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Performance of Seed Planter Metering Mechanisms under Simulated Conditions

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ABSTRACT: In rainfed conditions the success of crop production depends on timely seeding. The seed rate for various rainfed crops varies from 4 to 140 kg ha^{-1}. So, selection of a multi crop planter with replaceable metering rotor is crucial to meet the farm requirements and timeliness of operation. Though different types of planters having different seed metering mechanisms are marketed in India, single seed metered mechanical mechanisms are becoming popular as thier seeding performance is relatively better. To evaluate performance of such mechanisms quickly and optimize the parameters, a grease belt test rig was developed at CRIDA. The existing inclined plate metering mechanism and newly developed horizontal metering plate were tested for comparative performance at three speeds, 2.5, 3.5 and 5 km h^{-1} with castor and maize seeds using the test rig. The average number of seeds metered at different forward speeds for selected variety of maize varied from 367.5 to 239 for inclined plate and 308 to 281 for horizontal plate when compared to theoretical metered seed of 270. In horizontal plate, the seed metering was more consistent and did not varied much with respect to speed of rotor and delivered 14.02 to 4.03% higher seed rate for castor. The mean seed spacing ranged from 19.3 to 23.1 cm. The horizontal rotor metered 94 – 98 frequency percentile seeds within 15 – 30 cm spacing intervals at operation speeds of 2.5 to 3.5 km h^{-1}. It is concluded that, correct seed rate can be achieved with the selected speed ranges by re-designing the seed cells in horizontal plate rotor.

Key words: Test rig, metering mechanism, planter performance, precision application

Introduction

In rainfed farming, numerous crops are grown and the success of crop production depends on timely seeding of these crops with reduced drudgery of farm labour. With the introduction of subsidy for various agricultural implements and non availability of sufficient farm labour, various models of tractor drawn sowing implements becoming popular in dryland regions of India.

It is necessary for seeds to be placed at equal intervals within rows. In manual seeding with conventional practice, the higher and non-uniform plant population adversely affect grain yield of different crops (Singh *et al*., 2007). The ultimate objective of seed planting using improved sowing equipment is to achieve precise seed distribution within the row. The achievement of the set seed spacing majorly depends on the machine technical variables such as the type of seed pickup mechanism, the machine operating speed, overall gear ratio between drive wheel and seed rotor, and to some extent on seed quality.

Although there are many planters having different seed metering mechanisms, the application of single seed metered plate mechanisms (horizontal, vertical and inclined plate) has increased rapidly due to better seeding performance than that of other mechanical rotors. However, in recent times due to climate variability and lack of sufficient moisture in the soil for reasonably sufficient time in the sowing window period, farmers are preferring to operate the planters at higher speeds to complete the sowing operation of various rainfed crops within a short period. Thus, the metering mechanism should be accurate enough to plant seeds at the required seed to seed distance in a row. This accuracy is expressed as the quality of the planter. Therefore, the proper design of a seed metering mechanism is essential for satisfactory performance of any seed planter. The assessment of plant spacing and seed rate as provided by the planters is also crucial in analyzing its performance. A variety of methods have been evolved to assess the performance of planter metering mechanism. Measuring the spacing between germinated plants after planting with machine is most common method. The accuracy of this method seriously affected by weather condition and more importantly by seed quality/viability. The second most prevalently used method is the grease belt test rig under laboratory conditions, which is unaffected by crop and soil conditions. Hence, this study was taken up to develop a test rig, and evaluate inclined and horizontal plate seed metering mechanism by simulating planter operating conditions.

Materials and Methods

Fabrication and development of a test rig: A grease belt test rig that provides an environment for the determination of seed rate and seed placement of selected metering mechanism was developed to carry out the tests under the laboratory conditions. The test rig consisted of a rectangular frame of 400x60 cm made of 35x35x5 mm M S angle iron. Eight legs of 60 cm length were welded to the frame to give stability and proper ground clearance for work place. Two rollers of 41 cm length and 11 cm in diameter were fabricated and fitted over the frame using pedestal bearings 280 cm apart to run the grease belt. The distance between the two rollers is adjustable in 25 mm increments to tighten the belt when required. To mount different seed planter boxes for testing, a 90 cm height and 60 cm rectangular angle iron frame was fabricated and fitted near the drive roller. The drive transmission from the motor to the drive roller of endless belt and feed shaft is through sprocket and chain at speed ratio of 1:1. A 5 hp and 2 hp electrical motors fitted with variable frequency speed drives run drive roller and seed metering feed shaft, respectively. The variable speeds were obtained by variable frequency drive regulator, which in-turn changes the in-put voltage to the motors. Two in-built revolution per minute counters with digital read out greatly help to regulate the shaft out-put rpm with 98% accuracy**.** A specially fabricated 2.5 mm thick Poly Vinyl Chloride impregnated with nylon material and non-expandable single side grip flexible endless belt was used in the test rig.

Development of seed planter boxes: To carry out the study on different crop seeds, two metering mechanisms which facilitate the seed rotor plate's replacement were selected and fabricated in farm machinery workshop of the institute. A single existing box with inclined rotor plate and newly developed horizontal plate metering mechanism were evaluated using test rig. To provide the drive from test rig, the shorter 16 mm diameter shaft was replaced with similar diameter appropriate length shaft (Fig. 1).

The horizontal mechanism consists of three circular shape mild steel portions placed one over the other and locked while in position. The lower portion is cup shaped with 210 mm outer and 120 mm inner diameter with a 60 mm wide strip at the centre. An oblong shaped slot on one edge and a locking block on the opposite side were made to match the centre line of the 60 mm strip. Perpendicular to the central strip, two 30 mm diameter circular collars were provided at the lower edge of the cup to arrange the drive shaft with bushes. Three holes of suitable diameter were drilled in the strip to fix the cup on a frame. The middle portion of the mechanism is a simple circular shape ring with 25 mm width strip of 180 mm outer diameter made out of 8 mm thick mild steel plate. At the edge of the ring, a 85x20 mm size square block of same thickness with a 25x25 mm square hole at the centre was welded. The upper portion of the mechanism was also in circular ring shaped with 250 mm outer diameter and 35 mm width strip made of mild steel through casting technique. The central portion of this part was covered with 140 mm diameter circular cut part to which a central 5 mm thick wall collar bush of 20 mm inner diameter was provided at the lower side to facilitate for drive transfer to seed plate. The central metal cut part was very close to the seed metering plate and slightly tapered towards the outer edge to facilitate sliding of seeds towards the cells portion of the plate and also to reduce the exposure of seeds placed in the box with rotating plate. The central collar bush was designed such a way that, the central portion of the seed metering plate could be kept thicker to avoid shear way due to rotational movement and thin at the cells portion to avoid multiple seed pick- up in operation. This type of arrangement also facilitates to use the same metering mechanism for different types of crops by just changing the seed plate. A circular hopper of 230 mm diameter with 300 mm height made of fiber plastic was fitted over the top portion of the mechanism to keep the seeds (Fig. 2). In fabrication of both the seed metering mechanisms, the commercially available gears were considered in design to reduce the planter fabrication costs and easy maintenance.

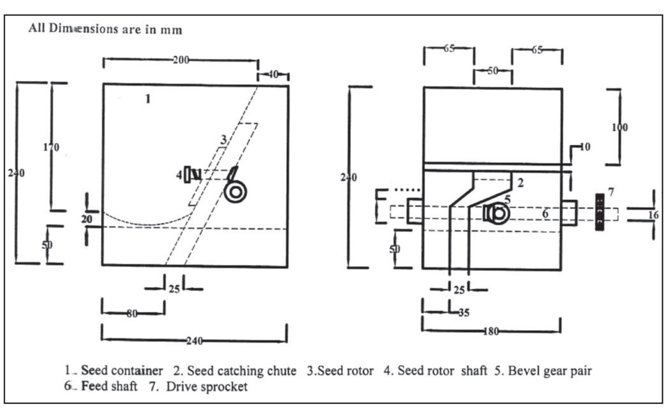

Fig 1 : Inclined plate metering mechanism with seed box

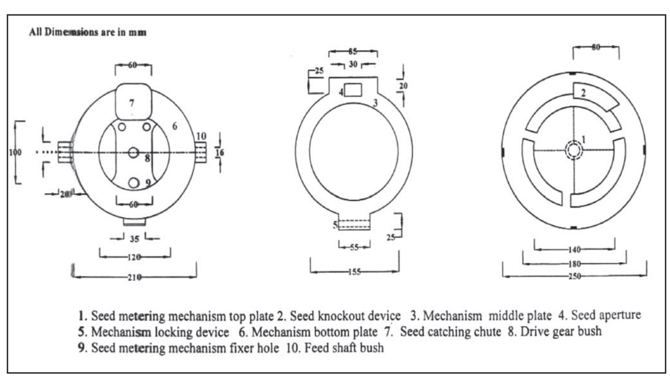

Fig 2 : Horizontal plate metering mechanism design details

Selection of variables for tests: To test the seed metering mechanisms using a grease belt test rig, few field trials were taken up with existing planter to verify and select the planter operating speed ranges in Indian conditions and ground wheel dimensions for seed rotor rpm calculation. It was observed that, in our field trials, different tractor operated planters were operated at forward speeds ranging from 1.75 – 3 km/h. The planter / seed drill ground wheels (drive transmission) effective diameters ranged from 30 – 45 cm. Hence, we selected the planter forward speeds 2.5, 3.5 and 5 km/h and ground wheel effective diameter as 38 cm for laboratory evaluation. Accordingly, the variable drives speeds were calculated and set for both belt and seed rotor (Table 1).

Castor and maize seeds were selected and physical properties were measured using standard procedure. By trial and error method, the diameters of the inclined and horizontal plate were fixed as 120 and 194 mm, respectively. The number of cells on the plates was calculated as 6 and 24 respectively as per the drive transmission ratios and recommended seed spacing in dryland conditions for both the test crops. A hard PVC sheet of 10 mm thick was chosen to fabricate seed metering plates for castor and maize. The specifications of selected seed planting mechanisms are presented in Table 2.

Experimental test procedure: The seed metering plate designed for selected test crops (castor/maize) was fitted in the seed box while testing that particular crop. Graded seed samples up to 3/4th capacity of seed hopper was filled, the unit was mounted on the test rig and fitted firmly. The hopper height was kept at 30 cm above the belt and was maintained constant throughout the experiment for each planter mechanism. The sliding baffle was fixed over the partition plate of the compartment in case of inclined plate metering mechanism, so that a seed column of 4 cm height was maintained over the seed plate. In case of horizontal plate planter, a knockout device was provided exactly over the seed catching aperture, no baffle plate was required. During the test runs of seed metering rotor, the seeds dropped in 45 cycles of feed shaft were collected for each run, seeds dropped and seeds damaged were counted manually and weight was noted using the electronic balance. To determine the seed spacing interval of metering mechanisms, grease was smeared as 3 mm thick layer on the top surface of endless belt along its length for easy adhering of seeds that were dropped from the seed box. The endless belt and feed shaft were operated simultaneously at required speeds through electric motors provided with variable speed drives. During test runs, the actual spacing between two consecutive seeds dropped on the grease belt were measured using a 100 cm length steel rule for a row length of 300 cm for each set of run. The number of replications was four for all the combinations of variables selected for the study. The data were analyzed statically following the Completely Randomized Design and using a software 'DRYSOFT' developed by Central Research Institute for Dryland Agriculture, Hyderabad.

Table 1 : Belt and seed rotor speeds used in the study

Planter operating Speed, km/h	Inclined plate metering mechanism		Horizontal plate metering mechanism	
	Belt drive roller (rpm)	Seed metering plate (rpm)	Belt drive roller (rpm)	Seed metering plate (rpm)
2.5	120	35	35	9
3.5	169	49	49	12
5.0	241	70	70	18

Table 2 : Specifications of seed metering mechanisms

Parameter	Inclined plate mechanism	Horizontal plate mechanism
Seed box shape & dimensions	Cuboid, 17.5x20(9)x22 cm	Circular, D = 25.5 cm
Material used for seed plate	Poly Vinyl Chloride	Poly Vinyl Chloride
Seed plate shape, diameter and thickness	Circular, d = 120 mm, t = 6 mm	Circular, d = 194 mm, t = 6 mm
Seed cells shape and No. of cells on plate	Elongated, 6 Nos	Circular, 24 Nos
Target seed spacing for maize	20 cm	20 cm
Target seed spacing for castor	20 cm	20 cm
Mean seed cell size		
Castor	104.667 sq.mm,(C.V=2.064)	89.272 sq.mm, (C.V. = 6.819)
Maize	136.33 sq.mm, (C.V=8.229)	58.272 sq.mm, (C.V. = 3.835)

Results and Discussion

The seed parameters play a major role in design of cell in a metering plate and flow through seed planter components (Table 3). The length, width and thickness of maize and castor seeds are 8.50, 8.15 and 4.10mm and 11.38, 7.83 and 5.56 mm respectively. The 1000-seed weight of maize and castor seeds was 183.5 and 255.7 g, respectively.

In general, movement of non-spherical or rough surface seed is slower under gravity, so cell size was kept little bigger for maize seed though the frontal area is lower than the castor. The other parameters such as sphericity, angle of repose, bulk density, moisture content also play a major role in design of various components of a seed planter.

Effect of operating speed on seed metering

The mean number of seeds dropped from the metering mechanisms at different forward speeds for selected variety of maize varied from 367.5 to 238.8, 300.4 to 285 for inclined plate and horizontal plate metering mechanisms, respectively, whereas for castor, the readings were in the range of 355 to 79.8 and 307.8 to 280.9.The theoretical number of seeds to be dropped from the seed plate in one cycle (45 rotations of feed shaft) are 270, however variation was observed in the actual number of seeds collected and counted by manual labour (Table.4).

The actual number of seeds dropped was little more than the theoretical number (270) using horizontal plate mechanism at all the speeds for both the crops tested. In this mechanism, manual counts also varied consistently, which indicates there exists possibility of improvising the seed rotor by decreasing seed cell size, so that optimum seeding rate could be obtained. In case of inclined plate mechanism, the manual count was more than the theoretical count at lower speeds and decreased to less than the theoretical count as the speed increased. In this case optimum seeding rate could not be obtained by simple modification of seed metering plate, the entire metering mechanism as a whole need to be examined with respect to the forward speed of the planter.

The percent cell fill of seed metering plates for maize and castor seed were also found to be varying depending upon the forward speed of the machine. Highest cell fill of 136.1 and 111.2% were recorded in case of maize using inclined

Table 3 : Selected parameters of maize and castor seeds

Seed	Length (mm)	Width (mm)	Thickness (mm)	Moisture content (%)	Bulk density (Mg m^{-3})	Sphericity (%)	Angle of repose degree	1000 -seed weight (g)
Maize	8.50	8.15	4.10	11.5	0.77	77	44.4	183.85
CV	5.48	6.23	17.08	12.2	0.55	7.32	2.689	1.01
Castor	11.34	7.83	5.56	12.0	0.58	69	32.84	255.7
CV	5.16	6.06	8.02	0.475	0.47	3.03	5.803	4.41

Table 4 : Performance of seed metering mechanisms at different operational speeds

Metering mechanism (%)	Forward speed (km h^{-1})	Mean number of seeds	Mean cell fill (%)	Broken seed (%)
Inclined plate	Maize			
	2.5	367.5	136.1	Nil
	3.5	327.37	121.3	Nil
	5.0	238.85	88.46	Nil
	Castor			
	2.5	355.00	131.4	0.55
	3.5	325.50	120.5	0.83
	5.0	79.87	29.58	0.97
Horizontal plate	Maize			
	2.5	300.37	111.20	Nil
	3.5	292.50	108.3	Nil
	5.0	285.00	105.55	Nil
	Castor			
	2.5	307.87	114.02	0.833
	3.5	297.25	110.09	0.97
	5.0	280.90	104.03	0.694

plate and horizontal plate metering mechanisms respectively at machine forward speed of 2.5 km h^{-1}. The same was 131.11 and 114.02% for castor at the same forward speed of the machine. When metering mechanisms are considered, the difference in the percent cell fill for the two crops may be due to the differences in the shape and size of the seed. The variation in cell fill using the same plate at different forward speeds of the machine may be due to the less time available for the seed to fill into the cell area or less time to drop into the chute at higher speed. This is in agreement with the findings of Wanjura and Hudspeth (1968).

The number of seeds actually metered from metering mechanisms (manually counted), when compared with theoretically calculated seeds for 45 cycles of feed shaft at different forward speeds (2.5, 3.5 and 5.0 km h^{-1}) for maize and castor seeds are shown in Fig 3. The mean number of seeds dropped and theoretically to be metered were considerably varied among the metering mechanisms at 3 rotor speeds. In horizontal plate metering mechanism, the variation between theoretical and practical count was in the range of 4 to 14% as for the rotor speed but variation was not much different among the crops. In inclined plate mechanism, overall, the difference between the number of seeds actually dropped and with that theoretical were found to be ranging from 36.1% excess to 11.5 % less, 31.4% excess to 70.5% less for maize and castor, respectively when speed varied from 2.5 to 5 km h^{-1} . The same were 5.55 to 11.2%, 4.03 to 14.02% more for maize and castor respectively with the other metering mechanism. This finding contradicts with the findings of Chauhan et.al (1999) for inclined plate meter with sunflower seed. This might be due to reason that the rotor speeds selected in the present study were higher.

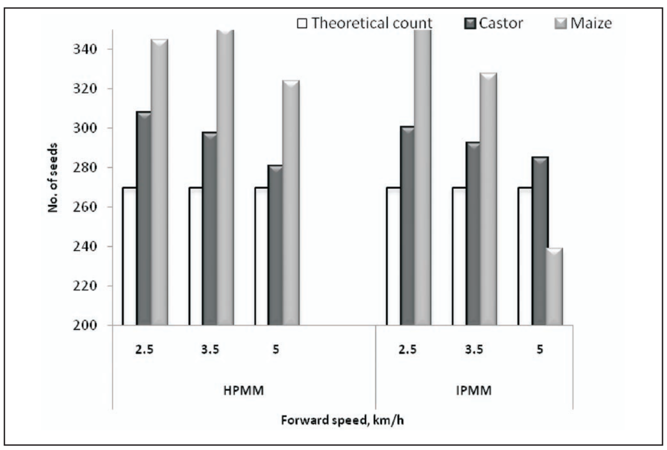

Fig 3 : Comparison of seed rotors in terms of number of seeds metered at different speeds

Effect of operational parameters on seed breakage

The seed breakage for castor varied in the range of 0.55 to 0.97 % and 0.69 to 0.97 % for inclined plate and horizontal plate metering mechanisms respectively, when forward speed increased from 2.5 to 5.0 km h^{-1}(Table 4). The seed breakage was due to shear rate between interface of seeds and metering plate. No seed breakage was observed while testing the metering mechanisms with maize seed.

Effect of operational parameters on performance of seed metering mechanism

The seeding rate remained more or less around 15 seed m^{-2} for maize in inclined metering mechanism at forward speeds of 2.5 and 3.5 km h^{-1}. Further increase in the forward speed of the planter to 5.0 km h^{-1}, decreased seeding rate to 9.87 (Table 5). However, in horizontal plate mechanisms, the seeding rate ranged from 12.4 to 11.2 within the selected speeds. Similar variations were also observed in seed rate of castor (Table 6). The two-way interaction statistical analysis showed that, the interaction effect as well as single parameter effect was highly significant at 1% level, indicating both speed and metering mechanism had significant effect on the seed metering efficiency of selected crop. In case of castor crop, inclined plate metering mechanism at 2.5 km h^{-1} speed and horizontal plate metering mechanism at all selected 3 speeds for both the crops gave seeding rate very close to recommended seed rate. These results revealed that seeding rate was higher at low forward speed and decreased with increase in forward speed in case of inclined plate metering mechanism. The higher seeding rate at low speed may be due to more number of seeds picked up by the cells. These finding are in close agreement with the results reported by Anantachar (2007) for peanut and chickpea varieties, and Sahoo and Srivastava (2000) for okra seed.

Table 5 : Effect of different metering mechanisms and operating speeds on seeding rate (No. m^{-2}) of maize

Forward speed (km h^{-1})	Rec. seeding rate (No. m^{-2})	Metering mechanism		
		IPMM	HPMM	Mean
2.5		15.44	12.403	13.92
3.5	11	15.180	11.54	13.36
5.0		9.875	11.20	10.79
Mean		14.726	11.71	13.22
Mechanism			Speed	
F-test	70.04**		F-test	270.88**
SEm	0.146		SEm	0.179
CD (P=0.05)	0.310		CD(P=0.05)	0.38
MM X FS				
F –test	69.51**			
SEm	0.254			
CD (P=0.05)	0.537			

IPMM=Inclined plate metering mechanism; HPMM=horizontal metering mechanism

Table 6 : Effect of different metering mechanisms and operating speeds on seeding rate (No. m^{-2}) of castor

Forward speed ($km\ h^{-1}$)	Rec. Seeding rate (No. m^{-2})	Metering mechanism		
		IPMM	HPMM	Mean
2.5	5.5	8.333	6.365	7.349
3.5		6.575	5.850	6.212
5.0		1.645	5.583	3.614
Mean		5.516	5.920	5.718
Mechanism			Speed	
F –test	556.73**		F-test	1314.23**
SEm	0.061		SEm	0.075
CD (P=0.05)	0.129		CD (P=0.05)	0.158
MM X FS				
F-test	138.02**			
SEm	0.106			
CD (P=0.05)	0.224			

IPMM = inclined plate metering mechanism; HPMM = horizontal plate metering mechanism

Effect of operational parameters on seed to seed distance

Among the two metering mechanisms, seed spacing interval was more erratic for inclined plate planter when compared with horizontal metering plate for both the crops. For horizontal plate metering mechanism, the seed spacing varied from 23.1 to 19.3 cm for maize and 22.7 to 19.9 cm in case of castor (Table 7). The lowest seed spacing was at 3.5 km h^{-1} operating speed of the planter. Horizontal metering plate recorded more consistent seed to seed spacing interval when compared with the other mechanism. The seed spacing interval increased with increase in forward speed in case of inclined plate metering mechanism for both the crops. The spacing interval ranged from 17.7 to 34.1 cm for maize and 25.4 to 33.9 cm for castor when operating speed was increased from 2.5 to 5.0 km h^{-1} and 2.5 to 3.5 km h^{-1}, respectively. This may be due to the fact that as the belt speed (planter forward speed) increases, the seed spacing increases causing decrease in the seeding rate in some of the planters. Similar results were reported by Zeliha and Aziz (2004) for maize varieties and Anantachar (2007) for chickpea and peanut varieties.

The peak percentile frequency for castor and maize ranged from 20 to 53% in case of horizontal plate with 20 – 25 cm spacing and the same was from 7 to 22% for inclined plate (Fig 4&5). Over all, in 15–30 cm spacing interval with speed ranges of 2.5 to 3.5 km h^{-1}, 94 to 98% seeds were metered in case of horizontal rotor and only 51 to 71% with inclined rotor plate. Both the metering plates performed better with

Table 7 : Seed spacing uniformity of seed planter metering mechanisms

	Horizontal plate metering mechanism			Inclined plate metering mechanism		
Forward speed km/h	2.5	3.5	5.0	2.5	3.5	5.0
Maize seed spacing (mm)	231.43	193.02	213.66	176.61	235.73	340.93
SD	74.51	48.28	66.71	81.68	120.48	229.72
CV	32.19	25.01	31.23	46.25	51.10	67.38
Castor seed spacing (mm)	215.42	199.03	222.62	254.03	339.69	Not able
SD	72.88	51.46	89.10	133.28	162.52	to record
CV	33.83	25.85	39.31	52.47	47.84	

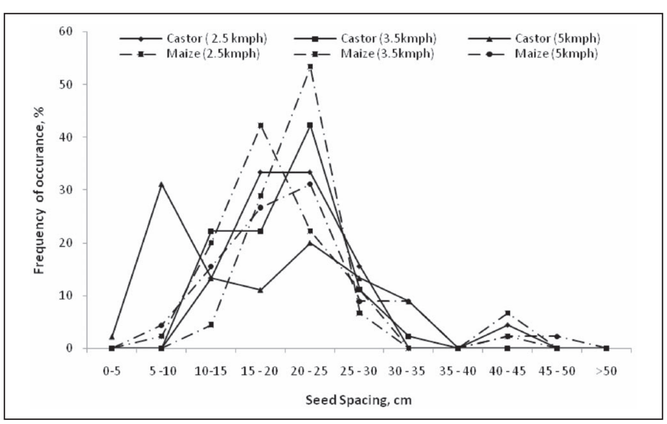

Fig 4 : Seed spacing distribution pattern of horizontal plate mechanism

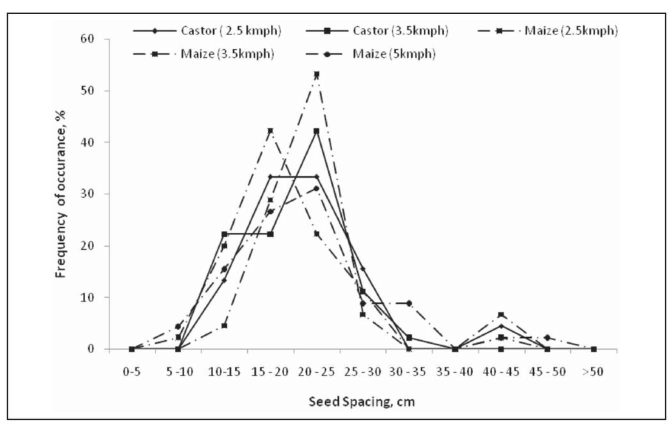

Fig 5 : Seed spacing distribution pattern of incline plate mechanism

castor seeds. This shows that horizontal Plate metering mechanism is more reliable than the inclined plate mechanism.

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