



## Integrated Application of Organic (PLBC and Biochar) and Inorganic Fertilizers for Sustainable Onion (*Allium cepa* L.) Production

Humayara Islam<sup>1,a</sup>, Md. Mamunur Rashid<sup>2,b</sup>, Md. Mainul Hasan<sup>1,c</sup>, Md. Mahmudul Hasan<sup>1,d</sup>,  
Md. Maniruzzaman Bahadur<sup>1,e</sup>, Abu Khayer Md. Muktarirul Bari Chowdhury<sup>1,f,\*</sup>

<sup>1</sup>Department of Crop Physiology & Ecology, Faculty of Agriculture, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh

<sup>2</sup>Department of Agronomy, Faculty of Agriculture, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh

\*Corresponding author

### ARTICLE INFO

### ABSTRACT

#### Research Article

Received : 26.01.2025  
Accepted : 27.02.2025

#### Keywords:

Organic manure  
Inorganic fertilizer  
Integrated fertilization  
Sustainable agriculture  
Onion

Excessive use of inorganic fertilizers degrades soil health by disrupting the microbiota, reducing organic matter, and leading to compaction, acidity, and nutrient imbalance. This study aimed at the combined application of organic and inorganic fertilizers as an environmentally friendly approach increasing soil organic matter and crop yields. From January to April 2022, a field experiment was carried out at the Crop Physiology & Ecology Department of Hajee Mohammad Danesh Science and Technology University in Dinajpur to assess the effects of integrated fertilization on onion (*Allium cepa* L.). Three replications employing a two-factorial Randomized Complete Block Design (RCBD) were performed to set up the experiment. Factor A contained three onion varieties (V<sub>1</sub>: Taherpuri, V<sub>2</sub>: BARI Piaz 4, and V<sub>3</sub>: BARI Piaz 6) while Factor B comprised four fertilization treatments: T<sub>1</sub> (RDF + Cowdung @ 5 t ha<sup>-1</sup>), T<sub>2</sub> (RDF + PLBC @ 5 t ha<sup>-1</sup>), T<sub>3</sub> (PLBC @ 15 t ha<sup>-1</sup>), and T<sub>4</sub> (Biochar @ 10 t ha<sup>-1</sup>). Measurements were made concerning growth traits such as plant height, leaf number, SPAD value, bulb diameter, neck diameter, average bulb weight, and total yield. The findings showed that variety and fertilization provided a significant effect on growth performance, yield and yield traits. Taherpuri (V<sub>1</sub>), performed better than V<sub>2</sub> and V<sub>3</sub>. The majority of growth and yield traits were most effectively performed by fertilization treatment T<sub>2</sub> (RDF + PLBC), which was followed by T<sub>1</sub>, T<sub>3</sub>, and T<sub>4</sub>. Performance appeared lowest for the V<sub>3</sub>T<sub>4</sub> interaction and got maximum for the V<sub>1</sub>T<sub>2</sub> interaction. These results demonstrate that the combination of organic and synthetic fertilizers leads to sustainable onion production.

<sup>a</sup> [humayara113@gmail.com](mailto:humayara113@gmail.com)

<sup>b</sup> <https://orcid.org/0009-0005-6718-7783>

<sup>b</sup> [mamunur.1501173@std.hstu.ac.bd](mailto:mamunur.1501173@std.hstu.ac.bd)

<sup>d</sup> <https://orcid.org/0009-0001-3419-5817>

<sup>c</sup> [mainulh1996@gmail.com](mailto:mainulh1996@gmail.com)

<sup>d</sup> <https://orcid.org/0009-0003-8060-2297>

<sup>d</sup> [mahmudulhasan5951@gmail.com](mailto:mahmudulhasan5951@gmail.com)

<sup>e</sup> <https://orcid.org/0009-0002-3590-1231>

<sup>e</sup> [nmbhstu@yahoo.com](mailto:nmbhstu@yahoo.com)

<sup>f</sup> <https://orcid.org/0009-0000-5797-383X>

<sup>f</sup> [minarbari07@gmail.com](mailto:minarbari07@gmail.com)

<sup>f</sup> <https://orcid.org/0000-0002-9523-5130>



This work is licensed under Creative Commons Attribution 4.0 International License

## Introduction

Onion (*Allium cepa* L.), a member of the Alliaceae family, is one of the world's most widely cultivated and valuable vegetables, with over 4,000 years of agriculture (Shigyo and Kik, 2008; Hanelt, 1990). It is grown commercially across the world, including Bangladesh. Onion is packed with nutritional value and is mostly consumed for its particular flavor or potential to increase the flavor of other dishes. It is a staple vegetable, spice, and condiment that contributes strongly to the human diet considering its nutritional and medicinal features, including its richness in vitamin C and E content (Randle, 2000) and about 2.547 million metric tons of onions were produced in Bangladesh (BBS, 2023).

Despite its importance, onion cultivation poses challenges, especially for small-scale farmers, due to the high expenses of chemical fertilizers and pest management. Excessive use of synthetic fertilizers decreases soil properties, reduces nutrient availability, and negatively impacts beneficial soil organisms, ultimately threatening long-term productivity (Blanco et al., 2013; Chhonkar, 2003). Organic manure, notably poultry manure, has emerged as an affordable and cost-effective solution to synthetic fertilizers. Poultry manure is abundant in vital nutrients consisting of nitrogen, phosphorus, and potassium, which improves soil characteristics and crop yields (Zang et al., 1998; Ishak et al., 1999). Biochar, another soil amendment, enhances organic fertilizers by

improving the quality and texture of the soil, promoting nutrient availability, and microbial activity (Haque et al., 2018; Gambo et al., 2008) and minimizing greenhouse gas emissions (Mukherjee and Lal, 2013; Jaafar et al., 2014).

The key problem with onion production is the low-quality soil of the majority of cultivated land, which is the result of continuous farming without a resting duration necessary to recover lost fertility. Supplying or combining the application of organic and inorganic fertilizers is the only approach addressing this threat (Santhi et al., 2005). While applied, inorganic fertilizers provide nutrients to crop plants rapidly for healthy growth and development. In addition, NPK fertilizer contains nitrogen, phosphorus, and potassium, the three main elements that plants need in big quantities. The application of organic manure with inorganic fertilizers such as nitrogen, phosphate, and potassium greatly increased bulb production in sandy loam soils, demonstrating that combining organic manure with inorganic fertilizers may improve onion yield (Stolton, 1997; Hossin et al., 2022) and additionally, applying of organic manure along with integrated inorganic fertilizers lead to improve the production, quality, and shelf life of the onion (Gupta et al., 1999)

To address increasing the production of onion in Bangladesh and concerns about soil degradation and establish sustainable strategies, this study aims to investigate the combined impacts of organic and inorganic fertilizers on onion growth performance, yield and yield traits. Findings determine that resource-efficient fertilization in an environmentally friendly approach improving onion production in sustainable ways.

## Material and Methods

### Location and duration

The experiment was carried out from January to April 2022 on the research sites of the Department of Crop Physiology and Ecology at Hajee Mohammad Danesh Science and Technology University in Dinajpur, Bangladesh. The field trial site is located in the Sadar Upazila in Dinajpur District.

### Soil Properties

The experimental site was in the Crop Physiology and Ecology Field of Hajee Mohammad Danesh Science and Technology University in Dinajpur, in the Old Himalayan Piedmont Plain (AEZ-1). The soil was categorized as a non-calcareous brown floodplain soil, derived from piedmont alluvium, with a sandy loam texture. The drainage system was moderately well-drained, and the topography was above flood level. The soil having a bulk density of 0.86 to 1.07 g cm<sup>-3</sup> and contains 60% sand, 27% silt, and 13% clay. Chemical examination found moderately acidic soil (pH 5.40-5.50), low organic carbon (0.69%), and very low total nitrogen (0.07%). The cation exchange capacity (CEC) was 5.60 meq/100g soil, whereas available phosphorus (6.75 mg/kg) was medium and exchangeable potassium (0.17 meq/100g soil) was medium to low. Soil analysis was performed at SRDI in Dinajpur, Bangladesh (Table 1).

### Weather and Climate

The experimental area in northern Bangladesh is located at 25.39° N latitude and 88.41° E longitude, at an elevation of 37.58 meters above sea level. The region is in the subtropical climatic zone, which can be recognized by significant rainfall, high humidity, high temperatures, and relatively long days during the Kharif season (April to September). In contrast, the Rabi season (October to March) is notable for less rainfall, low humidity, and shorter day lengths.

### Experimental Design and Layout

The study employed a two-factorial Randomized Complete Block Design (RCBD) with three replications, resulting in 12 treatment combinations (4 × 3). The experimental field was divided into three blocks, each with 12 plots, for a total of 36 unit plots (3 × 12). Each unit plot sized 1.5 m × 1.0 m. The spacing between plots and blocks was kept at 40 and 60 cm, respectively.

Table 1. Characteristics of the soil of the experimental site

General Characters	Description
Location	Crop Physiology and Ecology Field
AEZ	Old Himalayan Piedmont Plain (AEZ-1)
General soil type	Non-Calcareous Brown Floodplain Soil
Parent material	Piedmont alluvium
Soil series	Ranishankail
Drainage	Moderately well drained
Flood level	Above flood level
Topography	High land
Physical characteristics	Value
Bulk density (g cm <sup>-3</sup> )	0.86-1.07
Sand (2-0.02 mm)	60.0
Silt (0.02-0.002 mm)	27.0
Clay (< 0.002)	13.0
Textural class	Sandy loam
Chemical characteristics	Content
pH	5.40-5.50
Organic carbon (%)	0.69
Organic matter (%)	1.19
CEC (meq /100g soil)	5.60
Total N (%)	0.07
Available P (mg/kg )	16.75
Exchangeable K (meq/100g soil )	0.17
	Interpretation
	Moderately acidic
	Low
	Low
	Low
	Very low
	Medium
	Medium-low

Source: Analysis of initial soil samples was done in SRDI, Dinajpur, Bangladesh

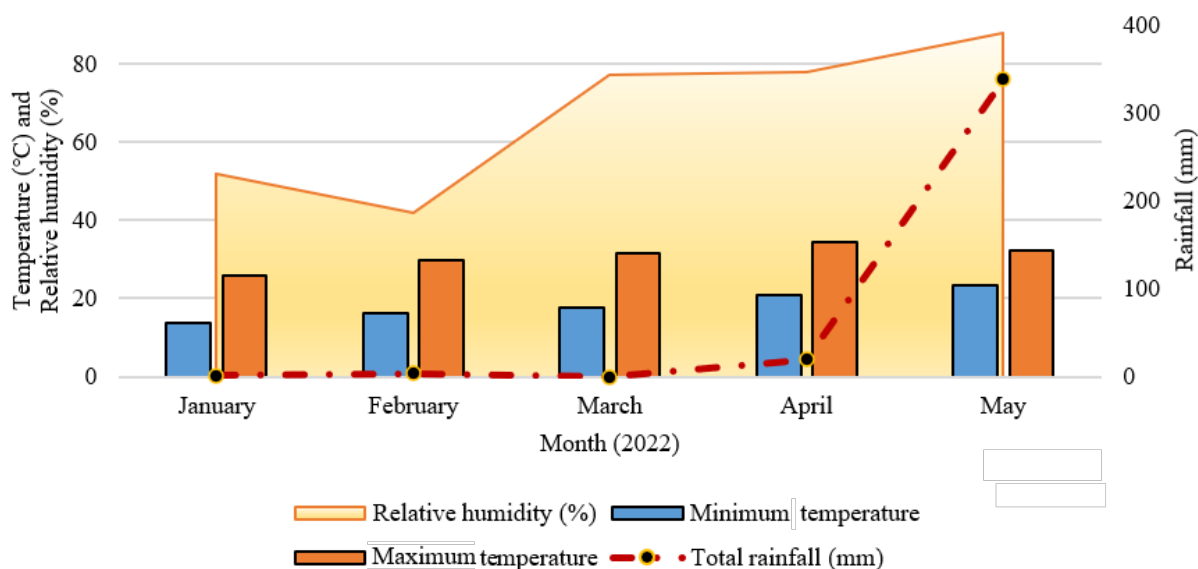


Figure 1. Maximum and minimum temperature, relative humidity and rainfall of the study region from January to May 2022

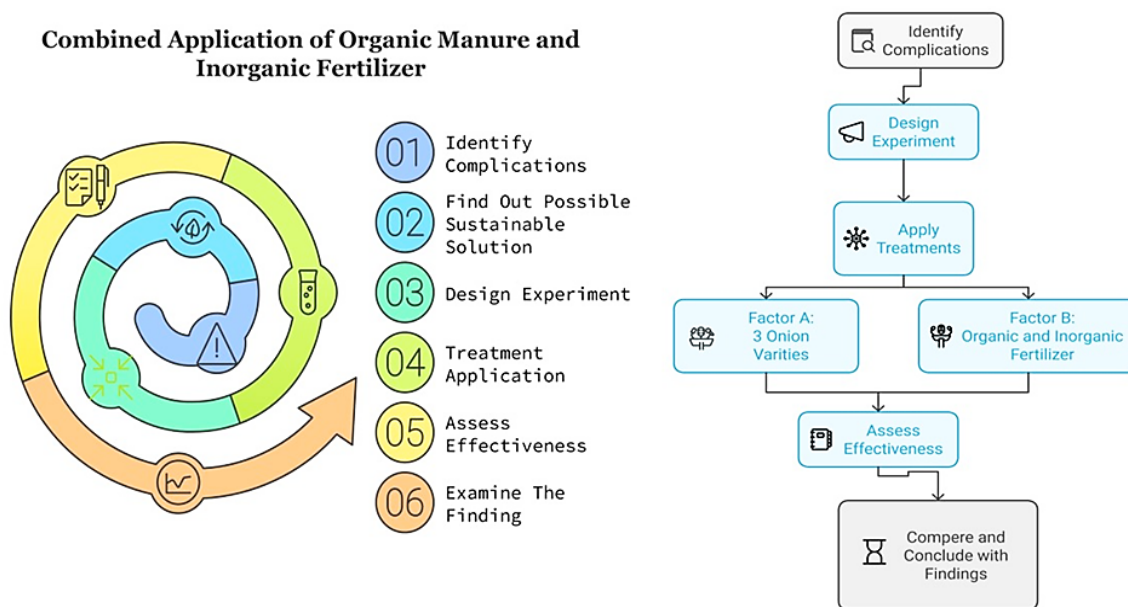


Figure 2. Overview of experimental design and treatment applications.

### Experimental Treatments

The investigation was conducted with two factors in mind. Factor A included three different onion varieties: V<sub>1</sub>: Taherpuri, V<sub>2</sub>: BARI Piaz-4, and V<sub>3</sub>: BARI Piaz-6, all of which were renowned in Bangladesh for their effective yield, pungency, size of the bulb, and additional features. In accordance with the study's objectives, factor B was generated for varying levels of organic and synthetic fertilizers. Different organic and synthetic fertilizer sources were used, using RDF (Recommended Dose of Fertilizer), CD (Cowdung), and PLBC (Poultry Litter-Based Compost). The study utilized four fertilization levels: T<sub>1</sub> (control): RDF + Cowdung (CD) @ 5 t ha<sup>-1</sup>, T<sub>2</sub>: RDF + Poultry Litter-Based Compost (PLBC) @ 5 t ha<sup>-1</sup>, T<sub>3</sub>: PLBC @ 15 t ha<sup>-1</sup>, and T<sub>4</sub>: Biochar @ 10 t ha<sup>-1</sup>. This arrangement allowed for an accurate assessment of the interaction effects between onion varieties and fertilization treatments.

### Application of Manure and Fertilizer

During land preparation, all cow dung, TSP, gypsum, biochar, and PLBC, as well as one-third of the urea and half of the MoP, got incorporated into the soil employing the experimental design. The remaining MoP and the second split of urea were utilized 21 days after transplantation, and the final split of urea was applied 45 days later (Table 2).

### Plantation and Intercultural Operations

The experiment included three onion varieties: Taherpuri, BARI Piaz 4, and BARI Piaz 6. BARI Piaz 4 and 6 were collected from the Bangladesh Agricultural Research Institute (BARI) in Dinajpur, whilst Taherpuri was sourced locally. Seedlings were treated with fungicide prior to transplantation by soaking their roots in a prepared solution for 15 minutes. Transplantation took place on January 4, 2022, with 10 cm plant-to-plant and 15 cm row-to-row spacing at a depth of 1.5 cm. Each plot had 150 seedlings, that were placed in 10 rows of 15 each.

Table 2. Doses of RDF fertilizers and Manure

Fertilizers and Manures	Dose/ha	Dose/Plot
Urea	150 kg	324.000 g
TSP	200 kg	58.500 g
MoP	175 kg	303.750 g
Gypsum	100 kg	24.750 g
Well-decomposed cow dung	5 ton	1.125 kg
Biochar	10 ton	2.250 kg
Poultry Litter Based Compost (PLBC)	15 ton	3.375 kg
Poultry Litter Based Compost (PLBC)	5 ton	1.125 kg

To promote aeration, suppress weeds, and preserve soil moisture, weeding was done by hand. A second weeding and thinning was done 40 days following the first one, which took place 21 days after the first sowing. Watering cans were used for irrigation at first, and flood irrigation was employed as necessary. Optimal soil condition was maintained by mulching and excess water drainage.

The fungicides Rovral 50 WP (2 g/L) and Acrobat MZ (4 g/L) were used as needed to control purple blotch. The flowering stalks, were cut off to encourage the growth of bulbs. The harvest took place on April 14, 2022. In accordance with Brewster (1994), plants were bent at the neck seven days before harvest in order to speed up maturity. To avoid damaging the bulbs, onions were carefully plucked. Drying took three days under a shed, following which tops were clipped to a 2 cm neck and bulbs were stored in a ventilated area.

#### Data collection

Data was collected by selecting randomly five plants per plot and analyzing multiple growth and yield and yield traits at 20-day intervals. The parameters measured include plant height, leaf number, leaf length, bulb diameter, neck diameter, SPAD value, bulb weight, and total yield. A measuring tape was used to measure the plant's height (cm) from the soil base to the tip of the longest leaf. The number of leaves was calculated by carefully counting all fully developed green leaves on each plant. Leaf length (cm) was determined by measuring the longest leaf from base to apex utilizing a measuring tape. A Vernier caliper was utilized to precisely measure the bulb diameter (cm) and neck diameter (cm) to determine the optimum bulb size and neck diameter. The SPAD value, which indicates darkness and photosynthetic efficiency, was determined using a SPAD meter. Individual bulb weights (g) were recorded on a digital weighing scale, and the average weight per plant was calculated. The total yield ( $t\ ha^{-1}$ ) was estimated by converting the plot yield to a per-hectare basis using the following formula:

$$\text{Total Yield (t ha}^{-1}\text{)} = \left( \frac{\text{Plot Yield (kg)}}{\text{Plot Area (m}^2\text{)}} \right) \times 10,000.$$

#### Statistical Analysis

The collected data was analyzed using Statistix 10 software and regression analysis was done using MS Excel program. Principal component analysis (PCA) biplot and dendrogram cluster analysis were performed on morphological attributes, including plant height, the number of leaves plant<sup>-1</sup>, neck diameter, bulb diameter, average bulb weight, and yield, using the OriginPro software. The diagram was designed using Napkin illustration.

## Results

### Plant height

The impact of various fertilization treatments and onion varieties on plant height at three growth stages: 20, 40, and 60 days after transplantation (DAT). Plant height varied significantly across treatments along with stages. At 20 DAT, the highest plants were recorded in V<sub>3</sub>T<sub>2</sub> (30.75 cm), followed by V<sub>1</sub>T<sub>2</sub> (29.29 cm), while V<sub>3</sub>T<sub>4</sub> had the shortest height (14.88 cm). Similarly, at 40 DAT, V<sub>3</sub>T<sub>2</sub> exhibited the longest height (34.49 cm), whereas V<sub>3</sub>T<sub>4</sub> attended the lowest (19.19 cm). By 60 DAT, V<sub>3</sub>T<sub>2</sub> had regained the maximum height (38.00 cm), outperforming the other treatments, while V<sub>3</sub>T<sub>4</sub> remained the shortest (22.53 cm). Statistical analysis found substantial variations in plant height between treatments, with coefficients of variation (CV) ranging from 11.29% at 20 DAT to 10.46% at 60 DAT, demonstrating data consistency across observations. These findings demonstrate the combined effect of fertilization and variety selection on onion growth performance (Table 3).

### Number of Leaf

A significant difference in the number of leaf was observed across treatments at all stages, as indicated by the degree of significance (\*). At 20 DAT, V<sub>1</sub>T<sub>1</sub> exhibited the greatest number of leaf (4.67), followed by V<sub>3</sub>T<sub>4</sub> with the least (2.80). At 40 DAT, V<sub>1</sub>T<sub>2</sub> produced the maximum number of leaf (7.00), whereas V<sub>3</sub>T<sub>4</sub> produced less (3.87). Similarly, at 60 DAT, V<sub>1</sub>T<sub>2</sub> retained the highest number of leaf (6.13), whereas V<sub>3</sub>T<sub>4</sub> had the lowest number of leaf (3.47). The coefficients of variation (CV) for 20, 40, and 60 DAT were 11.62%, 11.34%, and 14.69%, showing that the results varied significantly (Table 4).

### SPAD value

Table 4 shows the effect of different fertilization treatments and onion varieties on SPAD values, which are indicators of chlorophyll content, examined at 20, 40, and 60 days after transplanting (DAT). At 20 DAT, there were no significant variations across the treatments, with SPAD values ranging from 58.87 (V<sub>2</sub>T<sub>3</sub>) to 78.23 (V<sub>1</sub>T<sub>2</sub>). However, significant variation was observed at 40 and 60 DAT. At 40 DAT, V<sub>1</sub>T<sub>2</sub> exhibited the maximum SPAD value (32.9), while V<sub>2</sub>T<sub>4</sub> was the lowest (23.30). At 60 DAT, V<sub>1</sub>T<sub>4</sub> had the highest SPAD value (35.70), whereas V<sub>3</sub>T<sub>3</sub> had the least (26.47). The coefficients of variation (CV) were 16.88%, 8.12%, and 9.41% for DATs 20, 40, and 60, respectively, showing significant variability.

Table 3. Effect of different fertilization and varieties of onion on plant height

Treatment	Plant height (cm)		
	20 DAT	40 DAT	60 DAT
V <sub>1</sub> T <sub>1</sub>	28.29a	31.79a	33.41a-c
V <sub>1</sub> T <sub>2</sub>	29.29a	32.75a	35.79a-c
V <sub>1</sub> T <sub>3</sub>	25.37ab	27.99ab	31.92a-d
V <sub>1</sub> T <sub>4</sub>	18.99b-d	23.62ab	26.77b-d
V <sub>2</sub> T <sub>1</sub>	27.51a	31.22a	34.05a-c
V <sub>2</sub> T <sub>2</sub>	27.03ab	30.46ab	32.95a-c
V <sub>2</sub> T <sub>3</sub>	26.28ab	30.55ab	33.17a-c
V <sub>2</sub> T <sub>4</sub>	16.24cd	23.49ab	26.09cd
V <sub>3</sub> T <sub>1</sub>	23.26a-c	32.02a	35.39a-c
V <sub>3</sub> T <sub>2</sub>	30.75a	34.49a	38.00a
V <sub>3</sub> T <sub>3</sub>	27.79a	33.15a	36.15ab
V <sub>3</sub> T <sub>4</sub>	14.88d	19.19b	22.53d
Level of significance	*	*	*
CV (%)	11.29	13.18	10.46

\* denoted the significance at 5% level of probability

Table 4. Effect of different fertilization and varieties of onion on leaf number and SPAD value.

Treatment	Number of leaf			SPAD value		
	20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT
V <sub>1</sub> T <sub>1</sub>	4.67a	6.33ab	5.73ab	61.03	29.33ab	33.63ab
V <sub>1</sub> T <sub>2</sub>	4.33ab	7.00a	6.13a	78.23	32.90a	32.23ab
V <sub>1</sub> T <sub>3</sub>	4.13a-c	5.47a-c	5.33a-c	67.87	25.77b	31.33ab
V <sub>1</sub> T <sub>4</sub>	3.87a-c	5.27a-c	4.53a-c	75.33	27.23ab	35.70a
V <sub>2</sub> T <sub>1</sub>	3.87a-c	5.2a-c	4.20a-c	64.50	27.83ab	31.00ab
V <sub>2</sub> T <sub>2</sub>	4.13a-c	5.67a-c	5.27a-c	70.30	25.07b	31.73ab
V <sub>2</sub> T <sub>3</sub>	4.33ab	5.27a-c	5.00a-c	58.87	24.70b	27.37ab
V <sub>2</sub> T <sub>4</sub>	3.13bc	4.27c	4.00bc	64.63	23.30b	27.77ab
V <sub>3</sub> T <sub>1</sub>	3.87a-c	5.50a-c	5.17a-c	59.23	29.53ab	33.23ab
V <sub>3</sub> T <sub>2</sub>	4.27ab	5.67a-c	4.93a-c	59.23	28.80ab	33.30ab
V <sub>3</sub> T <sub>3</sub>	4.10a-c	5.00bc	4.40a-c	62.43	27.30ab	26.47b
V <sub>3</sub> T <sub>4</sub>	2.80c	3.87c	3.47c	59.53	25.80b	31.20ab
Level of significance	*	*	*	NS	*	*
CV (%)	11.62	11.34	14.69	16.88	8.12	9.41

\* denoted the significance at 5% level of probability

Table 5. Effect of different fertilization and varieties of onion on yield attributes

Varieties	Bulb diameter (cm)	Neck diameter(cm)	Average bulb weight (g)	Yield (t ha <sup>-1</sup> )
V <sub>1</sub> T <sub>1</sub>	3.67a	1.03a	20.55ab	8.46b
V <sub>1</sub> T <sub>2</sub>	3.47a	0.94ab	18.33a-c	12.77a
V <sub>1</sub> T <sub>3</sub>	3.09ab	0.80a-d	13.97c	7.56bd
V <sub>1</sub> T <sub>4</sub>	2.35b-d	0.62b-d	7.51d	3.45e
V <sub>2</sub> T <sub>1</sub>	3.04a-c	0.86a-c	17.48bc	6.58bd
V <sub>2</sub> T <sub>2</sub>	3.25ab	0.88ab	20.66ab	8.58b
V <sub>2</sub> T <sub>3</sub>	2.88a-c	0.76a-d	16.74bc	7.64b-d
V <sub>2</sub> T <sub>4</sub>	2.06cd	0.71a-d	6.75d	2.96e
V <sub>3</sub> T <sub>1</sub>	2.90a-c	0.76a-d	13.52c	5.75d
V <sub>3</sub> T <sub>2</sub>	3.67a	0.88ab	22.47a	8.06bc
V <sub>3</sub> T <sub>3</sub>	2.95a-c	0.55cd	16.28bc	6.26cd
V <sub>3</sub> T <sub>4</sub>	1.75d	0.49d	6.50d	1.60e
Level of significance	*	*	*	*
CV (%)	11.79	14.44	10.9	10.63

\* denoted the significance at 5% level of probability

**Bulb Diameter**

In terms of bulb diameter, significant variation was found across the treatments. V<sub>1</sub>T<sub>1</sub> had the largest bulb diameter (3.67 cm), followed by V<sub>3</sub>T<sub>2</sub> (3.67 cm) and V<sub>1</sub>T<sub>2</sub> (3.47 cm), with V<sub>3</sub>T<sub>4</sub> having the smallest bulb diameter (1.75 cm) (Table 5).

**Neck Diameter**

In regard to neck diameter, the largest (1.03 cm) was measured from V<sub>1</sub>T<sub>1</sub>, followed by 0.94 cm from V<sub>1</sub>T<sub>2</sub>, and the smallest (0.49 cm) from V<sub>3</sub>T<sub>4</sub> which was a notable difference among them (Table 5).

**Average Bulb Weight**

Similarly, Table 5 highlights that a range of variation was observed in average bulb weight. The average weight of the bulb varied from 6.50 g to 22.47g. A maximum of (22.47 g) was found in V<sub>3</sub>T<sub>2</sub> treatment, while the lowest was (6.50 g) in V<sub>3</sub>T<sub>4</sub>.

**Yield per Hectare**

Regarding yield, the impact of different combined fertilizer applications on onion resulted in significant. V<sub>1</sub>T<sub>2</sub> exhibited the maximum yield (12.77 t ha<sup>-1</sup>), followed by V<sub>1</sub>T<sub>1</sub> (8.46 t ha<sup>-1</sup>) and V<sub>2</sub>T<sub>2</sub> (8.58 t h<sup>-1</sup>). While extremely over V<sub>3</sub>T<sub>4</sub>, which provided the lowest yield (1.60 t ha<sup>-1</sup>) (Table 5).

**PCA biplot and dendrogram cluster analysis**

The Principal Component Analysis (PCA) biplot demonstrated the associations between treatments and yield and yield attributes, accounting for 83.41% of the variation in PC1 and 10.11% in PC2, for an overall figure

of 93.52% reported variance. The traits such as plant height, bulb diameter, average bulb weight, yield, leaf number, and neck diameter, with length and orientation showed the impact on the principal components. Findings including V<sub>1</sub>T<sub>2</sub>, V<sub>1</sub>T<sub>1</sub>, V<sub>2</sub>T<sub>2</sub>, and V<sub>3</sub>T<sub>2</sub> were more in line with attributes related to better yields and bulb size, however treatments like V<sub>1</sub>T<sub>4</sub>, V<sub>2</sub>T<sub>4</sub>, and V<sub>3</sub>T<sub>4</sub> form varying clusters, indicating distinctive characteristics. The research finds strong positive connections between parameters such as plant height, bulb diameter, and yield, while traits such as neck diameter have conflicting associations (Figure 3a).

The dendrogram depicted the hierarchical clustering of treatments (V<sub>1</sub>T<sub>1</sub> to V<sub>3</sub>T<sub>4</sub>) based on trait similarity. The clustering showed various groupings, featuring V<sub>1</sub>T<sub>1</sub>, V<sub>1</sub>T<sub>2</sub>, and V<sub>1</sub>T<sub>3</sub> forming an identical cluster and V<sub>1</sub>T<sub>4</sub>, V<sub>2</sub>T<sub>4</sub>, and V<sub>3</sub>T<sub>4</sub> were grouped individually, indicating divergent traits. Intermediate clusters, including V<sub>2</sub>T<sub>1</sub>, V<sub>2</sub>T<sub>2</sub>, and V<sub>2</sub>T<sub>3</sub>, indicated significant similarities according to their yield and yield attributes (Figure 3b).

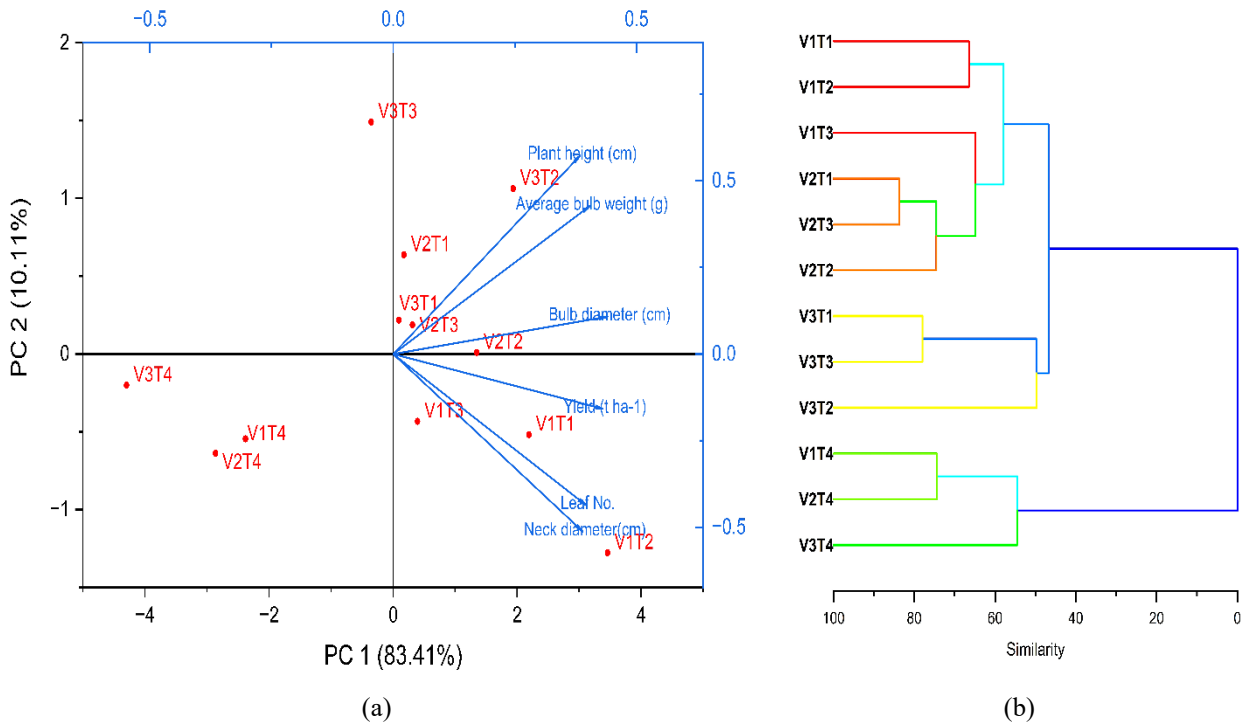


Figure 3. PCA biplot (3a) and dendrogram cluster (3b) analysis across the treatment

**Regression Analysis**

The relationship between plant height, leaf number, and important crop growth parameters such as bulb diameter, average bulb weight, and yield were depicted in Figure 4. Every parameter was subjected to regression analysis, and the findings showed strong positive connections. Regression analysis revealed a positive linear relationship between plant height and bulb diameter, described by the equation  $y=0.1143x-0.7561$  with an R<sup>2</sup> value of 0.7781. This indicates that approximately 77.81% of the variation in bulb diameter was attributable to changes in plant height. The strong correlation suggests that taller plants were associated with larger bulb diameters, highlighting the critical role of plant height as a determinant of bulb growth. Similarly, the equation  $y=1.0306x-18.108$  with the R<sup>2</sup> value of 0.7466 represented the correlation between plant

height and average bulb weight. According to the findings, plant height contributed to 74.66% of the variability in average bulb weight. The positive slope of the regression line illustrated the relationship between taller plants and heavier bulbs, indicating the role of plant height. The regression equation  $y=0.4965x-9.3396$ , with an R<sup>2</sup> value of 0.5978, showing a partially positive relationship between plant height and yield. Plant height contributed to approximately 59.78% of the variability in onion production, indicating that taller plants yielded higher. With an R<sup>2</sup> value of 0.6537, the regression equation  $y=0.6453x-0.204$  was established after evaluating the interaction between the number of leaves and bulb diameter. The number of leaves appeared to be responsible for 65.37% of the variation in bulb diameter.

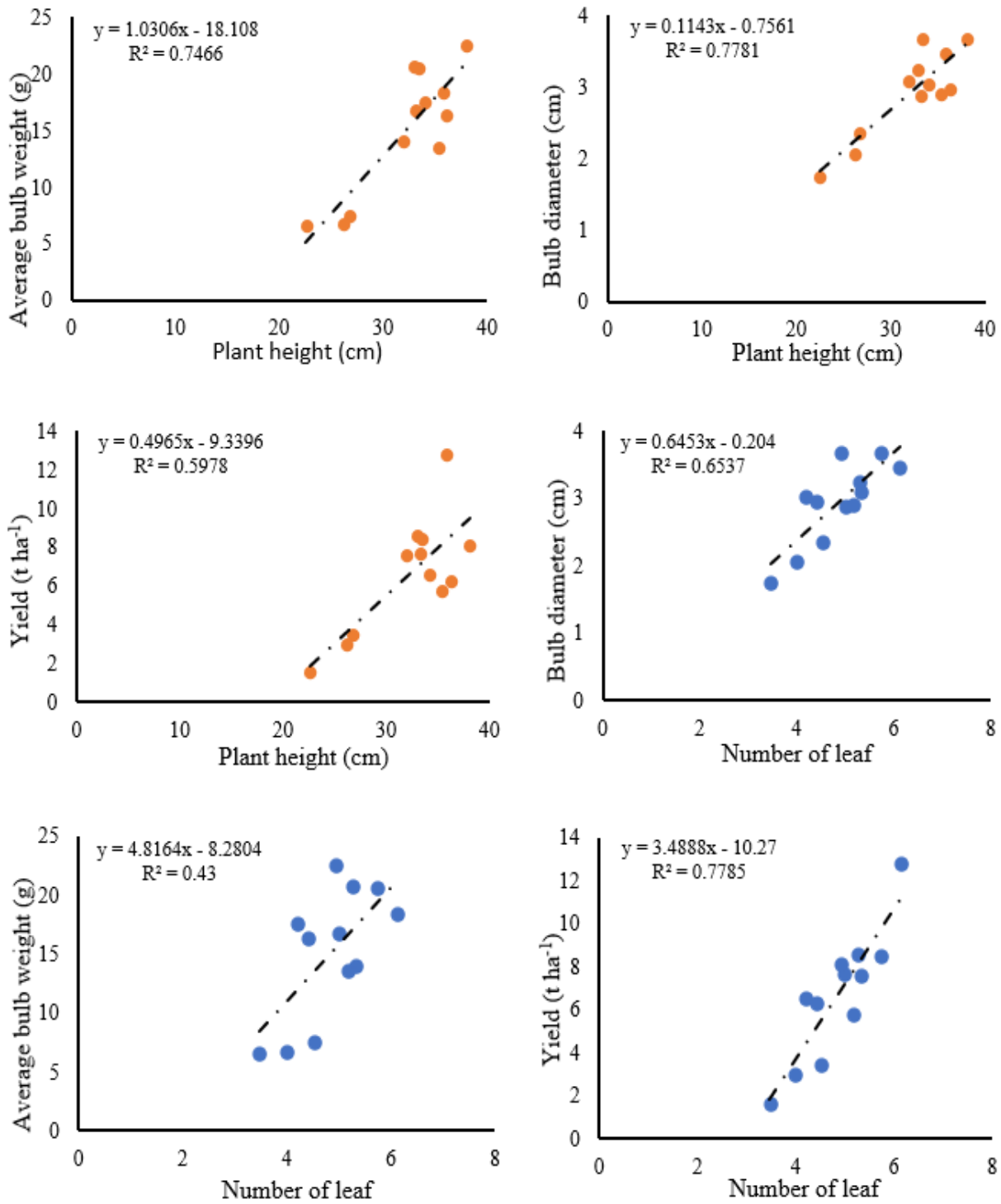


Figure 4. Illustration of the relationship between plant height, the number of leaves, and key growth features for a crop, including bulb diameter, average bulb weight, and yield.

Considering the regression equation  $y=4.8164x-8.2804$  and the  $R^2$  value of 0.43, there was a positive correlation between the average bulb weight and the number of leaves was slightly favorable. On average, it indicated that the number of leaves accounts for 43.00% of any disparity in bulb weight. Additionally, the equation  $y=3.4888x-10.27$  depicted the interaction between the number of leaves and yield, showing a strong positive correlation with an  $R^2$  value of 0.7785. The number of leaves accounted for about 77.85% of the variability in yield (Figure 4).

#### Discussion

Plant height is an important agronomic feature that influences plant vigor, photosynthetic efficiency, and the entire production in sight of the study. Deviations in plant height across various growth phases in onion production provide insight into the interaction of genetic potential with environmental factors such as combined fertilization. Significant variations in plant height were reported between fertilization practices and onion varieties at 20, 40, and 60 days after transplantation (DAT). The  $V_3T_2$

treatment provided the tallest plants at 20 DAT, whereas V<sub>3</sub>T<sub>2</sub> demonstrated the strongest growth at 40 and 60 DAT, showing that the applied approach possesses the potential for long-term growth. The coefficients of variation (CV) for plant height reduced from 11.29% at 20 DAT to 10.46% at 60 DAT, indicating that plants matured more consistently at significance ( $P > 0.05$ ) variation. The findings showed that taller plants produced better yields, which is according to the findings of Jayathilake et al. (2003). These findings highlight the importance of selecting appropriate fertilization strategies and varieties to maximize growth and productivity, with both organic and inorganic fertilization positively influencing plant growth and above-ground biomass, as reported by Anisuzzaman (2009) and Gererufael et al. (2020).

The number of leaves illustrated an effect on yield and quality since it contributes to bulb growth and nutrient uptake capacity (Arisha et al., 2013). A study by Mandal et al., (2013) confirmed that the application of organic fertilizer along with NPK increased the number of leaves. The combined impacts of fertilization and varietal selection were reflected in the significant differences in leaf number between treatments at all growth stages (20, 40, and 60 DAT). V<sub>1</sub>T<sub>1</sub> displayed the greatest number of leaf at 20 DAT, suggesting beneficial early vegetative growth, perhaps as a result of less-than-ideal nutritional conditions. V<sub>1</sub>T<sub>2</sub> had the highest number of leaves at 40 DAT, indicating that it had the most potential for further growth. At 60 DAT, the same trend persisted, with V<sub>1</sub>T<sub>2</sub> tending to be superior. Considering a range of 11.34% to 14.69%, the coefficients of variation (CV) indicated treatment variability while maintaining statistical reliability. According to Babajide et al. (2008), these results demonstrate the necessity of integrated fertilization approaches (V<sub>1</sub>T<sub>2</sub>) to enhance leaf production on particular onion varieties, enhancing photosynthetic efficiency and yield potential.

SPAD values, measuring chlorophyll content proved an essential role in determining photosynthetic efficiency and overall crop vigor (Islam et al., 2024; Babajide et al., 2008). Although there were no significant differences in SPAD values at 20 DAT. At 40 DAT, a significant variation demonstrated potential treatment effects, with V<sub>1</sub>T<sub>2</sub> having the highest value. At 60 DAT, V<sub>1</sub>T<sub>4</sub> showed the highest SPAD value, indicating that it is beneficial in preserving plant health and vigor in later growth stages. The CVs for SPAD values minimized from 16.88% at 20 DAT to 8.12% at 40 DAT and 9.41% at 60 DAT, indicating more reliability as the plants developed. There were also significant differences ( $P > 0.05$ ) at 40 and 60 DAT. Islam et al. (2024) also state that the influences of PLBC play an important role in the formation of chlorophyll content. These findings emphasize the importance of SPAD values as an indication for integrated fertilization with organic manure (PLBC) and (RDF)inorganic fertilizer to improve crop management practices.

The yield attributes of onions, consisting of bulb diameter, neck diameter, average bulb weight, and yield per hectare, are important indications of crop performance and productivity. Significant variations in bulb diameter, an important factor of accessibility and customer preference, were seen among treatments, with V<sub>1</sub>T<sub>1</sub> possessing the most significant diameters, demonstrating

its effect in increasing bulb size. Similarly, neck diameter, a crucial feature that influences storage quality and market value, ranged significantly, with V<sub>1</sub>T<sub>1</sub> having the maximum values, indicating particular varietal and fertilization implications. The average bulb weight, resulting in a direct impact on overall yield, performed better in V<sub>3</sub>T<sub>2</sub>, indicating that this treatment combination can assist in facilitating bulb development. Yield per hectare highlighted the significance of maximizing fertilization and variety selection, with V<sub>1</sub>T<sub>2</sub> achieving a superior yield, demonstrating its potential for maximum production under the given conditions. Furthermore, significant variations ( $P > 0.05$ ) appeared at 20, 40, and 60 DAT. El-Gizawy et al. (2013), Mouna et al. (2013), and Rizk et al. (2014) concluded that combining organic and inorganic fertilizers lead to higher yields and yield attributes for onion bulbs than using inorganic fertilizers alone, whereas Serana et al. (2010) noted that inorganic fertilizers alone produced higher yields than organic manure.

Additionally, the Principal Component Analysis (PCA) and dendrogram cluster analysis provided insightful data on the interactions between treatments and yield-related aspects (Ahmad et al., 2015). PCA concluded that plant height, bulb diameter, average bulb weight, yield, leaf number, and neck diameter together accounted for 93.52% of the variance, with PC1 and PC2 responsible for 83.41% and 10.11%, respectively. Plant height, bulb diameter, and yield all showed notable positive connections, although variables like neck diameter had conflicting associations, exhibiting the complexities of trait interaction. Treatments like V<sub>1</sub>T<sub>1</sub> and V<sub>1</sub>T<sub>2</sub> were strongly connected with increased yield and bulb size. Although regarding yield, V<sub>1</sub>T<sub>2</sub> demonstrated maximum. However, treatments like V<sub>1</sub>T<sub>4</sub>, V<sub>2</sub>T<sub>4</sub>, and V<sub>3</sub>T<sub>4</sub> constituted distinct clusters, indicating diverging growth patterns and reduced productivity.

Dendrogram analysis confirmed the indication of hierarchical clustering among treatments, with V<sub>1</sub>T<sub>1</sub> and V<sub>1</sub>T<sub>2</sub> clustering together due to improved performance, while V<sub>1</sub>T<sub>4</sub>, V<sub>2</sub>T<sub>4</sub>, and V<sub>3</sub>T<sub>4</sub> grouped separately, reflecting distinct but lower-performing characteristics. Intermediate clusters, such as V<sub>2</sub>T<sub>1</sub> and V<sub>2</sub>T<sub>2</sub>, attended moderate similarities, indicating the possibility of enhancing certain yield measuring factors. These findings emphasize the significance of combining fertilization studies such as PCA and clustering to identify optimal treatment combinations for increased productivity and provide complicated interactions across yield-related attributes. The same approach has been extended to various crops under varying environmental conditions (Islam et al., 2007; Ghodke et al., 2019; Kołton et al., 2020).

Regression studies showed considerable beneficial associations between these variables, emphasizing the importance of vegetative growth in bulb characteristics and productivity. Plant height emerged as a significant predictor, accounting for 77.18% of the variance in bulb diameter, with taller plants resulting in bigger bulb dimensions. Furthermore, plant height explained 74.66% of the variation in average bulb weight, highlighting the role it plays in increasing bulb size, similarly, its contribution to yield variability was significant, accounting for about 59.78% of the overall variation. Leaf numbers also played a crucial part, accounting for 65.37% of the

fluctuation in bulb diameter and having a positive impact on weight and yield. These findings indicate that improving vegetative growth parameters, specifically plant height and leaf number, can greatly improve bulb characteristics and increase production in onion farming.

## Conclusion

In conclusion, the findings of this study highlight the significant impact of fertilization and varietal differences on onion growth and yield. The combination of Poultry Litter-Based Compost (PLBC) @ 5 t ha<sup>-1</sup> and Recommended Doses of Fertilizer (RDF) (T<sub>2</sub>) were superior to other fertilization approach by increasing key morphological attributes such as plant height, leaf number, bulb diameter, and average bulb yield. The combination of Taherpuri with T<sub>2</sub> fertilization (V<sub>1</sub>T<sub>2</sub>) resulted in the maximum yield, demonstrating the synergistic effect of combining high-performing varieties with effective fertilization approaches. These findings suggest that applying the Taherpuri (V<sub>1</sub>) variety with the combination of (T<sub>2</sub>) fertilization is a promising strategy for increasing onion production under similar agroecological factors. Future research might investigate and explore the long-term consequences of these approaches and their viability across varied soil types and locations.

## Declarations

**Acknowledgement:** All the authors are thankful to the Chairman, Department of Crop Physiology & Ecology, HSTU, Dinajpur, Bangladesh for experimenting smoothly.

**Funding:** This research was funded by the Institute of Research and Training (IRT), Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh.

**Competing interests:** The authors have declared that no competing interests exist.

**Authors' contributions:** H.I.: Data curation, Investigation, Formal analysis, Validation. M.M.R.: Data curation, Formal analysis, Software, Visualization, Writing – Original Draft. M.M.H.: Investigation, Data curation, Validation. M.M.H.: Investigation, Data curation, Validation. M.M.B.: Supervision, Methodology, Writing - Review & Editing. A.K.M.M.B.C.: Project administration, Supervision, Resources, Funding acquisition, Methodology, Conceptualization, Writing - Review & Editing.

## References

- Ahmad, F., Hanafi, M. M., Hakim, M. A., Rafii, M. Y., & Arolu, I. W. (2015). Genetic divergence and heritability of 42 coloured upland rice genotypes (*Oryza sativa*) as revealed by microsatellites marker and agro-morphological traits. *PLoS One*, 10(9), e0138246. <https://doi.org/10.1371/journal.pone.0138246>
- Anisuzzaman, M., Ashrafuzzaman, M., Ismail, R., Uddin, M. K., & Rahim, M. A. (2009). Planting time and mulching effect on onion development and seed production. *African Journal of Biotechnology*, 8, 412–416. <https://www.ajol.info/index.php/ajb/article/view/59828>
- Arisha, H. M. E., Gad, A. A., & Younes, S. E. (2013). Response of some pepper cultivars to organic and mineral nitrogen fertilizer under sandy soil conditions. *Zagazig Journal of Agricultural Research*, 30, 1875–1899. <https://agris.fao.org/search/en/providers/122598/records/64723f8153aa8c8963034223>
- Babajide, P. A., Olabode, O. S., Akanbi, W. B., Olatunji, O. O., & Ewetola, E. A. (2008). Influence of composted Tithonia N-biomass and N-mineral fertilizer on soil physicochemical properties and performance of tomatoes (*Lycopersicon esculentus*). *Research Journal of Agronomy*, 2(4), 101–106. <https://www.oalib.com/research/1381614>
- Bangladesh Bureau of Statistics (BBS). (2023). *Agriculture Yearbook 2023. Statistics Bulletin of Bangladesh*. Bangladesh Bureau of Statistics, Ministry of Planning, Govt. of the People's Republic of Bangladesh, Dhaka. <http://203.112.218.65:8008/WebTestApplication/userfiles/Image/LatestReports/PB2015.pdf>
- Blanco-Canqui, H., & Schlegel, A. J. (2013). Implications of inorganic fertilization of irrigated corn on soil properties: Lessons learned after 50 years. *Journal of Environmental Quality*, 42(3), 861–871. <https://doi.org/10.2134/jeq2012.0451>
- Brewster, J. L. (1994). Environmental physiology of the onion: Towards quantitative models for the effects of photoperiod, temperature, and irradiance on bulbing, flowering, and growth. *International Symposium on Edible Alliaceae*, 433.
- Chhonkar, P. K. (2003). Organic farming science and belief. *Journal of the Indian Society of Soil Science*, 51, 365–367.
- El-Gizawy, E. S. A., Geries, L. S. M., & Mahmoud, E. K. (2013). Onion productivity and soil fertility status as influenced by integrated use of inorganic, compost tea, and N<sub>2</sub>-fixing bacterial fertilizers. *Journal of Plant Production, Mansoura University*, 4(2), 249–270. [https://jpp.journals.ekb.eg/article\\_68987\\_bb6794131c9fd86dd5ccf619626991ec.pdf](https://jpp.journals.ekb.eg/article_68987_bb6794131c9fd86dd5ccf619626991ec.pdf)
- Gambo, B. A., Magaji, M. D., Yakubu, A. I., & Dikko, A. U. (2008). Effects of farmyard manure, nitrogen, and weed interference on growth and yield of onion (*Allium cepa* L.) at the Sokoto Rima Valley. *Journal of Sustainable Development in Agriculture & Environment*, 3(2), 87–92.
- Gererufael, L. A., Abraham, N. T., & Reda, T. B. (2020). Growth and yield of onion (*Allium cepa* L.) as affected by farmyard manure and nitrogen fertilizer application in Tahtay Koraro District, Northwestern Zone of Tigray, Ethiopia. *Vegetos*, 33(4), 617–627. <https://doi.org/10.1007/s42535-020-00132-7>
- Ghodke, P. H., Ramakrishnan, S., Shirsat, D. V., Vani, G. K., & Arora, A. (2019). Morphological characterization of wheat genotypes for stay-green and physiological traits by multivariate analysis under drought stress. *Plant Physiology Reports*, 24, 305–315. <https://doi.org/10.1007/s40502-019-00458-8>
- Gupta, R. P., Sharma, V. P., Singh, D. K., & Srivastava, K. J. (1999). Effect of organic manures and inorganic fertilizers on growth, yield, and quality of onion variety Agrifound Dark Red. *Newsletter of the National Horticulture Research Development Foundation*, 19(2–3), 7–11. <https://worldveg.tind.io/record/27113>
- Hanelt, P. (1990). Taxonomy, evaluation, and history. In *Onions and Allied Crops* (Vol. 3). Boca Raton, Florida: CRC Press. <https://www.taylorfrancis.com/chapters/edit/10.1201/9781351075169-1/taxonomy-evolution-history-peter-hanelt>
- Haque, M. A., Haque, M. A., Barman, D. N., Das, S. R., & Prodhan, M. Y. (2018). Hydrothermal-assisted *Bacillus* sp. AY8 pretreatment on lignocellulose for the liquefaction and enhancement of enzymatic hydrolysis. *Asian Journal of Microbiology Biotechnology*, 3(2), 66–78. <https://ikpress.org/index.php/AJMAB/article/view/144>

- Hossain, M. S., Mukta, M. A., Hossain, M. D., Uddin, M. R., & Islam, M. K. (2022). Effects of poultry manure and inorganic fertilizers on the yield and yield contributing characters of onion. *World Journal of Agricultural Science*, 18(2), 68–73. <https://doi.org/10.5829/idosi.wjas.2022.68.73>
- Islam, S., Hasan, M. M., Sayed, M. Z. I., Sikder, S., & Chowdhury, A. K. M. M. B. (2024). Amelioration of the detrimental effects of water deficit stress on lentil (*Lens culinaris* Medik) through the utilization of poultry litter-based compost. *Turkish Journal of Agriculture and Food Science and Technology*, 12(6), 1080–1087. <https://doi.org/10.24925/turjaf.v12i6.1080-1087.6739>
- Islam, R. R., Hamid, A., Khaliq, Q. A., Ahmed, J. U., & Haque, M. M. (2007). Genetic variability in flooding tolerance of mungbean (*Vigna radiata* L. Wilczek) genotypes. *Euphytica*, 156, 247–255. <https://doi.org/10.1007/s10681-007-9372-z>
- Ishak, C. F., Bakar, R. A., Saud, H. M., & Abdullah, T. L. (1999). Application of sewage sludge from Indian water treatment plants. *Agro Search*, 6(1), 14–19.
- Jaafar, N. M., Clode, P. L., & Abbott, L. K. (2014). Microscopy observations of habitable space in biochar for colonization by fungal hyphae from soil. *Journal of Integrative Agriculture*, 13(3), 483–490. [https://doi.org/10.1016/S2095-3119\(13\)60703-0](https://doi.org/10.1016/S2095-3119(13)60703-0)
- Jayathilake, P. K. S., Reddy, I. P., Srihari, D., Reddy, K. R., & Neeraja, G. (2003). Integrated nutrient management in onion (*Allium cepa* L.). *Tropical Agriculture Research*, 15, 1–9. <https://dl.nsf.gov.lk/items/8b1ed8b0-e647-4399-b1bb-87cf4cea7f03>
- Kořton, A., Keęska, K., & Czernicka, M. (2020). Selection of tomato and cucumber accessions for waterlogging sensitivity through morphophysiological assessment at an early vegetative stage. *Agronomy*, 10, 1490. <https://doi.org/10.3390/agronomy10101490>
- Mandal, J., Ghosh, C., & Chattopadhyay, G. N. (2013). Proportional substitution of chemical fertilizers with vermicompost on growth and production potential of onion (*Allium cepa* L.). *International Journal of Bioresource and Stress Management*, 4(2), 356–357. <https://www.ojs.pphouse.org/index.php/IJBSM/article/view/389>
- Mouna, M. S., Wafa, S., Khaled, I., Azzaiz, & Mohamed, B. K. (2013). Evaluating pre-crops and organic fertilizers for effects on soil properties and organic onion growth and yield in eastern Tunisia. *Conférence Internationale des Energies Renouvelables (CIER)*, 2(13). <https://www.researchgate.net/publication/275956621>
- Mukherjee, A., & Lal, R. (2013). Biochar impacts on soil physical properties and greenhouse gas emissions. *Journal of Agronomy*, 3, 313–339. <https://doi.org/10.3390/agronomy3020313>
- Randle, W. M. (2000). Increasing nitrogen concentration in hydroponic solutions affects onion flavor and bulb quality. *Journal of the American Society for Horticultural Science*, 125, 254–259. <https://doi.org/10.21273/JASHS.125.2.254>
- Rizk, F. A., Shaheen, A. M., Abd El-Samad, E. H., & El-Labban, T. T. (2014). Response of onion plants to organic fertilizer and foliar spraying of some micro-nutrients under sandy soil conditions. *Journal of Applied Science Research*, 10(5), 383–392. [https://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=2812463](https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2812463)
- Santhi, R., Natesan, R., & Selvakumari, G. (2005). Integrated nutrient management in onion. *Indian Journal of Agricultural Research*, 39(3), 213–216.
- Serana, T. H., Srikrishnah, S., & Ahmad, M. M. Z. (2010). Effect of different levels of inorganic fertilizers and compost as basal application on the growth and yield of onion (*Allium cepa* L.). *Journal of Agricultural Science*, 5(2), 64–70. <https://doi.org/10.4038/jas.v5i2.2783>
- Shigyo, M., & Kik, C. (2008). Onion. In *Vegetables II: Fabaceae, Liliaceae, Solanaceae, and Umbelliferae* (pp. 121–159).
- Stolton, S. (1997). Ecology and farming. *International Magazine IFOAM*, 15, 35–37.
- Zang, W., Han, D. Y., Dick, W. A., Davis, K. R., & Hoitink, H. A. J. (1998). Compost and compost water extract induced systemic acquired resistance in cucumber and Arabidopsis. *Phytopathology*, 88, 450–455. <https://doi.org/10.1094/PHYTO.1998.88.5.450>