Original Research Article

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

ABSTRACT

The experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during Robi (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: Nitrogen management 4 levels; 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: Phosphorus management 4 levels; P_0= 0 kg/ha; P_1 = 15.84 kg/ha, P_2= 31.68 kg/ha, P_3= 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 seed yield (1.10 t ha^{-1}), germination percentage (87.33 %) and lowest value in EC test (13.87 dS/cm) were obtained from N_2, while the lowest seed yield (0.81 t ha^{-1}), germination percentage (79.33 %) and highest value in EC test (11.16 dS/cm) from N_0. For similar levels of phosphorus, the highest seed yield (1.05 t ha^{-1}), germination percentage (87.08 % and) and lowest value in EC test (13.35 dS/cm) were recorded from P_2, whereas the lowest seed yield (0.84 t ha^{-1}), germination percentage (79.91 %) and highest value in EC test (11.79 dS/cm) from P_0. Due to mutual effect, the highest seed yield (1.30 t ha^{-1}), germination percentage (91.33 %) and lowest value in EC test (14.83 dS/cm) were noted from N_2P_2, whereas the lowest seed yield (0.69 t ha^{-1}), germination percentage (72.66 %) and highest value in EC test (10.74 dS/cm) from N_0P_0. From the economic point of view, the highest 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. There are 23 calories in 100 grams of spinach. The seed is produced for commercial consumption and for seed companies that supply seed throughout the country. In Bangladesh spinach occupies 22000 acres [1] 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% [2]. Farmers save seeds are annual of about 50 tons and are used every year, which are in most cases of inferior in quality [3]. 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 allows a plant to grow more rapidly and produce large amounts of succulent, green foliage, which in turn can generate bigger yields [5]. Similarly, phosphorus (P) is an essential nutrient act as catalysts in the conversion of numerous key biochemical reactions in plants. P stimulated root development, improved flower formation, seed production and improvements in crop quality and increased resistance to plant diseases [6]. Leafy vegetables, particularly, the spinach is highly responsive to fertilization [7] and oxalates which 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 cause environmental pollution and economic losses [10]. [11] found that N increased the spinach yield and enhanced the accumulation of N and P in leaves. [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 over the control in the first and second seasons, respectively. [13] achieved the highest yield with 120 kg N ha^{-1} Farmers in Bangladesh generally do not use any improve or special techniques for quality seed production. To get higher seed yield with good quality fertilizer management is an important practice.

2. MATERIAL 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: Nitrogen management 4 levels; 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: Phosphorus management 4 levels; 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^{-1} well-decomposed cow dung was applied only control (as 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^{st} top dressing of urea was applied when seedlings established in the main field about 10 days after seed sowing. 2^{nd} top dressing of urea and the rest amount of MoP was applied about

25days after 1st top dressing. Then the rest amount of urea was applied as 3rd installment after flowering. Each top dressing was followed by manual irrigation.

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

Treatments	Available nutrients (kg ha^{-1})	Fertilizers (kg ha^{-1})	Doses (g plot^{-1})	Treatments	Available nutrients (kg ha^{-1})	Fertilizes (kg ha^{-1})	Doses (g plot^{-1})
	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

Here, N_0= 0 kg/ha; N_1=27.6 kg/ha; N_2= 55.2 kg/ha; N_3= 82.8 kg/ha; P_0= 0 kg/ha; P_1= 15.84 kg/ha; P_2= 31.68 kg/ha; P_3=47.52 kg/ha.

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:
Benefit-cost ratio (BCR) = Gross return (tk/ha) ÷ 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.

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 at before flowering and at the time of harvest respectively from N_3 and the lowest plant height 11.01 cm and 34.88 cm were obtained at 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 at 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 at before flowering and at the time of harvest, respectively was observed in N_3P_3 while the lowest plant height 10.10 cm and 27.7 cm at 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.

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_0 P_0	10.10	27.7	5.01
N_0 P_1	10.63	34.34	6.25
N_0 P_2	11.25	37.31	6.66
N_0 P_3	12.07	40.18	7.76
N_1 P_0	11.49	34.65	6.60
N_1 P_1	12.15	41.03	7.33
N_1 P_2	12.60	42.44	7.46
N_1 P_3	13.12	43.29	7.58
N_2 P_0	12.14	37.88	6.91
N_2 P_1	12.54	21.80	7.81
N_2 P_2	13.42	47.31	10.35
N_2 P_3	14.17	48.01	8.76
N_3 P_0	12.65	40.51	6.93
N_3 P_1	13.35	44.30	7.56
N_3 P_2	14.56	50.71	8.73
N_3 P_3	15.21	55.25	8.13

LSD	**1.75**	**6.25**	**1.08**
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.
P_0= 0 kg/ha; P_1= 15.84 kg/ha; P_2= 31.68 kg/ha; P_3= 47.52 kg/ha.

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).

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_2P_2 and the lowest number of inflorescence per plant (3.90) from N_0P_0.

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 (29.54cm) was recorded in N_2 and the lowest length of inflorescence (19.09 cm) from N_0. The highest length of inflorescence (28.97 cm) was recorded in P_3 and the lowest length of inflorescence (20.58 cm) was recorded in P_0 (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_2P_2 and the lowest length of inflorescence (15.19 cm) was recorded in N_0P_0.

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_2 (55.2 kg/ha) and the minimum (38.15) was observed from N_0. The highest seeds per inflorescence (57.19) were recorded from P_2 and the lowest number of seeds per inflorescence (39.13) in P_0 (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_2P_2 and the lowest number of seeds per inflorescence (35.33) in N_0P_0.

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_0	5.17	19.99	38.15
N_1	6.30	23.56	47.37
N_2	8.03	29.54	58.86
N_3	7.13	29.01	56.28
LSD	**0.47**	**1.857**	**3.40**
CV %	**8.48**	**8.73**	**8.12**

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 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_0	4.94	20.58	39.13
P_1	6.26	24.12	48.19
P_2	7.80	28.43	57.19
P_3	7.64	28.97	56.15
LSD	**0.48**	**1.85**	**3.39**
CV %	**8.48**	**8.73**	**8.12**

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 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_0 P_0	3.9	15.19	28.03
N_0P_1	5.03	18.95	35.33
N_0P_2	5.70	21.86	43.82
N_0P_3	6.06	23.96	45.43
N_1 P_0	5.08	19.91	36.27
N_1 P_1	6.23	22.91	47.79
N_1 P_2	6.75	24.72	51.74
N_1 P_3	7.15	26.69	53.70
N_2 P_0	5.23	22.84	45.25
N_2 P_1	7.05	26.15	54.29
N_2 P_2	10.53	35.04	70.41
N_2 P_3	9.31	34.15	65.48
N_3 P_0	5.55	24.38	47.00
N_3 P_1	6.73	28.48	55.34
N_3 P_2	8.21	32.10	62.80
N_3 P_3	8.03	31.10	60.00
LSD	**0.94**	**3.71**	**6.79**
CV (%)	**8.48**	**8.73**	**8.12**

Here, N_0= 0 kg/ha; N_1=27.6 kg/ha; N_2= 55.2 kg/ha; N_3= 82.8 kg/ha.
P_0= 0 kg/ha; P_1= 15.84 kg/ha; P_2= 31.68 kg/ha; P_3= 47.52 kg/ha.

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^{-1}) was recorded from N_2 and the lowest (0.81 t ha^{-1}) was recorded from N_0. The maximum seed yield (1.05 t ha^{-1}) was recorded from P_2 and the lowest (0.84 t ha^{-1}) was recorded from P_0 (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_2P_2 and the lowest (0.69 t ha^{-1}) was recorded from N_0P_0 treatment combination.

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_2 and the lowest (9.24 g) was recorded from N_0. The maximum 1000 seed weight (10.20 g) was recorded from P_2 and the lowest (9.23 g) was recorded from P_0 (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. [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). [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.

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_0P_0	0.69	8.77	72.66	14.83
N_0P_1	0.83	9.22	80.00	13.97
N_0P_2	0.85	9.43	81.00	13.37
N_0P_3	0.88	9.56	83.66	13.30
N_1 P_0	0.83	9.15	79.00	13.55
N_1 P_1	0.91	9.47	84.00	12.85
N_1 P_2	0.95	9.76	84.66	12.58
N_1 P_3	0.96	9.95	86.00	12.14
N_2 P_0	0.93	9.26	83.33	12.59
N_2 P_1	0.99	9.74	84.66	11.46
N_2 P_2	1.30	11.06	91.33	10.20
N_2 P_3	1.16	10.70	90.00	10.42
N_3 P_0	0.92	9.73	84.66	12.45
N_3 P_1	0.98	9.80	86.33	12.01
N_3 P_2	1.09	10.53	89.33	11.03
N_3 P_3	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_0= 0 kg/ha; N_1=27.6 kg/ha; N_2= 55.2 kg/ha; N_3= 82.8 kg/ha.
P_0= 0 kg/ha; P_1= 15.84 kg/ha; P_2= 31.68 kg/ha; P_3= 47.52 kg/ha.

4. CONCLUSION

Both seed yield and economic benefit of the crop are important for seed production. Application of optimum level of nitrogen represents higher seed yield in spinach than without no nitrogen and excessive nitrogen. According to the results of the present experiment, it may be concluded that the efficient production of spinach seed is increased by the application of the optimum level of phosphorus. The combined effect of nitrogen and phosphorus had a positive effect on morphological characters, yield contributing characters, yield and seed quality in spinach. Based on the benefit-cost ratio, it may be suggested that the application of N 55.2 kg/ha with P 31.68 kg/ha combination seemed to be more suitable for getting higher seed yield in spinach.

COMPETING INTERESTS

The authors have declared that no competing interests exist.

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