Design of seed metering system for jute seeds

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Abstract: Low cost mechanical seed metering system for jute seedplanter was designed to maintain plant to plant spacing. Different plant spacingwas achieved by changing the speed of seed metering unit which was varied from 30 to 60 rpm (0.10 to 0.21 m s^{-1}). In laboratory testing by sticky belt method, it was found that the average seed spacing for both the jute varieties (*Capsularies* and *Olitories*) were 11.49, 8.53, 6.69, 5.42 cm and 12.21,8.85,7.0,5.95 cm at 30, 40, 50 and 60 rpm respectively. With the increase in rpm of seed metering unit, the seed distribution efficiency decreased from 91% at 30 rpm (0.10 m s^{-1}) to 86% at 60 rpm (0.21 m s^{-1}) for *Capsulries* and for *Olitorius*seed distribution efficiency get decreased from 90% at 30 rpm (0.10 m s^{-1}) to 84% at 60 rpm (0.21 m s^{-1}). It was observed that seed damage rate increased with the increasing revolution per minute of the metering unit. Developed metering unit was observed for seed rate capacity of 4.47 and 5.23 kg ha^{-1} for *Capsularies* and *Olitories* seed respectively.

Keywords: jute mechanization, seed metering unit, irregular shape seed

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1 Introduction

Jute is one of the most important natural fibres after cotton (Chowdhury and Rashed, 2015). India is the leading producer of jute in the world (International Jute Study Group, 2014). Almost, 90% of the world's jute cultivation is shared by India and Bangladesh (Rahman, 2009). Table 1 shows the quantity of jute production in three leading countries in the world.

Table 1 Jute production (in tonne) of three leading countries

	2006	2007	2008	2009	2010	2011	2012
India	1857000	1840000	1425000	1608500	1349100	1324800	1912000
Bangladesh	884000	838682	841733	961939	956751	808000	1452044
China	48567	55500	400000	282000	340000	369000	45000

Note: Source: International Jute Study Group (2014).

Jute is a rain-fed crop with little need for fertilizer or pesticides. Broadcasting is the general practice for jute cultivation in most of the country. As jute seeds are generally broadcasted, broadcasting seed rate is 7-8 kg and 8-10 kg ha^{-1} for *olitorius* and *capsularis* respectively (Anonymous, 2013), hence there is uncontrolled plant density. Broadcasting method for jute seed planting is time consuming and creates constraints in weeding, thinning, fertilizer application and harvesting. Broadcasting method requires thinning operation within three weeks due to high plant population and providing better environment and high yield of fibre. Both weeding and thinning are done by hand hoe, which is tedious and time consuming operation. Weeding is one of the most important intercultural practices to save nutrients, moisture, light, space for main plant and sometimes controls many diseases, organisms and insect pest (Alam et al., 2010). The hand weeding is performed in bending or squatting posture, hence there is increased incidence of knee osteoarthritis amongst squatters who squat for hours a day for many years. Use of seed drill or planter for jute seed reduces burden in intercultural operation and makes the jute cultivation profitable by uniform plant population and saving of seed. Planting of jute seed at particular row to row and plant to plant spacing eliminate the thinning operation. The plant spacing is maintained at 10-15 cm and plant population 1.0 to 1.5 lakhs per acre by thinning

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operation in broadcasted field. The thinning gives best results if it is done within three weeks (Alim, 1978). Generally weeding and thinning operation are carried out manually. About 35% of the total cost of production is associated in manual weeding (Saraswat, 1980). It was also estimated that 75%-80% of fibre yield is lost due to the weed infestation, which is quite common in most of the jute growing situations (Sahoo and Saraswat, 1988). Weeding and thinning operation at proper time increase fibre yield. Two times weeding and one raking gave highest (3.12 t ha^{-1}) fibre yield (Masum et al., 2011). It is troublesome for weeding, thinning, fertilizer application in broadcasted field as compared to line showing method. Majority of the farmers control weed using hand tools like sickle, khurpi etc. During these activities, they adopt bending and squatting body posture due to which their physiological workload increases and also they face many types of physiological problems as a result of which the efficiency of worker decreases to a great extent (Sharma et al., 2015). The labour requirement for weeding and thinning operation for broadcasted jute is almost 40% of the total labour requirement for the crop (Islam, 2014). Thinning of jute plant is required twice in a whole season. Metering mechanism for jute seed drill was developed to carry 1 to 2 numbers of seeds with the cell dimensions of 2.5 mm diameter and 3 mm depth with cut-off mechanism (Chandel and Tewari, 2014). The design of the seed drill is done to avoid second thinning, which is compulsorily required in traditionally grown jute crop. Naik et al. (2017) developed conical frustum shaped seed hoppers of diameter of 9.7 cm and length 9.3 cm in the seed drill with a capacity of 0.699 litters made of tin sheet. During operation, seed falls freely by gravitational force, directly from the seed boxes through seed dispensing holes to the furrow and no seed tube are used. Fourteen holes of size 2.36 mm diameter were made on the periphery of the conical frustum seed boxes at equal interval of 2.74 cm to achieve plant to plant distance 5-7 cm in the field. Use of planter can maintain spacing between plants and rows, eliminate the numbers of thinning operation and as well as reduce weeding operation. This also makes the use of machinery for intercultural operation. As seed are very small, it needs to be dropped close to the furrow opener by gravity. Depth of planting and scattering from line of planting depends on the type of furrow opener (Karayel and Özmerzi, 2007). Plant spacing of 4, 6, 8, 10, 12 cm was studied for *corchorus capsularise, C. olitorious* and it was reported that green stalk, dry stalk and fibre yield were significantly affected by plant spacing (Nafees and Shah, 1983). Seed metering uniformity is impaired due to sudden release of seed batches due to small sizes of jute seed (Maleki et al., 2006). Spacing uniformity for graded seed increased as seed size increased with the metering system (Allen et al., 1983). In this study, seed metering mechanism was developed for sowing jute seeds and laboratory testing was carried out for its performance evaluation.

2 Materials and methods

2.1 Design consideration for jute seed drill

Maintaining of plant to plant and row to row spacing in jute cultivation is necessary for better yield of fibre and it is difficult to maintain plant to plant spacing in manual operation or using seed drill due to unequal and small size of jute seed. Therefore, metering unit for jute seed was designed to place jute seed at an equal distance in a row. Use of these metering mechanism helps to eliminate thinning operation and reduce the labour requirement for manual weeding as well as it provides sufficient row spacing for the use of mechanical power weeder.

2.2 Seed characteristic

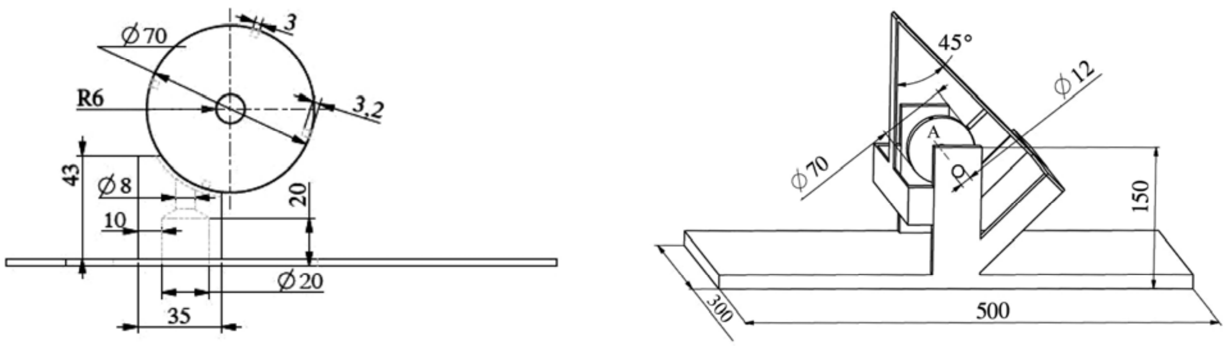
Jute seeds were irregular in shape and different in size, and were measured by a Vernier calliper with a sensitivity of 0.01 mm. The seed dimensions were measured from a randomly selected sample to design unique size of groove which holds at least one seed and not more than three seeds. Table 2 shows the physical properties of jute seed. Bulk density was measured by filling a 500 mL container with grain from a height of 15 cm, at table top levelling, weighing the material was done. Bulk density was determined by the ratio of that mass of sample of the grain to its total volume of sample (Gupta and Das, 1997). Where as the angle of repose defined as the angle with the horizontal at which the seed material will stand when piled, was determined by using the apparatus made up of a plywood box of size 290×150×30 mm with adjustable inclination. The box was filled with the sample and then the adjustable plate was inclined gradually allowing the seeds to flow (Varnamkhasti et al., 2008).

Table 2 Physical characteristics of jute seed

Variety of seed	Angle of repose (°)	Bulk density (g/cc)	Size (mm) (Range)		Co-efficient of variation (%)	
			Length	Width	Length	Width
Capsularis	29.15	0.7455	2.4-2.8	1.5-2.0	13.67	10.44
Olitorius	28.23	0.728	2.1-2.5	1.3-1.9	11.42	9.68

2.3 Design of seed metering mechanism

Considering minimum seed to seed spacing of 5 cm at selected minimum rpm of motor drive, four number of cell were placed on the periphery of the metering plate. Variation in seed size with respect to length, breadth of jute seed the cells on the roller was designed. As jute seed are irregular in shape, therefore number of seed that fill the cell varies, hence the major axis of jute seed was considered for designing of cell diameter and depth of cell. Cell diameter was designed as 1.1 time of major axis, and 1.15 time of major axis of jute seed was considered for design of depth of cell. Cell of diameter 3 mm and depth 3.2 mm were designed along the periphery of a roller of diameter 70 mm Figure 1a. These dimensions of cell allow minimum of a single seed and maximum of three seeds to get filled with. As jute seed are small and distinct in size, therefore number of seeds accumulated in the cell of metering unit varies. The discharge of seed occurred between 0° to 30°, after pick up from the hopper. The rotational direction of the seed metering plate was clock wise. The concept of this design was to maintain plant to plant spacing by allowing only one cell to open in between the angle of 0° to 30°, which maintain minimum damage of seed and the uniformity of seed placement with minimum coefficient of variation of seed spacing. The contact time of seed and mechanical parts is minimized by placing the seed hoper at an angle 45 degree from vertical. The outer periphery of seed metering unit is designed for rotation through uncovered path that eliminate the friction between seed and mechanical parts.



(a) (b)

Figure 1 (a) Seed metering plate and hopper attachment (b) Lab setup for seed metering

2.4 Seed spacing determination by sticky belt method

Sticky belt method was used in IARI, New Delhi for determining of seed spacing at different rotational speed of seed metering unit. Speeds of 30, 40, 50 and 60 rpm (0.10, 0.14, 0.18, 0.21 m s^{-1}) of seed metering unit were used for determining the seed spacing. Five replications were done for each rpm to evaluate the seed spacing. Sticky belt was run by a 5 hp motor and belt speed was controlled by AC (alternating current) motor controller. Jute seed metering unit was fitted over a base setup fitted 10 cm above the belt. Seeds are allowed to fall by gravitational action. Figure 2 shows the experimental setup used in this experiment.

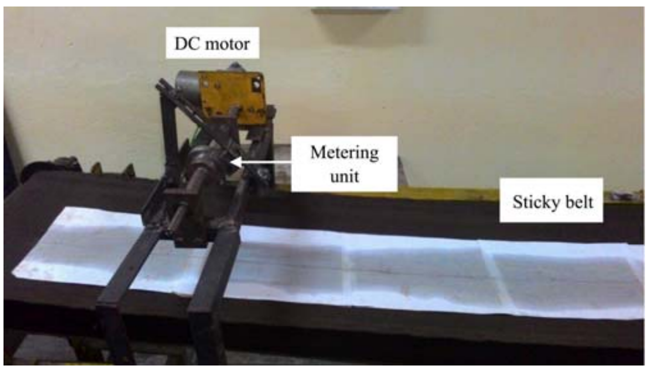


Figure 2 Experimental setup for seed metering unit

2.5 Laboratory testing of seed metering unit

The average seed spacing, seed distribution efficiency, coefficient of variance of seed spacing seed damage, and the percentage of seed distribution per spacing were used to quantify the seed metering mechanism. The above parameters determined throughout the laboratory experiments.

2.5.1 Coefficient of variation of seed spacing

The uniformity of seed spacing were analyzed in four meter of sticky belt, where average seed to seed spacing were measured and standard deviation was calculated to obtain the result.

2.5.2 Seed distribution efficiency

The percentage of seed distributed in six spacing group (3-5, 5-7, 7-9, 9-11, 11-13, 13-15 cm) were determined in four different speeds (30, 40, 50 and 60 RPM) of metering unit. Analysis helps to predict the percentage of dominating seed spacing at particular speed of seed metering unit. Seed distribution efficiency was determined by

$$S_e = \left(1 - \left(\frac{Y}{d}\right) \times 100\right) \quad \text{(Behera et al., 1995)} \qquad (1)$$

where, Y=Average numerical deviation of the number of seeds per meter length of row from the average number of seeds per meter length; d= Average numbers of seeds per meter length of row.

2.5.3 Seed damage

Mechanical friction between seed metering unit and seedcausesdamage to seed that was inspected visually to identify the appearance of crack. The percentage of seed damage was determined by following equations (Ani et al., 2016)

$$SD(\%) = \frac{TN_b}{TN_p} \times 100 \qquad (2)$$

where, SD = percentage seed damage; TN_b = Total number of broken seeds; TN_p = Total number of planted seeds.

3 Results and discussions

Operating speed applied in this experiment was decided on basis of spacing required for jute sowing. Seed metering unit was tested at different peripheral speeds for achieving seed spacing between 5 to 10 cm, which is preferred for high yield of jute fibre. The experimental results on seed distribution for *Capsularies* and *Olitorius* were presented in Table 3 and Table 4.

Table 3 Seed distribution for *Capsularies*

Operating speed (rpm) (m s^{-1})	Avg. num. of seed drop per heel	Average spacing for all groups (cm)	SD	Seed distribution per spacing group (%)					
				3-5 cm	5-7 cm	7-9 cm	9-11 cm	11-13 cm	13-15 cm
30 (0.10)	1.6	11.49	1.03	0	0	0	26	68	6
40 (0.14)	1.9	8.53	0.88	0	4	74	22	0	0
50 (0.18)	2.2	6.69	0.83	4	58	38	0	0	0
60 (0.21)	2.6	5.42	0.76	20	78	2	0	0	0

Table 4 Seed distribution for *Olitorius*

Operating speed (rpm) (m s^{-1})	Avg. num. of seed drop per heel	Average spacing for all groups (cm)	SD	Seed distribution per spacing group (%)					
				3-5 cm	5-7 cm	7-9 cm	9-11 cm	11-13 cm	13-15 cm
30 (0.10)	2.1	12.21	1.12	0	0	0	30	64	6
40 (0.14)	2.4	8.85	1.04	0	4	76	20	0	0
50 (0.18)	2.7	7.00	0.98	6	60	34	0	0	0
60 (0.21)	3.1	5.95	0.85	20	76	4	0	0	0

Table 3 and 4 showed that the trend of seed distribution percentage for both seed were similar. As the speed of seed metering unit increased, the seed spacing got reduced. In laboratory experiment, plant to plant spacing of 5.42, 6.69, 8.53 and 11.49 cm for *Capsularies* and 5.95, 7.0, 8.85 and 12.21 cm for *Olitorius* seeds were obtained at 0.21, 0.18, 0.14, 0.1 m s^{-1} respectively. Standard deviation of seed spacing from mean value for *Capsularies* and *Olitorius* seed were found to be decreased as rpm of the seed metering unit get increased. Therefore, at higher rpm the seed spacing was more uniform as compared to lower rpm. Variation of seed spacing is linear with the rpm of roller. At different rpm of seed metering unit, the average seed spacing for both *Capsularies* and *Olitorius* seed follow the same trend in decreasing order (Figure 3).

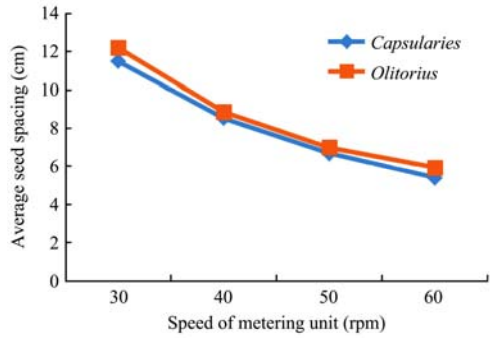


Figure 3 Average seed spacing in different rpm of metering unit

Generally, plant to plant spacing is kept between 5 to 15 cm in jute seed planting. Based on the requirement, metering unit was designed to achieve appropriate plant spacing. From the Figure 2, it was observed that plant to plant spacing varied from 11.49 to 5.42 cm (*Capsularies*) and 12.21 to 5.95 (*Olitorius*) at 30 to 60 rpm respectively. Plant spacing continuously decreased with the increase of rpm of metering unit. Uniformity of seed distribution of planter was evaluated in laboratory condition, as rpm of metering unit increased the co efficient of variation of seed spacing also increased as shown in Figure 4. As rpm of seed drill increased, the seed distribution efficiency of seed decreased as shown in Figure 5. Seed distribution efficiency were found as 91% at 30 rpm (0.1 m s^{-1}) and 86% at 60 rpm (0.21 m s^{-1}) of metering unit for *Capsularies* and for *Olitories* 90% at 30 rpm (0.1 m s^{-1}) and 84% at 60 rpm (0.21 m s^{-1}) were recorded.

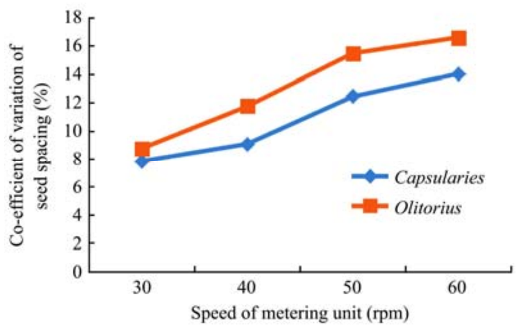


Figure 4 Co-efficient of variation of seed spacing in different rpm of metering unit

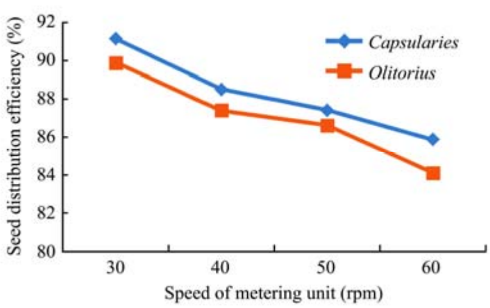


Figure 5 Seed distribution efficiency in different rpm of metering unit

Seed damage occurs in mechanical seed metering mechanism due to the friction between metering unit and seed. Experiment results showed that with the increase of rpm in metering unit, seed damage also increased. Metering unit was operated at four different speeds of 30, 40, 50, and 60 rpm to maintain plant to plant spacing. From Figure 6, it was seen that at 30 rpm (0.10 m s^{-1}) of speed, seed damage percentage was 0.5% and it went to 1.28% at 60 rpm (0.21 m s^{-1}) for *Capsularies*, while for *Olitories* seed damage was 0.45% at 30 rpm (0.10 m s^{-1}) to 1% at 60 rpm (0.21 m s^{-1}). Seed damage was higher for *Capsulries* because size was relatively big for *Capsulries.*

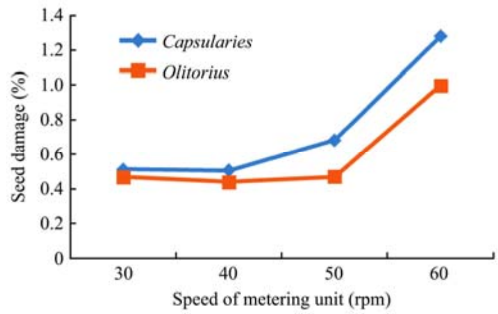


Figure 6 Seed damage percentage in different rpm of metering unit

Seed rate depends on the size andshapeof jute seed. Seed required for *Capsularies* per hectre was 4.47 kg whereas for *Olitories*seed, 5.23 kg (Figure 7) was observed in labrotary testing. Altough it is insignificant, seed rate was higher in case of *Olitories* seed because ofits seed size. The seed pickup and dropping per heel was more in case of *Olitories*as compared to *Capsularies* seed. Unequal shape and size of jute seed had effects on seed rate at different rpms, even this variation could be found in same rpm of metering unit at different times.

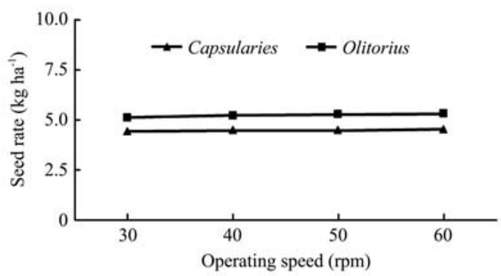


Figure 7 Seed rate in different rpm of metering unit

4 Conclusions

A new seed metering roller for jute was developed for placing the seeds at equal spacing while avoiding more than three seed dropping at a point. Laboratory testing using sticky belt at 30, 40, 50, 60 rpm (0.10, 0.14, 0.18, 0.21 m s^{-1}) of seed metering roller was carried out to examine the spacing of seeds, bouncing effect of jute seeds and mechanical damages of seed and seed rate. It was observed that as the rpm of seed metering roller increased, the spacing of seed got reduced. In term of CV (coefficient of variation) percentage of seed spacing, at 30 rpm (0.10 m s^{-1}) operating speed, the seed metering unit has lowest CV percentage, indicating that seed distribution was more uniform. Seed spacing of 11.49 and 12.21 cm for *Capsulries* and for *Olitorius* seeds respectively were recorded. With the increasing speed of metering unit, CV percentage of seed spacing got increased. Whereas with the increase in rpm of seed metering roller, the seed distribution efficiency got decreased from 91% to 86% and 90% to 84% at 30 and 60 rpm (0.10 to 0.21 m s^{-1}) for *Capsulries* and for *Olitorius* seed respectively. It was also observed that with the increase in rpm, the seed damage also increased for both type of seeds. In broadcasting method of jute seed, the seed rate is 7-8 and 8-10 kg ha^{-1} for *Olitorius* and *Capsularis* respectively, whereas in laboratory testing of newly designed seed metering mechanism the seed rate was found on an average of 4.47 and 5.23 kg ha^{-1} for *Capsularies* and *Olitories* seed respectively.

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