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ORIGINAL RESEARCH

Effective Weed Control and Fiber Yield Improvement in Jute Through Seeding and Row Spacing Strategies

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ABSTRACT: The production of jute fiber is seriously threatened by weeds, both in terms of quantity and quality, because they compete with it for vital resources, including sunlight, water, and nutrients. The present study was conducted at the Jute Agriculture Experimental Station (JAES) of the Bangladesh Jute Research Institute (BJRI) in Manikganj during 2019 to assess the effects of various seed rates and line-to-line spacing on weed dynamics and fiber yield of BJRI Tossa jute variety O-9897. A two-factor factorial experiment was implemented using a randomized complete block design (RCBD) with three replications. Five seed rates (4, 5, 6, 7, and 8 kg ha^{-1}) and four-line spacings (15, 20, 25, and 30 cm) were tested. SDR. The results revealed twelve weed species, with Cyperus rotundus exhibiting the highest summed dominance ratio (SDR) of 53.22%, followed by Digitaria sanguinalis (9.98%) and Echinochloa colonum (9.55%). Interaction effects of seed rate and line spacing significantly influenced weed density, with the highest densities recorded at the lowest seed rate (4 kg ha^{-1}) and widest spacing (30 cm). Conversely, the lowest weed densities were observed at the highest seed rate (8 kg ha^{-1}) and narrowest spacing (15 cm). Yield data collection included plant density, plant height, base diameter, and fiber and stick yields, which were later converted to metric tons per hectare. Economic analysis, based on labor costs and market prices, demonstrated the cost-effectiveness of treatments, while Principal Component Analysis (PCA) further elucidated weed management impacts. These findings contribute to optimizing jute cultivation practices by balancing weed suppression and maximizing fiber yield under various agronomic conditions.

KEYWORDS: Jute, seeding rate, row spacing, weeds

1. Introduction

Jute fiber, a very important plant-based fiber and environmentally friendly material, holds huge importance in multiple sectors. It not only stands out as the most economical vegetable fiber but also plays an essential role in the manufacturing of better industrial yarn, fabric, and net (Alam et al., 2010). This natural fiber possesses a captivating golden hue and a silky luster, making it highly sought after (Alam et al., 2019). Additionally, it is fully biodegradable and provides a multitude of environmental benefits. Jute, being a cash crop and the primary fiber crop, acts as a resource that renews annually and boasts impressive biomass production per unit of land. Moreover, jute items break down in the soil once they reach the end of their life cycle, further aiding in sustainability. In the current scenario of climate change, where synthetic materials are increasingly viewed as problematic, natural fiber products have been shown to be completely safe. Jute, a natural fiber, comes with a range of inherent advantages, including its shine, high tensile strength, low extensibility, moderate heat and fire resistance, and long staple lengths (Alam et al*.,* 2002). Furthermore, it outperforms synthetic materials in terms of benefits and acts as a safeguard for the environment while maintaining ecological balance (Alim, 1978).

Presently, there is a diverse array of more than 280 jute products being produced from jute, which are subsequently exported to various countries worldwide Anderson, 1977). Domestically, the demand for jute goods is steadily rising due to the enforcement of the mandatory Packaging Act-2010, which includes the packaging of essential commodities such as paddy, rice, wheat, maize, sugar, fertilizer, chilli, turmeric, onion, ginger, garlic, pulses, coriander, potato, flour, and tush-khud-kura (Al-Mamun et al., 2018). In recent years, there has been a remarkable surge in the demand for jute fibers both within Bangladesh and globally. This can be attributed to the versatile applications of jute and its positive environmental impact. Despite facing challenges from other crops and the decline in its usage due to the availability of cheaper synthetic fibers, the world is increasingly recognizing the importance of natural fibers in order to mitigate the harmful effects of synthetic alternatives on the environment. As a result, the demand for jute has experienced a significant boost, reflecting the growing global consciousness towards sustainability.

Jute, derived from two cultivated species, specifically *Corchorus capsularis* L. and *Corchorus olitorius* L., ranks as the second most crucial fiber crop after cotton (*Gossypium* sp) and acts as the primary cash crop in Bangladesh (Alam et al*.,* 2010). An estimated 1,534,814 tons of fiber are generated from around 7279,891 hectares of land in Bangladesh (BBS 2023). The jute industry has made a significant contribution to the national economy, generating approximately Tk. 882.445 crore through the export of raw jute and jute products, representing 4% of the national GDP (Alam et al*.,* 2019). The area of cultivable jute land experienced a significant decline from 15-16 lac hectares to 6.00-6.76 lac hectares between 1970 and 2010 (Yasmin, S. and Moniruzzaman, M., 2024). This reduction is attributed to factors such as the introduction of synthetic alternatives, fluctuating global demand, and shifts in agricultural priorities. Despite these challenges, recent years have seen efforts to revitalize the jute sector through technological advancements and policy interventions (Rahaman, 2024). However, despite this decrease in land availability, the national average yield of jute witnessed a notable increase from 1.59 to 2.15 tons per hectare. This rise in yield can be attributed to the adoption of high-yielding jute varieties and the implementation of improved production technologies. These advancements include the utilization of improved seed, line sowing techniques, recommended fertilizer application, and enhanced plant protection measures. As a result of these innovative practices, there has been a substantial improvement in fiber yield, with a respective increase of 20%, 23%, 27%, and 13% compared to conventional methods (Alam et al*.,* 2002).

The production of quality jute fiber involves several key steps. First, the jute plants are grown in suitable climates and harvested at the right time. Other important agronomic practices, namely seeding rate and row spacing, play a crucial role in managing weed pressure and subsequently impacting jute fiber production (Sadat et al., 2021). The seeding rate refers to the number of jute seeds sown per unit area. By increasing the seeding rate, a higher density of jute plants can be achieved. This higher density creates a dense canopy that effectively shades out weed seedlings, thus suppressing their growth and minimizing their impact on jute fiber production (Zehab SD, 2023). Similarly, row spacing also plays a significant role in managing weed pressure. By adjusting the distance between rows, it is possible to create an environment that is less favorable for weed growth. Narrower row spacing can result in a denser jute plant population, which further limits the space available for weed establishment and growth (Islam, 2014). Therefore, both seeding rate and row spacing are important considerations in the cultivation of better jute fiber in subtropical environments. Alternatively, jute cultivation is characterized by its labor-intensive nature. The practice of high-density sowing (HDS) by broadcasting jute seed is widely adopted by small and marginal farmers. This method results in a high plant stand at emergence, which subsequently leads to increased expenses in various operational activities such as weeding, thinning, sorting, and fiber extraction.

The density at which the crop is sown can have a substantial effect on its ability to compete with weeds for resources, thus playing a crucial role in determining the weed management approach. Studies indicate that the density of crops has a significant impact on the development of the canopy as well as the growth of weeds (Kaur et al., 2025). When lower seeding rates are employed, it results in sparser crop stands, thereby providing favorable conditions for weed proliferation. To address this challenge, it is advisable to utilize higher seeding rates than the standard recommendations. Research has demonstrated that a seeding rate of 500 seeds m^{-2} not only reduces weed growth but also marginally enhances crop yield when compared to a seeding rate of 300 seeds m^{-2} (Jena, Mukesh, Mitra, & Paikray, 2017). Furthermore, in situations where there is intense competition from weeds, it is suggested to employ rice seeding rates exceeding 80 kg ha^{-1} (Ahmed et al*.,* 2014).

Additionally, it has been observed that aligning the seeding rows in an east-west direction minimizes the loss of crop yield in the presence of weeds (Dempsey, 1975; Gomez and Gomez, 1984). While previous studies have established the importance of plant density and uniformity in crop emergence and yield (Grichar et al*.,* 2004), there is limited information specifically addressing how varying seed rates and row spacings influence weed pressure in jute cultivation in Bangladesh. This study seeks to fill that gap by directly assessing the interactions between seed rate, row spacing, and weed proliferation in jute fields. Unlike earlier studies that focused on rice or general crop systems, this research examines the impact of these factors on weed communities and the resulting jute fiber and stick yields in Bangladesh's subtropical agroecological context.

Therefore, the primary objective of this research initiative was to evaluate the optimal seed density and plant spacing to effectively address the issue of weed infestation in sustainable jute cultivation. Additionally, it aimed to ascertain the yield of *Corchorus olitorius* by implementing the most economically viable seed rate and line spacing, while considering the impact on weed pressure, yield, and quality of tossa jute production. By focusing on these specific interactions in jute cultivation, this study not only supplements the existing research but also provides in-depth insights that are critical for the development of integrated weed management practices tailored to the needs of Bangladeshi jute farmers.

2. Material and methods

2.1 Experimental locations

The research was initiated at the Jute Agriculture Experimental Station (JAES), a facility under the Bangladesh Jute Research Institute (BJRI), situated in Manikganj in 2019. This location is positioned between latitudes 23°38' and 24°03' north and longitudes 89°41' and 90°08' east. The region is characterized by non-calcareous dark grey floodplain soil, which is typical of the Young Brahmaputra Floodplain Agro-ecological Zone "AEZ-8," as delineated by the UNDP and FAO in 1988 (UNDP and FAO, 1998).

2.2 Treatment and design

BJRI Tossa Jute variety O-9897 (*Corchorus olitorius*) was selected for the study. The study was carried out using a randomized complete block design (RCBD) with three replications. It involved a two-factor factorial experiment, with Factor-A representing seed rate and Factor-B representing line-to-line spacing. The seed rate levels were 4 kg ha^{-1} (S_1), 5 kg ha^{-1} (S_2 - control), 6 kg ha^{-1} (S_3), 7 kg ha^{-1} (S_4), and 8 kg ha^{-1} (S_5), respectively. The line-to-line spacing levels were 15 cm (L_1), 20 cm (L_2), 25 cm (L_3), and 30 cm (L_4 - control).

2.3. Land Preparation

The experimental field was prepared by dry ploughing and harrowing, without puddling. The seed rate and line spacing were determined based on the experimental treatment. The plots were dry farmed and harrowed during land preparation, with supplemental irrigation provided as needed. Following BJRI guidelines, each plot measuring 4 m × 2.5 m received specific amounts of urea, TSP, MoP, Gypsum, and Zinc Sulphate at rates of 200, 50, 60, 95, and 110 kg ha^{-1}, respectively. Half of the urea and full rates of other fertilizers were applied as basal dosage during final plot preparation, while the remaining 50% of urea (100 kg ha^{-1}) was broadcast at 45 days after sowing (DAS). Plant protection measures were implemented to prevent negative effects from insects or pathogens.

2.4 Data collection

2.4.1 Weed density, dry matter and summed dominance ratio

The weed samples were collected randomly at 30 DAS by placing quadrates measuring 0.5 m x 0.5 m at four different locations within each plot. The weeds were then cut at the base, cleaned, identified, and assigned individual numbers. Weed density (WD) was calculated as the number of weeds per square meter (m^{-2}). The separated weed species were oven-dried at 70^{o}C for 72 hours to determine weed dry matter (WDM) in grams per square meter (g m^{-2}). The summed dominance ratio (SDR) proposed by Janiya and Moody (1989) was used to identify the predominant weed species at the experimental plots (equation 1-4).

2.4.2 Yield data

During the harvest period, 1 square meter rectangular areas were deliberately positioned lengthwise at three specific points within each experimental plot. The number of plants within these areas was meticulously tallied and then averaged to establish the plant density (PD) per square meter. To determine the plant height (PH), the distance from the base to the apex of ten randomly selected jute plants was measured and averaged, with the measurement presented in centimeters. After the jute plants were harvested, the base diameter (BD) of ten arbitrarily chosen plants was gauged, and the average diameter was documented in millimeters as BD. Subsequently, the fiber and stick components of the jute plants were separated, thoroughly cleansed, and then completely dried under direct sunlight. The weight of the fiber (FY) and stick (SY) was then weighed and recorded in kilograms per plot. These measurements were later converted to metric tons per hectare (t ha^{-1}) for further analysis and comparison.

2.4.3 Fiber quality data

Following the harvest of the crop and the collection of the dry fiber, an analysis is performed at BJRI laboratories to assess several characteristics of fiber quality, including bundle strength, fineness, and brightness.

2.5 Economic analysis

An economic assessment was carried out to analyze the cost-effectiveness of different herbicidal techniques, utilizing the methodologies suggested by Hussain et al. (2008) and Parvez et al. (2013). The researchers posited that six rounds of manual weeding, requiring around 106 workers, would be adequate to maintain weed-free crop plots throughout the growing period.

$$\text{SDR of a weed species} = \frac{\text{Relative density (RD)} + \text{Relative Dry Matter (RDM)}}{2} \quad \text{(Equation 1)}$$

$$\text{Where, RD} = \frac{\text{Density of a specific weed species}}{\text{Total weed density}} \times 100 \quad \text{(Equation 2)}$$

$$\text{RDM} = \frac{\text{Dry matter of a specific weed species}}{\text{Total weed dry matter}} \times 100 \quad \text{(Equation 3)}$$

$$\text{NR (Tk ha}^{-1}) = \text{Gross Return (Tk ha}^{-1}) - \text{Total Cost of Production (Tk ha}^{-1}) \quad \text{(Equation 4)}$$

$$\text{BCR} = \frac{\text{Gross Return (Tk/ha)}}{\text{Total Cost of Production (Tk/ha)}} \quad \text{(Equation 5)}$$

Where: BCR indicates Benefit-Cost Ratio; NR, Net Return; TK, Taka; ha, Hectare.

Each laborer was paid a daily wage of 400 taka, with jute fiber and sticks priced at 55 taka and 5 taka per kilogram, respectively. The net return (NR) was computed by deducting the total expenses (inclusive of fixed costs and weed management expenditures) from the gross income (GI) (Equation 4). The benefit-cost ratio (BCR), gross return divided by total cost, was calculated using the equation (5) provided by Hasan et al. (2002), which represents the returns in taka per unit of investment.

2.6 Statistical analysis

The data were subjected to an analysis of variance (ANOVA) to compare means, employing a protected least significant difference (LSD) test at a 5% level of significance. The Statistical Analysis System (SAS 9.1) software was used to perform the ANOVA. To address data normalization, a square root transformation was applied to weed dry weight and density data before analysis. Furthermore, a principal component analysis (PCA) was conducted on weed dry matter data using the 'FactoMineR' and 'factoextra' packages in R. This multivariate analysis aimed to evaluate the effectiveness of different weed management strategies and to identify patterns in weed community responses.

3. Results

3.1 Weed species diversity and dominance at thirty DAS in jute

In the study of *Corchorus olitorius*, a total of twelve weed species were identified at thirty days after sowing (DAS). Among these, nine species were classified as annuals while three were perennials, as detailed in Table 1. The identified species included four broadleaf weeds (1-4), seven grass species (5-11), and one sedge (12). Specifically, seven of the weeds were categorized under the Poaceae family, two under Euphorbiaceae, and the remaining species belonged to the Cyperaceae, Solanaceae, and Asteraceae families.

The study results indicated that *Cyperus rotundus* had the highest RD at 55.03% and RDM at 51.42%. Despite the low presence of *Physalis heterophylla* at an RD of 1.15%, it had the fourth highest RDM at 5.66% (Refer to Table 1). *Cyperus rotundus* was identified as the most dominant species with an SDR of 53.22%, while *Digitaria sanguinalis* was the second most common weed in the area at 9.98%. The next five prevalent weed species after *Digitaria sanguinalis* were *Echinicloa colonum* (9.55%), *Eleosine indica* (5.04%), *Phyllanthus niruri* (4.08%), *Physalis heterophylla* (3.40%), and *Paspalum distichum* (2.97%), as illustrated in Table 1. The study findings highlighted that *Paspalum comersoni* had the lowest SDR at 0.82% among the various weeds observed in the experimental site. Subsequent investigation revealed that sedges had the highest SDR at 53.22%, outperforming grass at 36.18% and broadleaves at 10.60%, as depicted in Table 1.

3.2 Interaction effect between seed rate and line spacing on weed density (WD) in jute

The density of weeds in the jute field was significantly influenced by the combined effects of seed rate and line-to-line spacing, as detailed in Table 2. Among the different weed species found in the tossa jute field, *Cyperus rotundus* had the highest weed density at 372.56 m^{-2}, followed by *Echinochloa colonum* at 78.67 m^{-2}, *Digitaria sangiunalis* at 71.67 m^{-2}, *Eleusine indica* at

Table 1. Identification of weed species in a jute field at 30 DAS, including family, life cycle, types, density, and dry matter.

Sl	Local Name	Weeds with Scientific name	Family name	Weed type/Life cycle	Density (m^{-2})	Dry matter ($g\ m^{-2}$)	RD (%)	RDM (%)	SDR (%)
1.	Foskabegun	*Physalis heterophylla*	Solanaceae	BA	7.78	13.97	1.15	5.66	3.40
2.	Helencha	*Enhydra fluctuans*	Asteraceae	BA	3.30	3.07	0.49	1.24	0.87
3.	Hajardana	*Phyllanthus niruri*	Euphorbiaceae	BP	20.84	12.56	3.08	5.09	4.08
4.	Sotododhia	*Euphorbia microphylla*	Euphorbiaceae	BA	14.24	5.90	2.10	2.39	2.25
5.	Shialleza	*Setaria viridis*	Poaceae	GA	20.86	6.92	3.08	2.81	2.94
6.	Goicha	*Paspalum comersoni*	Poaceae	GA	5.00	2.22	0.74	0.90	0.82
7.	Khudeshama	*Echinochloa colonum*	Poaceae	GA	78.67	18.46	11.62	7.48	9.55
8.	Angulighas	*Digitaria sanguinalis*	Poaceae	GA	71.67	23.11	10.58	9.37	9.98
9.	Chapra	*Eleosine indica*	Poaceae	GA	33.67	11.81	4.97	4.78	4.88
10.	Durbaghas	*Cynodon dactylon*	Poaceae	GP	32.67	12.97	4.82	5.26	5.04
11.	Gitlaghash	*Paspalum distichum*	Poaceae	GA	15.81	8.87	2.34	3.60	2.97
12.	Mutha	*Cyperus rotundus*	Cyperaceae	SP	372.56	126.86	55.03	51.42	53.22
	Total				677.06	246.72	100	100	100

Note: G, Grass; S, Sedge; B, Broadleaf; P, Perennial; A, Annual; RD, Relative density; RDM. Relative Dry Matter and SDR, Summed Dominance Ratio

33.67 m^{-2}, *Cynodon dactylon* at 32.67 m^{-2}, *Setaria viridis* at 20.86 m^{-2}, and so forth. Conversely, the lowest weed density was observed in *Paspalum comersonii* at 5.00 m^{-2} when the seed rate and line to line spacing were 4 kg ha^{-1} × 30 cm. Specifically for *Cyperus rotundus*, the highest weed density was seen under the interaction of seed rate and line to line spacing of 4 kg ha^{-1} × 30 cm, followed by 4 kg ha^{-1} × 25 cm at 320.67 m^{-2}, 4 kg ha^{-1} × 20 cm at 295.67 m^{-2}, 4 kg ha^{-1} × 15 cm at 280.67 m^{-2}, and 5 kg ha^{-1} × 30 cm at 271 m^{-2}. The lowest weed density of *Cyperus rotundus* was recorded at the interaction of seed rate and line-to-line spacing of 8 kg ha^{-1} × 15 cm, with a density of 122.67 m^{-2}. Similar patterns were observed for all other weed species in response to the interaction of seed rate and line-to-line spacing, as previously mentioned in this study.

Table 2. Interaction effect between seed rate and line spacing on weed density (m^{-2}) at 30 days after sowing in jute.

S × L	Cyperus rotundus	Echinochloacolonum	Digitariasanguinalis	Eleosine indica	Cynodon dactylon	Paspalum distichum	Physalis heteropfylla	Enhydra lactuans	Phyllanthus niruri	Setariaviridis	Euphorbia microphylla	Paspalum comersonii
S_1 L_1	280.67d	68.67d	52.11d	27.33c	26.67bc	11.12d	6.00c	2.39bc	15.15d	18.58c	10.31cd	3.85ab
S_1 L_2	295.67c	72.33c	57.44c	28.67c	28.07b	12.77c	6.33c	2.52bc	17.63c	19.70b	11.51bc	3.97ab
S_1 L_3	320.67b	74.67b	61.78b	32.00b	31.45a	14.02b	7.00b	2.91ab	18.67b	19.99ab	12.63ab	4.09ab
S_1 L_4	372.56a	78.67a	71.6a	33.67a	32.67a	15.81a	7.78a	3.30a	20.84a	20.86a	14.24a	5.00a
S_2 L_1	227.78h	63.67gh	36.71h	20.00f	22.08e-g	6.33g	4.22ef	1.52de	6.47h	14.81f	7.40fg	3.34a-d
S_2 L_2	241.33g	65.00fg	40.74g	22.67e	23.91de	7.67f	4.33ef	1.52de	7.75g	15.87e	7.47f	3.41a-d
S_2 L_3	254.33f	66.00ef	42.79f	24.00de	24.54c-e	8.75e	4.70e	1.52de	8.90f	17.53d	8.09ef	3.54a-c
S_2 L_4	271.00e	66.89e	48.00e	25.33d	25.75b-d	9.54e	5.33d	1.93cd	11.38e	18.41cd	9.36de	3.71ab
S_3 L_1	192.00jk	55.33k	23.01l	13.67hi	18.89hi	4.89hi	3.89f	0.73fg	4.07kl	7.24i	4.66hi	2.28a-d
S_3 L_2	199.67j	58.33j	26.67k	14.33h	20.00g-i	5.00hi	4.00f	0.99ef	4.30jk	10.52h	5.67gh	2.48a-d
S_3 L_3	211.67i	60.00i	28.70j	16.67g	21.33f-h	5.33h	4.00f	1.44de	5.07ij	12.85g	6.61fg	2.58a-d
S_3 L_4	222.33h	63.00h	32.71i	18.67f	22.89ef	5.67gh	4.00f	1.52de	5.93hi	14.67f	6.95fg	3.33a-d
S_4 L_1	160.89mn	41.67o	17.33no	11.67jkl	15.33jk	4.00jk	1.48i	0.00h	2.28n	3.75lm	2.33k-m	2.00b-d
S_4 L_2	165.11m	45.33n	18.41n	12.00jk	16.00jk	4.00jk	2.33h	0.33gh	2.41n	3.97kl	2.67j-l	2.00b-d
S_4 L_3	178.22l	48.33m	19.00mn	12.67ij	16.0 jk	4.00jk	3.00g	0.67fg	2.73mn	4.75jk	3.67i-k	2.11b-d
S_4 L_4	183.78kl	52.33l	20.47m	13.00hij	17.78ij	4.44ij	3.22g	0.67fg	3.35lm	5.60j	4.33h-j	2.78a-d
S_5 L_1	122.67q	30.00s	12.44q	8.33n	4.44n	3.22k	0.78j	0.00h	1.94n	1.95o	0.33n	0.67d
S_5 L_2	134.67p	32.00r	14.40p	9.00mn	8.22m	3.44k	1.00ij	0.00h	2.07n	2.08o	0.67mn	0.84cd
S_5 L_3	145.22o	34.67q	15.00p	10.33lm	12.00l	3.93jk	1.00ij	0.33gh	2.19n	2.40no	1.67l-n	1.33b-d
S_5 L_4	156.56n	37.67p	16.00op	10.65kl	14.22kl	4.00jk	1.22ij	0.33gh	2.22n	3.02mn	2.00k-n	2.00b-d
$LSD_{0.05}$	8.538	1.430	1.746	1.488	2.472	0.816	0.524	0.620	0.862	0.905	1.772	2.773
CV (%)	2.38	1.55	3.22	4.94	7.44	7.16	8.38	30.44	7.18	5.01	17.49	60.64

Note: In a column, means with the same letter do not differ significantly according to DMRT. S = Seed rate (kg ha^{-1}); L = Line to line spacing (cm); S_1 = 4 kg ha^{-1}, S_2 = 5 kg ha^{-1}, S_3 = 6 kg ha^{-1}, S_4 = 7 kg ha^{-1}, and S_5 = 8 kg ha^{-1}; L_1 = 15 cm, L_2 = 20 cm, L_3 = 25 cm and L_4 = 30 cm.

Table 3. Interaction effect between seed rate and line spacing on weed dry matter (g m^{-2}) at 30 days after sowing in jute

S × L	Cyperus rotundus	Echinochloacolonum	Digitaria sanguinalis	Eleosine indica	Cynodondactylon	Paspalum distichum	Physalis heteropfylla	Enhydra flactuans	Phyllanthus niruri	Setariaviridis	Euphorbia microphylla	Paspalum comersonii
S_1 L_1	95.63d	15.96d	16.94d	9.56c	10.42bc	6.21d	11.34c	2.12b-d	8.85d	5.73c	4.20cd	1.68a-c
S_1 L_2	100.51c	17.06c	18.53c	10.01c	11.20b	7.08c	12.06bc	2.26bc	6.89c	6.48b	4.73bc	1.81ab
S_1 L_3	108.98b	17.53b	19.93b	11.15b	12.39a	7.91b	13.00b	2.59ab	11.17b	6.68ab	5.17ab	1.88ab
S_1 L_4	126.86a	18.46a	23.11a	11.81a	12.97a	8.87a	13.97a	3.07a	12.56a	6.92a	5.90a	2.22a
S_2 L_1	77.23g	14.87f	11.76h	6.95f	8.71fg	3.55g	7.81ef	1.41ef	3.72h	5.09de	3.03fg	1.54a-d
S2 L_2	82.50f	15.33e	13.15g	7.98e	9.43d-f	4.34f	7.81ef	1.52e	4.73g	5.33d	3.24e-g	1.64a-d
S2 L_3	85.58e	15.65de	13.75f	8.39de	9.86c-e	4.90e	8.48e	1.57de	5.41f	5.84c	3.47d-f	1.76a-c
S_2 L_4	93.11d	15.80d	15.34e	8.86d	10.31b-d	5.37e	9.84d	1.80c-e	6.89e	6.47b	3.87de	1.86ab
S_3 L_1	65.60ij	12.99i	7.37l	4.76hi	7.46h	2.75hi	7.26f	0.70g	2.35jk	2.46h	2.01hi	1.09a-d
S_3 L_2	68.12i	13.78h	8.58k	5.04h	7.97gh	2.80hi	7.55ef	0.90fg	2.58j	3.57g	2.45gh	1.21a-d
S_3 L_3	71.94h	14.18g	9.17j	5.85g	8.54fg	3.00h	7.65ef	1.36ef	3.13i	4.24f	2.92fg	1.27a-d
S_3 L_4	76.17g	14.87f	10.46i	6.500f	9.20ef	3.17gh	7.69ef	1.55de	3.43hi	4.84e	3.21e-g	1.55a-d
S_4 L_1	54.59lm	9.86m	5.58op	4.07jk	6.15j	2.25j-l	2.80i	0.00h	1.31m	1.26kl	1.03j-l	0.98a-d
S_4 L_2	56.28l	10.64l	5.98no	4.23jk	6.49ij	2.27j-l	4.41h	0.32gh	1.50m	1.35jk	1.18jk	1.00a-d
S_4 L_3	60.73k	11.42k	6.18mn	4.44ij	6.45ij	2.28j-l	5.66g	0.67g	1.67lm	1.60j	1.55i-k	1.05a-d
S_4 L_4	63.05jk	12.21j	6.58m	4.56h-j	7.19hi	2.54ij	5.98g	0.66g	2.07kl	1.96i	1.80h-j	1.37a-d
S_5 L_1	41.89p	7.04q	3.99s	2.95n	1.80m	1.82l	1.50j	0.00h	1.18m	0.69n	0.17m	0.36d
S_5 L_2	45.49o	7.52p	4.58r	3.16mn	3.32l	1.98kl	1.89ij	0.00h	1.30m	0.73mn	0.37lm	0.46cd
S_5 L_3	49.73n	8.14o	4.84qr	3.48lm	4.88k	2.25j-l	1.93ij	0.33gh	1.41m	0.82mn	0.76k-m	0.69b-d
S_5 L_4	53.32m	8.94n	5.18pq	3.78kl	5.73jk	2.28jk	2.33ij	0.35gh	1.52m	1.03lm	1.01j-l	0.99a-d
$LSD_{0.05}$	2.904	0.337	0.562	0.521	0.981	0.458	0.959	0.595	0.513	0.306	0.793	1.307
CV (%)	2.38	1.55	3.22	4.94	7.40	7.14	8.23	31.22	7.10	5.07	18.43	59.83

Note: In a column, means with the same letter do not differ significantly according to DMRT. S = Seed rate (kg ha^{-1}) and L = Line to line spacing (cm); S_1 = 4 kg ha^{-1}, S_2 = 5 kg ha^{-1}, S_3 = 6 kg ha^{-1}, S_4 = 7 kg ha^{-1}, and S_5 = 8 kg ha^{-1}; L_1 = 15 cm, L_2 = 20 cm, L_3 = 25 cm and L_4 = 30 cm

3.3 Interaction effect between seed rate and line spacing on weed dry matter (WDM) in jute

The dry matter content of different weed species in the jute field was significantly impacted by the combined effects of seed rate and line-to-line spacing, as detailed in Table 3. Among the weed species grown in jute fields, *Cyperus rotundus* showed the highest dry matter content (126.86 g m^{-2}), followed by *Digitaria sangiunalis* (23.11 g m^{-2}), *Echinochloa colonum* (18.46 g m^{-2}), *Physalis heterophylla* (13.97 g m^{-2}), *Cynodon dactylon* (12.97 g m^{-2}), *Phyllanthus niruri* (12.56 g m^{-2}), *Eleosine indica* (11.81 g m^{-2}), *Paspalum distichum* (8.87 g m^{-2}), and so forth. Conversely, *Paspalum comersonii* had the lowest dry matter content (2.22 g m^{-2}) at the seed rate and line-to-line spacing combination of 4 kg ha^{-1} × 30 cm. For *Cyperus rotundus*, the highest dry matter content was observed at the seed rate and line-to-line spacing combination of 4 kg ha^{-1} × 30 cm (108.98 g m^{-2}), followed by 4 kg ha^{-1} × 25 cm (100.51 g m^{-2}), 4 kg ha^{-1} × 20 cm (95.63 g m^{-2}), 4 kg ha^{-1} × 15 cm (93.11 g m^{-2}), and 5 kg ha^{-1} × 30 cm (41.89 g m^{-2}) had the lowest weed density for *Cyperus rotundus*. Similar patterns were noted for other weed species to the interaction of seed rate and line-to-line spacing, as previously mentioned in this section.

3.4 Interaction effect of seed rate and line spacing on yield attributes, yield and fiber quality of *Corchorus olitorius* jute

The data presented in Table 4 offers a comprehensive overview of the characteristics and attributes of the plant under study. These factors include plant population, height, base-diameter, fiber yield, bundle strength, fineness, brightness, and stick yield. Plant population refers to the number of plants per unit area, which can have an impact on overall yield and growth patterns. Height and base diameter are important indicators of plant health and maturity, with taller plants typically indicating better growth conditions. Fiber yield is a crucial measure for evaluating the quantity of usable fiber that can be obtained from the plant, while bundle strength measures the durability and resilience of the fibers. Fineness and brightness are qualities that can affect the overall quality and marketability of the fibers produced.

3.4.1 Plant population

Plant population was significantly affected in the case of the interaction between seed rate and line-to-line spacing in jute (Table 4). The highest plant population was observed at the interaction between seed rate and line to line spacing 8 kg ha^{-1} × 15 cm (58.0 plant m^{-2}) followed by 8 kg ha^{-1} × 20 cm (57.03 plant m^{-2}), 8 kg ha^{-1} × 25 cm (57.29 plant m^{-2}), 8 kg ha^{-1} × 30 cm (55.11 plant m^{-2}), 7 kg ha^{-1} × 15 cm (53.02 plant m^{-2}) and the lowest plant population was found at the interaction 4 kg ha^{-1} × 30 cm (33.25 plant m^{-2}).

3.4.2 Plant height

Plant height and plant base diameter were significantly affected in the case of the interaction of seed rate and line-to-line spacing in jute (Table 4). The highest plant height was observed at the interaction between seed rate and line to line spacing 7 kg ha^{-1} × 20 cm (3.31 m) followed by 7 kg ha^{-1} × 25 cm (3.28 m), 7 kg ha^{-1} × 30 cm (3.24 m), 7 kg ha^{-1} × 15 cm (3.23 m), 7 kg ha^{-1} × 15 cm (3.21 m) and the lowest plant height were found at the interaction 4 kg ha^{-1}× 15 cm (2.40 m).

Table 4. Interaction effect of seed rate and line spacing on yield attributes, yields and fiber quality of tossa jute.

Seed rate × Line spacing		Plant population (m^{-2})	Plant height (m)	Base diameter (mm)	Fiber yield(t ha^{-1})	Stick yield(t ha^{-1})	Bundle strength (lb mg^{-1})	Fineness (µ)	Brightness (%)
4 kg ha^{-1}	15 cm	36.07 q	2.40 n	16.24 c	2.44 m	4.79 m	7.67 l	23.25 c	41.04 d
	20 cm	35.00 r	2.69 k	16.53 b	2.87 j	5.65 j	7.44 m	23.54 b	43.51 a
	25 cm	34.33 s	2.57 l	16.73 b	2.66 k	5.20 k	7.17 n	23.91 a	42.38 b
	30 cm	33.25 t	2.53 m	17.09 a	2.55 l	5.01 l	7.03 o	24.05 a	41.72 c
5 kg ha^{-1}	15 cm	43.21 m	2.91 j	14.27 e	2.93 ij	5.75 ij	7.95 ij	22.06 e	37.65 g
	20 cm	42.27 n	2.99 h	14.52 d	3.05 fg	5.99 fg	7.90 j	22.16 e	38.84 e
	25 cm	41.30 o	2.96 i	14.58 d	3.02 gh	5.93 gh	7.81 k	22.47 d	38.30 f
	30 cm	40.24 p	2.94 i	14.66 d	2.97 hi	5.84 hi	7.75 k	22.61 d	37.96 fg
6 kg ha^{-1}	15 cm	48.14 i	3.07 g	13.36 f	3.08 fg	6.07 f	8.37 g	20.33 gh	35.63 i
	20 cm	47.10 j	3.12 f	13.40 f	3.18 d	6.27 d	8.33 g	20.52 g	36.48 h
	25 cm	46.43 k	3.11 f	13.43 f	3.16 de	6.22 de	8.17 h	21.26 f	36.11 hi
	30 cm	45.59 l	3.09 g	13.48 f	3.10 ef	6.11 ef	8.02 i	21.36 f	35.90 i
7 kg ha^{-1}	15 cm	53.02 e	3.23 cd	12.19 j	3.22 cd	6.34 cd	8.80 d	18.77 j	30.30 l
	20 cm	52.48 f	3.31 a	12.79 i	3.34 a	6.58 a	8.71 e	19.06 i	34.29 j
	25 cm	51.11 g	3.28 b	13.15 h	3.30 ab	6.50 ab	8.52 f	20.19 h	33.36 k
	30 cm	50.12 h	3.24 c	13.44 g	3.26 bc	6.42 bc	8.45 f	20.29 h	30.57 l
8 kg ha^{-1}	15 cm	58.00 a	3.17 e	9.23 n	1.90 p	3.81 p	9.07 a	17.72 m	26.35 p
	20 cm	57.03 b	3.21 d	9.94 m	2.31 n	4.52 n	8.97 b	18.07 l	28.48 m
	25 cm	56.29 c	3.19 e	10.25 l	2.15 o	4.20 o	8.92 bc	18.39 k	27.98 n
	30 cm	55.11 d	3.18 e	10.74 k	1.95 p	3.82 p	8.86 cd	18.58 jk	27.08 o
$LSD_{0.05}$		0.526	0.019	0.232	0.067	0.132	0.077	0.209	0.496
CV (%)		0.69	0.38	1.06	1.45	1.44	0.57	0.60	0.85

Note: In a column, means with the same letter do not differ significantly according to DMRT.

3.4.3 Plant base diameter

Plant base diameter significantly responded in case of the interaction between seed rate and line-to-line spacing in jute (Table 4). The highest base diameter was observed at the interaction between seed rate and line to line spacing 4 kg ha^{-1} × 30 cm (17.09 mm) followed by 4 kg ha^{-1} × 25 cm (16.73 mm), 4 kg ha^{-1} × 20 cm (16.53 mm) and the lowest was at 4 kg ha^{-1} × 15 cm (16.24 mm), 5 kg ha^{-1} × 30 cm (14.66 mm) and the lowest b ase diameter was observed interaction between seed rate and line to line spacing 8 kg ha^{-1} × 15 cm (9.23 mm).

3.4.4 Fiber yield

Fiber yield of jute was significantly responded due to different seed rates and line-to-line spacing interaction (Table 4). The highest fiber yield was recorded at the interaction between seed rate and line to line spacing 7 kg ha^{-1} × 20 cm (3.34 t ha^{-1}) followed by 7 kg ha^{-1} × 25 cm (3.30 t ha^{-1}), 7 kg ha^{-1} × 30 cm (3.26 t ha^{-1}), 7 kg ha^{-1} × 15 cm (3.22 t ha^{-1}), 6 kg ha^{-1} × 20 cm (3.18 t ha^{-1}) and the lowest fiber yield was found at the interaction between seed rate and line to line spacing 8 kg ha^{-1} × 15 cm (1.90 t ha^{-1}).

3.4.5 Stick yield

Stick yield of jute was significantly affected due to different seed rates between line-to-line spacing interaction (Table 4). The highest stick yield was recorded at the interaction of seed rate with line to line spacing 7 kg ha^{-1} × 20 cm (6.58 t ha^{-1}) which were followed by 7 kg ha^{-1} × 25 cm (6.50 t ha^{-1}), 7 kg ha^{-1} × 30 cm (6.42 t ha^{-1}), 7 kg ha^{-1} × 15 cm (6.34 t ha^{-1}), 6 kg ha^{-1} × 20 cm (6.27 t ha^{-1}) and the lowest stick yield was found at the interaction between seed rate and line to line spacing 8 kg ha^{-1} × 15 cm (3.81 t ha^{-1}).

3.4.6 Fiber bundle strength

Bundle strength was significantly reflected based on the interaction between seed rates and line-to-line spacing of jute (Table 4). The highest bundle strength was observed at the interaction of seed rate with line to line spacing 8 kg ha^{-1} × 15 cm (9.07 lb mg^{-1}) followed by 8 kg ha^{-1} × 20 cm (8.97 lb mg^{-1}), 8 kg ha^{-1} × 25 cm (8.92 lb mg^{-1}), 8 kg ha^{-1} × 30 cm (8.86 lb mg^{-1}), 7 kg ha^{-1} × 15 cm (8.80 lb mg^{-1}) and the lowest bundle strength was recorded at 4 kg ha^{-1} × 30 cm (7.03 lb mg^{-1}).

3.4.7 Fiber fineness

Fineness was significantly affected based on the interaction between seed rates and line-to-line spacing of jute (Table 4). The highest fineness was found at the interaction of seed rate with line to line spacing 4 kg ha^{-1} × 30 cm (24.05 µ) followed by 4 kg ha^{-1} × 25 cm (23.91 µ), 4 kg ha^{-1} × 20 cm (23.54 µ), 4 kg ha^{-1} × 15 cm (23.25 µ), 5 kg ha^{-1} × 30 cm (22.61 µ) and the lowest fineness was found at 8 kg ha^{-1} × 15 cm (17.72 µ).

3.4.8 Fiber brightness

Brightness was affected significantly due to the interaction between seed rates and line to line spacing of jute (Table 4). The highest brightness was found at the interaction between seed rate and line-to-line spacing 4 kg ha^{-1} × 20 cm (43.51%) followed by 4 kg ha^{-1} × 25 cm (42.38%), 4 kg ha^{-1} × 30 cm (41.72%), 4 kg ha^{-1} × 15 cm (41.04%), 5 kg ha^{-1} × 20 cm (38.84%) and the lowest brightness was found at the interaction between seed rate and line to line spacing 8 kg ha^{-1} × 15 cm (26.35%).

3.5 Economic assessment in response to the interaction of seed rate and line spacing in *Corchorus olitorius* jute

From the economic analysis of this experiment in response to interaction of seed rate and line spacing, it was found that among all the treatments the highest gross return (GR) and BCR was recorded in response to interaction between seed rate and line spacing 7 kg ha^{-1} × 20 cm (GR 215050 Tk ha^{-1} and BCR 1.64) followed by 7 kg ha^{-1} × 25 cm (GR 212600 Tk ha^{-1} and BCR 1.62), 7 kg ha^{-1} × 30 cm (GR 209956 Tk ha^{-1} and BCR 1.60), 7 kg ha^{-1} × 15 cm (1.58). The lowest gross income and BCR were observed at the interaction between 8 kg ha^{-1} × 15 cm (GR 126533 Tk ha^{-1} and BCR 0.96) (Table 5).

Table 5. Economic assessment of several weed control treatments in *Corchorus olitorius.*

Treatment	FY (kg ha^{-1})	FP (Tk ha^{-1})	SY (kg ha^{-1})	SP (Tk ha^{-1})	GI (Tk ha^{-1})	TC (Tk ha^{-1})	NR (Tk ha^{-1})	BCR (Tk ha^{-1})
	1	2	3	4	5 (2+4)	6	7 (5-6)	8(5/6)
$S_1 L_1$	2437	134017	4793	23967	157983	130530	27453	1.21
$S_1 L_2$	2873	158033	5647	28233	186267	130530	55737	1.43
$S_1 L_3$	2660	146300	5197	25983	172283	130530	41753	1.32
$S_1 L_4$	2550	140250	5007	25033	165283	130530	34753	1.27
$S_2 L_1$	2932	161272	5753	28767	190039	130751	59288	1.45
S2 L_2	3050	167750	5993	29967	197717	130751	66966	1.51
S2 L_3	3018	165978	5927	29633	195611	130751	64860	1.50
$S_2 L_4$	2969	163289	5840	29200	192489	130751	61738	1.47
$S_3 L_1$	3084	169644	6337	31683	201328	130972	70356	1.54
$S_3 L_2$	3183	175083	6577	32883	207967	130972	76995	1.59
$S_3 L_3$	3160	173800	6497	32483	206283	130972	75311	1.58
$S_3 L_4$	3103	170683	6424	32122	202806	130972	71834	1.55
$S_4 L_1$	3220	177100	6069	30344	207444	131193	76251	1.58
$S_4 L_2$	3340	183700	6270	31350	215050	131193	83857	1.65
$S_4 L_3$	3300	181500	6220	31100	212600	131193	81407	1.62
$S_4 L_4$	3262	179422	6107	30533	209956	131193	78763	1.60
$S_5 L_1$	1600	88000	3100	15500	103500	131414	- 27914	0.79
$S_5 L_2$	2310	127050	4520	22600	149650	131414	18236	1.14
$S_5 L_3$	2150	118250	4200	21000	139250	131414	7836	1.06
$S_5 L_4$	1953	107433	3820	19100	126533	131414	-4881	0.96

Note: S = Seed rate (kg ha^{-1}) & L = Line to line spacing (cm); S_1 = 4 kg ha^{-1}, S_2 = 5 kg ha^{-1}, S_3 = 6 kg ha^{-1}, S_4 = 7 kg ha^{-1}, & S_5 = 8 kg ha^{-1}; L_1 = 15 cm, L_2 = 20 cm, L_3 = 25 cm and L_4 = 30 cm; FY = Fiber yield, FP = Fiber price, SY = Stick yield, SP = Stick price, GI = Gross income, TC = Total cost, NR = Net Return, BCR = Benefit-Cost Ratio. Calculation was done as per labor wedges @ 400 Tk/person/day (Probidhi, 2016)

4. Discussion

According to Rana and Rana (2016), Jute is typically cultivated from April to September. The warm and humid weather conditions, as well as the wet soil during the sowing period, are conducive to uniform germination and the abundant growth of weeds. Heavy weed infestation is a common occurrence in jute fields. Tossa jute, in particular, cannot withstand stagnant water, so it is grown on high land with seeds sown from mid-April to mid-May. The weeds that tend to germinate profusely with this crop in the uplands in April-May include *Cyperus rotundus, Echinochloa colona, Cynodon dactylon, Eleucine indica, Leptochloa chinensis*, and a few broad-leaved weeds such as *Amaranthus spinosus, Amaranthus viridis, Euphorbia hirta*, and *Portulaca oleracea* (Mishra et al*.,* 1998). Recent studies have also identified these species as prevalent weeds in various crop fields across Bangladesh and other regions, underscoring their widespread occurrence and impact on crop production (Kobir et al., 2021; Saif et al., 2023; Islam, 2014).

The researchers noted that among 129 species categorized into 99 genera or 39 families, 27 species exhibited significant levels of infestation in jute fields, influenced by various agronomic conditions. In the fields of *Corchorus olitorius*, 19 weed species competed aggressively with the jute crop, demonstrating superior growth and occupying more space than the jute plants themselves. The identified species included: Dicotyledons such as *Allernanthra sasillis* (Compositae), *Amaranthus spinosus* (Amaranthaceae), *Enhydra fluctuans* (Compositae), *Leucas aspera* (Lamiaceae), *Mimosa pudica* (Mimosaceae), and *Portulaca quadrifida* (Portulacaceae). Monocotyledons included *Cynodon dactylon* (Gramineae) and *Cyperus iria* (Cyperaceae) (Mishra et al*.,* 1998). A similar pattern of weed presence was observed in this study. Previous research has indicated that enhancing weed suppression can be achieved by reducing crop row spacing or increasing crop density, resulting in a more uniform growth pattern even in the absence of weed pressure. Research has indicated that narrower row spacing can effectively suppress weeds in wheat (Drews et al*.,* 2009) and rice (Chauhan and Johnson, 2011). A similar pattern was observed with other weed species. The findings of this study align with those of Islam et al. (2021) and Karimi et al. (2021). In densely populated crops, weed species struggle to obtain adequate space, light, air, water, and a conducive environment for optimal growth, resulting in a reduced number of weeds and lower dry matter due to the increased seed rate. This trend was consistent across all other weed species examined. Islam et al. (2014) noted that competition between crops and weeds significantly impacts sesame seed yield, highlighting that seed rates notably influence weed populations.

The highest weed density and dry matter were recorded at the lowest seed rate of 6 kg ha^{-1}, while the highest seed rate of 10 kg ha^{-1} resulted in the lowest weed density and dry matter (Islam et al*.,* 2014). These findings are also consistent with those of Hossain et al. (2003). The lower density of weed infestation in areas with a higher seed rate can be attributed to several factors. According to Guillermo et al. (2009), higher plant densities can provide a competitive advantage over weeds due to fast canopy development. Additionally, a higher seeding rate may help control weed flora through a smothering effect, as suggested by Mahajan et al. (2010). Mohler (1996) also found that a higher seeding rate can give crop plants a competitive advantage over weeds by allowing them to absorb limited resources more quickly. However, it's important to note that an increased seeding rate may not always enhance weed competitiveness and could lead to greater intra-crop competition, potentially impacting crop production, especially under stressful environmental conditions (Krikland et al*.,* 2000). Therefore, the findings of the present study align with these observations. It's also worth noting that planting date and plant population are often determined by factors other than weed management, such as agronomic studies focused on achieving the best yield. Increasing the density of crop plants can lead to a decrease in weed growth and density, as demonstrated by Rana and Rana (2016). They observed that with 25 cm rows, the higher seeding rate resulted in lower yield loss from weeds, and this trend continued until the rows were 102 cm wide. The populations of crop plants are influenced by the row-spacings required for planting, cultivating, and harvesting machines.

The correlation between seed rate and yield-related characteristics has been found to closely align with various existing research findings (Zhao et al*.,* 2007; Lin et al*.,* 2009). El-Kady et al. (2009) observed that increasing the seed rate of jute led to higher plant population and plant height, but a decrease in base diameter. This could be attributed to the high seeding rate creating intense competition among plants for moisture, nutrients, and light. The trend of the results was consistent with growth, yield, and yield components, which is in line with the findings of Nayyar et al. (1983), Idris (1989), Mishra et al. (1998), Bandyopadhyay et al. (1991), El-Gazzar (2001a and 2001b), Masum et al. (2011), and Ghorai and Chakraborty (2020). Despite the higher plant population at a seed rate of 8 kg ha^{-1}, the plant height and base diameter did not favor increased yields. The plant populations and base diameter at 8 kg ha^{-1} were less than at 7 kg ha^{-1}. The highest fiber and stick yield were observed at a seed rate of 7 kg ha^{-1}, suggesting that this may be the optimal seed rate for tossa jute. According to Islam et al. (2014), seed rate significantly influences sesame yield, which is associated with weed competition and the overall performance of the crop. Yield increased with seed rates up to 9 kg ha^{-1} before declining (Islam et al. 2014). This pattern was consistent with the trends observed in growth, yield, and yield components. These results align with the findings of Nayyar et al. (1983), Idris (1989), Mishra et al. (1998), Bandyopadhyay et al. (1991), and El-Gazzar (2001a and 2001b), as well as Masum et al. (2011). Table 4 illustrates that bundle strength, fineness, and brightness were significantly influenced by the seed rate of tossa jute, with the highest bundle strength recorded at a seed rate of 8 kg ha^{-1}, followed by 7, 6, 5, and 4 kg ha^{-1}. When the strength of the bundle increased, the quality of the jute fiber improved. Conversely, a decrease in bundle strength resulted in lower quality fiber. Additionally, the fineness of the fiber was also an important quality characteristic. The finest fiber was obtained at a seed rate of 4 kg ha^{-1}, followed by 5, 6, 7, and 8 kg ha^{-1}. It was noted that the lower fineness corresponded to better quality fiber.

Furthermore, the treatment with the highest seed rate (8 kg ha^{-1}) produced the finest fiber, indicating better quality compared to coarse fiber. Brightness was also identified as a crucial quality characteristic for attracting clients. The highest brightness was achieved at a seed rate of 4 kg ha^{-1}, followed by 5, 6, 7, and 8 kg ha^{-1}. These findings were consistent with those reported by El-Kady et al. (2009) and other researchers such as Nayyar et al. (1983), Idris (1989), Mishra et al. (1998), Bandyopadhyay et al. (1991), and El-Gazzar (2001a and 2001b). The plant population was highest at a line spacing of 15 cm (47.69 m^{-2}), with the next highest populations found at 20 cm, 25 cm, and the lowest at 30 cm. The tallest plants were observed at a line spacing of 20 cm, followed by 25 cm, 30 cm, and the shortest at 15 cm. The largest base diameter was seen at a line spacing of 30 cm, followed by 25 cm, 20 cm, and the smallest at 15 cm. Fiber and stick yields were highest at a line spacing of 20 cm, followed by 25 cm, 30 cm, and the lowest at 15 cm. These findings align with those of Karimi et al. (2021), as narrower line spacing resulted in higher plant populations and taller plants due to the limited growing space, while wider spacing led to decreased plant height but increased base diameter. The highest base diameter in the field was found to result from maximum line spacing. Islam et al. (2014) observed that the tallest plant and highest plant population were found at the lowest spacing, while the shortest plant and lowest plant population were found at higher spacing. This led to maximum yield, attributed to dense plant population with moderately higher plant height. El-Kady et al. (2009) noted that decreasing the line spacing of jute increased plant population and plant height but decreased base diameter. The trend of results was similar to that of yield and yield components. This finding is consistent with Nayyar et al. (1983), Idris (1989), Mishra et al. (1998), Bandyopadhyay et al. (1991), El-Gazzar (2001a and 2001b), and Masum et al. (2011). Similar results were also reported by Islam (2014), Maity et al. (2012), and Masum et al. (2011).

The characteristics of bundle strength, fineness, and brightness were significantly influenced by the line spacing of tossa jute. The maximum bundle strength was observed at a line spacing of 15 cm, followed by 20, 25, and 30 cm. An increase in bundle strength corresponded to an improvement in fiber quality, whereas a decrease in strength resulted in lower quality. Fineness, another critical attribute of jute fiber, reached its peak at a line spacing of 30 cm (21.38 µ), with subsequent values recorded at 25, 20, and 15 cm. In this context, better quality fiber is associated with lower fineness values. Brightness, a vital quality characteristic of jute fiber, was highest at a line spacing of 20 cm (36.32%), followed by 25, 30, and 15 cm. A higher brightness value indicates superior fiber quality. El-Kady et al. (2009) reported similar findings in their research. These results align with those of Nayyar et al. (1983), Idris (1989), Mishra et al. (1998), Bandyopadhyay et al. (1991), and El-Gazzar (2001a and 2001b), and are consistent with the findings of Maity et al. (2012). The productivity of various crops is positively linked to the number of plants per unit area. Deviating from the optimal plant population can have a detrimental impact on the final yield (Alam et al., 2002). Achieving the desired plant density in jute cultivation relies significantly on the ideal seed rate, which ensures appropriate spacing for uniform stand establishment, fostering optimal growth and development. Effective weed management plays a crucial role in determining crop yield. The warm and humid climate, along with sporadic rainfall during the jute cultivation period, creates favorable conditions for weed proliferation, leading to intense competition with the crop (Saraswat, 1999) and causing yield losses ranging from 75 to 80% (Sahoo and Saraswat, 1988). Weeding is a fundamental cultural practice that not only aids in maintaining crop health but also helps in managing diseases, pests, and other harmful organisms (Alam et al., 2010). The findings of our study align with previous research. It was observed that utilizing a minimal seed rate alongside maximum line spacing resulted in increased plant base diameter in the field. Similar outcomes were documented by Islam (2014), Maity et al. (2012), Masum et al. (2011), Islam et al. (2014), Nayyar et al. (1983), Idris (1989), Mishra et al. (1998), Bandyopadhyay et al. (1991), and El-Gazzar (2001a and 2001b), as well as Masum et al. (2011). These results are consistent with the findings of Maity et al. (2012). The interaction of seed rate and line spacing at 8 kg ha^{-1} × 15 cm resulted in a higher plant population; however, this did not interpret into increased yields due to the unfavorable plant height and base diameter.

Conversely, the combination of seed rate and line spacing at 7 kg ha^{-1} × 15 cm produced lower plant height and base diameter, leading to the lowest yields of both fiber and stick. Therefore, it can be concluded that the optimal combination for achieving higher yields of tossa jute in Bangladesh is 7 kg ha^{-1} × 20 cm. This conclusion aligns with the findings of Nayyar et al. (1983), Idris (1989), Mishra et al. (1998), Bandyopadhyay et al. (1991), and El-Gazzar (2001a and 2001b), as well as Masum et al. (2011). Additionally, this result is consistent with the observations made by Maity et al. (2012). It was noted that lower fineness resulted in better quality fiber, while higher fineness corresponded to lower quality. Brightness is a significant quality characteristic in jute fiber, which is also supported by the research of Nayyar et al. (1983), Idris (1989), Mishra et al. (1998), Bandyopadhyay et al. (1991), and El-Gazzar (2001a and 2001b) and this result is also in line with the study of Maity et al. (2012). The highest level of brightness was observed when the seed rate was combined with a line spacing of 4 kg ha^{-1} × 20 cm, followed by seed rate with line spacing 4 kg ha^{-1} × 25 cm, seed rate with line spacing 4 kg ha^{-1} × 30 cm, seed rate with line spacing 4 kg ha^{-1} × 15 cm, and the lowest brightness was found when seed rate was combined with line spacing 8 kg ha^{-1} × 15 cm. The higher brightness value indicates better quality of the fiber. This finding is consistent with the study conducted by Maity et al. (2012). An economic analysis revealed that the highest gross return and BCR were found at the combination of 7 kg ha^{-1} seed rate and 20 cm line spacing (GR 215050 Tk ha^{-1} and BCR 1.64). This finding is consistent with the results reported by Dempsy (1975). Alam et al. (2019), Masum et al. (2011), and Islam et al. (2014) have also highlighted the significant impact of seed rate on sesame yield and economic performance, which is closely linked to weed infestation. The yield showed an increase with the rise in seed rate up to 9 kg ha^{-1}, after which it declined (Islam et al., 2014).

5. Conclusion

In conclusion, this study has demonstrated that seed rate and line spacing significantly influence weed growth, fibre yield, and quality parameters in tossa jute (*Corchorus olitorius*). The findings highlight that the most effective combination for achieving higher yields and superior fibre quality under subtropical conditions was a seed rate of 7 kg ha^{-1} with a line spacing of 20 cm. This combination not only minimized weed density and dry weight but also produced the highest gross return (215,050 Tk ha^{-1}) and benefit-cost ratio (1.64). The interactions among seed rate, line spacing, and weed management underscore the importance of these agronomic factors in enhancing jute cultivation practices in Bangladesh.

However, it is crucial to note that this study was conducted over a single growing season. Given that environmental factors such as rainfall patterns, temperature fluctuations, and soil conditions can vary significantly from year to year, further multi-year trials are warranted to validate these findings and ensure their consistency across diverse climatic conditions. Additionally, future studies could consider controlling for or accounting for other biotic and abiotic variables that may have influenced the observed weed dynamics and yield outcomes. This would strengthen the reliability and applicability of the results, contributing to the development of more robust integrated weed management practices for sustainable jute production.

Author Contribution

Conceptualization, Mohammad Shahadat Hossain and Md. Romij Uddin; Data curation, Mohammad Shahadat Hossain, M. Kamrujjaman and M. Al-Mamun; Formal analysis, Jannatul Ferdous and Arju Miah; Funding acquisition, Mohammad Shahadat Hossain and Md. Romij Uddin; Investigation, Mohammad Shahadat Hossain, Ahmed Khairul Hasan, Md. Parvez Anwar and Mahfuza Begum; Supervision, Md. Romij Uddin; Writing – original draft, Mohammad Shahadat Hossain and M. Al-Mamun. All authors have read and agreed to the published version of the manuscript.

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