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Seed Yield and Quality of Late Season Direct Seeded Kenaf (*Hibiscus cannabinus* L.) as Influenced by Spacing and Time of De-topping

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Abstract

An experiment was conducted at the Bangladesh Jute Research Institute (BJRI), Regional Station, Kishoreganj during July to December of 2010 and 2011 to investigate the effect of spacing and de-topping on yield and quality of kenaf seeds cv. HC-95 grown under direct seeding method. Three plants spacings (40 cm × 15 cm, 30 cm × 15 cm and 20 cm × 15 cm) and four de-topping treatments (no de-topping, de-topping at 15, 30 and 45 days after emergence (DAE) were applied in a Randomized Complete Block Design (RCBD) with three replications. The highest yield of kenaf seed (1403 and 1646 kgha^{-1} in 2010 and 2011, respectively) was obtained from sowing at 30 cm × 15 cm spacing. The best quality seed in respect to germination and vigour was also obtained from sowing at 30 cm × 15 cm spacing. The highest seed yield, germination and vigour of seed were obtained for de-topped at 45 days after emergence. It is concluded that the highest seed yield and quality of late season direct seeded kenaf could be obtained by sowing at a spacing of 30 cm x 15 cm and de-topping at 45 days after emergence.

Keywords: Kenaf, de-topping, plant spacing, yield, branching, germination, vigour.

1. Introduction

Kenaf (*Hibiscus cannabinus* L.) is a fibre crop belonging to the family Malvaceae. It is a highly profitable crop in Bangladesh. At present, kenaf is grown in 0.04 million ha of land in Bangladesh, which required 480tons of seeds. Government and other seed producing organizations in the country are not able to meet up the requirement. Hiron *et al*. (2006) stated that kenaf can give high yield even in the marginal, fallow and char lands with less care. In marginal land, kenaf cultivation is profitable than jute because it can be produced at minimal management practices with less labour and lower cost. The prices of jute and kenaf fibres are almost same, and as a consequence, kenaf is replacing jute in the marginal areas. Kenaf is a crop of multiple uses. This can be used as good source of fibre, fuel, and has substantial impact on alleviating environmental degradation. Area expansion of kenaf in Bangladesh has been restricted by shortage of quality seed. The supply of seeds from local and exotic sources is not sufficient. Generally, farmers produce kenaf seeds by conventional method. In this method kenaf seed is sown during March-April and the crop is harvested in the month of December-January for seed collection. Conventionally, after harvesting pods, the plants are used for fibre collection. The quality of both fibre and seed are very poor in this system. The crop stays in the field for long time and thus it is affected by drought, hailstorm, flood, disease and insect pest infestation during its prolonged stay in the field. Consequently the plants become physiologically weak and produce low yield of poor quality seeds. Production of seed from March - April planted crop occupies the far longer time and hamper *Aman* rice and Rabi (winter crops) crop production. This method is no longer profitable and farmers are not interested to grow seed in this method. Kenaf seed produced in the conventional methods lose viability rapidly in storage. Because of these problems, farmers are not interested to produce kenaf seed.

Conventional method of seed production successfully replaced by off or late season jute seed production technology. Bangladesh Agricultural Development Corporation and many farmers are now producing jute seed following this technology. However research reports relate to late season seed production technology in kenaf are rather insufficient. Since, kenaf is a short day plant like jute, late season seed production of this crop is presumably possible in Bangladesh. Seed production of kenaf in late season could be done by direct seeding on dry cultivated land like jute. The crop is planted at 30-cm row spacing to maximize biomass yield (Berti *et al.*, 2013). However the optimal spacing for seed production has not yet been determined. Kenaf is an indeterminate crop and therefore, de-topping may have influence on its branching and pod formation. De-topping is the removal of the apical bud to release the lower auxiliary buds from apical dominance in order to increase branching and stimulate auxiliary bud development, increase higher number of branches plant^{-1}, pods plant^{-1} and seeds pod^{-1}. The kenaf seedlings can produce more branches after de-topping, which increase the number of flowers, fruits and seed yield (Mollah *et al*., 2015). Adjustment of planting spacing in relation to de-topping practice could also be a useful agronomic management option for increasing the yield and quality of kenaf seed. However, information on time of de-topping and agronomic management of kenaf for seed production is highly scarce in the Asian countries. Therefore, the present study was undertaken with a view to find out the effect of spacing and time of de-topping on yield and quality of kenaf seed under direct seeded method in Bangladesh.

2. Materials and Methods

The experiment was conducted at the Bangladesh Jute Research Institute (BJRI), Regional Station (24°38´North latitude and 90°13´ East longitudes and at an altitude of 18 m), Kishoreganj, Bangladesh during July to December 2010 and 2011. The soil of the studied area belongs to Old Brahmaputra Floodplain Agro Ecological Zone, 'AEZ-9' (UNDP and FAO, 1988). The field was medium high land having well-drained silty loam soil with p^{H} 6.75. The experiment comprised of four times of de-topping viz., no de-topping, de-topping at 15, 30 and 45 days after emergence (DAE) and three plant spacing viz., 40 cm × 15 cm, 30 cm × 15 cm and 20 cm × 15 cm. The trial was laid out in a randomized complete block design with three replications. The unit plot size was 3 m × 2 m. Kenaf variety HC-95 was used as test crop. The experimental plots were fertilized with urea, triple super phosphate (TSP), muriate of potash (MoP) and gypsum @ 180-50-20-50 kg ha^{-1}, respectively. All fertilizers except urea were applied during final land preparation. Urea was top dressed in three equal splits at 15, 30 and 45 days after sowing (DAS). The seed was sown @ 12 kg ha^{-1} on 30 July in both the years. Weeding was done by hand at 25 and 45 days after sowing (DAS). Thinning was done to maintain plant to plant distances of about 15 cm in line along with the weeding operation. The crop was infested by mealy bug and white fly at the vegetative stage those were successfully controlled by spraying Ripcord 10 EC @ 2mlL^{-1} of water for three times at an interval of 10 days. No irrigation was needed while excess water was drained out as and when necessary. Prior to harvesting, 10 plants from each plot were harvested to collect data on different crop characters, such as number of pods $plant^{-1}$, seeds pod^{-1}, 1000-seed weight, seed yield $plant^{-1}$. The crop was hand harvested at maturity i.e. when 80% of the capsules become brown in color. Threshing was done with a hammer after 2-3 days sun drying. Then seeds were sun dried on jute mat placed on cemented floor for 5-6 days to have around 8% moisture content. After cleaning, the seed was stored in thick polythene bags and kept in the laboratory until further use for quality tests. Standard laboratory germination test, electrical conductivity and accelerated ageing tests were done to record on germination and vigour of seed. A brief description on different laboratory tests is given below.

2.1 Laboratory germination test

The test was conducted on top of the paper method. One hundred seeds in four replications were placed on the moist paper (two fold of Bashundhara kitchen towel) in petridish (11 cm diameter). The petridishes were kept in the germinator maintain temperature at 30 ±1^{o}C. Daily counting of the germinating seedlings were done up to 8 days of seed setting. The number of normal seedling was counted at 8 DAS and the germination percentage of seed was measured with the following formula:

Germination (%) =

$$\frac{\text{Numberof normal seedling}}{\text{Numberof seedsset for germination}} \times 100$$

2.2 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):

$$VI = \frac{\text{Number of germinated seed}}{\text{Days of first count}} + \cdots + \frac{\text{Number of germinated seed}}{\text{Days of final count}}$$

2.3 Electrical conductivity (EC) test

Randomly selected 50 seeds were taken in a 250 ml flasks containing 75 ml de-ionized water and were kept at 20^{o}C(±1°C). Electrical conductivity of seed leachate was measured after 24 hours using a conductivity meter (Model-YSI 3200) and the values were expressed inµs$cm^{-1}g^{-1}$ (AOSA, 1983). Four replicates of 50 seed from each seed lot were used in the test.

2.4 Accelerated ageing (AA) test

Accelerated ageing seed was done by taking 15 g seed in accelerated ageing chamber and exposing the seeds to 41^{0}C temperature and 100% RH for 72 hours. For conducting the AA test, seeds were weighed and placed on a screen tray (10.0 × 3.5 × 3.0 cm) which is inserted into an inner chamber (plastic box: 10.0 × 6.0 × 4.0 cm) containing 50 ml of water. The boxes were covered with lids and kept airtight. The inner chamber is placed into an accelerated ageing (outer) chamber. During the ageing period the seeds absorb moisture from the humid environment within the inner chamber and are stressed by high temperature and RH. After accelerated ageing, germination test of seeds was done using modified paper folding method (ISTA, 1999).

2.5 Statistical analysis of data

The collected data on different yield related characters and seed quality parameters were subjected statistical analysis following ANOVA technique. Differences among treatment means were adjusted by Duncan's Multiple Range Test with the help of a computer based statistical package program MSTAT-C (Gomez and Gomez, 1984).

3. Results and Discussion

3.1 Effect of spacing

Plant spacing had significant effect on almost all the parameters in both the years (Table 1-3). In year 2010 and 2011, significantly, the highest plant population of 35.21 and 30.58 respectively was found in 20 cm × 15 cm spacing while the lowest plant population of 18.86 and 18.26, respectively was achieved from 40 cm × 15 cm spacing. Plant height was significantly influenced by plant spacing in 2010 but not in 2011. Significantly the tallest plant (183 cm) was obtained from 20 cm × 15 cm spacing and the shortest (172.50 cm) was in plant spacing of 40 cm × 15 cm in 2010. The highest base diameter (9.40 mm and 9.38 mm at 2010 and 2011, respectively) was found in 30 cm × 15 cm spacing and the lowest (8.59 mm and 8.61 mm at 2010 and 2011, respectively) in plant having 20 cm ×15 cm spacing **(**Table 1). The highest number of branches plant^{-1} (1.69 and 1.24 at 2010 and 2011, respectively) was found from the plant having 30cm × 15cm spacing and the lowest number of branches plant^{-1} (1.23 and 0.89 at 2010 and 2011, respectively) was recorded from 20 cm × 15cm spacing. The highest number of pods plant^{-1}(21.77 and 27.27 at 2010 and 2011, respectively) was observed from 30 cm × 15 cm spacing, while, the lowest number of pods plant^{-1} (17.39 and 21.39 at 2010 and 2011, respectively) was produced by 20 cm × 15 cm spacing. The number of seeds pod^{-1}was significantly influenced only at 2011 due to spacing. In 2011, the highest number of seeds pod^{-1} (17.30) was obtained in 30 cm × 15 cm spacing and the lowest number (16.70) was found from 20 cm × 15 cm plants spacing. The highest seed yield plant^{-1} (5.99 g and 8.99 at 2010 and 2011, respectively) was obtained from 30 cm × 15 cm plant spacing and the lowest seed yield plant^{-1} (4.3 g and 7.4 g at 2010 and 2011, respectively) was recorded from plants of 20 cm × 15 cm spacing (Table 2). The present study revealed that the highest seed yield (1403 kg ha^{-1} and 1646 kg ha^{-1} at 2010 and 2011, respectively) was obtained from 30 cm × 15 cm spacing and the lowest seed yield (904 kg ha^{-1} and 1203 kg ha^{-1} at 2010 and 2011, respectively) was obtained from 40cm × 15cm spacing (Table 2). Seed quality of kenaf seed varied significantly due to plant spacing. In 2010 and 2011, the best quality seed (84.7% and 85.1% at 2010 and 2011, respectively) in term of germination, (44.77 SVI and 44.87 SVI at 2010 and 2011, respectively) in term of seed vigour, (29.29 and 25.61 µscm^{-1}g^{-1} at 2010 and 2011, respectively) in term of electrical conductivity value and (68.1% and 69.5% at 2010 and 2011, respectively germination) in term of germination (%) after accelerated ageing test was obtained in 40cm × 15cm spacing and the inferior quality seed was found in 20 cm × 15 cm spacing (Table 3).

Planting spacing influences the yield and quality of kenaf seed. Optimum planting density ensures kenaf plants to grow uniformly and properly through efficient utilization of moisture, nutrients and light, and thus contributes to maximize the yield of pods as well as seed. The present study showed that the highest seed yield from 30 cm × 15 cm spacing and the lowest seed yield from 40 cm × 15 cm spacing (Table 2). The result showed that the yield for 30 cm × 15 cm and 20 cm × 15 cm spacing were statistically at per (Table 2) in both the years. It was also noted that the number of branches plant^{-1}, pods plant^{-1} and seeds pod^{-1} were significantly the highest for 30 cm × 15 cm spacing and was the lowest for 20 cm × 15 cm spacing. The higher seed yield in the closer spacing was therefore, mainly attributed to higher number plants m^{-2} (Table1). It was also observed that although the yield was similar both in 30 cm × 15 cm and 20 cm × 15 cm spacing, there was a tendency of decreased yield at 20 cm × 15 cm spacing in both the years. Thus it indicates that further increase in plant population would reduce the yield. Therefore, kenaf should be planted between 30 cm and 20 cm row spacing with a plant spacing of 15 cm. The present significant yield variation in kenaf seed due to variation in planting spacing could be supported by Scott and Cook, (1995) and Webber and Bledsoe, (2002). The experiment also indicated that the row spacing closer than 20 cm would reduce seed yield in kenaf which was in the line of the report of (Webber and Bledsoe, 2002 and Mollah *et al.*, 2015).

Plant height was significantly influenced by planting spacing. The plant height increased significantly with narrower plant spacing from 40 cm × 15 cm to 30 cm × 15 cm but further narrowing of spacing did not increase the plant height (Table 2). The decrease in row spacing increased the plant population which increased the plant height, probably because of mutual shading that usually results in stem elongation. The increase in plant height is associated with internode elongation. The internodal elongation (etiolation effect) due to mutual shading is believed to be an auxin response (Rahman *et al.*, 2004). The present study also revealed that the plant height did not increase significantly due to further decrease of row spacing after 30 cm. This type of response is probably related to the fact that the plants suffer from shortage of assimilates at ultra high plant density that retard the further increase in plant height.

Seed quality attributes were affected significantly by planting spacing for direct seeding method. The result showed that the highest seed germination and vigour were found for 40 cm × 15 cm spacing (Table 3). It was also noted that the germination and vigour of seed for 30 cm × 15 cm spacing were statistically similar to those of 40 cm × 15 cm spacing. For direct seeding method of planting, the lowest seed quality was observed for the crop from 20 cm × 15 cm spacing.

Table 1. Effect of de-topping and spacing on plant population, plant height and base diameters of kenaf in 2010 and 2011

Treatment	Plant population m^{-2} (no.)		Plant height (cm)		Base diameter (mm)	
De-topping	2010	2011	2010	2011	2010	2011
D_0	26.70	24.30	189.1a	187.7a	8.94b	9.15
D_1	26.71	24.48	183.7a	186.6a	8.72b	8.75
D_2	26.69	24.37	173.7b	177.8ab	9.06ab	8.84
D_3	26.70	23.94	168.8b	172.8b	9.40a	9.12
$S\bar{x}$	0.0926	0.2946	2.3573	3.8791	0.1222	0.1389
CV (%)	1.04	3.64	3.95	6.42	4.06	4.65
Level of sig.	NS	NS	***	*	**	NS
Spacing						
S_1	18.86c	18.26c	172.5b	177.7	9.098a	8.910b
S_2	26.03b	23.97b	181.0a	180.5	9.400a	9.381a
S_3	35.21a	30.58a	183.0a	185.5	8.586b	8.608b
$S\bar{x}$	0.0802	0.2551	2.0415	3.3594	0.1059	0.1203
CV (%)	1.04	3.64	3.95	6.42	4.06	4.65
Level of sig.	***	***	**	NS	***	***

CV= Coefficient of variation, *= Significant at 5% level, **= Significant at 1% level, ***= Significant at 0.1% level, NS= Not significant

In a column, figures having similar letter(s) do not differ significantly at 5% level as per DMRT

Note: D_0= No de-topping, D_1= de-topping at 15 days after emergence(DAE) , D_2 = de-topping at 30 DAE, and D_3 = de-topping at 45 DAE; S_1= 40 cm × 15 cm, S_2 = 30 cm×15 cm and S_3= 20 cm×15 cm.

Table 2. Effect of de-topping and spacing on number of branches plant^{-1}, number of pods plant^{-1}, number of seeds pod^{-1}, seed yield plant^{-1} and seed yield of Kenaf in 2010 and 2011

De-topping.	Number of branches plant^{-1}		Number of pods plant^{-1}		Number of seeds pod^{-1}		Seed yield plant^{-1} (g)		Seed yield (kg ha^{-1})	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
D_0	0.00d	0.00d	15.32c	21.93c	16.79	17.13ab	4.26c	7.39c	994d	1343c
D_1	0.62c	0.30c	15.83c	22.53c	17.77	17.43a	4.99b	7.58c	1140c	1381bc
D_2	2.30b	1.66b	21.21b	25.30b	16.47	16.72b	5.52a	8.27b	1264b	1489b
D_3	2.78a	2.26a	25.09a	27.49a	16.46	16.75b	5.90a	9.48a	1397a	1679a
$S\bar{x}$	0.0521	0.0486	0.3126	0.4432	0.4585	0.2105	0.1429	0.2020	37.4842	37.6163
CV (%)	10.97	13.86	4.84	5.47	8.15	3.71	8.29	7.41	9.38	7.66
Level of sig.	***	***	***	***	NS	*	***	***	***	***
Spacing										
S_1	1.35b	1.03b	18.93b	24.27 b	16.76	17.02ab	5.24b	8.18 b	904c	1203 b
S_2	1.69a	1.24a	21.77a	27.27a	17.43	17.30 a	5.99a	8.99a	1403a	1646a
S_3	1.23b	0.89c	17.39c	21.39 c	16.42	16.70 b	4.27c	7.37c	1289b	1573a
$S\bar{x}$	0.0451	0.0421	0.2707	0.3838	0.3971	0.1823	0.1237	0.1750	32.4622	32.5767
CV (%)	10.97	13.86	4.84	5.47	8.15	3.71	8.29	7.41	9.38	7.66
Level of sig.	***	***	***	***	NS	*	***	***	***	***

The differences in the seed quality response of kenaf in direct seeding method for planting spacing could be related to the plant population establishment differences between the methods. The plant population at 30 cm × 15 cm was 25 plants m^{-2}. The plant density at 20 cm × 15 cm for direct seeding was 32 plants m^{-2}. It was noted that the pods under high density crop remained wet or damp for longer time in the field than those at low density crop. This was because of the fact that the high population at 20 cm × 15 cm could have restricted the proper movement for rapid drying of pods. This damp condition in the field during the period of ripening might have affected the seed quality adversely at the low density crops. Rashid and Singh (2000) reported the best quality okra seed from wider spaced crop than the closer spaced one.

3.2 Effect of de-topping

Almost all the parameters were found statistically significant in terms of de-topping in both the years (Table 1-3). Plants of without de-topping produced the tallest plant (189.10 cm and 187.70 cm at 2010 and 2011, respectively) which was identical with that of de-topping at 15 DAE (183.70 cm and 186.60 cm at 2010 and 2011, respectively). The shortest plant of 168.80 cm and 172.80 cm was obtained from the plants of de-topping at 45 DAE at 2010 and 2011, respectively (Table 1). Plant base diameter was significantly influenced by de-topping only in 2010. The present study revealed that de-topping at 45 DAE produced the widest (9.40 mm) plant and de-topping at 15 DAE produced the narrowest (8.72 mm) plant in 2010 (Table 1). De-topping had significant effect on number of branches plant^{-1} in both the years. The present study revealed that the maximum number of branches plant^{-1} (2.78 and 2.26 at 2010 and 2011, respectively) was obtained from de-topping at 45 DAE and the lowest number of branches plant^{-1} was received from plants of no de-topping (Table 2). Significantly the highest number of pods plant^{-1} (25.09 and 27.49 at 2010 and 2011, respectively) was obtained from de-topping at 45 DAE and no de-topping gave the lowest (15.32 and 21.93 at 2010 and 2011, respectively) number of pods plant^{-1} (Table 2) in both the years. In 2011, number of seeds pod^{-1} was significantly influenced due to de-topping but was not significant in 2010 (Table 2).

Table 3. Seed germination, Seed vigor index, electrical conductivity and accelerated ageing germination (%) of kenaf seed as influenced by de-topping in 2010 and 2011

De-topping.	Germination (%)		Seed Vigor Index		Electro-conductivity (µscm^{-1}g^{-1})		Accelerated ageing germination (%)	
	2010	2011	2010	2011	2010	2011	2010	2011
D_0	83.67	83.67	43.98	44.13	25.73b	23.81b	64.92ab	67.50
D_1	82.17	83.67	42.85	43.81	27.94a	23.86b	60.92 c	66.50
D_2	82.58	84.08	43.47	43.99	26.43b	24.39a	63.75bc	66.92
D_3	84.08	84.17	44.02	44.16	24.33c	23.74b	67.08a	68.92
S $\bar{x}$	0.9988	0.8225	0.4909	0.5708	0.4145	0.1126	1.0178	0.8478
CV (%)	4.16	3.40	3.90	4.49	5.50	1.70	5.49	4.35
Level of sig.	NS	NS	NS	NS	***	**	**	NS
Spacing								
S_1	84.69a	85.13a	44.77a	44.87a	23.40c	22.47c	68.06a	69.50a
S_2	83.31ab	84.31a	43.79a	44.35a	25.63b	23.77b	63.69b	68.38a
S_3	81.38b	82.25b	42.18b	42.84b	29.29a	25.61a	60.75c	64.50b
S $\bar{x}$	0.8650	0.7123	0.4251	0.4944	0.3590	0.0975	0.8814	0.7342
CV (%)	4.16	3.40	3.90	4.49	5.50	1.70	5.49	4.35
Level of sig.	*	*	***	*	***	**	***	***

CV= Coefficient of variation, *= Significant at 5% level, **= Significant at 1% level, ***= Significant at 0.1% level.
In a column, figures having similar letter(s) do not differ significantly at 5% level as per DMRT
Note: D_0= No de-topping, D_1= de-topping at 15 days after emergence (DAE) , D_2 = de-topping at 30 DAE, and D_3 = de-topping at 45 DAE
S_1= 40 cm × 15 cm, S_2 = 30 cm × 15 cm and S_3= 20 cm × 15 cm.

Table 4. Relationship between plant characters and plant height

Plant characters	Plant height(r value)	
	2010	2011
Number of branches plant^{-1}	-0.83323	-0.88227
Number of pods plant^{-1}	-0.74899	-0.79134
Seed yield plant^{-1}	-0.646451	-0.83537

De-topping at 15 DAE showed higher number of seeds pod^{-1}(17.43)and the lowest number of seeds pod^{-1} (16.72) was counted from the plants of de-topping at 30 DAE and the highest seed yield plant^{-1} (5.90 g and 9.48g at 2010 and 2011, respectively) was obtained from the plants of de-topping at 45 DAE and the lowest seed yield (4.26g and 7.39 g at 2010 and 2011, respectively) was recorded from plant of no de-topping (Table 2) in both the years. The highest seed yield (1397kg ha^{-1} and 1679 kg ha^{-1} at 2010 and 2011, respectively) was recorded from the plants de-topped at 45 DAE and the lowest seed yield (994 kg ha^{-1} and 1343 kg ha^{-1} at 2010 and 2011, respectively) was found from the plants of without de-topping system (Table 2) in both the years. Due to heavy rainfall and storm most of the plants lodged during crop growing season of 2010 and for that all types of seed yield become reduced. Percent germination and seed vigour index were not significantly influenced by de-topping system in any year. In 2010 and 2011, it was found that electrical conductivity (EC) value of kenaf seed was the highest of 27.94 µscm^{-1}g^{-1} and 24.39 µscm^{-1}g^{-1},respectively under de-topping at 15 DAE and the lowest EC value was found in de-topping at 45DAE (24.33 µscm^{-1}g^{-1}and 23.74 µscm^{-1}g^{-1} at 2010 and 2011, respectively). Significant variation was found in germination percent after accelerated ageing (AA) of kenaf seed in 2010 but was not in 2011. The best quality seed (67.08% germination) was found from the plants of de-topping at 45 DAE. The most inferior quality of seed (60.92% germination) was identified from the plants of de-topping at 15 DAE (Table 3).

De-topping has significant influenced on yield of kenaf seed. In the present study, the highest yield of kenaf seed was recorded from de-topping at 45 days after emergence (DAE) (Table 2). It was found that de-topping earlier than 45 DAE reduced seed yield (Table 2). The highest yield for de-topping at 45 DAE under direct seeded method was related to number of branches plant^{-1}, pod plant^{-1} (Table 1) and seed yield plant^{-1} (Table 2). It was found that the delay in de-topping reduced the plant height but increased the base diameter of kenaf plant in both the years. For all the cases de-topping always produced shorter plants than non-detopped plants. The decrease in plant height of kenaf for de-topping was probably related to the apical dominance phenomena. Removal of top (de-topping) reduced the auxin content in the top portion of the plants that retarded the increase of height in plant. Singh *et al*. (2002) stated that de-topping of okra plant produced the higher number of seeds pod^{-1} compared to that of pods taken from non-detopped plants. In pigeon pea, Sharma *et al.* (2003) reported that nipping of terminal bud at 50 DAS significantly reduced the height of the plant and increased the number of primary and secondary branches, pods plant^{-1} and seed yield. Uddin (2006) reported that top removal in okra produced the maximum seed yield over no de-topped plants. Mollah*et al*. (2015) also reported that seed yield in the de-topped plants was much higher than of normal plants in kenaf (*Hibiscus cannabinus* L.). These reports support the results of the present study that the highest yield of kenaf seed could be obtained by de-topping at 45 DAE. Seed quality attributes such as germination and vigour showed significantly highest performance for de-topping at 45 days after emergence (Table 3). The vigour was evaluated in term of vigour index, accelerated ageing germination and electrical conductivity test. All these vigour tests confirmed that the seed obtained from the crop de-topped at 45 DAE gave the highest vigour. Thus it could be concluded that both the highest yield and quality of kenaf seed could be obtained by de-topping at 45 DAE.

3.3 Relationship among the plant characters

The simple correlation study indicated that the number of branches plant^{-1}, number of pods plant^{-1} and seed yield plant^{-1} had negatively insignificant correlation with plant height (Table 4).

4. Conclusions

The result of the present study concludes that the highest yield of kenaf seed was obtained for the crops sown at 30 cm × 15 cm spacing and de-topped at 45 DAE. The best quality seed in respect to germination and vigour was also obtained for at 30 cm × 15 cm spacing. The study concludes that late season kenaf produces highest seed yield with best quality when sown at 30 cm × 15 cm spacing and for de-topping at 45 DAE.

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