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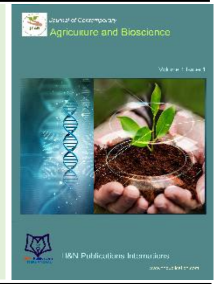

Research Article

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Influence and Efficacy Assessment of Planting Geometry and Planting Method on Seed Yield Components and Seed Yield of Kenaf (*Hibiscus cannabinus* L.) Cultivar HC-95 in Coastal Region of Bangladesh

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A b s t r a c t

Kenaf (*Hibiscus cannabinus* L.) is a plant fiber with high cellulose content, used for livestock feed and making rope, carpet, and twine. The future of kenaf cultivation in Bangladesh looks promising due to its industrial uses and environmental benefits. Increasing kenaf seed production in Bangladesh can ensure a steady supply and support the industry and sustainability. Keeping this view in mind, the study was conducted at the Jute Research Substation in Kalapara, Patuakhali, from September 2022 to February 2023, to determine the optimal planting geometry and method for Kenaf seed production in coastal areas. The experiment used a completely randomized block design (RCBD) with three replications, including three row-to-row distances (30 cm, 40 cm, and 50 cm) and four plant-to-plant distances (continuous line sowing, 10 cm, 15 cm, and 20 cm). The results showed significant differences in yield and yield attributes due to planting geometry and methods. The highest seed yield (138.09 g per square meter) was achieved with seedlings transplanted at 40 cm row spacing and 15 cm plant spacing. This configuration also positively influenced plant height, base diameter, number of pods per plant, number of seeds per pod, and 1000-seed weight. Seed germination percentage, seed vigor index (SVI), germination percentage after accelerated aging (AA), and electrical conductivity (EC) values were significantly affected by the interaction of planting geometry and method. The highest germination percentage (98%), SVI (47.01), and germination percentage after AA (71.45) were recorded for the 40 cm row and 15 cm plant spacing, while the lowest EC value (19.46 µS cm^{-1} g^{-1}) was observed at 30 cm row and 10 cm plant spacing. Therefore, for optimal seed yield, seed quality, and economic benefits, transplanting Kenaf seedlings at 40 cm row and 15 cm plant spacing is recommended.

Keywords: *Kenaf, planting geometry, planting method, seed yield and accelerated ageing.*

Introduction

Kenaf (*Hibiscus cannabinus* L.), originally from Africa where it still grows wild, is now cultivated as an annual warm-season crop worldwide (Cheng et al., 2004). Kenaf is emerging as a promising new fiber crop in Bangladesh, with the country cultivating it on 0.04 million hectares of land and producing between 0.08 and 0.09 million tons (Islam, 2019). Growing Kenaf has attracted increased attention due to its high biomass production and fiber content worldwide. It holds significant potential to become a valued biomass product in the future as a fibrous crop (Alexopoulou et al., 2000). In numerous districts across Bangladesh, a considerable quantity of Kenaf is being cultivated. However, the domestic production of Kenaf seeds fails to meet the demand, necessitating substantial imports from overseas sources. Therefore, it is very important to invent appropriate production technology of producing more Kenaf seeds in the right way.

Typically, in Bangladesh, direct seeding of Kenaf on arid agricultural land is employed to generate seeds during the latter phase of the growing season. Kenaf seed production can be done using three different methods of planting such as direct seeding, seedling transplanting and top cutting. To increase biomass yield, the crop is planted at a 30-cm row spacing (Berti et al., 2013). Mollah et al. (2017) concluded that the highest yield of Kenaf seed was obtained for crops sown at 30 cm × 15 cm spacing and detopped at 45 DAE (Days after Emergence). Several studies in different countries have shown that the plant population/ha and row spacing have a significant influence on seed yield and seed quality of Kenaf. Positive yield responses from higher plant populations have been shown in several studies in the southeast United States (Bhangoo et al., 1986). Plant population and row spacing can also affect seed yields and plant composition, by affecting the number of seeds, seed capsules, and branches/plant (Mullens, 1998). Webber et al. (2001) while describing of Kenaf production, mentioned the final plant density of 185,000 to 370,000 plants per hectare as the desirable for maximum yields. In addition to that, by minimizing the length of time the plant stays on the ground, transplantation can be a good approach for producing Kenaf seeds. It reduces input requirements and weed pressure. Each plant receives additional space during transplantation, which allows for better root and leaf development. It lessens the requirement for a broad workforce as well (FAO, 1977).

Several positive impacts have been found on different seed crop production such as Maize, Wheat, Jute, Kenaf, when the crops were transplanted instead of direct seeding (Dale and Drennan,1997; Mollah et al., 2017; Haque et al., 2016; Huang et al., 2012). However, the optimal and efficient planting geometry in combination with appropriate planting method for seed production of Kenaf has not yet been vastly determined in different conditions of Bangladesh. This research therefore seeks to determine appropriate planting geometry and proper planting method that will have positive effect on yield-determining traits of Kenaf seed which finally results in increased seed yield from HC 95 cultivar in the coastal ecology of Patuakhali.

Materials and method

Experimental site

The study was conducted at the Jute Research Substation in Kalapara, Patuakhali, from September 2022 to February 2023 (Location: 21°59'54.4''N, 90°13'53.6''E, Altitude: 3.45 meters). The experimental area is classified as medium high land within the Ganges Tidal Floodplain (AEZ 13), which is a large tidal floodplain region in the southwest of Bangladesh. The soil in this area is clay loam, neutral to slightly acidic, and has low levels of organic matter and nitrogen (SRDI, 2018).

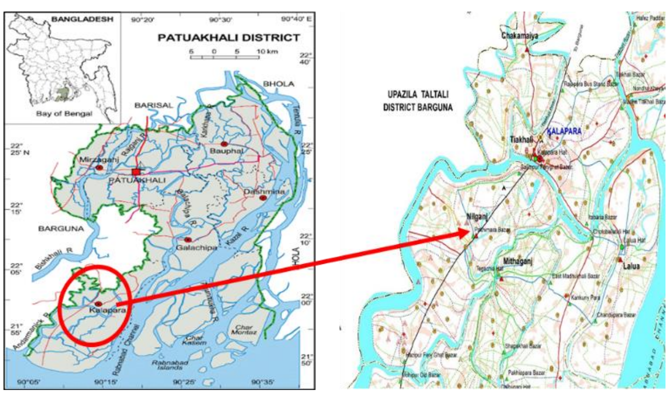

Fig-1. Map of the study area

Soil and climate

Before beginning the experiment, an initial soil sample was taken from a depth of 0-10 cm. The soil analysis showed an electrical conductivity (EC) of 3.18 dS/m and a pH of 5.05. The soil contained 21.3 ppm of available phosphorus, 31.4 ppm of sulfur, 0.31 mEq of exchangeable potassium per 100 grams of soil, and 0.15 mg of chloride per 100 grams of soil (Table 1). The experimental site is located in a subtropical zone characterized by heavy rainfall from April to September, followed by minimal rainfall for the rest of the year. The Rabi season (October to March) experiences lower temperatures and ample sunshine from November to February (Khanam et al., 2020; Jerin et al., 2020).

Table 1. Initial soil properties of the experimental site

Soil properties	Values
Electrical conductivity (EC: Ds/m)	3.18 dS/m*
pH (0-10 cm soil depth)	5.05
Available phosphorus (P)	21.3 ppm*
Available Sulphur (S)	31.4 ppm
Exchangeable K	0.31 mEq/100 g soil*
Chloride	0. 15 mg/100 g soil*

* dS/m= Decisiemens *per* metre, ppm= Parts Per Million, mEq/100 g soil= miliequivalente per 100-gram soil, mg/100 g soil= milligram per 100-gram soil

Experimental design, factors and setup

The study employed a Randomized Complete Block Design with three replications, each plot measuring 2.5 meters by 2 meters. Two factors were investigated: Row-to-Row spacing (Factor 1) and Plant-to-Plant distance (Factor 2). The treatments for each factor were as follows:

Factor 1 (Row to Row spacing): $F1_A$= 30 cm (control), $F1_B$= 40 cm, $F1_C$= 50 cm.

Factor 2 (Plant to Plant distance): $F2_A$= Continuous line sowing-CLS (control), $F2_B$= 10 cm, $F2_C$= 15 cm, $F2_D$= 20 cm.

Seeds were sown using continuous line sowing in the designated plots on September 3, 2022. On the same day, a seedbed was prepared for Kenaf seedlings, and seeds were broadcasted in this seedbed. After 30 days, the seedlings were transplanted from the seedbed to the main experimental plots. The combination of the two factors determined the plant population per hectare.

Management of the seed crop production

Fertilizer dose (Recommended by BJRI): Organic fertilizer (cow dung) was applied at a rate of 6 tons per hectare both in the seedbed and in the main experimental plot during final land preparation. Inorganic fertilizers were also applied during final land preparation as a basal dose: 35 kg/ha of Diammonium Phosphate (DAP), 15 kg/ha of Muriate of Potash (MoP), 1 kg/ha of boron, and 1 kg/ha of zinc. Urea was applied in three split doses: 20 kg/ha at 20 days after sowing, 30 kg/ha at 45 days after sowing, and 20 kg/ha during the first flowering stage.

Intercultural operation and Pest control: Pest control, weeding, thinning (for continuous line sowing), gap filling (for transplanting), de-topping, irrigation etc. were done according to the guideline of BJRI.

Harvesting: When more than 80%of the pods were mature and turn into gray color, then the plants were harvested.

Data collection

Field data will include information on the dates of direct seeding in the main plot and seed sowing in the seedbed, along with transplanting and harvest dates. Additionally, it will cover parameters such as days from sowing to first flowering, average flowering duration, crop duration, days from sowing to average pod maturation, plant height, base diameter, plant density per square meter, pods per plant, seeds per pod, and yield per hectare. Laboratory analysis will involve obtaining data on germination percentage, Seedling Vigor Index (SVI), Electrical Conductivity (EC) measurements, and results from the Accelerated Ageing (AA) test.

Laboratory germination test: the top-of-paper method was employed. One hundred seeds were placed in four replicates onto moist paper within petri dishes (11 cm diameter). These dishes were then placed in a germinator set at a temperature of 30 ± 10°C. Daily observation and counting of germinating seedlings were conducted for up to 8 days after seed setting. The number of normal seedlings was tallied at 8 days after sowing (DAS), and the germination percentage was calculated using the following formula:

Germination (%) = (Number of normal seedling /Number of seed sown) ×100

Vigour index (VI): The numbers of germinated seedlings were counted daily from the germination test up to 8 days. The seed vigor index (VI) was then calculated by following formula (AOSA, 1983):

VI = (Number of germinated seed/ Days of first count) + (Number of germinated seed/Days of final count)

Electrical conductivity (EC) test: In the seed quality assessment, 50 randomly selected seeds were placed in 250 ml flasks containing 75 ml of de-ionized water and maintained at a temperature of 20°C (±1°C). After 24 hours, the electrical conductivity of the seed leachate was measured using a conductivity meter (Model-YSI 3200), with values expressed in $\mu scm^{-1}g^{-1}$ (AOSA, 1983). Four replicates of 50 seeds from each seed lot were subjected to this test.

For the Accelerated Ageing (AA) test, 15 g of seeds were placed in an accelerated ageing chamber and exposed to a temperature of 41°C and 100% relative humidity for 72 hours. Seeds were weighed and placed on a screen tray (10.0 × 3.5 × 3.0 cm) within an inner chamber (plastic box: 10.0 × 6.0 × 4.0 cm) containing 50 ml of water. The boxes were sealed airtight and inserted into the outer chamber for ageing. During this process, seeds absorbed moisture from the inner chamber's humid environment and were stressed by high temperature and relative humidity. Following the accelerated ageing, germination tests were conducted using a modified paper folding method (ISTA, 1999).

Data Analysis:

Statistical analysis of the collected data on various yield-related parameters and seed quality was performed using Analysis of Variance (ANOVA), with differences among treatment means adjusted by Duncan's Multiple Range Test using SPSS statistical software.

Table 2. Effect of planting geometry and planting method on plant population and mortality %

Factor 1 (Row to Row spacing in cm)	Factor 2 (Plant to plant distance in cm)	Plant population/m^2 at harvest	Mortality %
30	CLS	92 a	10 f
	10	82 a	6.8 h
	15	50 c	7.14 g
	20	38 de	2.56 kl
40	CLS	66 b	7.04 gh
	10	59 bc	6.34 h
	15	40 d	4.76 j
	20	29 f	3.33 jk
50	CLS	52 c	8.77 g
	10	47 cd	6 hi
	15	34 e	2.86 k
	20	**25 f**	**0.00 l**
Level of significance		*	**

Results and discussion

The present study revealed that all planting for direct seeding method showed the highest plant population while mortality % was comparatively lower in transplanting method (Table 2). Highest plant population (92) was obtained when seeds are sown in continuous line sowing at 30 cm row spacing. Mortality % was also higher (10) in this geometrical method. Lowest plant population was obtained (25) when Kenaf seedling were transplanted at 20 cm plant to plant and 50 cm row to row distance (Table 2). Lowest mortality % (0) was obtained when seeds were sown as 20 cm plant to plant and 50 cm row to row distance. Plant population/m^2 at harvest was found significant at 5% level while mortality % was found significant at 1% level (Table 2). Pant and Sah (2020) Argued that Maintaining optimal plant population and competition is crucial for efficient resource use and maximizing economic yield in field crops.

Table 3. Effect of planting geometry and method of planting on seed yield and yield contributing character of Kenaf.

Factor 1 (Row to Row spacing in cm)	Factor 2 (Plant to plant distance in cm)	Number of branches/plant	Number of pod/ plant	Seed yield/plant (g)	Seed yield (g/m^2)
30	CLS*	0 f	13.22j	4.28jkl	117.23hi
	10	0 f	17.24gh	4.78efgh	112.67ij
	15	0 f	21.31ab	4.36ij	112.19jk
	20	0 f	19.43de	5.03cd	118.25ef
40	CLS	0 f	16.08hi	5.31c	123.03c
	10	0 f	20.67b	6.81b	130.30b
	15	0 f	22.79a	7.65a	138.09a
	20	0 f	21.56a	6.73bc	129.54bc
50	CLS	0 f	14.69ij	4.56hi	120.24de
	10	0 f	19.21efg	6.89ab	133.05ab
	15	0 f	20.10bc	5.01def	117.81fgh
	20	0 f	19.88cd	3.21l	99.32l
Level of significance		**	*	*	*

*CLS= Continuous Line Sowing

Table 4 indicates Effects of planting geometry and method on days to first flowering, average flowering and harvesting of Kenaf. The results indicate that planting geometry had barely any significance in days to first flowering, days to average flowering and days to harvesting.

Table 4. Effects of planting geometry and method on days to first flowering, average flowering and harvesting of Kenaf

Factor 1 (Row to Row spacing in cm)	Factor 2 (Plant to plant distance in cm)	Days to 1st flowering	Days to average flowering	Days to harvesting
30	CLS	87	98	149
	10	85	96	148
	15	86	97	147
	20	85	96	145
40	CLS	89	96	150
	10	89	99	148
	15	90	98	150
	20	88	98	148
50	CLS	83	96	150
	10	8	97	149
	15	86	98	149
	20	85	98	146

Kenaf normally came to first flowering stage from 83- 90 days, average flowering from 96-98 days and days to harvesting from 145-150 days. Partially similar result was found from Mehriya et al. (2022) who concluded that Chamomile's dried and fresh flower

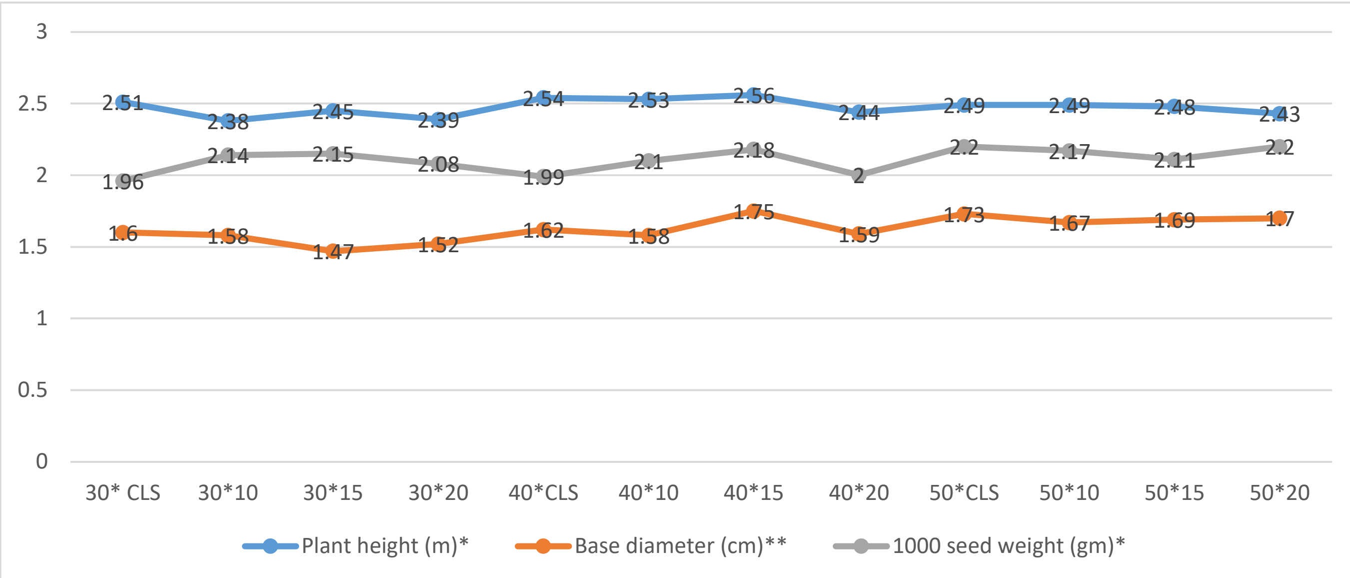

Figure 2: Effect of Planting geometry and method on plant height, base diameter, and 1000 seed weight of Kenaf (*significant at 5% lavel, ** significant at 1% level)

yields, and the number of flowers per plant, were significantly influenced by plant spacing and sowing date.

Table 4. Effect of planting geometry and planting method on germination %, electrical conductivity (EC), seedling vigor index (SVI), germination % after accelerated ageing (AA)

Factor 1 (Row to Row spacing in cm)	Factor 2 (Plant to plant distance in cm)	Germination %	Electrical conductivity (EC) (µscm^{-1}g^{-1})*	Seedling Vigor Index (SVI)	Germination % after accelerated ageing (AA)
30	CLS	85	24.31bc	46.61a	64.54c
	10	91bc	19.46g	42.43de	65.76bc
	15	89cd	24.65b	42.34cd	62.34d
	20	90c	27.52a	45.61a	60.23f
40	CLS	91bc	26.61a	42.93d	61.97de
	10	96a	23.34de	45.31b	60.35e
	15	98a	22.76ef	47.01a	71.45a
	20	95a	24.12cd	45.43ab	68.73b
50	CLS	88d	21.23g	45.87a	63.32cd
	10	96a	25.65ab	41.07f	71.23a
	15	95a	24.32b	43.61c	69.06a
	20	98a	23.09e	44.53bc	68.77ab
Level of significance		*	*	*	*

* µscm^{-1}g^{-}1= Microsiemens per centimeter per gram

Figure 2 indicates effect of Planting geometry and method on plant height, base diameter, and 1000 seed weight of Kenaf. Highest plant height was obtained (2.56 m) at 40*15 (R-P) planting geometry while seedlings were transplanted. Highest base diameter (1.75 cm) was obtained in 40*15 (R-P) planting formation. In case of 1000 seed weight, highest 1000 seed weight was obtained (2.2 gm) in 50* CLS and 50*20 planting formation. (Figure 2). Plant height and 1000 seed weight was found significant at 5% level while base diameter was found significant at 1% level. (Figure 2). Normally, early flowering is bad for seed crops because early flowering reduces the vegetative phase and the volume of dry matter production to support the assimilate requirement for proper fruit and seed development (Mullen, 1998). Thapa et al. (2011) stated that wider spacing reduced competition for light, water, space, and nutrients, enhancing light interception, root distribution, and nutrient availability, which are crucial for plant growth.

Table 4 indicates the effect of planting geometry and planting method on germination %, electrical conductivity (EC), seedling vigor index (SVI), germination % after accelerated ageing (AA). All of the four indicators were found significant at 5% level. Result showed that the highest germination percentage (98), seed vigor index (SVI) (47.01) and germination (%) after AA (71.45) obtained from 40*15 (R-P) method. On the other hand, lowest EC (19.46 µscm^{-1}g$^{-1)}$ was found while planting at 30*10 (R-P) method. It was clear that transplanting method was more effective in producing quality seeds of Kenaf (Table 4). The highest quality of seed in respect to laboratory germination, vigor index, EC and AA-germination was found in transplanted crop for all the dates of planting in the present study.

Conclusions

It was clear from the experiment that planting geometry and planting method had a significant influence on Kenaf seed production and transplanting method could give highest seed yield and improved the seed yield attributes. In order to improve seed yield and reduce the seed deficiency of Kenaf in Bangladesh, the planting geometry of 40 cm× 15 cm R-P method can be followed in the afformentioned regions. Additionally, this finding can improve farmers' income and livelihood by boosting the seed yield of Kenaf**.**

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