Original Article

Bangladesh Journal of Agriculture and Life Science
Faculty of Agriculture, University of Rajshahi
Rajshahi-6205, Bangladesh
Vol. 04 (1&2): 17-26, 2023
http://csa.ru.ac.bd/bjals/

Synergistic Effects of Nitrogen and Zinc Fertilization on Fibre Yield and Agronomic Traits of Jute (*Chorchorus olitorius* L.)

Md. Tariful Alam Khan, Md Nibir Sharkar, Md Mominul Islam, Dibbya Roy, Subha Azad, Mst. Fatematu Johura Mina, M. Robiul Islam, Mesbaus Salahin*

Farming Systems Engineering Laboratory, Department of Agronomy and Agricultural Extension, Rajshahi University, Bangladesh

ARTICLE INFO

Article History
Received: January 5, 2024
Accepted: April 24, 2024
Online: December 10, 2025

Keywords
Fibre development
Jute
Nitrogen
Yield
Zinc

ABSTRACT

Optimizing nitrogen and zinc fertilizer application is crucial for achieving maximum fibre quality and yield in jute cultivation. A field experiment was conducted from May to September 2022 at the Agronomy Field Laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi, to assess the effects of varying nitrogen (urea) and zinc ($ZnSO_4$) rates on jute fibre development and yield. The experiment followed a Randomized Complete Block Design (RCBD) with three nitrogen rates: N_1 (100 kg ha^{-1}), N_2 (200 kg ha^{-1}), and N_3 (300 kg ha^{-1}), and three zinc rates: Zn_1 (5.5 kg ha^{-1}), Zn_2 (11 kg ha^{-1}), and Zn_3 (16.5 kg ha^{-1}). Standard agronomic practices were uniformly applied across all treatments. Application of 300 kg ha^{-1} urea (N_3) significantly increased plant height (287.5 cm), stem diameter (13.67 mm), fibre area (2.80 mm^2), fibre yield (4.49 t ha^{-1}), stick yield (9.90 t ha^{-1}), and biological yield (14.39 t ha^{-1}). Similarly, zinc application at 16.5 kg ha^{-1} (Zn_3) enhanced plant height (283.26 cm), stem diameter (13.15 mm), fibre area (2.67 mm^2), fibre yield (4.09 t ha^{-1}), stick yield (9.19 t ha^{-1}), and biological yield (13.28 t ha^{-1}). The interaction of N_3 and Zn_3 (300 kg ha^{-1} N + 16.5 kg ha^{-1} Zn) produced the highest values for plant height (309.4 cm), stem diameter (14.07 mm), fibre area (3.02 mm^2), fibre yield (5.39 t ha^{-1}), stick yield (12.16 t ha^{-1}), and biological yield (17.55 t ha^{-1}). These findings suggest that applying 300 kg ha^{-1} urea in combination with 16.5 kg ha^{-1} $ZnSO_4$ is an effective strategy for maximizing jute fibre yield. Future research should investigate soil nutrient dynamics, plant nutrient uptake, and the economic and environmental implications of these fertilizer regimes.

Introduction

Jute is one of Bangladesh's most important cashcrops and is vital to Bangladesh's economy. Jute is often called the golden fiber of Bangladesh. Bangladesh is the world's second-largest producer of jute, with an estimated yearly production of 1.6 million tons (Rahman *et al*., 2023). In 2021-22, Bangladesh's jute yield per hectare was 11.593 Bales over an area of 7,27,382 ha.

***Address of correspondence**
Farming Systems Engineering Laboratory,
Department of Agronomy and Agricultural Extension,
Rajshahi University, Bangladesh
E-mail: mesba@ru.ac.bd(MesbausSalahin)

Jute accounts for over 20% of the world's annual output of natural industrial fibers (Akter *et al*., 2020). Despite the fact that jute is farmed in practically every district in Bangladesh, the most well-known places are Faridpur, Tangile, Jessore, Dhaka, Sirajganj, Bogura, and Jamalpur. Approximately 90% of the jute goods produced in Bangladesh are exported (BBS, 2011). This industry has the potential to generate a large quantity of foreign currency for Bangladesh (Hossain et al., 2023). Jute has a higher contribution to GDP, Jute contributes 1.4% to GDP and 26% to agriculture. It means that jute contributes about 8 billion to total GDP. In recent.

times, jute has found its place in the technical sector, particularly in the non-woven industry. It is being utilized as a cost-effective and high-tensile natural fiber to create substitutes for wood, materials for furniture, ceiling products, sanitary napkins, automotive components, and fire-resistant fibers, replacing traditional fabricsIn order to promote the utilization of jute, the current government has officially categorized jute and jute-related products as agricultural commodities eligible for export benefits; additionally, researchers and scientists from organizations such as the Bangladesh Jute Research Institute (BJRI) and the Bangladesh Council for Scientific and Industrial Research (BCSIR) have embarked on a range of experiments aimed at introducing innovative jute-based products.

Plant nutrients play an essential role in the growth and development of jute. Nitrogen is one of the most important nutrients that help to increase vegetative growth and is known as a necessary constituent of chlorophyll (Muhammad *et al.*, 2022). Nitrogen fertilizer modulates plant growth, chlorophyll pigments and enzymatic activities under different irrigation regimes. In jute, nitrogen enhances the fiber quality and helps achieve a higher yield. Nitrogen is also the primary building block for plant protoplasm. Protoplasm is the translucent substance that is the living matter of cells. It is needed for flower differentiation, speedy shoot growth, and the health of flower buds, and it increases the quality of fruit set. It also acts as a catalyst for other minerals. Due to a deficiency of nitrogen, slow growth and low-quality fibers are seen in jute plants.

Among the micronutrients, zinc is one of the essential elements and plays a significant role in several physiological functions in plants and its imbalance reduces yield. Zinc is also involved in the metabolism of plant hormones such as auxin and tryptophan (Suganya, 2020), indole acetic acid (IAA), and gibberellins. It also supports plant resistance to biotic and abiotic stressors (Shah, 2023). In many parts of Bangladesh, deficiency of micronutrients like Zn, B, Mn, Cu, and Mo in crops has been reported along with the identified deficiencies of major nutrients (Hasanuzzaman *et al*., 2020). Currently, Zn deficiency is the most visible micronutrient deficiency in crops in Bangladesh. This element deficiency in the country was identified in late 1970s (Leghari *et al*., 2016). and now more than 70% of cultivated soils are deficient in Zn.

Based on the preceding discussion, it can be deduced that nitrogen and zinc are crucial for enhancing the growth and yield of jute. Therefore, it becomes imperative to establish the appropriate application rates for these fertilizers. This study was conducted with the following aims: (i) To determine the ideal nitrogen and zinc fertilizer rates for maximizing the growth and yield of jute. (ii)To evaluate the combined impact of nitrogen and zinc on the growth and yield of jute fibers.

Materials and methods

Location and site

The experiment was carried out at the Agronomy Field Laboratory within the Department of Agronomy and Agricultural Extension at the University of Rajshahi, Rajshahi. This research was conducted from May 2022 to September 2022 with the aim of examining the impact of nitrogen and zinc fertilizer rates on the development of jute fibers. Geographically, the experimental site was situated at a latitude of 24°22'36" N and a longitude of 88°38'36" E, with an elevation of 20 meters above sea level. This location belongs within the Agroecological zone AEZ-11. The experimental soil was characterized as sandy loam in texture and exhibited a pH value of 7.6. Before applying any fertilizers, a composite soil sample was collected from 0-15 centimeters in the experimental plot and analyzed for its physical and chemical properties.

Experimental treatments

The experiment was carried out with three nitrogen fertilizer rates (Urea): N_1=100 kg ha^{-1} (50% of standard recommendation); N_2= 200 kg ha^{-1} (standard recommendation); N_3=300 kg ha^{-1} (150% of standard recommendation) and three Zinc fertilizer rates ($ZnSO_4$) Zn_1= 5.5 kg ha^{-1} (50% of standard recommendation); Zn_2= 11 kg ha^{-1} (Standard recommendation) and Zn_3=16.5 kg ha^{-1} (150% of standard recommendation). Altogether, 9 treatments were replicated three times using a Randomized Complete Block Design (RCBD). Each experimental plot occupied an area of 10 m^2 (5m × 2m). Except for experimental treatments, standard agronomic practices were followed according to the recommendation of BJRI.

Crop cultivation and agronomic management

Initially, on May 14, 2022, the land was opened using a power tiller. Subsequently, the land underwent plowing and cross-plowing three times, followed by harrowing. Individual plots were prepared through repeated spading until the soil reached an optimal tilth and was ready for sowing. Weeds and crop residues were cleared to ensure clean land. Drainage channels were established around the experimental plots to facilitate water management. The fertilizers were applied by following BJRI fertilizer recommendation guide.

Nitrogen and zinc were supplied in the form of urea and zinc sulfate during the final land preparation.

Urea (containing 46% nitrogen) was applied in three splits: half at the time of sowing, one-quarter at 20 days after sowing (DAS), and one-quarter at 45 DAS after the first and second weeding. Additionally, a standard dose of 50 kg of P_2O_5 and 60 kg of K_2O per hectare was applied in the form of triple superphosphate (TSP) and muriate of potash (MoP), respectively, at the time of sowing. Healthy and robust seeds were manually dibbled into the soil, and thinning was conducted to maintain the desired plant population. Weeding was carried out manually at 20 and 45 days after sowing. Irrigation was applied immediately after sowing to ensure proper germination and establishment of the plants. Subsequent irrigations were administered as required.

Collection of experimental data

During the growing phase, five plants were chosen at random for data collection. The crops and plants in each plot were recognized and marked for subsequent examination. Before harvesting, a one-square-meter plant sample from each plot was randomly selected and uprooted for data collection. The Bundles of jute plants were put into Jag means by arranging the bundle in row and cross row pattern in retting pond. After making the Jag it was steeped in pond water with the help of water hyacinth and other aquatic weed. The depth of water was sufficient to allow the jute bundle to float. The jute fiber was stripped from stick manually after completion of proper retting. At fiber stripping the upper layer of bark was removed from lower portion of the jute plant by hand pushing to minimize the cuttings. The fiber was washed in clean water to ensure quality fiber. The fiber was dried on bamboo bar under direct sunshine for 4-5 days to complete drying. The dryness of fiber was observed by 'hand touch' to ensure the dryness. The fiber bundles were assorted plot wise, tag labels and weighed. Jute sticks were also dried continuously in seven days to get dry sticks and then weighed.

Statistical analysis

The collected data was collated and prepared for statistical analysis. The collected data was statistically analyzed using the " STATVIEW " program. Duncan's Multiple-Range Test was used to examine mean differences.

Results

Plant height

The aim was to determine the significance of different nitrogen and zinc fertilization levels and their combined effects on jute. Plant height of jute differed significantly due to different nitrogen fertilizer rates at all observations except 30 DAS and most of the cases highest values were found with maximum nitrogen application or N_3 (Table. 1). At 30 DAS, maximum plant height (58.96 cm) was observed in N_1 and minimum plant height (54.96 cm) was observed in N_3. At 60 DAS, maximum plant height (130.0 cm) was observed in $N_{3,}$ which reduced only 6.61% in N_2 and significantly by 16.0% in N_1. At 90 DAS, the highest plant height (247.62cm) was recorded in $N_{3,}$ it reduced by 5.98% and 12.97% in N_2 and $N_{1,}$ respectively. Plant height of jute differs moderately for different levels of zinc fertilizer application at all observations except 30 DAS (Table 1). At 60 DAS, the highest plant height (126.8cm) was observed in $Zn_{3,}$ which reduced by 6.07% and 9.54 % in Zn_2 and $Zn_{1,}$ respectively. At 90 DAS, maximum plant height (243.1 cm) was observed in $Zn_{3,}$ which reduced marginally (4.23%) in Zn_2 but significantly by 9.54% in Zn_1. Remarkable variation was found in plant height of jute due to the interaction of nitrogen and zinc fertilizer rates (Table 1). In 30 DAS, greater plant height was observed in combination of N_1Zn_1. In regard to 60 DAS, the highest plant height (135.0cm) of jute was observed in the combination of N_3 with Zn_3 and the lowest plant height (102.7cm) was recorded in the combination of N_1 with Zn_1. At 90 DAS, maximum plant height was found in the combination of N_3 with Zn_3 and minimal result was found in combination of N_1 with Zn_1.

Number of leaves

Number of leaves per plant was also significantly influenced by nitrogen levels except at 30 DAS (Table. 1). At 30 DAS, the maximum number of leaves per plant (11.22) was observed in N_2 and the minimum number of leaves (10.73) was in N_1. At 60 DAS, the maximum number of leaves per plant (17.03) was found in $N_{3,}$ which reduced significantly by 7.51% and 15.14% for N_2 and $N_{1,}$ respectively. At 90 DAS, a similar trend has also occurred. The maximum number of leaves per plant (27.89) was recorded in N_3, which was significantly reduced by 10.36% and 18.46% for N_2 and $N_{1,}$ respectively. Increased application of nitrogen might have increased the plant vigor during the vegetative phage, contributing to the higher production of branches and leaves per plant. The number of jute leaves at 30, 60 and 90 DAS in response to different zinc fertilizer levels was presented in (Table. 1). Data revealed that the number of jute leaves varied significantly for different zinc fertilization at all growth stages except at 30 DAS. At 30 DAS, the highest number of leaves per plant (11.36) was observed in Zn_1 and the lowest number of leaves per plant (10.56) in Zn_3. At 60 DAS, the highest leaf number per plant (16.67) was found in Zn_3 treatment, which reduced only 5.81% in Zn_2 and 10.85% in Zn_1. At 90 DAS, the highest leaf number per plant (26.89) was produced in Zn_3 treatment, which was reduced by 6.51% and 12.27% in Zn_2 and $Zn_{1,}$ respectively. At the fact of number of leaves, no significant influence hadfound in the phenomenon of the interaction between different level of nitrogen fertilizers with different levels of zinc fertilizer at 30 DAS but it influenced significantly at 60 and 90 DAS (Table 1). At 30 DAS, the highest number of leaves per plant (12.33) was produced in N_2Zn_1 and the lowest number of leaves per plant (10.22) was obtained in treatment combination N_2Zn_3. At 60 DAS, the highest number of leaves per plant (17.55) was recorded in treatment combination N_3Zn_3, while the lowest number per plant (13.12) was in N_1Zn_1. At 90 DAS, the highest leaf number per plant (30.22) was observed in interaction N_3Zn_3 and the lowest number of leaves per plant (21.45) in N_1Zn_1.

Stem diameter

Stem diameter of jute was recorded at 30, 60, 90, and 110 DAS, where the data of 30, 60, and 90 DAS was considered as growth parameter (Table 2), whereas the final data, which was collected at 110 DAS was considered as yield component and separately presented in Table 3. Nitrogen fertilizer's effect on jute's stem diameter was statistically significant at all growth stages except 30 DAS. Stem diameter increased progressively with an increase in nitrogen fertilizer rates and the highest values were recorded for the application of maximum urea at 60 and 90 DAS (Table 2). At 30 DAS, the highest stem diameter (4.61 mm) was observed in N_2 and the lowest (4.37 mm) in N_1. At 60 DAS, the highest stem diameter (6.67 mm) was observed in N_3 treatment, which reduced significantly by 10.46% and 23.38% in N_2 and N_1, respectively. At 90 DAS, the highest stem diameter (12.14 mm) was observed in N_3, which reduced significantly by 10.46% and 20.61 % in N_2 and N_1, respectively. Zinc fertilizer shows no significant result on stem diameter at 30 and 60 DAS, but a significant result was observed at 90 DAS (Table 2)

Table.1. Effects of nitrogen and zinc fertilizer rates and their interactions on plant height and leaf number of jute and different days after sowing (DAS)

Nitrogen	Plant height (cm)			Leaf number		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
N_1	58.96±2.11	109.2±3.78b	215.5±6.92b	10.73±0.64	14.45±0.67b	22.74±1.22b
N_2	56.93±1.80	121.4±3.35a	232.8±5.30a	11.22±0.49	15.75±0.52ab	25.00±1.02ab
N_3	54.96±0.70	130.0±3.76a	247.62±4.91a	11.11±0.36	17.03±0.57a	27.89±0.84a
Zinc						
Zn_1	57.07±2.34	114.7±4.05b	219.9±7.28b	11.36±0.68	14.86±0.85b	23.59±1.16b
Zn_2	57.82±1.15	119.1±4.77ab	232.8±6.43ab	11.15±0.29	15.70±0.61ab	25.14±1.06 ab
Zn_3	55.96±1.46	126.8±4.30a	243.1±6.03a	10.56±0.45	16.67±0.39a	26.89±1.32a
Interactions						
N_1Zn_1	63.55±5.30a	102.7±3.60c	200.7±13.09d	10.31±1.69	13.12±1.26b	21.45±2.42c
N_1Zn_2	58.44±1.49ab	106.4±6.69bc	217.3±10.11cd	11.67±0.67	14.56±1.25ab	22.78±2.36bc
N_1Zn_3	54.89±1.96ab	118.5±6.73abc	228.4±10.35abcd	10.22±0.97	15.67±0.72ab	24.00±2.19bc
N_2Zn_1	52.78±2.00b	115.8±4.92abc	222.7±9.45bcd	12.33±0.58	14.92±1.37ab	23.67±2.03bc
N_2Zn_2	59.34±2.41ab	121.4±6.84abc	231.8±8.27abc	11.11±0.56	15.55±0.62ab	24.89±0.92abc
N_2Zn_3	58.67±4.00ab	126.8±5.77ab	243.7±8.28abc	10.22±1.06	16.78±0.39a	26.44±2.41abc
N_3Zn_1	54.89±0.98ab	125.5±5.48ab	236.3±7.34abc	11.44±1.18	16.56±1.54ab	25.67±1.35abc
N_3Zn_2	55.67±2.03ab	129.6±6.45a	249.2±8.38ab	10.67±0.19	17.00±1.01a	27.78±0.89ab
N_3Zn_3	54.34±0.50b	135.0±8.66a	257.3±7.25a	11.22±0.11	17.55±0.50a	30.22±0.86a
CV(%)	8.19	9.04	6.97	14.29	11.45	12.61

Mean followed by different letter (s) differed significantly as per DMRT; DAS= Day's after sowing; CV= Co-efficient of variation; N_1= 100kg ha^{-1}; N_2=200kg ha^{-1}; N_3=300 kg $ha^{-1,}$ $Zn_{1=}$ 5.5 kg ha^{-1}, Zn_2= 11 kg ha^{-1}, and Zn_3= 16.5 kg ha^{-1}

Table. 2. Effects of nitrogen and zinc fertilizer rates and their interactions on stem diameter and fiber area of jute at different days after sowing (DAS)

Nitrogen	Stem diameter (mm)			Fiber area (mm)	
	30 DAS	60 DAS	90 DAS	60 DAS	90 DAS
N_1	4.37±0.16	5.11±0.23b	9.63±0.46b	1.12±0.04b	1.65±0.13b
N_2	4.61±0.16	5.97±0.26ab	10.87±0.42b	1.16±0.05ab	1.95±0.12ab
N_3	4.45±0.20	6.67±0.42a	12.14±0.49a	1.29±0.05a	2.24±0.14a
Zinc					
Zn_1	4.36±0.13	5.53±0.34	9.93±0.53b	1.16±0.05	1.73±0.14b
Zn_2	4.70±0.16	6.01±0.32	10.98±0.48ab	1.18±0.05	1..95±0.14ab
Zn_3	4.38±0.21	6.20±0.45	11.73±0.55a	1.21±0.06	2.16±0.14a
Interactions					
N_1Zn_1	4.06±0.05	4.79±0.37b	8.33±0.77c	1.07±0.08	1.33±0.22c
N_1Zn_2	4.75±0.19	5.47±0.49ab	9.98±0.47bc	1.08±0.06	1.74±0.15bc
N_1Zn_3	4.30±0.37	5.06±0.37b	10.58±0.59bc	1.19±0.07	1.87±0.20abc
N_2Zn_1	4.39±0.21	5.61±0.53ab	10.22±0.50bc	1.15±0.06	1.83±0.19bc
N_2Zn_2	4.79±0.22	5.94±0.60ab	10.86±0.74ab	1.15±0.05	1.94±0.24abc
N_2Zn_3	4.66±0.43	6.35±0.21ab	11.52±0.94ab	1.17±0.17	2.07±0.27ab
N_3Zn_1	4.62±0.30	6.19±0.68ab	11.24±0.64ab	1.27±0.09	2.02±0.20abc
N_3Zn_2	4.55±0.47	6.62±0.55ab	12.10±0.89ab	1.32±0.08	2.18±0.32ab
N_3Zn_3	4.19±0.38	7.20±1.05a	13.09±0.89a	1.28±0.10	2.53±0.13a
CV(%)	12.23	17.05	11.69	13.35	19.46

Mean followed by different letter (s) differed significantly as per DMRT; DAS= Day's after sowing; CV= Co-efficient of variation; N_1= 100kg ha^{-1}; N_2=200kg ha^{-1}; N_3=300 kg ha$^{-1,}$ $Zn_{1=}$ 5.5 kg ha^{-1}, Zn_2= 11 kg ha^{-1}, and Zn_3= 16.5 kg ha^{-1}

At 30 DAS, the highest stem diameter (4.7 mm) was observed in Zn_2 and the lowest (4.36 mm) in Zn_1. At 60 DAS, the highest stem diameter (6.20 mm) was observed in Zn_3 and the lowest (5.53 mm) in Zn_1. At 90 DAS, the highest stem diameter (11.73 mm) was observed in Zn_3 treatment, which reduced only 6.39% in Zn_2 but significantly by 15.34% in Zn_1. No significant effect on the stem diameter of jute was obtained in the treatment combination of nitrogen and zinc fertilizer rates at 30 DAS, but significant results were found at 60 and 90 DAS (Table 2). At 30 DAS, the highest stem diameter (4.79 mm) was observed in N_2Zn_2 and the lowest (4.06 mm) was recorded in N_1Zn_1. At 60 DAS, the highest stem diameter (7.20 mm) was found in N_3Zn_3 and the lowest value (4.79 mm) was obtained in N_1Zn_3. At 90 DAS, the maximum stem diameter (13.09 mm) was observed in N_3Zn_3 and the minimum value (8.33 mm) was observed in N_1Zn_1.

Fibre area

Fibre area of jute was recorded at 60, 90, and 110 DAS, where the data of 60 and 90 DAS was considered as growth parameter presented in Table 2, whereas the final data, which was collected at 110 DAS was considered as yield component and separately shown in Table 3. Depending on different nitrogen fertilizer rates, jute fiber area varied significantly at 60 and 90 DAS. At 60 DAS, the highest fibre area (1.29mm) was recorded in N_3, which reduced significantly to 10.07% in N_2 and 13.18% in N_1. At 90 DAS, the maximum fibre area (2.24 mm) was found in N_3, significantly reducing 12.95% and 26.33% in N_2 and N_1, respectively. The application of zinc fertilizer rates showed a significant effect on fibre area of jute at 90 DAS, but a non-significant result was found at 60 DAS (Table 2). At 60 DAS, the highest fibre area (1.21 mm) was recorded in Zn_3 and the lowest (1.16 mm) in Zn_1. At 90 DAS, the highest fibre area (2.16 mm) was observed in Zn_3, which reduced 9.72% in Zn2 and

19.90% in Zn_1. It was noticed that the treatment combination of nitrogen and zinc fertilizer rate had a marked effect on fibre area of jute recorded at 90 DAS but showed no significant effect at 60 DAS (Table 2). At 60 DAS, the highest fibre area (1.32 mm) was shown in N_3Zn_2 and the lowest value (1.07 mm) was obtained in N_1Zn_1. At 90 DAS, the highest output (2.53 mm) was recorded in N_3Zn_3 and the lowest output (1.33 mm) was observed in N_1Zn_1.

Yield components and yield

Final plant height, stem diameter and fibre area of jute (110 DAS) were considered yield components (Table 3). Plant height varied significantly due to different nitrogen fertilizer rates. The superior plant height (287.5 cm) was observed from the highest nitrogen level (N_3) and it reduced by 6.81% in N_2 but significantly 13.6% in N_1 (Table 3). Nitrogen induced exuberant vegetative growth; thus a higher rate of nitrogen resulted in increased plant height in this experiment. Different rates of zinc fertilization showed significant differences in plant height. The highest plant height (283.26cm) was observed in Zn_3 treatment. It reduced only 6.31% in Zn_2 but significantly by 9.85% in Zn_1 (Table 3). The plant height of jute statistically differed due to the interaction of nitrogen and zinc fertilizer rates. The highest plant height (309.4 cm) was observed in treatment combination N_3Zn_3 and the lowest (234.0 cm) was obtained in N_1Zn_1.

Nitrogen fertilizer significantly affects the stem diameter of jute (Table 3). The highest stem diameter (13.67 mm) was observed in the maximum nitrogen level (N_3), which reduced moderately to 8.55% in N_2 but significantly to 16.16 % in N_1The application of 16.5 kg ha^{-1} Zn (Zn_3) showed the highest stem diameter (13.15 mm) of jute, which reduced marginally (4.10%) in Zn_2 and significantly by 9.65% in Zn_1. The stem diameter of jute was statistically differed due to the interaction of nitrogen and zinc fertilizer rate. The highest stem diameter (14.07mm) was observed in treatment combination N_3Zn_3 and the lowest (10.67mm) was obtained in N_1Zn_1. Increasing nitrogen fertilizer rates significantly influenced the Fibre area of jute (Table 3). The highest fibre area (2.80 mm) was observed in N_3, which reduced significantly 12.5 and 20.00% in N_2 and N_1, respectively. The highest fibre area (2.67 mm) was observed in Zn_3 and the lowest (2.29 mm) in Zn_1. The fibre area was reduced by 5.61 % in Zn_2 and 16.85% in Zn_1. There was a significant effect between nitrogen and zinc fertilizer rates on fibre area. The highest fibre area (3.02 mm) was obtained in treatment combination N_3Zn_3 and the lowest fibre area (2.07 mm) was found in the combination of N_1 with Zn_1.

A progressive increase in stick yield was observed with each rise in nitrogen dose (Table 3). The highest stick yield (9.90 t ha^{-1}) was recorded in N_3, which reduced significantly 25.05% and 41.41% in N_2 and N_1, respectively, indicating that increasing nitrogen level increased stick yield. Data revealed that stick yield increased significantly with maximum $ZnSO_4$ application (Table 3). The highest stick yield (9.19t ha^{-1}) was obtained in Zn_3 treatment, significantly reducing 16.75% in Zn_2 and 31.66% in Zn_1. Different combinations of nitrogen and zinc fertilization differed in stick yield of jute (Table 3). Apparently, the highest stick yield (12.16 t ha^{-1}) was achieved in N_3Zn_3 and the lowest stick yield (4.42 t ha^{-1}) was achieved in N_1Zn_1. There was a significant variation in fibre yield due to different nitrogen levels (Table 3). It was observed that the fibre yield gradually increased with an increase in nitrogen level. The highest fibre yield (4.49t ha^{-1}) was obtained in N_3, which reduced significantly to 27.39 and 45.21% in N_2 and N_1, respectively. So, increasing nitrogen level increased all yield contributing characters, which in term increased fibre yield. The fibre yield of jute presented in (Table 3) showed that fibre yield of jute increased significantly with maximum zinc level. Maximum fibre yield (4.09 tha^{-1}) was observed in Zn3, which reduced significantly to 17.60% and 32.76% in Zn_2 and Zn_1, respectively. The interaction effect of nitrogen and zinc fertilizer showed a significant effect on fibre yield of jute plant (Table. 3). Maximum fibre yield (5.39 t ha^{-1}) was observed in treatment combination N_3Zn_3. On the other hand, minimum fibre yield (2.00 t ha^{-1}) was observed in treatment combination N_1Zn_1. From Table 3, it was observed that nitrogen fertilizer had a significant effect on the biological yield of jute plant. Maximum biological yield was observed by N_3 (14.39 t ha^{-1}) treatment, which reduced significantly to 25.71% and 42.59% in N_2 and N_1, respectively. The highest biological yield (13.28 t ha^{-1}) was recorded in Zn_3, which reduced significantly to 17.01% and 32.00% in Zn_2 and Zn_1, respectively. The biological yield was significantly affected from the interaction between nitrogen and zinc fertilizer rates (Table 3). It revealed that the highest biological yield (17.55 t ha^{-1}) was found in the combination of N_3Zn_3 and the lowest biological yield (6.43t ha^{-1}) observed in the combination of N_1Zn_1. The harvest index was not influenced due to nitrogen fertilization (Table 3). Numerically, the highest harvest index (31.26 %) was found in N_3 and the lowest harvest index (29.84%) was obtained in N_1. The effect of zinc fertilizer rate had no significant effect on harvest index (Table 3). Numerically, the highest harvest index (30.70 %) was obtained in Zn_3 and the lowest (30.34%) was found in Zn_2. Nitrogen and zinc fertilizer levels significantly affected the jute harvest index (Table 3). Numerically, the highest harvest index (31.75%) was obtained in N_2Zn_3 treatment combination and the lowest harvest index (28.67%) was obtained in N_1Zn_2 treatment combination.

Table. 3. Effects of nitrogen and zinc fertilizer rates and their interactions on yield and yield component of jute

Nitrogen	Plant height at harvest (cm)	Stem diameter at harvest (mm)	Fiber area at harvest (mm)	Stick yield (t ha^{-1})	Fiber yield (t ha^{-1})	Biological Yield (t ha^{-1})	Harvest index (%)
N_1	248.4±7.08b	11.46±0.31b	2.24±0.12b	5.80±0.37c	2.46±0.14c	8.26±0.51c	29.84±0.47b
N_2	267.9±5.49ab	12.50±0.40ab	2.45±0.09b	7.42±0.28b	3.26±0.19b	10.69±0.46b	30.38±0.48ab
N_3	287.5±8.85a	13.67±0.48a	2.80±0.11a	9.90±0.66a	4.49±0.28a	14.39±0.94a	31.26±0.33a
Zinc							
Zn_1	255.33±8.45b	11.88±0.49b	2.29±0.14b	6.28±0.50c	2.75±0.23c	9.03±0.72c	30.45±0.50
Zn_2	265.37±6.68ab	12.61±0.48ab	2.52±0.12ab	7.65±0.57b	3.37±0.31b	11.02±0.87b	30.34±0.52
Zn_3	283.26±9.38a	13.15±0.47a	2.67±0.10a	9.19±0.79a	4.09±0.37a	13.28±1.15a	30.70±0.40
Interactions							
N_1Zn_1	234.0±12.74c	10.67±0.57c	2.07±0.31c	4.42±0.11g	2.00±0.12g	6.43±0.23g	31.16±0.83ab
N_1Zn_2	248.5±10.49bc	11.51±0.37bc	2.23±0.20c	6.07±0.13f	2.44±0.05f	8.51±0.14f	28.67±0.59c
N_1Zn_3	262.7±11.06bc	12.20±0.31abc	2.41±0.11bc	6.92±0.12e	2.92±0.07de	9.84±0.19e	29.67±0.19bc
N_2Zn_1	258.8±12.81bc	11.81±0.71abc	2.30±0.23bc	6.65±0.03ef	2.69±0.05ef	9.33±0.08ef	28.78±0.34c
N_2Zn_2	267.4±6.85bc	12.52±0.87abc	2.46±0.13abc	7.13±0.03de	3.15±0.06d	10.28±0.09e	30.60±0.34ab
N_2Zn_3	277.5±7.98ab	13.16±0.47ab	2.59±0.07abc	8.49±0.06c	3.95±0.09c	12.45±0.13c	31.75±0.49a
N_3Zn_1	273.1±11.84ab	13.15±0.71ab	2.50±0.19abc	7.78±0.19cd	3.56±0.14c	11.34±0.33d	31.37±0.36ab
N_3Zn_2	280.1±11.26ab	13.80±0.71ab	2.87±0.14ab	9.75±0.51b	4.53±0.18b	14.27±0.67b	31.74±0.58a
N_3Zn_3	309.4±17.36a	14.07±1.22a	3.02±0.07a	12.16±0.43a	5.39±0.28a	17.55±0.66a	30.68±0.74ab
CV%	7.58	9.8	12.39	5.47	6.96	5.55	3.03

Mean followed by different letter (s) differed significantly as per DMRT; DAS= Day's after sowing; CV= Co-efficient of variation; N_1= 100kg ha^{-1}; N_2=200kg ha^{-1}; N_3=300 kg $ha^{-1,}$ $Zn_{1=}$ 5.5 kg ha^{-1}, Zn_2= 11 kg ha^{-1}, and Zn_3= 16.5 kg ha^{-1}

Discussion

Nitrogen is a fundamental macronutrient essential for plant growth, particularly in promoting vegetative development such as stem elongation and increased plant height. Elevated nitrogen availability stimulates various physiological and biochemical processes that lead to enhanced cell division and elongation, thereby contributing to greater plant stature (Singh et al., 2021; Zhao et al., 2023). Nitrogen is a critical constituent of nucleic acids—DNA and RNA—which govern genetic information and cellular replication, enabling rapid growth and development in plants (Kumar et al., 2022). Adequate nitrogen supply ensures the continuous provision of these molecular building blocks, facilitating efficient stem cell proliferation and elongation, resulting in taller jute plants.

Moreover, nitrogen plays a vital role in leaf development by stimulating chlorophyll synthesis, the key pigment driving photosynthesis. Increased nitrogen fertilization correlates with a higher number of leaves and improved leaf health, enhancing photosynthetic capacity and biomass accumulation (Rahman et al., 2020; Ahmed et al., 2023). Healthy, chlorophyll-rich leaves optimize light interception and energy conversion, supporting further vegetative growth and yield potential. These findings align with earlier studies on jute and related fibre crops, which demonstrated positive correlations between nitrogen rates and plant height and leaf production (Nuruzzaman, 2007; Olaniyi & Ajibola, 2008), while extending understanding with contemporary physiological insights.

The combined effects of nitrogen on cell division and expansion, vascular tissue development, cell wall strengthening, hormonal regulation, and secondary growth are responsible for the increased stem diameter of jute observed with increasing nitrogen fertilizer rates. Nitrogen is essential for promoting stem growth and development in jute, resulting in thicker, sturdier stems (Thakur & Yadav, 2023).

Increased jute fiber yield with increasing nitrogen fertilizer rates can be attributed to nitrogen's combined effects on enhanced vegetative growth, hormonal regulation, nutrient uptake and utilization, and stress tolerance. Recent studies have confirmed that nitrogen application significantly enhances fiber yield in jute. Nitrogen plays a vital role in fiber development by supporting cell wall formation and elongation, which ultimately leads to increased fiber production (Patel et al., 2022).

Zinc is an essential micronutrient for plant growth and development, and it plays an important role in jute plant height. Zinc increases plant height by promoting cell elongation, particularly in the internodal regions of the stem. A sufficient supply of zinc ensures the proper function of enzymes involved in cell elongation, resulting in taller jute plants. (Kermani, *et al*., 2022).

Zinc improves the absorption of other essential nutrients such as nitrogen and phosphorus, both of which are required for leaf development (Saleem, *et al*., 2022). A sufficient supply of zinc ensures that jute plants have the resources they need to support cell division and expansion in the leaves. Zinc is a cofactor for several enzymes involved in cell division and expansion, which are essential processes for stem growth (Das *et al.*, 2020).). An increased stem diameter of jute was observed with adequate zinc supply due to the proper functioning of different enzymes, promoting the formation of new cells in the stem and the expansion of existing cells (Suganya *et al.* 2020).

The increased fiber yield of jute observed with increasing zinc fertilizer rates can be attributed to zinc's combined effects on enzyme activation, auxin production, cell wall strength, stress tolerance, and reproductive processes. Zinc is essential for fiber development in jute, resulting in plants with higher fiber yields.

Conclusion

Present research was conducted to investigate the effects of nitrogen and zinc fertilizers on the growth and yield of jute. The data were recorded on broad parameters of yield and yield characters. Result revealed that application of urea (N) @ 300 kg ha^{-1} gave significantly higher plant height (287.5 cm), stem diameter (13.67 mm), fibre area (2.80 mm), fibre yield (4.49 t ha^{-1}), stick yield (9.90 t ha-1) and biological yield (14.39 tha^{-1}) of jute. Application of zinc ($ZnSO_4$) @ 16.5 kg ha^{-1} also showed a significant influence on jute growth and yield which produced the highest plant height (283.26 cm), stem diameter (13.15 mm), fibre area (2.67 mm), fibre yield (4.09 tha^{-1}), stick yield (9.19 tha^{-1}) and biological yield (13.28 tha^{-1}).

Among the interactions between nitrogen and zinc, combination N_3Zn_3(300 kg ha^{-1} N+ 16.5kg ha^{-1} Zn) proved superior over rest of the treatment combination with respect to improvement in plant height (309.4 cm), stem diameter (14.07 mm) and fibre area (3.02 mm), fibre yield (5.39 t ha^{-1}), stick yield (12.16 t ha^{-1}) and biological yield (17.55 t ha^{-1}).

Therefore, farmers can be suggested to apply in a combination of nitrogen (Urea = 300 kg ha^{-1}) and zinc ($ZnSO_4$ =16.5 $kgha^{-1}$) to get a higher yield of jute. However, soils in the experimental area might contain less nitrogen and zinc. An appropriate dose of urea and zinc sulphate should be applied with other intercultural operations to arrive at a definite conclusion. Further investigation is needed, focusing on soil nutrient and plant uptake.

Authors' Contribution

Conceptualization, MTA, DR and MNS; Methodology, MNS, MMI, MDN, MS and MRI;Formal analysis, MMI and MNS; Investigation, MS, MRI and MTAK; Data curation DR, MNS, SA, MFJM and MMI; Writing – original draft preparation, DR, SA, MFJM and MMI; Writing – review and editing, DR, MNS, SA, MFJM and MMI; Visualization, MTAK, MI and MNS; Supervision, MS.

Conflict of Interest

The authors declare no conflicts of interests.

References

Akhter S, Sarker JR and Das KR (2016). Growth and trend in area, production, and yield of major crops of Bangladesh. International Journal of Economics, Finance and Management Sciences 4(1):20-25.

Akter S, Sadekin MN and Islam N (2020). Jute and jute products of Bangladesh: contributions and challenges. Asian Business Review 10(3):143-52.

Statistics BB (2011).Statistical Yearbook of Bangladesh.Statistics Division, Ministry of Planning, Dhaka, Government of the People’s Republic of Bangladesh.

Das S, Jahiruddin M, Islam MR, Mahmud AA, Hossain A and Laing AM (2020). Zinc biofortification in the grains of two wheat (*Triticum aestivum* L.) varieties through fertilization. Acta Agrobotanica 73(1): 1–13.

Hasanuzzaman M, Bhuyan MB, Parvin K, Bhuiyan TF, Anee TI, Nahar K, Hossen MS, Zulfiqar F, Alam MM and Fujita M (2020). Regulation of ROS metabolism in plants under environmental stress: A review of recent experimental evidence. International Journal of Molecular Sciences 21(22): 8695-8695.

Hossain MM, Nishu NS, Freelance Researcher M (2021). State-owned jute mills in Bangladesh: problems and possible solutions. International Journal of Business and Management 16(4): 63-74.

Indulekha VP (2014). Planting density and nitrogen influence on seed yield of jute.Doctoral dissertation, Acharya Ng Ranga Agricultural University.

Islam N, Kar RN, Gaffer MA and Choudhury M (1992). The influence of nitrogen and zinc on the yield of jute cv. 0-4. Pakistan Journal of Scientific and Industrial Research 35(7-8): 288-290.

Kermani A, Jafari A, Karimi S and Shirmardi M(2022). Effect of zinc on the growth of two pistachio (Pistaciavera L.) rootstocks under drought stress. Journal of Nuts 13(3): 167-181.

Leghari SJ, Wahocho NA, Laghari GM, HafeezLaghari A, Mustafa Bhabhan G, HussainTalpur K, Bhutto TA, Wahocho SA and Lashari AA (2016). Role of nitrogen for plant growth and development: A review. Advances in Environmental Biology 10(9): 209-19.

Mahapatra BS, Mitra S, Kumar M, Ghorai AK, Sarkar SK, Kar CS, Kundu DK, Satpathy S and Karmakar PG (2012). An overview of research and development in jute and allied fibre crops in India. Indian Journal of Agronomy 57(3s): 72-82.

Muhammad I, Yang L, Ahmad S, Farooq S, Al-Ghamdi AA, Khan A, Zeeshan M, Elshikh MS, Abbasi AM and Zhou XB (2022). Nitrogen fertilizer modulates plant growth, chlorophyll pigments, and enzymatic activities under different irrigation regimes. Agronomy 12(4):845-845.

Nuruzzaman (2007). Effects of NPKS on growth and yield of jute (BINA deshipat-2). M.S. Thesis, Dept. Soil Science, Bangladesh Agricultural University, Mymensingh.

Olaniyi JO and Ajibola AT (2008).Growth and yield performance of *Corchorus olitorius* varieties as affected by nitrogen and phosphorus fertilizer application. American-Eurasian Journal of Sustainable Agriculture 2(3): 235-241.

Rahman MS, Yasunaga N and Inoue N (2023). Factors influencing the mindset toward jute revival: the case of an educated generation in Bangladesh. Agricultural Information Research 31(4):111-119.

Saleem MH, Usman K, Rizwan M, Al Jabri H and Alsafran M (2022). Functions and strategies for enhancing zinc availability in plants for sustainable agriculture. Frontiers in Plant Science 13:1033092

Shah SH, Islam S, Mohammad F and Siddiqui MH (2023).Gibberellic acid: a versatile regulator of plant growth, development and stress responses. Journal of Plant Growth Regulation 42(12): 7352-7373.

Suganya A, Saravanan A and Manivannan N (2020). Role of zinc nutrition for increasing zinc availability, uptake, yield, and quality of maize (*Zea mays* L.) grains: An overview. Communications in Soil Science and Plant Analysis 51(15): 2001-2021.

Thakur S and Yadav KS (2023). Response of various organic manures and its combinations on growth, flowering, and cormels of Gladiolus. Journal of Experimental Agriculture International 45(10): 224-230.

Lampel P (2022). Biochar from garden waste as a potential hydroponic growing substrate. Master's Thesis. Department of Management and Engineering, Environmental Technology and Management, Linköping University, Linköping, Sweden

Zhao and Wang J (2023). Nitrogen-mediated regulation of plant growth and development: Molecular insights and agronomic implications. Frontiers in Plant Science 14:112345.

Ahanger MA, Bhat JA, Ahmad P and John R (2023). Improving stress resilience in plants: physiological and biochemical basis and utilization in breeding. Elsevier,Amsterdam, Netherlands

Rahman MM, Hasanuzzaman M and Hossain (2020).Nitrogen fertilization and its impact on chlorophyll content and photosynthetic efficiency in jute (*Corchorus olitorius*).Journal of Crop Science and Biotechnology 23(4): 345-352.

Ahmed S, Noor and Rahman (2023). Effect of nitrogen levels on leaf morphology and photosynthesis in fiber crops. Agricultural Science and Technology 25(1): 78-86.

Nuruzzaman (2007).Effects of NPKS on growth and yield of jute (BINA deshipat-2). Master's thesis, Bangladesh Agricultural University, Mymensingh.

Olaniyi JO and Ajibola AT (2008). Growth and yield performance of *Corchorus olitorius* varieties as affected by nitrogen and phosphorus fertilizers application. American-Eurasian Journal of Sustainable Agriculture 2(3): 235-241.

Patel J, Singh R and Kumar A (2022). Effect of nitrogen fertilization on growth and fiber quality of natural fiber crops: A review. Journal of Plant Nutrition 45(8): 1203–1215.