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Effects of sewage sludge on the growth and yield of jute

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ABSTRACT

An outdoor research was executed to assess the impact of sewage sludge and inorganic fertilizer on the fertility of soil and yield of jute, utilizing the high-yielding variety of jute (*Corchorus olitorius* L.) O-9897 as the sample plant. Six treatments of treated sewage sludge (SS) and suggested amounts of chemical fertilizers (RDF) with three replications were as T_1: (Control), T_2: (SS 5 t ha^{-1}), T_3: (SS 5 t ha^{-1} + ½ RDF), T_4: (SS 5 t ha^{-1} + ¾ RDF), T_5: (SS 5 t ha^{-1} + ¼ RDF), and T_6: RDF. It was found that the treatment T_4 (SS + ¾ RDF) as well as T_5 (SS + ¼ RDF) had the highest growth and yield of jute, where the plant height, base diameter, fiber yield and stick weight were increased 67.65, 48.28, 60, and 63.49%, respectively in comparison to the control. The maximum amounts of organic matter and zinc were found for treatment T_3, whereas nitrogen, phosphorus, potassium and sulfur were also noted as highest in treatment T_4. The implementation of sewage sludge alone enhanced jute growth, yield, and soil nutrient levels compared to the control. However, combining sewage sludge with chemical fertilizers produced improved outcomes in boosting the fertility of soil and the yield of jute.

Keywords: Jute plant, Sewage sludge, Soil fertility, Organic matter, Nutrient elements

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Introduction

In Bangladesh, jute (*Corchorus olitorius*) O-9897, the oldest and most important fibrous material crop in the genus Corchorus and family Tiliaceae, is a significant cash crop that is also environment friendly. Tossa jute (C. *olitorius*) and white jute (C. *capsularis*) are the main constituents of jute fiber. Jute cultivation is crucial in the Indian subcontinent in terms of economics, agriculture, industry, and commerce.

Jute has traditionally been used in the production of construction fabrics, carpets, sackings, and wrapping materials. Jute products are durable, reusable, economical, and superior to artificial fibre (Basu and Roy, 2008). In addition to being eaten as a vegetable in many countries, young jute leaves have also been used as herbal medicine. They are superior to synthetics, preserve the ecological balance, and safeguard the environment (Hossain *et al.,* 2024). Young green jute plants are being used as raw materials for domestic purposes. Jute leaves, roots and its residues may be applied as organic materials to improve soil physicochemical characteristics. According to Hasan *et al.* (2019), jute seeds offer a significant amount of N, P, K, S, Ca, Mg, and Zn. Their use also increases soil fertility and jute output.

Bangladesh occupies an area of 1,48,460 square kilometers and is located in northeastern South Asia between latitudes 20^0 84' and 26^0 38' north and longitudes 92^0 40' east. It is a tropical and sub-tropical country located on the deltas of the Ganges and the Brahmaputra Rivers of the world. This area is suitable for jute cultivation. However, the natural conditions are very conducive to the disintegration of organic matter, leading to the depletion of organic components from soil and deterioration of the physicochemical properties of soil. The organic matter content in Bangladesh soil is significantly low as compared to the recommended 2.5% and above (Islam, 1999; BARC, 2018). This situation has been further aggravated by the addition of very little or no organic matter to the land. The excessive use of chemical fertilizers that are out of balance and increased cropping intensity has resulted in the extraction of natural plant nutrients from soils, causing fertility status to decrease drastically with time (Ali *et al.*, 1997).

In addition to our limited land resources and the nation's growing population, intense cropping and cropping patterns will become increasingly necessity in the near future. Along with the minimal usage of organic materials, soil fertility was rapidly depleted by the application of chemical fertilizers that were out of balance (Bhuiyan, 1992; Islam, 2008). In such a situation, it is very alarming to use organic materials with chemical fertilizers for future agricultural production. The organic matter content of top soils under high land and medium high land are declining over time as a result of using unbalanced doses of chemical fertilizers and applied no or little amount of organic matter to the soils (Zahid *et al.*, 2011). Therefore, there is no alternative without organic materials used in soil to increase soil fertility.
Sewage sludge a non-traditional source of organic matter enriched with nitrogen, phosphorous, potassium and other nutrients for plants. Sewage sludge contains considerable concentrations of organic carbon, nitrogen, phosphorous and potassium. Application of sewage sludge can increase the availability of phosphorus in soil (Bulegoa and Komunikazio, 2009). Sewage sludge is typically utilized to increase plant-available nutrients and boost soil fertility and productivity due to its beneficial agronomic qualities, which include a high level of organic matter, nitrogen, and phosphorus (Boen *et al.*, 2013). The decomposition of organic materials in sewage sludge can enhance soil microbial activity, respiration, and enzyme activity (Andres *et al.*, 2011). The increased organic carbon in the sewage sludge is primarily responsible for the enhanced microbial biomass in sludge-fertilized soils (Sing and Agrawal, 2008).

Microbial immobilization of phosphorus is improved by using organic amendments like sewage sludge (Wu *et al.*, 2007). Soil structure and water retention can be enhanced by the organic matter in sludge. Sewage sludge might boost the soil's physical and chemical characteristics, improve microbial activity, and enhance the amount of organic matter present. It may also improve the availability of nutrients for the pants. It also helps to maintain C: N ratio in soil and also increases soil health. Considering the foregoing, the current study was conducted to investigate the impacts of sewage sludge on jute growth, yield, and quality.

Materials and Methods

Site of the experiment

The Bangladesh Jute Research Institute (BJRI) central station, located on Manik Mia Avenue in Dhaka, served as the site of the field experiment. This location falls within the Young Brahmaputra, Jamuna Floodplain, and AEZ-8.

Obtaining a sample of soil and plants

Prior to land preparation, the first soil samples were collected from the investigational plots. At a deepness of 0-15 cm, soil samples were randomly taken from various locations. From the eighteen experimental plots, post-harvest soil and plant samples were gathered, placed in polythene bags, rubber-tagged, and labeled for analysis.

Sludge collection from sewage

The Sewage Treatment Plant's lagoons at Pagla were used to gather samples of processed sewage sludge. After being tagged, the treated sewage samples were placed in plastic containers and brought to the lab for analysis. After being allowed to air dry, the collected sewage sludge was filtered through a 0.5 mm sieve and well combined. Following preparation, the samples were gathered in plastic containers for chemical analysis.

Preparation of the land

Power tilling, harrowing, and laddering were used to prepare the soil. In order to limit the lateral flow of irrigation and drainage the 7.5 cm height and 10 cm depth plots were set. Three blocks were created from the entire experimental area, and there were six experimental plots in each block. Three replicates were used for each of the six treatment levels, which included control. A randomized complete block design (RCBD) was used to assign the eighteen experimental plots. Each plot measured 3 m by 2 m, with space between plots and blocks.

Applying fertilizers with sewage sludge

At a rate of 5 ton per hectare (t/ha), treated sewage sludge (SS) was used as an organic matter source, Treatment T_6 (SS) = 5 ton/hectare SS, recommended dose of the fertilizers (RDF), Treatment T_5 = (200 kg urea + 50 kg TSP + 60 kg MP + 100 kg Gypsum) (BARC, 2018). RDF Sewage sludge and RDF treatment combinations were as follows: Treatment T_2 (SS + ¼ RDF) = 5 ton per hectare SS + 50 kg urea + 12.5 kg TSP + 15 kg MP + 25 kg gypsum, Treatment T_3 (SS + ½RDF) = 5 ton per hectare SS + 100 kg urea+ 25 kg TSP+30kg MP+ 50 kg Gypsum, Treatment T_4 (SS + ¾ RDF) = 5 ton per hectare SS + 150 kg urea+ 37.5 kg TSP+30 kg MP+ 50 kg Gypsum and Treatment T_1 = Control (without SS and chemical fertilizers).

The planting processes

A 30 cm space was left between each line in the plots and high-yielding jute seeds, the variety Olitorius-9897 were planted 10 cm apart. To keep the water supply to the plot's constant irrigation was carried out using a furrow irrigation method. A hoe was used to loosen the soil twenty-five days after the seeds were sown. Seeds were sown, and weeding and thinning were carried out 8, 25, and 45 days later.

Harvesting and collecting of jute

When the plants were harvested, they were 120 days old. Plant height, base diameter, fiber weight, and stick weight of the ten randomly chosen harvested jute plants were among the plant characteristics assessed after the jute plants from each experimental plot were tied into bundles using a tagged rope. After the jute fibers were retted and dried, the fiber weight was measured. Stick weight was measured once the jute sticks had dried in the sun. Following the jute plant harvest, leftover soil samples were taken from every experimental plot for chemical examination. Following the procedures outlined in Chowdhury *et al.* (2010), the soil samples were processed and examined.

Analysis of sample

The samples were analyzed in the laboratory to determine the different physical, chemical and physicochemical properties of soil, following the methods outlined by Huq and Alam (2005). Various physical, chemical and physico-chemical properties of the soil samples (e.g. moisture content, particle size analysis, bulk density, particle density, pH, organic matter content, total contents of calcium, magnesium, nitrogen, phosphorous, potassium, sulfur and zinc, and available nitrogen, phosphorous, potassium and sulfur) were analyzed in the laboratory following the procedures described in Huq and Alam (2005).

Statistical analysis

The data were subjected to statistical analysis and presented graphically using Minitab v.18 and Microsoft Excel 2016 software.

Results and Discussion

Properties of soil

Physical and chemical properties of the studied soil were assessed following standard methods. The results of those analyses are given in Table 1.

Table 1. Physical and chemical properties of the studied soil.

Characteristics	Values
Moisture content (%)	25.00
Bulk density (g/L)	1.23
Particle density (g/L)	2.35
Textural class	Silt loam
Sand (%)	8.00
Silt (%)	63.0
Clay (%)	29.00
pH	6.35
Organic carbon (%)	0.62
Organic matter (%)	1.07
Total nitrogen (%)	0.43
Total phosphorous (%)	0.08
Total potassium (%)	0.32
Total sulfur (%)	0.03
Available nitrogen (ppm)	23.00
Available phosphorous (ppm)	15.60
Available potassium (ppm)	57.00
Available sulfur (ppm)	32.00
Total calcium (ppm)	75.00
Total magnesium (ppm)	60.00
Total zinc (ppm)	25.0

Properties of sludge

Physical and chemical properties of the studied sewage sludge were assessed following standard methods. The results of those analyses are given in Table 2.

Table 2. Physical and chemical properties of the sewage sludge.

Properties	Sewage Sludge
Moisture content (%)	55.00
Organic carbon (%)	2.38
Organic matter (%)	4.09
pH	7.35
Total N (%)	0.52
Total P (%)	0.86
Total K (%)	0.45
Total S (%)	0.47
Available N (%)	0.34
Available P (%)	0.02
Available K (%)	0.02
Zn (ppm)	27.60
Mg (ppm)	97.48
Ca (ppm)	7.05
Fe (ppm)	6.26
Pb (ppm)	14.40
Cr (ppm)	17.80
Ni (ppm)	16.68

The analysis of sewage sludge samples revealed concentrations of Pb (14.40 ppm), Cr (17.80 ppm), and Ni (16.68 ppm), all of which are below the maximum permissible limits established by the USEPA (40 CFR Part 503) and the EU Directive 86/278/EEC. These findings suggest that the sewage sludge meets the criteria for safe application in agricultural practices as per these international standards.

The percent increment of nutrient status from initial soil to post-harvest soil

Table 3 shows that the increment of nutrients from the initial soil to post-harvest soil increased. The highest increment of organic matter and total Zn content over initial soil were found in treatment T_3 (SS 5t/ha + 1⁄2 RDF) and values were 21.32% and 50.01%. In control treatment, the increment was also increased over the initial soil. The percent increment of total N, total P, total K and total S were found to have the highest increment at treatment T_4 (SS 5t/ha + 3/4 RDF). The maximum total nitrogen increment was 24.45%, total P 48.80%, total K 32.28% and total S was 49.18% over initial soil in post-harvest jute cultivated soil. Table 3 also showed that all the values at different treatments in post-harvest soil were higher than in the initial soil. So, we can say that the production of jute and the fertility status of soil improved due to the application of sewage sludge or chemical fertilizer alone or integrated use of chemical fertilizer and sewage sludge. But it is also noted that integrated application treatments gave better results compared to others.

The findings of the present study align with those of Shan *et al.* (2021), who reported that the concentration of total N and P, alkaline N, and available P in mudflat soils increased with increasing sewage sludge application rate. Compared to the control soil, there were increases in soil EC by 1.5%, 5.8%, 10.7% and 12.4% at 0.5%, 1.0%, 1.5% and 2.5% SS application rates, respectively.

Table 3. The percent increment of nutrient status from initial soil to post-harvest soil.

Parameters	Initial Soil	T_1-Control	T_2-SS* 5t/ha	T_3-SS 5t/ha+1/2 RDF	T_4-SS 5t/ha+3/4 RDF	T_5-SS 5t/ha+1/4 RDF	T_6-RDF**
OM (%)	1.040	8.85	17.05	21.32	18.32	15.08	12.30
N (%)	0.068	20.00	23.60	23.60	24.45	22.73	21.81
P (ppm)	8.500	12.82	42.88	44.44	48.80	44.44	39.29
K (%)	0.086	9.47	16.50	17.31	32.28	23.89	14.00
S (ppm)	6.200	21.52	45.61	46.55	49.18	46.09	25.30
Zn (ppm)	71.600	22.17	46.25	50.01	47.43	46.88	31.68

**SS-Sewage sludge and **RDF-Recommended dose of fertilizer*

Jute production and growth with various sewage sludge treatments

The growth and production of jute plants with different treatments through the application of sewage sludge or chemical fertilizer or integrated application of organic (sewage sludge) and chemical fertilizers was observed. The results are listed in Table 4.

Table 4. Jute production and growth with various sewage sludge treatments.

Parameters	T_1-Control	T_2-SS* 5t/ha	T_3-SS 5t/ha+1/2 RDF	T_4-SS 5t/ha+3/4 RDF	T_5-SS 5t/ha+1/4 RDF	T_6-RDF**	
Plant height (m)	1.10	3.10	2.98	3.20	3.40	3.10	LSD 5%=0.24 LSD 1%=0.34
Base diameter (mm)	9.00	17.30	16.80	17.40	16.70	16.30	LSD 5%=0.39 LSD 1%=0.55
Fibre yield (t/ha)	1.20	2.99	2.89	3.10	3.00	2.99	LSD 5%=0.19 LSD 1%=0.27
Stick yield (t/ha)	2.30	6.10	5.00	6.30	6.20	6.10	LSD 5%=0.30 LSD 1%=0.42

**SS-Sewage sludge and **RDF-Recommended dose of fertilizer*

Yield characteristics of stick of jute plant

The yield of stick of the jute plant is very important for an economic view. The yield of jute increased when sewage sludge was used as organic fertilizer with chemical fertilizer, and the same experiment was carried out for jute by Gani *et al.* (1999) by using poultry litter with chemical fertilizer.

In the above Table 4, the stick yield was obtained at different treatments with significant treatment differences. The highest stick yield was 6.30 t/ha at T_4 (Sewage sludge 5t/ha+1/2 RDF) with a significant difference. The same value was recorded at 6.10 t ha^{-1}, which was obtained at the T_2 (SS 5t/ha) and T_6 (RDF) treatment. The treatment can be arranged in order of $T_4>T_5>T_6=T_2>T_3>T_1$ (Fig. 1).

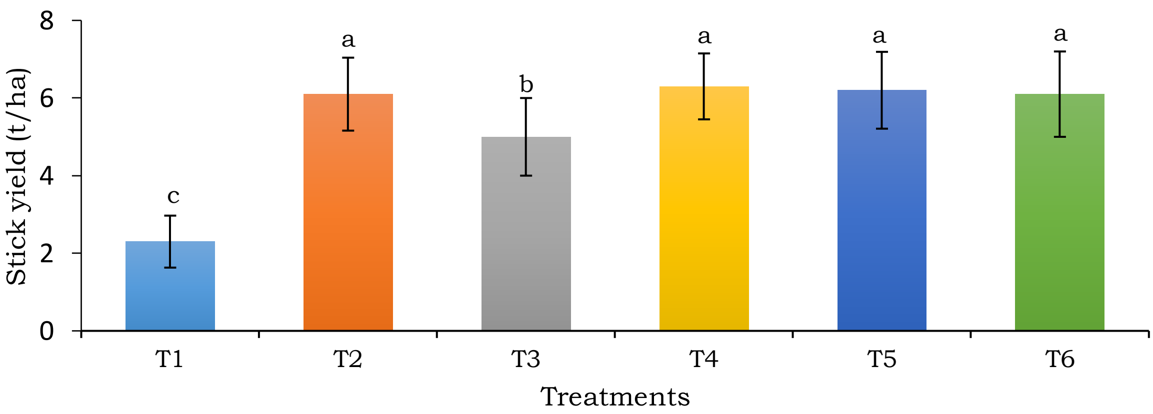

Fig. 1. Stick yield of jute plants at different treatments.

Plant height of jute plant

Plant height is a crucial agronomic characteristic of the jute crop that directly influences its yield. Table 4 shows that the highest plant was achieved at T_5 (Sewage sludge 5t/ha+1/4 RDF), which was 3.40 m with a significant difference at 5% level. The second highest was obtained at T_4 (Sewage sludge 5 t/ha+ 1/2 RDF).

The sequence of treatment from highest to lowest $T_5>T_4>T_6=T_2>T_3>T_1$. All the observations clearly indicated that the integrated treatments increased the plant height of the jute plants more than the application of chemical fertilizers with sewage sludge. Both the application of sewage sludge and the use of broiler litter resulted in taller jute plants, achieving a plant height rate higher than what Mitchell and Tu (2005) allowed for other crops. The variation in plant height of jute plant among the treatments is presented in Figure 2.

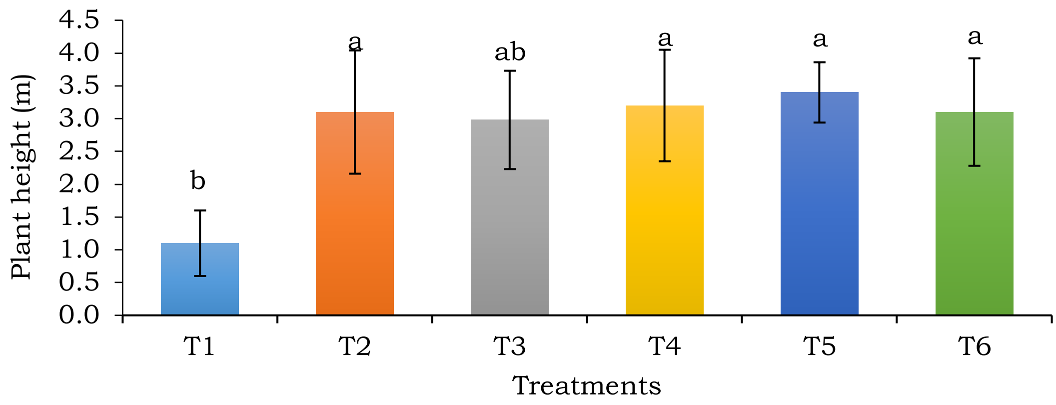

Fig. 2. Plant height of jute plants at different treatments

Percent increment of growth and yield of jute over control

The results clearly indicated that all the variables of % increment of growth and yield were increased with the different treatments over the control. Highest increment of plant height 67.65%, base diameter 48.28%, fibre yield 60% and stick yield 63.49% (Table 5).

Data in Table 5 showed that the application of sewage sludge highly influenced the parameters of growth and yield of jute. The treatment T_5 (SS 5 t ha^{-1} + 1/4 RDF) was given 60% yield. The result showed that sewage sludge is a promising source of organic matter (OM) for jute cultivation. Similar to the combined use of sewage sludge and chemical fertilizer, Mukherjee *et al.* (2006) also observed that applying chemical fertilizer and poultry litter resulted in the highest growth and yield of rice.

Table 5. Percent increment of growth and yield of jute over control.

Parameters	T_1-Control	T_2-SS* 5t/ha	T_3-SS 5t/ha+1/2 RDF	T_4-SS 5t/ha+3/4 RDF	T_5-SS 5t/ha+1/4 RDF	T_6-RDF**
Plant height (%)	-	64.52	63.09	65.63	67.65	64.52
Base diameter (%)	-	47.98	46.43	48.28	46.11	47.98
Fibre yield (%)	-	59.87	58.48	32.26	60.00	59.89
Stick yield (%)	-	62.30	54.00	63.49	62.90	62.30

**SS-Sewage sludge and **RDF-Recommended dose of fertilizer*

Economic analysis of jute production per year

The economic analysis considered all the costs of jute cultivation, from land preparation to fibre drying. The results are focused on a higher benefit-cost ratio (BCR) than T_6 (RDF) and control (Table 6).

Table 6. Economic analysis of jute production per year.

Treatments	T_1-Control	T_2-SS* 5t/ha	T_3-SS 5t/ha+1/2 RDF	T_4-SS 5t/ha+3/4 RDF	T_5-SS 5t/ha+1/4 RDF	T_6-RDF**
Gross return (GR)	72900	183300	173950	170500	183600	182750
Variable cost (VC)	86165	88665	91865	93465	90265	92265
Marginal return (MR)	-	94634	82085	77035	93335	90185
Benefit cost ratio (BCR)	-	2.07	1.89	2.20	2.03	1.98

**SS-Sewage sludge and **RDF-Recommended dose of fertilizer*

Recommendation

It is recommended that sewage sludge with inorganic fertilizer be used most efficiently in jute cultivation. Considering the highest BCR, the treatment T_4 is the most suitable dose for maximum jute yield. The toxic material of soil should be analyzed for 3-4 years of use of sewage sludge.

Conclusion

The experiment's findings demonstrated that sewage sludge may be utilized to improve the soil's qualities with chemical fertilizer, restoring its nutrient status and boosting jute production and growth annually at minimal expense but with additional advantages. In order to improve soil fertility and Bangladesh's low level of organic matter status, research on the combined application of organic and inorganic fertilizer on crops and cropping patterns is urgently needed. The overall results showed that using organic materials is our only remaining option. Therefore, if we can correctly implement this strategy, the usage of integrated organic and chemical fertilizer will become essential for enhancing crop output. Future research should focus on optimizing sludge application rates to enhance fiber yield and quality without compromising soil health or environmental safety. Long-term field trials are essential to assess the cumulative effects of heavy metals, nutrient availability, and microbial activity in jute-growing soils.

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