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Optimization of the shape and size of seed plate orifice for accurate single seed planting of the crops

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■ ABSTRACT : The shape and size of seed plate orifice were decided on the basis of the dimensions of the different seeds. For all the seeds, the shape of the seed plate orifice showed its effect upon the planting accuracy. For cotton, groundnut and sesame seeds, best results were found with elliptical shaped orifice, with longer and shorter axis (5, 4.50), (3, 2.50) and (1.50, 1) mm, respectively. Whereas, for okra seed, the optimum seed plate orifice shape was circular with 3 mm diameter. For positive release of the sesame seed, air velocity of 3 m/s through chamber open to atmosphere showed best results.

■ KEY WORDS : Pneumatic planter, Single seed planting, Orifice size, Lighter, Bold seed planting

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India has more than 74 per cent population supported on agriculture and agriculture contributes about 25 per cent of the domestic product of 1.8 lakh Crores. Crops like cotton, groundnut, sesame and vegetable are some of the main cash crops grown in the country. The total foreign exchange of the country from groundnut, cotton, sesame and vegetable was 557.16, 731.67, 272.79 and 589 crores, respectively in 1999 (Indian Agriculture, 1999). There is a need to stabilize or improve the production of the above crops to have their greater contribution to the Indian economy. This could be achieved by improving the productivity of the above crops in the country. Several researchers in the country and abroad have developed animal drawn and tractor operated planters for planting of these crops (Majumdar *et al.*, 2002). However, their extent of use has been limited due to their limitation in precise planting of the seeds.

Tractor operated pneumatic planters have also been developed in India and abroad (Kumaran and Kumar, 2004 and Ziadi *et al.*, 1998) adoption of these machines has been quite limited, due to their higher initial cost. These machines use vacuum seed metering principle. The principle offers several advantages, especially the single seed picking, no mechanical damage to the seed and their capability to deal with both bolder and lighter seeds. These machines have great potential for adoption for production of high value cash crops; especially requiring highly viable seeds.

The size, shape and weight of the individual seed has predominant effect upon the performance of the pneumatic seed metering mechanism. Variation of sizes and weight of the seeds would require variation in size of orifice on the seed plates and range of suction pressures for effective single seed pick up without misses. The leakage of the suction pressure from the vacuum chamber into the chamber open to the atmosphere, in the pneumatic disc would result in improper release of the lighter seeds. These aspects need suitable solution for development of an effective pneumatic planter for adoption.

A study was made by Short and Hubber (1970) to determine minimum nozzle air velocity to pickup single seed. He suggested a mathematical expression for minimum airflow velocity required to hold single seed. On the basis of his study, he concluded that orifice air velocity was a critical factor in picking up one seed at a time. For vacuum nozzles with small diameter holes, the seed must be nearly in contact with orifice for the proper attachment. The per cent of theoretical drop was almost independent of seeding rate for 1.5 to 6 seeds per second for 1/16" diameter nozzle and velocities equal or greater than 80 ft/s.

Sial and Persson (1984) evaluated seven vacuum nozzles and showed that the pressure difference, needed to pickup a seed increased with the fourth power of pickup height for height more than one seed radius per nozzle. Pickup of more than one seed per nozzle occurred more frequently, if the pickup height was less than one seed diameter. Pressure reversal was required to remove all seeds from the nozzles, even when low-pressure difference had been used for pickup and transport.

Shafii and Holmes (1990) investigated metering of seeds by an air jet, flowing through a conical cavity. Pressure distribution and force exerted on the seeds were measured for different cone configuration, orifice diameters and cone-seed clearance. Test result showed that cone angle of 90^0 and 1.59 mm orifice developed highest retaining force.

Shafii *et al.* (1991) developed an air-jet singulator. In working, a low volume pressurized air stream was used to blow the loosely held extra seeds off. Test results showed that the mechanism worked very well with 100.2 per cent planting efficiency, 93 per cent single, 4.7 per cent skip, 2.3 per cent doubles and no multiples.

Schmidt (1992) studied the drilling quality of pneumatic drill. The influences of air speed and delivery pipe shape on seed distribution were examined.

Keska and Maciaszeh (1994) carried out and investigation into pneumatic transportation of grain along the channel from seed metering device to the coulter of drill to optimize the design of channel. Laboratory and field tests were carried out to determine the energy and material saving, resulting from optimization.

Guarella *et al.* (1996) conducted experiments on performance of vacuum seeder nozzle for vegetable seeds. The experimental pickup tests with depression upto 80 kPa showed that the increase in nozzle increase in nozzle diameter resulted in increase in pick up distance, in the range of 0-20 kPa, resulted in big increase in pick up distance.

Min and Ming (1996) showed that vacuum capacity was dependent up on cross sectional area of the outlet vent. Increase in cross-sectional area resulted in an increase in the vacuum capacity, whereas decrease in cross- sectional area of outlet vent resulted in increase in air speed, an increase in system temperature and energy loss in the system.

Barut and Ozmeri (2002) studied the effect of different seed plate hole shapes (perforated square, equilateral triangle, oblong, circular) of seed plate, using vacuum type precision drill. He showed that proper orificeshape varied according to the shape of seed and was circular for round seeds, oblong for flat and longer seeds.

Singh *et al.* (2004) studied the shape of entry hole, disc speed, vacuum pressure on a sticky belt in laboratory. The performance was based on the induces, such as mean seed spacing, minimum misses and multiple indices highest quality of feed index and precision. Statistical analysis showed that 2.5 mm with 120^0 cone angle yielded best mean seed spacing of 25.07 cm against a theoretical value of 25 cm at 2 kPa in the disc speed range of 0.29 to 0.42 m/s. the minimum miss and multiple indices was recorded 1.33 and 4 per cent, respectively for thr highest quality of feed index of 94.66 per cent and precision of 8.55 per cent.

■ METHODOLOGY

Different shapes of orifice openings on the seed plate :

For analyzing the effect of seed plate orifice size and shape upon the planting efficiency, seed plate orifices of different shapes *viz.*, circular, elliptical and triangular were selected. The sizes of all the shapes were determined, with the consideration that the exposed area to the seed is same for all the three shaped orifices.

Dimension of different shaped seed plate orifices:

The sizes of different seed plate orifices were

Table A : Physical properties of different seeds

	Groundnut	Cotton	Sesame	Ladyfinger
Variety	Vaishali	Jk-4	Local	Anamika
Ave. Length, mm	11.51	7.78	3.19	5.80`
Ave. width, mm	6.76	4.35	2.24	5.03
Ave.thickness mm	7.49	3.50	0.80	4.70
Wt. of 1000 grain, g	460	59	2.37	56
Sphericity, %	73	63	54	89
Size of seed plate orifice, mm	4.5	2.6	1.37	3.0

decided, practically on the basis of the dimension of the seeds, *i.e.* average length, average width and average thickness. The dial gauge vernier caliper was used to measure the dimensions of the seeds.

Circular shaped orifice :

For deciding the dimensions of different shaped orifices on the seed plates, the exposed area to the seed on a seed plate with circular orifice was taken as a consideration. The size of metering orifice was determined from the following relationship (Bosoi, 1987),

$$do = 0.6\ bav$$

where,

do =Size of metering orifice, mm.

bav=Average width of seed to be held, mm.

Then, the seed exposed area was calculated from the equation;

$$A\ Z\ \frac{\Pi\ do^2}{4}$$

where,

A = Seed exposed area, mm^2

do = Size of metering orifice, mm.

Elliptical shaped orifice :

For finding the dimension of the elliptical shaped orifice, the ratio of the average length and average width was taken and the length of the longer axis of elliptical shaped hole was taken equal to the multiplication of the ratio to the shorter axis. Mathematically,

$$A\ Z\ \Pi . a.b$$

where,

A = Seed exposed area, mm^2

a = Longer axis of the elliptical shaped hole, mm $= \gamma . b$

b= Shorter axis of the elliptical shaped hole, mm

γ = Ratio of the average length to the average width of the seed

Triangular shaped orifice :

The dimension of the triangular shaped orifice was calculated from the equation;

$$A\ Z\ \frac{b.h}{2}$$

where,

A = Seed exposed area, mm^2

b = Base of the triangular orifice, mm

h = Height of the triangular orifice, mm

RESULTS AND DISCUSSION

Physical properties of different seeds were studied to decide the shape and size of the seed plate orifice for their single seed pickup. Studies were then conducted to optimize the suction pressure requirement for the single seed pickup with circular orifice seed plate and performance of the different shapes of the orifices on the single seed pickup of different types of the seeds.

Performance of the circular orifice seed plate under varying suction pressure for groundnut seed :

The study for groundnut seed was carried out with seed plate with circular shaped orifice of diameter 4.5 mm with 4 number of orifices. While for cotton and okra seed, seed plate orifice with 3 mm diameter orifice was used. Whereas, for sesame seed, seed plate with 1.5 mm diameter seed plate was used for the testing (Table 2).

Effect of the shape of the seed plate orifice upon the pneumatic planting of different seeds :

For studying the effect of the seed plate orifice shape upon the planting of different seeds, seed plate of circular, elliptical and triangular shaped orifices was selected. The

Table 1 : Performance of the 4.5 mm circular orifice seed plate under varying suction pressure for groundnut seed

Sr. No.	Suction pressure inside pneumatic disc, N/m^2	Particulars of seed per hole	% Picking
1.	3500	Skip (0)	32
		Single (1)	68
		Multiple (>1)	0
2.	4500	Skip (0)	14
		Single (1)	84
		Multiple (>1)	2
3.	5000	Skip (0)	0
		Single (1)	93
		Multiple (>1)	7
4.	5400	Skip (0)	0
		Single (1)	87
		Multiple (>1)	13

Table 2 : Effect of the shape of the seed plate orifice upon the pneumatic planting of the different shaped seeds

Sr. No	Seed	Particulars	Shape of the seed plate orifice		
			Circular	Elliptical	Triangular
1.	Ground nut	Mean spacing, cm	12.31	12.26	12.38
		Miss index, %	0	0	5
		Multiple index, %	8	4	7
		Quality of feed index, %	92	96	87
		Precision	0.87	0.75	1.09
2.	Cotton	Mean spacing, cm	12.3	12.27	12.60
		Miss index, %	0	0	9
		Multiple index, %	10	6	3
		Quality of feed index, %	90	94	88
		Precision	0.87	0.71	2.1
3.	Sesame	Mean spacing, cm	12.25	12.31	12.31
		Miss index, %	0	0	3
		Multiple index, %	9	5	11
		Quality of feed index, %	91	95	86
		Precision, %	0.73	0.65	0.81
4.	Ladyfinger	Mean spacing, cm	12.3	12.29	12.38
		Miss index, %	0	0	6
		Multiple index, %	5	4	5
		Quality of feed index, %	95	96	89
		Precision, %	0.69	0.70	0.88

Table 3 : Effect of the size of the seed plate orifice upon pneumatic planting

Sr. No.	Seed	Shape of the orifice	Dimension (mm)	Miss	Single	Multiples
1.	Groundnut	Elliptical	(5.5 x 5)	0	89	11
			(5 x 4.5)	0	93	7
2.	Cotton	Elliptical	(3.5 x 3)	0	86	14
			(3 x 2.5)	0	92	8
3.	Ladyfinger	Circular	3.50	0	87	13
			3.0	0	91	9
4.	Sesame	Elliptical	(2 x 1.5)	0	87	13
			(1.5 x 1)	0	93	7

Values in the bracket show the dimensions of the longer and shorter axis, respectively

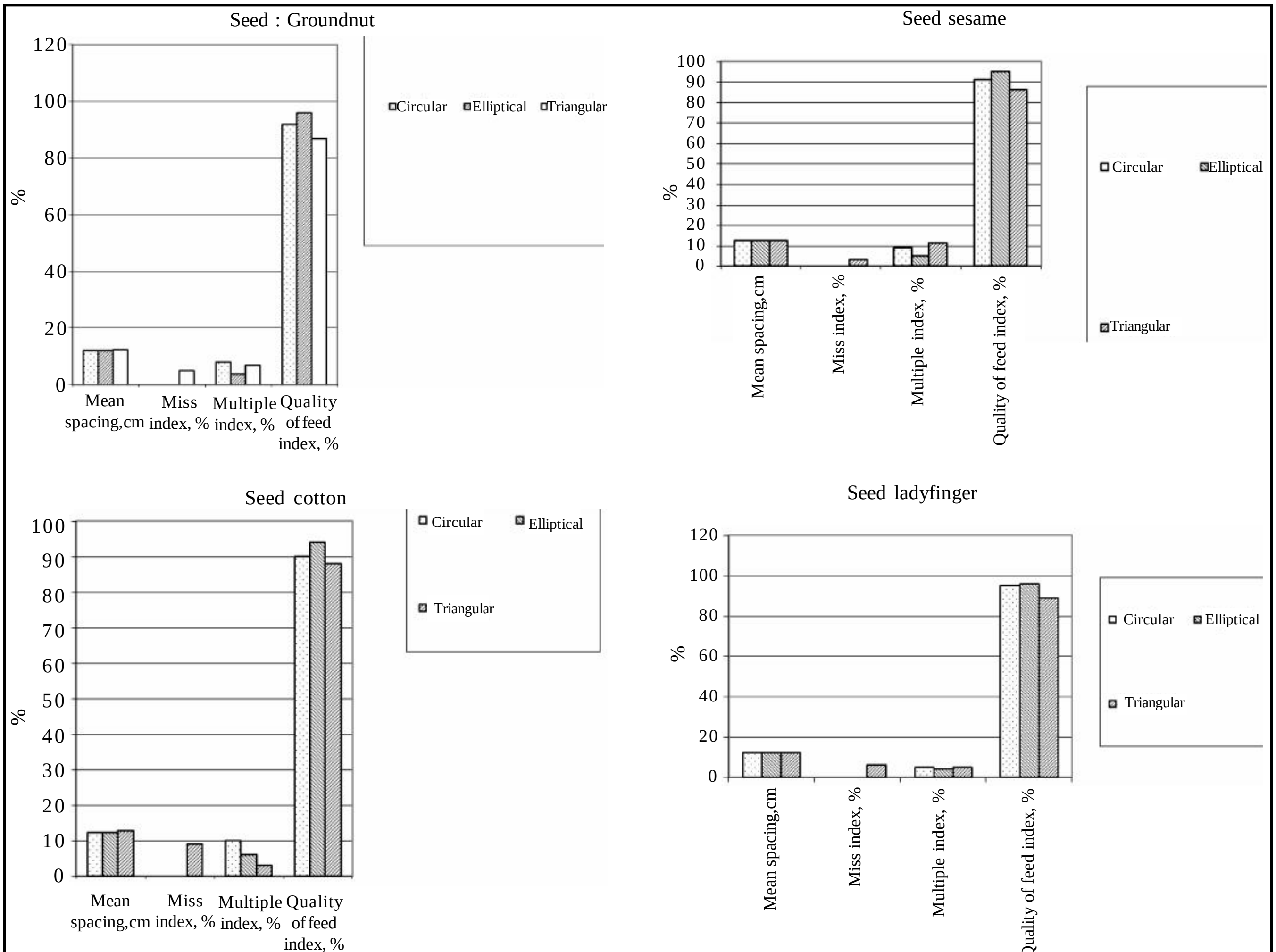

Fig. 1 : Effect of the shape of the seed plate orifice upon the planting of different shaped seeds

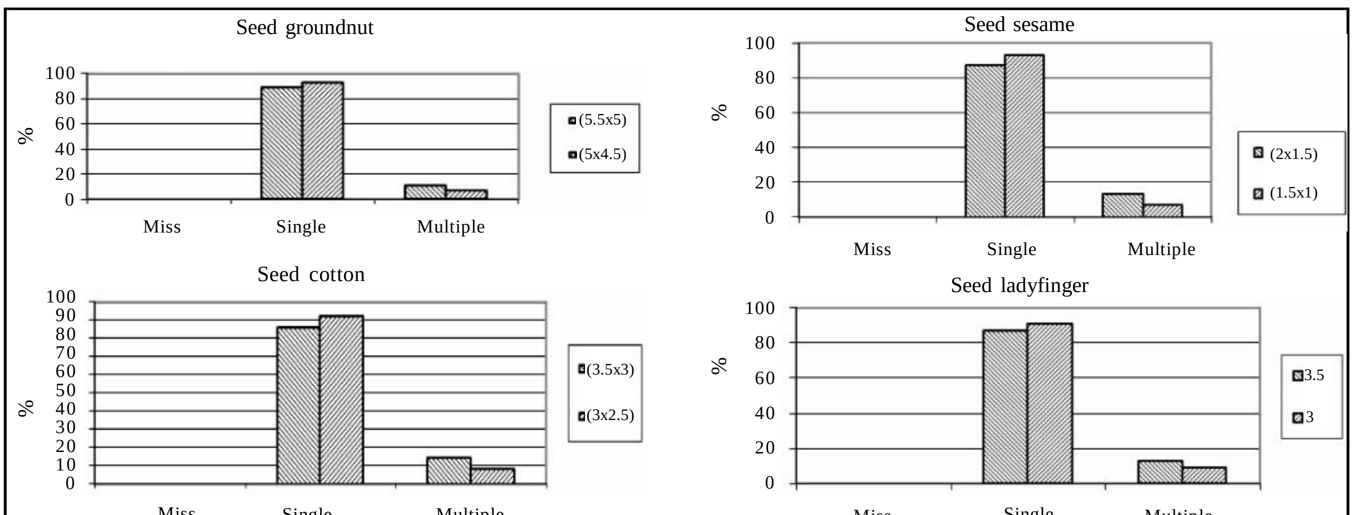

Fig. 2 : Effect of the sizes of seed plate orifice upon single seed planting

seed exposed area of circular shaped orifice was taken as a reference for designing other orifice. After determining the dimension of the different shaped seed plates, the test was conducted at the optimized suction pressure (Table 3).

Effect of the size of the seed plate orifice upon pneumatic planting :

For studying the effect of the sizes of the seed plate orifices upon the pneumatic planting of the single seeds, tests were connected at the optimized suction pressure of the different seeds, using the seed plates of different shapes.

Conclusion :

– The shape of the seed plate orifice has considerable effect upon the pneumatic planting of the different seeds. The elliptical shape orifice for elliptical seeds like groundnut and cotton and for flat seeds like sesame was adequate. Whereas, for the round seeds like okra seed, the circular shaped seed plate gave best results.

– The optimum dimension of the seed plates for groundnut, cotton and sesame seed were elliptical shaped orifice with longer and shorter axis (5,4.5), (3, 2.50) and (1.50, 1) mm, respectively. While, for round seed like okra, circular orifice with diameter 3 mm was found optimum.

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