8 kg/ha, and factor B: Four levels of phosphorus; P<sub>0</sub>= 0 kg/ha; P<sub>1</sub> = 15.84 kg/ha, P<sub>2</sub>= 31.68 kg/ha, P<sub>3</sub>= 47.52 kg/ha. There were 16 treatment combinations in the experiment and laid out in Randomized Complete Block Design (RCBD) with three replications. Quality tests of seeds were done based on the germination test (%), seed vigor test (Electrical conductivity). In case of nitrogen, the highest

\*Corresponding author: E-mail: shawonjess@gmail.com, shawonjess01@gmail.com;

seed yield ( $1.10 \text{ t ha}^{-1}$ ), germination percentage (87.33%) and lowest value in EC test ( $11.87 \text{ dS/cm}$ ) were obtained from  $N_2$ , while the lowest seed yield ( $0.81 \text{ t ha}^{-1}$ ), germination percentage (79.33%) and highest value in EC test ( $13.87 \text{ dS/cm}$ ) from  $N_0$ . For phosphorus levels, the highest seed yield ( $1.05 \text{ t ha}^{-1}$ ), germination percentage (86.58 %) and lowest value in EC test ( $11.79 \text{ dS/cm}$ ) were recorded from  $P_2$ , whereas the lowest seed yield ( $0.84 \text{ t ha}^{-1}$ ), germination percentage (79.91%) and highest value in EC test ( $13.35 \text{ dS/cm}$ ) from  $P_0$ . Due to mutual effect, the highest seed yield ( $1.30 \text{ t ha}^{-1}$ ), germination percentage (91.33%) and lowest value in EC test ( $10.2 \text{ dS/cm}$ ) were noted from  $N_2P_2$ , whereas the lowest seed yield ( $0.69 \text{ t ha}^{-1}$ ), germination percentage (72.66%) and highest value in EC test ( $14.83 \text{ dS/cm}$ ) from  $N_0P_0$ . From the economic point of view, the highest Benefit-Cost Ratio (BCR) (1.59) was found in the treatment of  $N_2P_2$  and the lowest BCR (1.01) was found in the treatment of  $N_0P_0$ . It is apparent that the treatment combination  $N_2P_2$  gave the best performance for the seed yield and economic benefit of spinach.

**Keywords:** Growth; nitrogen; phosphorus; seed yield.

## 1. INTRODUCTION

Spinach (*Spinacia oleracea*) is a leafy green cool-season vegetable that is known for its nutritive value and is considered one of the most popular vegetables in Bangladesh. It is believed to have originated from Persia. Its leaves are a common edible vegetable. By weight, spinach consists of 91.4% water, 3.6% carbons, and 2.9% protein [1]. There are 23 calories in 100 grams of spinach and further benefits of spinach leaves consumption can be of more value e.g vital mineral elements in spinach compared to other vegetables e.g iron which is very good for women. The seed is produced for commercial consumption and for seed companies that supply seed throughout the country. In Bangladesh spinach occupies 22000 acres [2] with an annual production of 66000 tons. In comparison to other countries, this yields much lower. So, to use of quality seeds of high yield varieties are the foremost important technique for maximizing yield per unit area. Quality seed can increase vegetable production by up to 25-50% [1]. Farmers save seeds annually of about 50 tons and used every year, which in most cases are of inferior in quality [3]. Appropriate fertilizer application to the plants greatly affects their growth and production. Nitrogen strongly stimulates growth, expansion of the crop canopy and interception of solar radiation [4]. Increasing the levels of nitrogen during the vegetative stage can strengthen and allow a plant to grow more rapidly and produce large amounts of succulent, green foliage, which in turn can generate higher yields [5]. Similarly, phosphorus (P) is an essential nutrient act as catalysts in the conversion of numerous key biochemical reactions in plants. Phosphorus stimulates root development, improves flower formation, seed production and improves crop quality and

increases resistance to plant diseases [6]. Leafy vegetables, particularly, spinach is highly responsive to fertilization [7] and oxalates are the main indexes of the quality due to a very efficient uptake system and inefficient reductive systems [8]. The fertilizer requirements on sandy and sandy loams are 85 to 120 kg N, 75 to 85 kg  $P_2O_5$ , and 85 to 150 kg  $K_2O$ . On heavier clay soils, 75 kg  $ha^{-1}$  of each nutrient should be adequate. If the fertilizer is banded at seeding it should be placed along each side of the rows 2 to 3 inches below the level of the seed and 6 inches to the side of the row; fertilizer should never come in contact with the seed and two or three splits of 85 to 120 kg  $ha^{-1}$  N would be adequate as side-dressing [9]. An adequate supply of fertilizers can promote plant growth and increase crop production, but excessive and inappropriate use of chemical fertilizers causes accumulation of compounds in the edible products which can be detrimental to human health in addition cause environmental pollution and economic losses [10]. Fadaly and Mishriky [11] found that N increased the spinach yield and enhanced the accumulation of N and P in leaves. Assiouty et al.[12] reported that application of 40 kg N + 15.0 kg  $P_2O_5$  increased plant fresh yield by 27.2 and 42.3% and 16.3 and 10.4% in seed yield in relation to the control in the first and second seasons, respectively. Boroujerdnia and Ansari [13] achieved the highest yield with 120 kg N  $ha^{-1}$  Farmers in Bangladesh generally do not use any improved or special techniques for quality seed production. There for to achieve higher seeds yield with good quality fertilizer management is an important practice which cannot be emphasized. The present study was thus undertaken to evaluate the effects of nitrogen and phosphorus on the growth, yield and economic benefit of spinach (*Spinacia oleracea*) seed.

## 2. MATERIALS AND METHODS

### 2.1 Experimental Site

The experiment was conducted at the Agronomy Research Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh from November 2017 to March 2018. Experimental site situated an elevation of 8 meters above the sea level in the Agro-ecological zone of "Madhupur Tract" (AEZ-28). The soil was sandy loam and medium high land in texture having pH 5.46- 5.62.

### 2.2 Experiment Frame Work

The research was consisted of two factors: Factor A: Four levels of nitrogen;  $N_0= 0$  kg/ha,  $N_1= 27.6$  kg/ha,  $N_2=55.2$  kg/ha,  $N_3= 82.8$  kg/ha, and factor B: Four levels of phosphorus;  $P_0= 0$  kg/ha;  $P_1 = 15.84$  kg/ha,  $P_2= 31.68$  kg/ha,  $P_3= 47.52$  kg/ha. The two factors experiment was laid out following the Randomized Complete Block Design (RCBD) with three replications. The experiment was divided into three equal blocks where each block was divided into 16 plots. Then 16 treatment combinations were allotted randomly in each block. The size of each unit plot was 1.5 m × 1 m. The distance maintained between two blocks and two plots were 0.75 m and 0.5 m, respectively. Row to row distance was 30 cm and plant to plant distance was 20 cm.

### 2.3 Application of Manure and Fertilizers

About 5 t ha<sup>-1</sup> well-decomposed cow dung was applied as the control ( $N_0P_0$ ) treatment) plot and incorporated adequately to the soil during final land preparation whereas other plots were applied with inorganic fertilizer as per treatment. Doses of inorganic fertilizers (Urea and Triple

superphosphate) were applied in the experimental plot according to the treatments (Table 1). The whole amount of TSP and half the amount of urea and MoP (180 kg/ha) were also applied as basal dose before sowing of seed in the main field. 1<sup>st</sup> top dressing of urea was applied when seedlings established in the main field about 10 days after seed sowing. 2<sup>nd</sup> top dressing of urea and the rest amount of MoP was applied about 25 days after 1st top dressing. Then the rest amount of urea was applied as 3<sup>rd</sup> installment after flowering. Each top dressing was followed by manual irrigation.

### 2.4 Economic Analysis

The cost of production was analyzed in order to find out the most economic treatment of nitrogen and phosphorus for quality seed production of spinach. All the non-material and material input costs and interests in running capital were considered for computing the cost of production. The benefit-cost ratio (BCR) was calculated by the following formula:

$$\text{Benefit-cost ratio (BCR)} = \frac{\text{Gross return (tk/ha)}}{\text{Total cost of production (tk/ha)}}$$

### 2.5 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment by using the STATISTIX-10 computer package program. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means was estimated by the Least Significant Different Test (LSD) at 5% level of probability.

**Table 1. Doses of nutrients application in the main field as per treatment**

Treatments	N rates (kg ha <sup>-1</sup> )	Fertilizers (kg ha <sup>-1</sup> )	Doses (g plot <sup>-1</sup> )	Treatments	P rates (kg ha <sup>-1</sup> )	Fertilizes (kg ha <sup>-1</sup> )	Doses (g plot <sup>-1</sup> )
	N	Urea	Urea		P	TSP	TSP
$N_0$	0	0	0	$P_0$	0	0	0
$N_1$	27.6	60	9	$P_1$	15.84	75	11.25
$N_2$	55.2	120	18	$P_2$	31.68	150	22.5
$N_3$	82.8	180	27	$P_3$	47.52	225	33.75

### 3. RESULTS AND DISCUSSION

#### 3.1 Plant Height (cm)

A significant variation was observed on the plant height of spinach due to the application of different levels of nitrogen (Table 2). The highest plant height 13.94 cm and 47.69 cm were obtained before flowering and at the time of harvest respectively from  $N_3$  while the lowest plant height 11.01 cm and 34.88 cm were obtained before flowering and at the time of harvest respectively from  $N_0$ .  $P_3$  showed the highest plant height 13.64 cm and 46.68 cm before flowering and at the time of harvest respectively and the lowest plant height 11.60 cm and 35.18 cm at before flowering and at the time of harvest respectively in  $P_0$  (Table 3).

The combined effect of different levels of nitrogen and phosphorus application showed a significant effect on the plant height of spinach (Table 4). The highest plant height 15.21 cm and 55.25 cm before flowering and at the time of harvest, respectively was observed in  $N_3P_3$  while the lowest plant height 10.10cm and 27.7 cm before flowering and at the time of harvest, respectively in  $N_0P_0$ .

#### 3.2 Number of Leaves per Plant

The effect of nitrogen on the number of leaves per plant of spinach was significant (Table 2). The highest number of leaves (8.46) was produced from  $N_2$  and the lowest number of leaves (6.42) was observed in  $N_0$ .  $P_2$  showed the maximum leaves per plant (8.30) and the minimum leaves per plant (6.36) was observed in  $P_0$  (Table 3).

The combined effect of different levels of nitrogen and phosphorus showed a significant effect on the number of leaves per plant of spinach (Table 4). The maximum leaves per plant (10.35) were observed in  $N_2P_2$  and the lowest leaves per plant (5.01) were recorded with  $N_0P_0$ . [14] also found a similar result.

#### 3.3 Number of Inflorescence per Plant

Statistically significant differences were found on the number of inflorescence per plant of spinach due to the application of nitrogen (Table 5). The highest number of inflorescence per plant (8.03) was recorded from  $N_2$  whereas, the lowest number (5.17) was observed from  $N_0$ . The highest number of inflorescence per plant (7.80) was recorded from  $P_2$  and the lowest (4.94) was found from  $P_0$  (Table 6).

**Table 2. Effect of nitrogen on plant height (before flowering and at the time of harvest) leaves per plant of spinach**

Treatments	Plant height before flowering (cm)	Plant height at the time of harvest (cm)	Leaves per plant
$N_0$	11.01	34.88	6.42
$N_1$	12.34	40.35	7.24
$N_2$	13.07	43.75	8.46
$N_3$	13.94	47.69	7.84
LSD	0.87	3.12	0.54
CV %	8.34	9.00	8.70

Here,  $N_0= 0$  kg/ha;  $N_1=27.6$  kg/ha;  $N_2= 55.2$  kg/ha;  $N_3= 82.8$  kg/ha

**Table 3. Effect of phosphorus on plant height (before and at the time of harvest), Leaves per plant of spinach**

Treatments	Plant height before flowering	Plant height at the time of harvest	Leaves per plant
$P_0$	11.60	35.18	6.36
$P_1$	12.16	40.37	7.24
$P_2$	12.96	44.44	8.30
$P_3$	13.64	46.68	8.06
LSD	0.87	3.11	0.543
CV %	8.34	9.00	8.70

Here,  $P_0= 0$  kg/ha;  $P_1= 15.84$  kg/ha;  $P_2= 31.68$  kg/ha;  $P_3= 47.52$  kg/ha

**Table 4. Combined effect of nitrogen and phosphorus on the plant height (before and at the time of harvesting), leaves per plant of spinach**

Treatments	Plant height before flowering (cm)	Plant height at the time of harvest (cm)	Leaves per plant
N <sub>0</sub> P <sub>0</sub>	10.10	27.7	5.01
N <sub>0</sub> P <sub>1</sub>	10.63	34.34	6.25
N <sub>0</sub> P <sub>2</sub>	11.25	37.31	6.66
N <sub>0</sub> P <sub>3</sub>	12.07	40.18	7.76
N <sub>1</sub> P <sub>0</sub>	11.49	34.65	6.60
N <sub>1</sub> P <sub>1</sub>	12.15	41.03	7.33
N <sub>1</sub> P <sub>2</sub>	12.60	42.44	7.46
N <sub>1</sub> P <sub>3</sub>	13.12	43.29	7.58
N <sub>2</sub> P <sub>0</sub>	12.14	37.88	6.91
N <sub>2</sub> P <sub>1</sub>	12.54	21.80	7.81
N <sub>2</sub> P <sub>2</sub>	13.42	47.31	10.35
N <sub>2</sub> P <sub>3</sub>	14.17	48.01	8.76
N <sub>3</sub> P <sub>0</sub>	12.65	40.51	6.93
N <sub>3</sub> P <sub>1</sub>	13.35	44.30	7.56
N <sub>3</sub> P <sub>2</sub>	14.56	50.71	8.73
N <sub>3</sub> P <sub>3</sub>	15.21	55.25	8.13
LSD	1.75	6.25	1.08
CV %	8.34	9.00	8.70

Here, N<sub>0</sub>= 0 kg/ha; N<sub>1</sub>=27.6 kg/ha; N<sub>2</sub>= 55.2 kg/ha; N<sub>3</sub>= 82.8 kg/ha.  
P<sub>0</sub>= 0 kg/ha; P<sub>1</sub>= 15.84 kg/ha; P<sub>2</sub>= 31.68 kg/ha; P<sub>3</sub>= 47.52 kg/ha.

The combined effect of nitrogen and phosphorus showed significant variation in the number of inflorescences per plant (Table 7). The highest number of inflorescence per plant (10.53) was recorded from N<sub>2</sub>P<sub>2</sub> and the lowest number of inflorescence per plant (3.90) from N<sub>0</sub>P<sub>0</sub>.

### 3.4 Length of Inflorescence

A significant variation was observed on the length of an inflorescence of spinach when different levels of nitrogen were applied (Table 5). The highest length of inflorescence (29.54 cm) was recorded in N<sub>2</sub> and the lowest length of inflorescence (19.09 cm) from N<sub>0</sub>. The highest length of inflorescence (28.97 cm) was recorded in P<sub>3</sub> and the lowest length of inflorescence (20.58 cm) was recorded in P<sub>0</sub> (Table 6).

The combined effect of different levels of nitrogen and phosphorus showed a significant effect on the length of inflorescence (Table 7). The highest length of inflorescence (35.04 cm) was observed in N<sub>2</sub>P<sub>2</sub> and the lowest length of inflorescence (15.19 cm) was recorded in N<sub>0</sub>P<sub>0</sub>.

### 3.5 Number of Seeds per Inflorescence

Statistically significant differences were found on the number of seeds per inflorescence of spinach due to the application of different nitrogen levels

(Table 5). The maximum seeds per inflorescence (58.68) was recorded from N<sub>2</sub> (55.2 kg/ha) and the minimum (38.15) was observed from N<sub>0</sub>. The highest seeds per inflorescence (57.19) were recorded from P<sub>2</sub> and the lowest number of seeds per inflorescence (39.13) in P<sub>0</sub> (Table 6).

The number of seeds per inflorescence was significantly influenced by the combined application of nitrogen and phosphorus (Table 7). The maximum number of seeds per inflorescence (70.41) was recorded from N<sub>2</sub>P<sub>2</sub> and the lowest number of seeds per inflorescence (35.33) in N<sub>0</sub>P<sub>0</sub>.

### 3.6 Seed Yield per Hectare (Ton)

Statistically significant differences were found for seed yield per hectare of spinach due to different nitrogen levels (Table 8). The maximum seed yield (1.10 t ha<sup>-1</sup>) was recorded from N<sub>2</sub> and the lowest (0.81 t ha<sup>-1</sup>) was recorded from N<sub>0</sub>. The maximum seed yield (1.05 t ha<sup>-1</sup>) was recorded from P<sub>2</sub> and the lowest (0.84 t ha<sup>-1</sup>) was recorded from P<sub>0</sub> (Table 9.). The combined effect of nitrogen and phosphorus showed significant variation in the seed yield of spinach (Table 10). The highest seed yield (1.30 t/ha) was recorded from the combination of N<sub>2</sub>P<sub>2</sub> and the lowest (0.69 t ha<sup>-1</sup>) was recorded from N<sub>0</sub>P<sub>0</sub> treatment combination.

**Table 5. Effect of nitrogen on number of inflorescence per plant, inflorescence length and seeds per inflorescence of spinach**

Treatments	Number of inflorescence per plant	Inflorescence length (cm)	Seeds per inflorescence
N <sub>0</sub>	5.17	19.99	38.15
N <sub>1</sub>	6.30	23.56	47.37
N <sub>2</sub>	8.03	29.54	58.86
N <sub>3</sub>	7.13	29.01	56.28
LSD	0.47	1.857	3.40
CV %	8.48	8.73	8.12

Here, N<sub>0</sub>= 0 kg/ha; N<sub>1</sub>=27.6 kg/ha; N<sub>2</sub>= 55.2 kg/ha; N<sub>3</sub>= 82.8 kg/ha.

**Table 6. Effect of phosphorus on number of inflorescence per plant, inflorescence length and seeds per inflorescence of spinach**

Treatments	Number of inflorescence per plant	Inflorescence length (cm)	Seeds per inflorescence
P <sub>0</sub>	4.94	20.58	39.13
P <sub>1</sub>	6.26	24.12	48.19
P <sub>2</sub>	7.80	28.43	57.19
P <sub>3</sub>	7.64	28.97	56.15
LSD	0.48	1.85	3.39
CV %	8.48	8.73	8.12

Here, P<sub>0</sub>= 0 kg/ha; P<sub>1</sub>= 15.84 kg/ha; P<sub>2</sub>= 31.68 kg/ha; P<sub>3</sub>= 47.52 kg/ha.

**Table 7. Combined effect of nitrogen and phosphorus on number of inflorescence per plant, inflorescence length and seeds per inflorescence of spinach**

Treatments	Number of inflorescence per plant	Inflorescence length (cm)	Seeds per inflorescence
N <sub>0</sub> P <sub>0</sub>	3.9	15.19	28.03
N <sub>0</sub> P <sub>1</sub>	5.03	18.95	35.33
N <sub>0</sub> P <sub>2</sub>	5.70	21.86	43.82
N <sub>0</sub> P <sub>3</sub>	6.06	23.96	45.43
N <sub>1</sub> P <sub>0</sub>	5.08	19.91	36.27
N <sub>1</sub> P <sub>1</sub>	6.23	22.91	47.79
N <sub>1</sub> P <sub>2</sub>	6.75	24.72	51.74
N <sub>1</sub> P <sub>3</sub>	7.15	26.69	53.70
N <sub>2</sub> P <sub>0</sub>	5.23	22.84	45.25
N <sub>2</sub> P <sub>1</sub>	7.05	26.15	54.29
N <sub>2</sub> P <sub>2</sub>	10.53	35.04	70.41
N <sub>2</sub> P <sub>3</sub>	9.31	34.15	65.48
N <sub>3</sub> P <sub>0</sub>	5.55	24.38	47.00
N <sub>3</sub> P <sub>1</sub>	6.73	28.48	55.34
N <sub>3</sub> P <sub>2</sub>	8.21	32.10	62.80
N <sub>3</sub> P <sub>3</sub>	8.03	31.10	60.00
LSD	0.94	3.71	6.79
CV (%)	8.48	8.73	8.12

Here, N<sub>0</sub>= 0 kg/ha; N<sub>1</sub>=27.6 kg/ha; N<sub>2</sub>= 55.2 kg/ha; N<sub>3</sub>= 82.8 kg/ha.  
P<sub>0</sub>= 0 kg/ha; P<sub>1</sub>= 15.84 kg/ha; P<sub>2</sub>= 31.68 kg/ha; P<sub>3</sub>= 47.52 kg/ha.

### 3.7 1000 Seed Weight (g)

Statistically significant differences were found for 1000 seed weight of spinach due to the nitrogen level (Table 8). The maximum 1000 seed weight (10.19 g) was recorded from N<sub>2</sub> and the lowest

(9.24 g) was recorded from N<sub>0</sub>. The maximum 1000 seed weight (10.20 g) was recorded from P<sub>2</sub> and the lowest (9.23 g) was recorded from P<sub>0</sub> (Table 9). The combined effect of nitrogen and phosphorus showed significant variation in 1000 seed weight of spinach (Table

10). The highest 1000 seed weight (11.06 g) was recorded from the combination of  $N_2P_2$  and the lowest (8.77 g) from  $N_0P_0$ .

### 3.8 Germination Percentage

A significant difference was found on germination % due to fertilizer level (Table 8). The maximum germination percentage (87.33%) was recorded from  $N_2$  and the minimum (79.33%) was found in  $N_0$ . Zaki and Halawa [15] reported that seed yield and its quality of spinach obtained that increasing the rate of nitrogen levels up to the levels at 60 kg N produced higher seed yield with the best quality, germination percentage and germination rate. The maximum germination percentage (87.08%) was recorded from  $P_3$  and the minimum (79.91%) was found from  $P_0$  (Table 9).

The combined effect of nitrogen and phosphorus was significant on the germination percentage of spinach (Table 10). The highest germination percentage (91.33%) was recorded from the combination of  $N_2P_2$  and the lowest germination percentage (72.66%) was recorded in  $N_0P_0$  (control). Ambia et al. [14] experimented on the farm of the Department of Horticulture, BSMRAU, Salna, Gazipur on 6 spinach genotypes to observe their seed production potentiality and to evaluate the quality of produced seed. They reported that the quality test of seed was done based on germination test

(%), seed vigor test (Electrical conductivity), moisture test (%) and thousand seed weight (g) of seeds.

### 3.9 Electrical Conductivity Test

A significant difference was found in electrical conductivity test value due to the application of different levels of nitrogen (Table 8). The highest EC test value (13.87 dS/cm) was recorded from treatment  $N_0$  whereas, the minimum (11.16 dS/cm) was found in  $N_2$ . The maximum EC test value (13.35 dS/cm) was recorded from treatment  $P_0$  and the lowest EC test value (11.79 dS/cm) was recorded in  $P_2$  (Table 9). The combined effect of nitrogen and phosphorus was significant on the EC test value of spinach (Table 10). The highest EC test value (14.83 dS/cm) was recorded from the combination ( $N_0P_0$ ) and the lowest EC test value (10.20 dS/cm) was recorded with  $N_2P_2$  treatment combination. Why highest in  $N_2P_2$  and not  $N_3P_3$ .

### 3.10 Benefit Cost Ratio (BCR)

The combination of nitrogen and phosphorus showed different benefit cost ratio. The highest benefit cost ratio (1.59) which is economically more benefitted was obtained from  $N_2P_2$  and the lowest benefit cost ratio (1.01) which is economically less benefitted was obtained from the treatment combination of  $N_0P_0$  (Table 11).

**Table 8. Effect of nitrogen on seed yield per hectare 1000 seed weight, germination percentage and electrical conductivity test**

Treatments	Seed yield per hectare (t)	1000 seed weight (g)	Germination (%)	Electrical conductivity test (ds/cm)
$N_0$	0.81	9.24	79.33	13.87
$N_1$	0.91	9.58	83.41	12.78
$N_2$	1.10	10.19	87.33	11.16
$N_3$	1.01	10.14	87.25	11.73
LSD	0.06	0.75	4.95	0.85
CV (%)	8.28	9.19	7.05	8.25

**Table 9. Effect of phosphorus on seed yield per hectare, 1000 seed weight, germination percentage and electrical conductivity test**

Treatments	Seed yield per hectare (t)	1000 seed weight (g)	Germination (%)	Electrical conductivity test (ds/cm)
$P_0$	0.84 c	9.23 b	79.91	13.35
$P_1$	0.93 b	9.56 ab	83.75	12.57
$P_2$	1.05 a	10.20 a	86.58	11.79
$P_3$	1.01 a	10.18 a	87.08	11.81
LSD	0.067	0.75	4.95	0.85
CV (%)	8.28	9.19	7.05	8.25

Here,  $P_0= 0$  kg/ha;  $P_1= 15.84$  kg/ha;  $P_2= 31.68$  kg/ha;  $P_3= 47.52$  kg/ha.

**Table 10. The combined effect of nitrogen and phosphorus seed yield per hectare, 1000 seed weight, germination percentage and electrical conductivity test**

Treatments	Seed yield per hectare (t)	1000 seed weight (g)	Germination (%)	Electrical conductivity test (ds/cm)
N <sub>0</sub> P <sub>0</sub>	0.69	8.77	72.66	14.83
N <sub>0</sub> P <sub>1</sub>	0.83	9.22	80.00	13.97
N <sub>0</sub> P <sub>2</sub>	0.85	9.43	81.00	13.37
N <sub>0</sub> P <sub>3</sub>	0.88	9.56	83.66	13.30
N <sub>1</sub> P <sub>0</sub>	0.83	9.15	79.00	13.55
N <sub>1</sub> P <sub>1</sub>	0.91	9.47	84.00	12.85
N <sub>1</sub> P <sub>2</sub>	0.95	9.76	84.66	12.58
N <sub>1</sub> P <sub>3</sub>	0.96	9.95	86.00	12.14
N <sub>2</sub> P <sub>0</sub>	0.93	9.26	83.33	12.59
N <sub>2</sub> P <sub>1</sub>	0.99	9.74	84.66	11.46
N <sub>2</sub> P <sub>2</sub>	1.30	11.06	91.33	10.20
N <sub>2</sub> P <sub>3</sub>	1.16	10.70	90.00	10.42
N <sub>3</sub> P <sub>0</sub>	0.92	9.73	84.66	12.45
N <sub>3</sub> P <sub>1</sub>	0.98	9.80	86.33	12.01
N <sub>3</sub> P <sub>2</sub>	1.09	10.53	89.33	11.03
N <sub>3</sub> P <sub>3</sub>	1.04	10.50	88.66	11.41
LSD	0.13	1.50	9.91	1.70
CV (%)	8.28	9.19	7.05	8.25

Here, N<sub>0</sub>= 0 kg/ha; N<sub>1</sub>=27.6 kg/ha; N<sub>2</sub>= 55.2 kg/ha; N<sub>3</sub>= 82.8 kg/ha.  
P<sub>0</sub>= 0 kg/ha; P<sub>1</sub>= 15.84 kg/ha; P<sub>2</sub>= 31.68 kg/ha; P<sub>3</sub>= 47.52 kg/ha.

**Table 11. Cost and return analysis of spinach seed considering nitrogen and phosphorus**

Treatments	Seed yield (t/ha)	Gross return (Tk/ha)	Total cost of production(Tk)	Net return (Tk/ha)	Benefit cost ratio (BCR)
N <sub>0</sub> P <sub>0</sub>	0.69	117000	116656.8	13156	1.01
N <sub>0</sub> P <sub>1</sub>	0.83	124500	118342	6158	1.05
N <sub>0</sub> P <sub>2</sub>	0.85	127500	120027.3	7472.7	1.06
N <sub>0</sub> P <sub>3</sub>	0.88	132000	121712.5	10287.5	1.08
N <sub>1</sub> P <sub>0</sub>	0.83	124500	117870.1	6629.9	1.05
N <sub>1</sub> P <sub>1</sub>	0.91	136500	119555.4	16944.6	1.14
N <sub>1</sub> P <sub>2</sub>	0.95	142500	121240.6	21259.4	1.17
N <sub>1</sub> P <sub>3</sub>	0.96	144000	122925.9	21074.1	1.17
N <sub>2</sub> P <sub>0</sub>	0.93	133500	119083.5	14416.5	1.12
N <sub>2</sub> P <sub>1</sub>	0.99	148500	120768.8	27731.2	1.22
N <sub>2</sub> P <sub>2</sub>	1.30	195000	122454	72546	1.59
N <sub>2</sub> P <sub>3</sub>	1.16	174000	124139.3	49860.7	1.40
N <sub>3</sub> P <sub>0</sub>	0.92	138000	120296.9	17703.1	1.14
N <sub>3</sub> P <sub>1</sub>	0.98	147000	121982.1	25017.9	1.20
N <sub>3</sub> P <sub>2</sub>	1.09	163500	123667.4	39832.6	1.32
N <sub>3</sub> P <sub>3</sub>	1.04	156000	125352.6	30647.4	1.24

Here,

- Sale of marketable seed @ Tk.150/kg
- Gross return = Marketable yield x Tk./kg
- Net income = Gross return-Total cost of production
- BCR = Gross return ÷ cost of production

#### 4. CONCLUSION

Both seed yield and economic benefit of crop are important for the seed production. Application of nitrogen (55.2 kg/ha) represents higher seed

yield in spinach than without no nitrogen and (82.8 kg/ha) nitrogen. According to the results of the present experiment it may be concluded that efficient production of spinach seed is increased by the application of phosphorus (31.68 kg/ha).

The combined effect of nitrogen and phosphorus had positive effect on morphological characters, yield contributing characters but seed yield and seed quality of spinach increased by the combined application of (N 55.2 kg/ha+ P 31.68 kg/ha). On the basis of benefit cost ratio, it may be suggested that application of N 55.2 kg/ha with P 31.68 kg/ha combination seemed to be more suitable for the highest values of gross return, net return as well as highest beneficial cost ratio of spinach..

### COMPETING INTERESTS

The authors have declared that no competing interests exist.

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