Optimizing Nitrogen and Phosphorus Fertilization for Improved Onion (*Allium cepa L.*) Growth and Yield in Bangladesh

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Abstract

Background: Onion (*Allium cepa L.*) is a crucial crop in Bangladesh, serving as both a vegetable and spice, but the country faces a significant onion production gap. This study investigates the effects of nitrogen (N) and phosphorus (P) fertilizers on onion growth and yield to optimize agricultural practices. Objective: To evaluate the individual and combined effects of different doses of nitrogen and phosphorus on onion growth and yield in Bangladesh. Methods: A field experiment was conducted in Niamatpur, Naogaon, Bangladesh, using a Randomized Complete Block Design (RCBD) with 16 treatment combinations of N (0, 50, 70, 90 kg/ha) and P (0, 40, 60, 80 kg/ha), replicated three times. The Taherpuri variety of onion was used. Growth and yield parameters, including plant height, number of leaves, bulb size, and yield per hectare, were recorded. Results: Nitrogen and phosphorus significantly impacted plant growth and bulb yield. The highest plant height (39.14 cm), leaf number (7.22), bulb length (4.08 cm), and bulb diameter (4.38 cm) were observed with 90 kg N/ha and 80 kg P/ha. The highest fresh bulb weight (21.36 g) and yield (21.36 t/ha) were recorded with 70 kg N/ha and 80 kg P/ha. These treatments outperformed the control, which showed the lowest values across parameters. Conclusion: The combined application of 70 kg N/ha and 80 kg P/ha significantly improved onion growth and yield in Bangladesh, offering a promising approach to enhancing production and reducing the supply-demand gap. Further studies could explore the long-term sustainability and economic viability of these fertilizer applications.

Keywords: Onion, nitrogen, phosphorus, fertilizer, growth, yield, Bangladesh, agriculture, nutrient management.

Significance | This study provides valuable insights into optimizing nitrogen and phosphorus fertilization, enhancing onion growth, yield, and agricultural sustainability in Bangladesh.

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1. Introduction

Onion (*Allium cepa L.*), a member of the family Alliaceae, is among the earliest cultivated spice and vegetable crops, holding immense global and national significance. It is the most important herbaceous bulb crop in Bangladesh, where it is widely consumed and an integral part of the daily diet, playing a central role in almost all traditional food preparations (Hossain & Islam, 1994). Globally, cultivated onions are believed to have originated from wild relatives native to the mountainous regions of Central Asia (Brewster, 1994). In Bangladesh, onion ranks first in terms of production and second in cultivated area among spice crops (BBS, 2010). As a vegetable, it is second in importance only to tomatoes.

The nutritional and medicinal value of onions is noteworthy. The bulbs are rich in essential amino acids such as lysine and

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phenylalanine, as well as phosphorus, calcium, carbohydrates, protein, and vitamin C. Additionally, onions exhibit preservative properties and are considered beneficial for human health (Marschner, 1995). This versatile crop grows in almost all districts of Bangladesh, with significant commercial cultivation concentrated in Faridpur, Comilla, Dhaka, Mymensingh, Rajshahi, Rangpur, Pabna, and Jessore (BBS, 2006).

Despite its importance, onion production in Bangladesh faces several challenges. The area under onion cultivation was 126,174.9 hectares, with a production of 1,051,523 metric tons and an average yield of 8.33 metric tons per hectare in the fiscal year 2010–2011 (BBS, 2011). However, the country has historically faced a significant demand-supply gap of 42–45%, necessitating annual imports costing over Tk 10 billion (Yasir Wardad, 2012). Currently, the national demand stands at 1.75–1.8 million metric tons. Thus, enhancing onion yield through improved agricultural practices is a critical priority.

One major barrier to achieving higher yields is the limited adoption of modern agricultural technologies. Many farmers rely on traditional practices and apply fertilizers based on intuition rather than scientific recommendations. This is particularly true for essential nutrients such as nitrogen (N) and phosphorus (P), which are critical for onion growth and yield. Nitrogen, comprising approximately 7% of plant dry matter, is a key component of cellular structures, while phosphorus plays a vital role in energy transfer, root and leaf growth, and bulb development (Marschner, 1995; Bungard et al., 1999). Deficiencies in phosphorus have been linked to reduced root and leaf growth, smaller bulb size, delayed maturation, and lower yields (Brewster, 1994).

The combined application of nitrogen and phosphorus fertilizers has been shown to enhance nutrient availability in the soil and improve plant uptake. These nutrients are particularly crucial during the vegetative growth stage, where they contribute to bulb enlargement and overall yield (Steward, 1963; Rai, 1981). Given these considerations, this research aims to investigate the individual and combined effects of nitrogen and phosphorus fertilization on the growth and yield of onions in Bangladesh, with the goal of providing evidence-based recommendations for optimizing fertilizer use.

2. Materials and Methods

2.1 Location and Soil Characteristics

The experiment was conducted at an experimental farm located in the village of Niamatpur Upazila, Naogaon district, within Agro-Ecological Zone (AEZ)-26, also known as the High Barind Tract. The study was carried out during the winter growing season, from December to April. The soil in the experimental area was clay loam, characterized by high water-holding capacity. The site was selected based on its suitability, being high land that was well-drained, well-aerated, and exposed to ample sunlight. The *Taherpuri* variety of onion was chosen as the planting material for the study.

2.2 Experimental Design

The experiment was designed as a two-factor study, arranged in a Randomized Complete Block Design (RCBD) with three replications. The two factors included four levels of nitrogen (0, 50, 70, and 90 kg/ha) and four levels of phosphorus (0, 40, 60, and 80 kg/ha), resulting in 16 treatment combinations. Each replication included all 16 treatments, creating a total of 48 experimental plots ($4 \times 4 \times 3 = 48$). Each plot measured 1 m × 1 m (1 m^2), with a spacing of 50 cm between blocks and 30 cm between individual plots.

2.3 Fertilizer Application

Fertilizers were applied according to the respective treatment combinations. Urea was used as the nitrogen source, and triple superphosphate (TSP) was used as the phosphorus source. The full dose of phosphorus and half the dose of nitrogen were applied at the time of transplanting. The remaining half of the nitrogen dose was side-dressed 35 days after transplanting (DAT). Other essential fertilizers were applied uniformly across all plots according to the recommended doses for onion cultivation.

Standard agronomic practices and intercultural operations, such as weeding, irrigation, and pest management, were performed as needed throughout the growing period. The crop was harvested 88 days after transplanting.

2.4 Statistical Analysis

Data were collected on a range of growth and yield parameters, including plant height, number of leaves per plant, fresh weight of individual bulbs, oven-dry weight of bulbs, dry matter percentage of bulbs, bulb length, bulb diameter, total yield per plot, and yield per hectare. The recorded data were analyzed statistically using the MSTAT-C program to determine the effects of the treatments on the measured parameters.

3. Results and Discussion

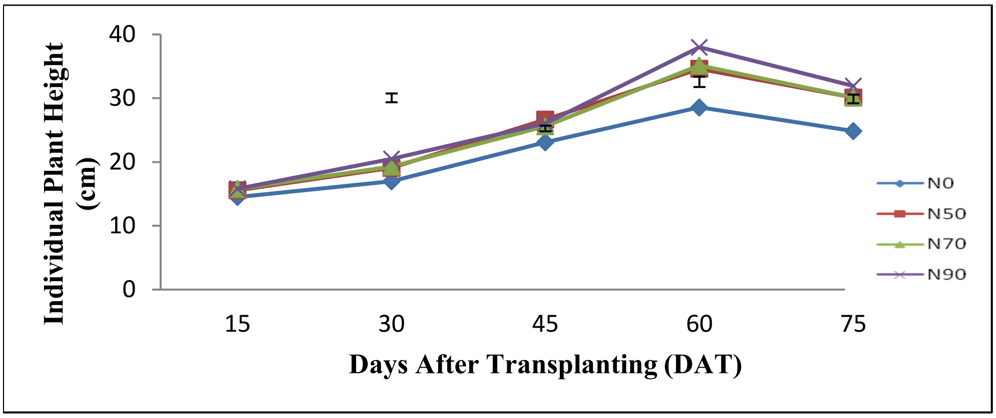
The experiment investigated the single and combined effects of different doses of nitrogen and phosphorus on the growth and yield performance of onions.

3.1. Plant Height

The highest dose of nitrogen (90 kg N/ha) produced the tallest plants (38.00 cm), whereas the control treatment resulted in the shortest plants (28.58 cm) at 60 DAT (Figure 1). Similarly, for phosphorus, the tallest plants (36.39 cm) were observed with 80 kg P/ha, and the shortest plants (29.29 cm) were seen in the control treatment at 60 DAT (Figure 2). The combination of 90 kg N/ha and 80 kg P/ha produced the tallest plants (39.14 cm) (Table 1).

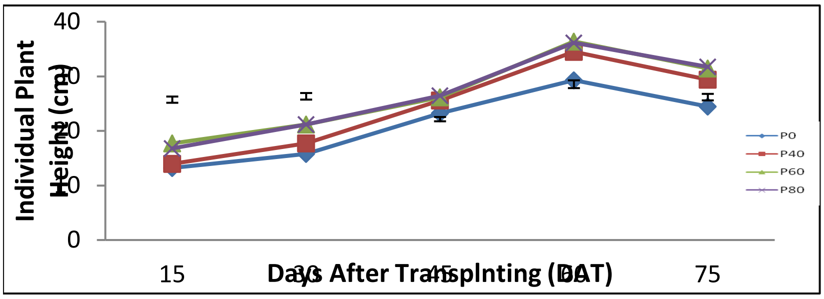
3.2. Number of Leaves

Nitrogen significantly influenced the number of leaves per plant, with the maximum number (6.47) observed at 70 kg N/ha and the minimum (5.24) in the control treatment (Figure 3). Similarly,



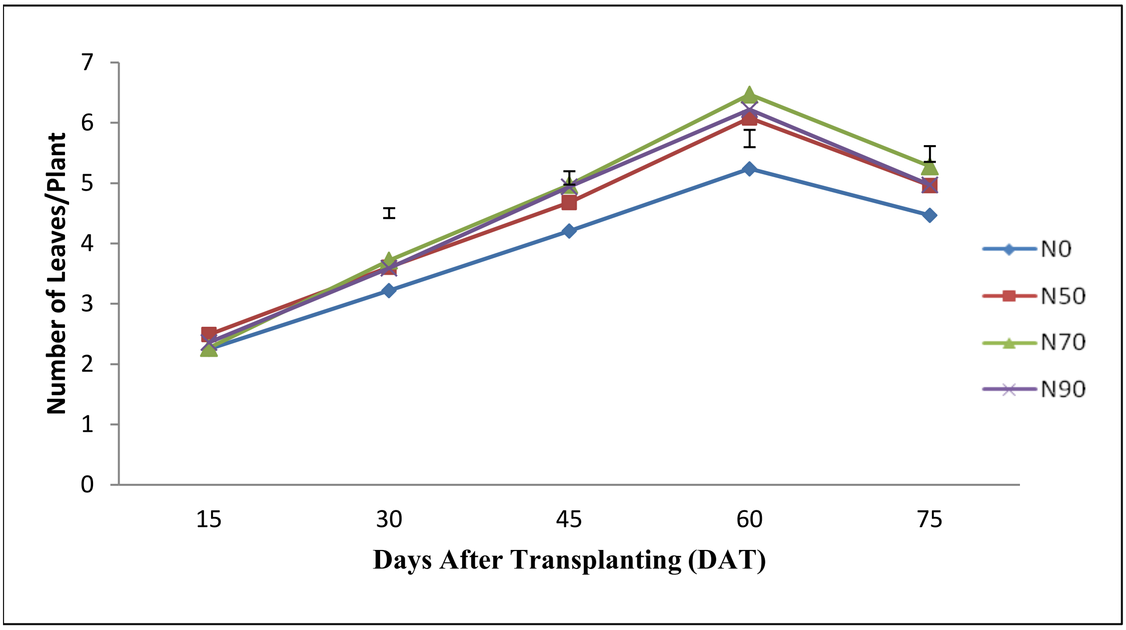
N_0 = 0kg N/ha, N_{50} = 50kg N/ha, N_{70} = 70kg N/ha & N_{90} = 90kg N/ha

Figure 1. Effect of different doses of nitrogen on plant height at different days after transplanting of onion (Vertical bar represents LSD at 0.05 levels)



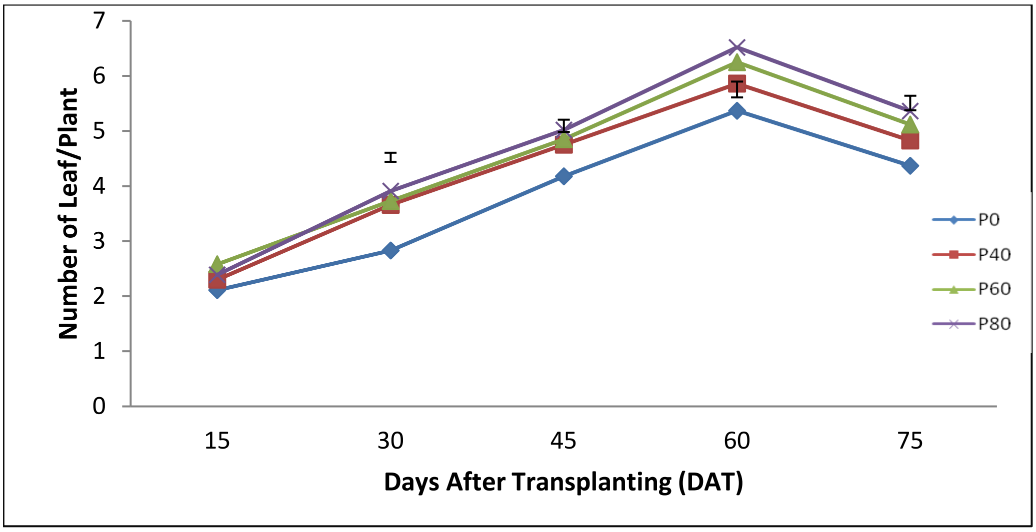
P_0 = 0kg P/ha, P_{40} = 40kg P/ha, P_{60} = 60kg P/ha & P_{80} = 80kg P/ha

Figure 2. Effects of different doses of phosphorus on plant height at different days after transplanting of onion (Vertical bar represents LSD at 0.05 levels).



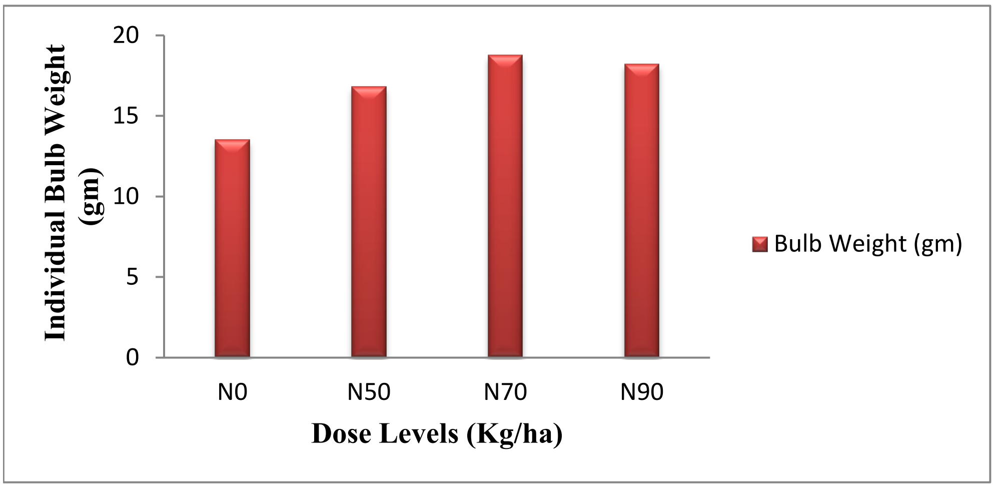
N_0 = 0kg N/ha, N_{50} = 50kg N/ha, N_{70} = 70kg N/ha & N_{90} = 90kg N/ha

Figure 3. Effect of different doses of nitrogen on number of onion leaves at different days after transplanting (Vertical bar represents LSD at 0.05 levels)



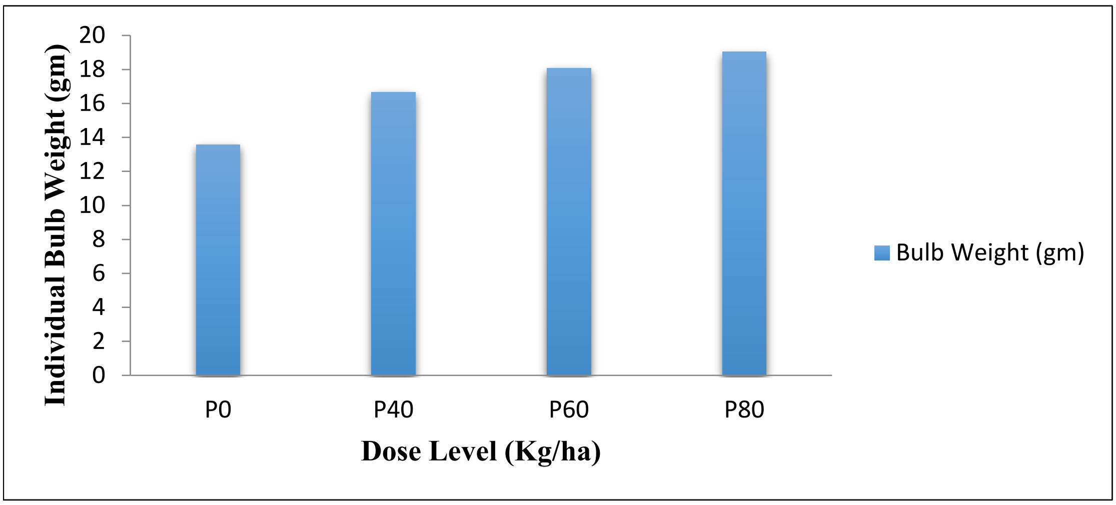
P_0 = 0kg P/ha, P_{40} = 40kg P/ha, P_{60} = 60kg P/ha & P_{80} = 80kg P/ha

Figure 4. Effects of different doses of phosphorus on number of onion leaves at different days after transplanting (Vertical bar represents LSD at 0.05 levels)



N_0 = 0kg N/ha, N_{50} = 50kg N/ha, N_{70} = 70kg N/ha & N_{90} = 90kg N/ha

Figure 7. Effects of different dose levels of nitrogen on individual bulb weight of onion



P_0 = 0kg P/ha, P_{40} = 40kg P/ha, P_{60} = 60kg P/ha & P_{80} = 80kg P/ha

Figure 8. Effects of different dose levels of phosphorus on individual bulb weight of onion

3.6. Dry Matter Content of Bulb

Table 1. Combined effects of nitrogen and phosphorus on plant height of onion at different days after transplanting (DAT)

Treatment combination	Plant height (cm) at different days after transplanting (DAT)				
	15DAT	30DAT	45DAT	60DAT	75DAT
N_0P_0	10.72g	12.90f	18.49d	21.96	17.47e
N_0P_{40}	13.93def	16.66cde	22.80c	28.07	24.98d
N_0P_{60}	17.46abc	18.96bcd	24.98bc	32.07	28.18cd
N_0P_{80}	15.87bcde	19.45b	26.10ab	32.22	28.83bc
$N_{50}P_0$	14.05def	16.25de	25.08bc	29.94	25.39d
$N_{50}P_{40}$	13.09fg	17.47bcde	26.76ab	34.76	30.35abc
$N_{50}P_{60}$	17.55abc	19.48b	27.04ab	36.54	32.27ab
$N_{50}P_{80}$	17.58ab	23.08a	27.71a	37.08	32.37ab
$N_{70}P_0$	12.82fg	16.16e	24.60bc	30.24	25.29d
$N_{70}P_{40}$	14.91cdef	17.53bcde	26.26ab	36.30	29.80abc
$N_{70}P_{60}$	19.23a	23.80a	26.06ab	37.93	32.57a
$N_{70}P_{80}$	16.21bcde	19.73b	25.47ab	36.09	32.77a
$N_{90}P_0$	15.23bcdef	17.81 bcde	24.67bc	35.01	29.76abc
$N_{90}P_{40}$	13.94ef	19.23bc	26.50ab	38.85	32.46a
$N_{90}P_{60}$	16.57bcd	22.42a	26.51ab	39.00	32.65a
$N_{90}P_{80}$	17.51abc	22.47a	26.51ab	39.14	32.91a
Level of Significance	*	*	**	NS	**

N.B: Means followed by the same letter(s) do not statistically differ at 5% level tested by DMRT

NS= Non Significant, LSD= Least Significant Difference

N_0= 0 kg Nitrogen per hectare | P_0= 0 kg Phosphorus per hectare

N_{50}= 50 kg Nitrogen per hectare | P_{40}= 40 kg Phosphorus per hectare

N_{70}=70 kg Nitrogen per hectare | P_{60}=60 kg Phosphorus per hectare

N_{90}=90 kg Nitrogen per hectare | P_{80}=80 kg Phosphorus per hectare

Table 4. Single Effect of phosphorus on the growth and yield of onion.

Phosphorus levels (kg/ha)		Bulb length (cm)	Bulb diameter (cm)	Fresh weight of individual bulb (g)	Oven dry weight of Individual bulb (g)	Dry Matter content of bulb (%)	Yield of bulb (kg/plot)	Yield of bulb (tone/ha)
P_0		2.46b	2.39b	13.58b	2.51b	18.27	1.36 b	13.58c
P_{40}		3.35ab	3.39a	16.67ab	3.07ab	18.48	1.67 ab	16.67b
P_{60}		3.50ab	3.54a	18.07a	3.47a	19.16	1.81 a	18.07ab
P_{80}		3.73a	3.81a	19.03a	3.66a	19.09	1.91 a	19.03a
Level of significance		**	**	*	*	NS	*	**
LSD	at 5%	0.7696	0.6239	4.191	0.8421	-	0.4152	4.191

N.B: Means followed by the same letter(s) do not statistically differ at the 5% level tested by DMRT.

NS= Non Significant | P_0= 0 kg Phosphorus per hectare

LSD = Least Significant Difference | P_{40}= 40 kg Phosphorus per hectare

P_{60}=60 kg Phosphorus per hectare

P_{80}=80 kg Phosphorus per hectare

Table 2. Combined effects of nitrogen and phosphorus on leaf number of onion at different days after transplanting (DAT)

Treatment combination	Number of leaves per plant at different days after transplanting (DAT)				
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT
N_0P_0	1.89	2.11d	3.50c	4.28c	3.86b
N_0P_{40}	2.22	3.34abc	4.22bc	4.88bc	4.28ab
N_0P_{60}	2.33	3.65abc	4.45abc	5.68abc	4.79ab
N_0P_{80}	2.55	3.76abc	4.67ab	6.10abc	4.96ab
$N_{50}P_0$	1.88	3.00c	4.00bc	5.66abc	4.37ab
$N_{50}P_{40}$	2.55	3.78abc	4.78ab	6.00abc	4.94ab
$N_{50}P_{60}$	2.76	3.65abc	4.89ab	6.22ab	5.14ab
$N_{50}P_{80}$	2.77	4.00ab	5.05ab	6.44ab	5.37ab
$N_{70}P_0$	2.33	3.22bc	4.32abc	5.67abc	4.58ab
$N_{70}P_{40}$	2.22	3.68abc	5.00ab	6.42ab	5.24ab
$N_{70}P_{60}$	2.77	3.89ab	5.11ab	6.55ab	5.41ab
$N_{70}P_{80}$	1.78	4.11a	5.45a	7.22a	5.89a
$N_{90}P_0$	2.34	3.00c	4.89ab	5.88abc	4.66ab
$N_{90}P_{40}$	2.22	3.89ab	5.00ab	6.12abc	4.88ab
$N_{90}P_{60}$	2.44	3.72abc	4.95ab	6.55ab	5.14ab
$N_{90}P_{80}$	2.44	3.77abc	4.93ab	6.31ab	5.21ab
Level of Significance	NS	*	*	**	**

N.B: Means followed by the same letter(s) do not statistically differ at 5% level tested by DMRT

NS= Non Significant, LSD = Least Significant Difference

N_0= 0 kg Nitrogen per hectare

N_{50}= 50 kg Nitrogen per hectare

N_{70}=70 kg Nitrogen per hectare

N_{90}=90 kg Nitrogen per hectare

P_0= 0 kg Phosphorus per hectare

P_{40}= 40 kg Phosphorus per hectare

P_{60}=60 kg Phosphorus per hectare

P_{80}=80 kg Phosphorus per hectare

Table 3. Main Effect of nitrogen on the growth and yield of onion**.**

Nitrogen levels (kg/ha)	Bulb length (cm)	Bulb diameter (cm)	Fresh weight of the individual bulb (g)	Oven dry weight of Individual bulb (g)	Dry Matter content of bulb (%)	Yield of bulb (kg/plot)	Yield of bulb (tone/ha)
N_0	2.56 b	2.57b	13.53b	2.46b	18.02	1.35 b	13.53b
N_{50}	3.29ab	3.35ab	16.83ab	3.15ab	18.65	1.68 ab	16.83ab
N_{70}	3.61 a	3.67a	18.77a	3.68a	19.61	1.88 a	18.77a
N_{90}	3.59 a	3.53a	18.22a	3.40ab	18.72	1.82 a	18.22a
Level of significance	*	**	*	**	NS	*	*
LSD at 5%	0.7696	0.6239	4.191	0.8421	-	0.4152	4.191

N.B: Means followed by the same letter(s) do not statistically differ at 5% level tested by DMRT.

NS= Non-Significant

LSD = Least Significant Difference

N_0= 0 kg Nitrogen per hectare

N_{50}= 50 kg Nitrogen per hectare

N_{70}=70 kg Nitrogen per hectare

N_{90}=90 kg Nitrogen per hectare

Table 5. Combined effects of nitrogen and phosphorus on the growth and yield of onion

Treatment combination	Bulb length (cm)	Bulb diameter (cm)	Fresh weight of individual bulb (g)	Oven dry weight of Individual bulb (g)	Dry matter content of bulb (%)	Yield of bulb (kg/plot)	Yield of bulb (ton/ha)
N_0P_0	1.8d	2.03e	7.48d	1.30c	17.08	0.75c	7.48d
N_0P_{40}	2.45cd	2.57de	14.64c	2.59b	17.72	1.47b	14.64c
N_0P_{60}	2.76bcd	2.60de	15.18bc	2.82b	18.63	1.52ab	15.18bc
N_0P_{80}	3.23abc	3.09bcd	16.82abc	3.14ab	18.65	1.68ab	16.82abc
$N_{50}P_0$	2.41cd	2.39de	14.30c	2.65b	18.46	1.43b	14.30c
$N_{50}P_{40}$	3.45abc	3.54abc	16.30bc	3.04ab	18.54	1.63ab	16.30bc
$N_{50}P_{60}$	3.52abc	3.64ab	18.01abc	3.41ab	18.89	1.80ab	18.01abc
$N_{50}P_{80}$	3.76ab	3.85ab	18.72abc	3.51ab	18.71	1.87ab	18.72abc
$N_{70}P_0$	2.78bcd	2.43de	16.91abc	3.25ab	19.27	1.69ab	16.91abc
$N_{70}P_{40}$	3.72ab	3.78ab	17.58abc	3.33ab	19.03	1.76ab	17.58abc
$N_{70}P_{60}$	3.87ab	4.08a	19.23abc	3.83ab	19.93	1.92ab	19.23abc
$N_{70}P_{80}$	4.08a	4.38a	21.36a	4.32a	20.21	2.14a	21.36a
$N_{90}P_0$	2.87bcd	2.70cde	15.62bc	2.83b	18.28	1.56ab	15.62bc
$N_{90}P_{40}$	3.77ab	3.67ab	18.14abc	3.32ab	18.63	1.81ab	18.14abc
$N_{90}P_{60}$	3.86ab	3.83ab	19.85ab	3.80ab	19.19	1.98ab	19.85ab
$N_{90}P_{80}$	3.87ab	3.93ab	19.24abc	3.65ab	18.80	1.94ab	19.24abc
Level of Significance	**	**	**	**	NS	**	**

N.B: Means followed by the same letter(s) do not statistically differ at the 5% level tested by DMRT

NS= Non-Significant, LSD = Least Significant Difference

N_0= 0 kg Nitrogen per hectare

N_{50}= 50 kg Nitrogen per hectare

N_{70}=70 kg Nitrogen per hectare

N_{90}=90 kg Nitrogen per hectare

P_0= 0 kg Phosphorus per hectare

P_{40}= 40 kg Phosphorus per hectare

P_{60}=60 kg Phosphorus per hectare

P_{80}=80 kg Phosphorus per hectare

phosphorus application at 80 kg P/ha resulted in the highest number of leaves (6.52), while the control treatment showed the lowest (5.37) (Figure 4). The combination of 70 kg N/ha and 80 kg P/ha produced the maximum number of leaves (7.22), which was statistically significant (Table 2). This finding aligns with Abdissa et al. (2011).

3.3. Bulb Length

Both nitrogen and phosphorus significantly affected bulb length. The maximum bulb lengths of 3.61 cm and 3.73 cm were recorded at 70 kg N/ha and 80 kg P/ha, respectively. The combination of 70 kg N/ha and 80 kg P/ha resulted in the highest bulb length (4.08 cm), while the shortest bulb length (1.80 cm) was observed in the control treatment (Table 3).

3.4. Bulb Diameter

The diameter of the bulb was significantly influenced by nitrogen and phosphorus levels. Nitrogen at 70 kg/ha and phosphorus at 80 kg/ha produced the largest bulb diameters (3.67 cm and 3.81 cm, respectively), while the smallest diameters (2.57 cm and 2.39 cm, respectively) were found in the control treatments. The combination of 70 kg N/ha and 80 kg P/ha resulted in the highest bulb diameter (4.38 cm), which was similar to the treatments N70P60, N70P40, N90P40, N90P60, and N90P80 (Table 3).

3.5. Weight of Individual Bulb

The fresh weight of the bulb per plant was significantly influenced by nitrogen and phosphorus levels. The highest fresh weights of bulbs (18.77 g and 19.03 g) were observed with 70 kg N/ha and 80 kg P/ha, respectively, while the lowest fresh weights (13.53 g and 13.58 g) were recorded in the control treatments (Figures 5 and 6). The combination of 70 kg N/ha and 80 kg P/ha produced the highest fresh weight (21.36 g) (Table 3). This finding is consistent with Singh and Dhankar (1988).

3.6. Dry Matter Content

Dry matter content was not statistically significant across treatments; however, the combination of 70 kg N/ha and 80 kg P/ha produced the maximum dry matter content (20.21%), while the minimum (17.08%) was recorded in the control treatment (Table 3).

3.7. Yield of Bulb Per Plot

Significant variations in bulb yield per plot were observed among treatment combinations. The highest yield (2.14 kg/plot) was obtained with 70 kg N/ha and 80 kg P/ha, while the lowest yield (0.75 kg/plot) was observed in the control treatment (Table 5). This increased yield may be attributed to the higher number of leaves per plant, which enhances photosynthesis and biomass storage in onion bulbs.

3.8. Yield of Bulb Per Hectare

The application of nitrogen and phosphorus significantly increased bulb yield per hectare. The highest yields (18.77 t/ha and 19.03 t/ha) were recorded with 70 kg N/ha and 80 kg P/ha, respectively, while the lowest yields (13.53 t/ha and 13.58 t/ha) were observed in control treatments. The combination of 70 kg N/ha and 80 kg P/ha produced the maximum yield (21.36 t/ha), followed by treatments such as N50P60, N50P80, N70P60, N90P40, N90P60, and N90P80. The lowest yield (7.48 t/ha) was recorded in the control treatment (Table 4). These findings are in agreement with Mandaria and Khan (2003).

4. Conclusion

The study demonstrated that nitrogen and phosphorus application significantly enhance onion growth and yield. Among the treatments, 70 kg N/ha combined with 80 kg P/ha consistently produced superior results across key parameters, including plant height, number of leaves, bulb size, fresh weight, and total yield. This optimal nutrient combination yielded 21.36 t/ha, outperforming all other treatments. These findings highlight the critical role of balanced fertilization in achieving higher onion productivity in Bangladesh. Adoption of these evidence-based fertilizer practices could reduce the demand-supply gap, improve farm profitability, and support national food security, making this approach invaluable for onion cultivation.

Author contributions

M.A.M. and M.K.A. conceptualized the study and defined its objectives. J.R. and M.K.F. conducted the literature review and managed references. M.M. and A.H. contributed to data analysis and interpretation. M.A. drafted the manuscript, and M.K.A. performed the final revisions. All authors reviewed and approved the final manuscript for submission.

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Competing financial interests

The authors have no conflict of interest.

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