Design and Development of Cup in Cup Feed Metering Seed Drill for Seed Pattern Characteristics Study of Paddy Seeds

by

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Abstract

Proper design of cup in cup feed metering seed drill is very important to enhance the performance of a seed drill. Earlier the cups used were of semi circular type. Due to vibration and shock, the seed retention and release for these cups were poor. So the cups were modified to cylindrical at top and conical at the bottom. An experimental test rig was developed in the laboratory in the Department of farm Machinery and Power, OUAT, Bhubaneswar, Odisha during the year 2009-10 to evaluate the best suitable dimensions of cup for the paddy variety pathara. Five different sizes of cups i.e. 14.83 mm, 11.71 mm, 9.48 mm, 7.84 mm and 6.58 mm depths with diameters of 8 mm, 9 mm, 10 mm, 11 mm and 12 mm respectively were prepared keeping the volume constant and were used for the study. The five different peripheral speeds of the cup discs were chosen to 6.28 m/min, 9.42 m/min, 12.55 m/min, 18.84 m/min and 23.56 m/min. The belt speed was calculated and maintained to study the seed rate deviation, seed distribution and seed damage. It was found that the dimensions of cup of 10 mm × 9.48 mm were found best with a permissible peripheral velocity up to 23.56 m/min. and an overall efficiency of 80.94 %. The above dimensions of the cup may be taken to develop a suitable seed drill for use in the field condition for sowing of paddy seeds.

Introduction

The seed metering mechanism is the most vital component of the seed drill. The performance of a seed drill is mainly dependent on the type of metering device. In addition to this, the type of soil and field condition, preparation of seed bed, speed of operation and power source also affect the performance of the seed drill (Kepner *et al.*, 2000). The crop yield is also affected by plant population, row spacing, plant to plant spacing, type and variety of seed and their emergence (Ojha and Micheal, 1978).

The fluted roller feed type metering device is very popular in India. This type of metering device is very much suitable for grain crops and not for large seeds. Moreover there is a concern for this type of metering device when the seed damage exceeds 3 % (Goel and Verma, 2000). Another metering device used was of cell feed type for manually operated seed drill. In this type of metering device, controlling of the seed rate was difficult. It was reported that the slightest displacement of brush contact varied the seed rate to a great extent under the field condition. In recent past, semi-circular type cups have been introduced for seed metering device in manufacturing of seed drill (Sahoo and Srivastava, 2000). Due to vibration and shock, the seed retention and release for these cups were poor. So the cups were modified to cylindrical at top and conical at the bottom for better retention of seeds.

The socio-economic conditions of Indian farmers do not permit them to have different seed drills for different crops. They are, therefore, bound to follow the traditional practice and face difficulty in intercultural operations and overall management of their crop. As the yield rate is low, farmers derive marginal benefit out of these crops. However the seed drills having cup feed metering mechanism can be suitably utilized for various crops only by changing the cups and with minor modifications (Garg and Dixit, 2003). Hence, the seed drill with cup type metering mechanism can be suitably used as a multi crop seeder for the crops like paddy, groundnut, green gram and black gram. So, studies on cup feed metering mechanism will help in developing a multi crop seeder for its versality in line sowing of various crops and enhancing the production and productivity.

Considering the above aspects, the present study was undertaken with the following objectives for sowing of paddy seeds.

1. To optimize the dimensions of the cup for sowing of paddy seeds
2. To optimize the peripheral speed of cup disc for the above mentioned seed
3. To evaluate the cup-feed metering device for seed-pattern characteristics considering seed rate deviation, seed distribution and seed damage for sowing of paddy

The spatial dimensions of the seed of the promising variety were measured. The dimensions of cup and peripheral speed of cup disc were optimized using the developed test rig (Goswami 2001) to achieve the desired seed pattern.

Theoretical Consideration

The suitable size of cup for the promising variety of paddy i.e. Pathara has been standardized using a test rig. This variety was selected as it is generally grown under upland conditions in Odisha with a yield potential of 30-35 quintals /ha. In order to develop and evaluate a multi crop seeder the standardized cups are used as cup feed metering mechanism and the cups are made replaceable. The details of theoretical aspects for the study are presented below;

Thousand grain weight

Thousand grain weight can be calculated taking approximately 500 grains from the sample at random. Subsequently thousand grain weight can be calculated using the following formula.

The weight of 1000 grains on 'as is' basis = ((a × 1,000) / b) gm;

where

a = weight of the whole grains, gm;

b = number of whole grains in the sample weighed

Bulk density

Bulk density of seed is defined as the total weight of the seeds per unit total volume.

B.D. = W / V;

where

B.D. = Bulk density, gm/cm³;

W = weight of seed sample, gm and

V = volume of seed sample, cm³

Seed rate deviation

The seed rate deviation was calculated using the following formula.

Seed rate deviation, % = ((-) Actual amount of seeds collected in 5 m length / Theoretical amount of seeds to fall in 5m length) × 100

The seed rate deviation was taken positive in all cases.

Seed distribution

The seed distribution was calculated using the following formula.

Se = (1 - Y / d) × 100;

where,

Se = Seed distribution, %;

Y = average numerical deviation of number of seeds per meter length of row from average number seeds per metre run;

d = average number of seeds per metre length of row

Seed damage

The seed damage was calculated taking nearly one kg of sample and using the following formula.

Seed damage, % = (Weight of the damaged seeds from the sample / Weight of the sample) × 100

The seeds before metering were tested to ensure their invisible damage and the seeds after passing through metering were tested for visible damage.

Table 1 Physical properties and overall dimensions of selected seeds

Seed variety	1,000 grains weight (gm)	Moisture content (%) (w.b)	Bulk density (gm/cc)	Average length (L) (mm)	Average breadth (B) (mm)	Average thickness (T) (mm)	Average size (S) (mm) S = (LBT) ⅓	Sphericit y = S/L	Spacing (cm)	Seed Rate (kg/ha)
Paddy Pathara	33.73	10.876	0.456	8.7	2.5	1.99	3.51	0.403	20 × 10	85

Table 2 Calculation of dimensions of cup for selected seed

Variety	Cup diameter (mm)	Cylindrical height (mm)	Cone height (mm)	Total height (mm)
Paddy: Pathara	8	5.93	8.9	14.83
	9	4.68	7.03	11.71
	10	3.79	5.69	9.48
	11	3.14	4.7	7.84
	12	2.63	3.95	6.58

Materials and Methods

The spatial dimension of paddy variety, Pathara, was studied (**Table 1**) and accordingly the cup dimensions were fixed (**Table 2**). The peripheral speed of cup disc was varied from 6.28 m/min to 23.56 m/min. The experiment was conducted using the test rig (**Fig. 1**) developed in the laboratory. The experimental test rig having hopper and cup feed

Fig. 1 Test rig for metering of seeds through sticky belt

Table 3 Peripheral speed of cup disc and belt speed for maintaining desired spacing

Diameter of cup disc (cm)	Rpm of cup disc	Peripheral speed of cup disc (m/min)	No. of cups in cup disc	Canvas Belt speed (km/hr)	Spacing to be maintained (cm)
10	20	6.28	8	0.97	10
10	30	9.42	8	1.44	10
10	40	12.55	8	1.92	10
10	20	6.28	10	1.21	10
15	40	18.84	12	2.4	10
15	50	23.56	12	3.6	10

seed metering mechanism was evaluated in the sticky belt. The design considerations for the sticky belt method are shown below.

1. A 2 HP electric motor with speed reduction unit was used for the drive mechanism.
2. The uniform speed of the canvass belt was maintained at 1 to 2.5 km/h with suitable belt pulley arrangement.
3. The endless canvass belt was prepared having 10.5 m length so as to take observations from top 5 m length.
4. The width of the belt should be at least 80 cm to evaluate four rows having spacing of 20 cm.
5. The canvass belt was graduated at the side so as to take observations easily.
6. A thin layer of grease was applied on the canvass belt so that the seeds would not be displaced after dropping.

Details of Test Rig of Testing

The test rig (**Fig. 2**) developed to evaluate the cup feed metering device consisted of two major sections. In the section one, the hopper, pickup chamber funnel in feed shaft with cup discs and 65 watts power source with suitable belt and pulley for power drive and variac were included. A stroke counter was used to measure the revolutions of feed shaft. In the section two, 1,492 watts power source with speed reduction unit, suitable belt and pulley for power drive, endless canvas belt 10.8 m length and 80 cm width, frame rollers and idler were included.

A thin layer of grease was applied to the belt so as to facilitate the proper embedding of seeds without any displacement. The belt used

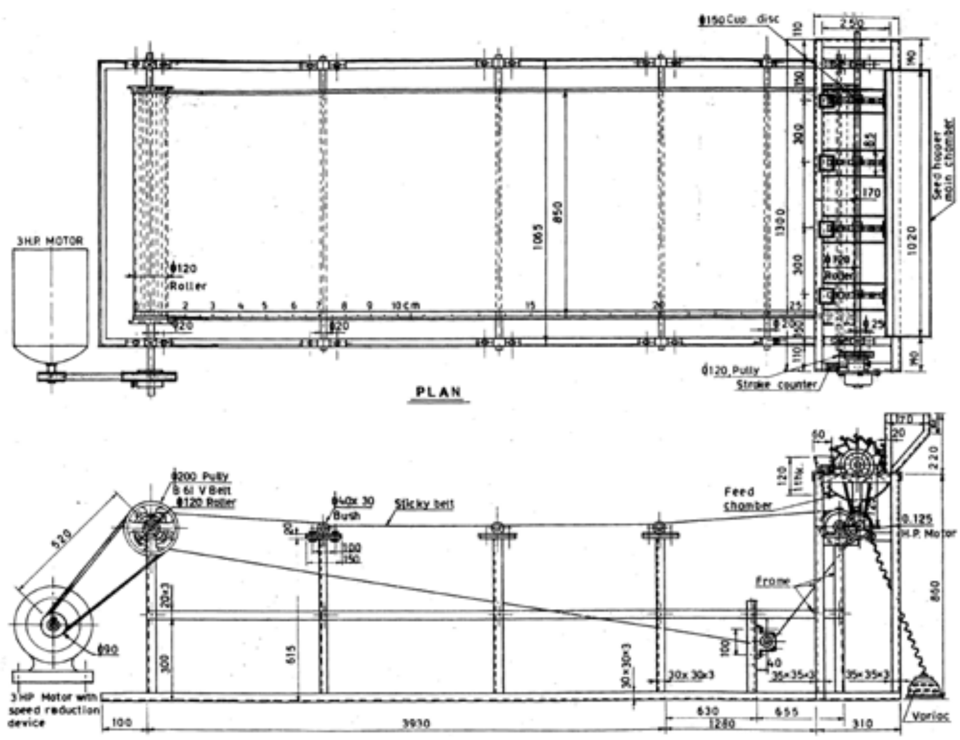

Fig. 2 Test rig for performance evaluation of cup feed metering device

was demarcated for four rows and one side was marked in centimeters for easy reading. A stroke counter was used to measure the revolutions of driving shaft. The test rig was used to get the peripheral speed of cup disc from 6.28 m/min to 23.56 m/min with a belt speed from 0.97 km/h to 2.4 km/h to get the desired spacing as has been presented in **Table 3**. Five different sizes of cups i.e. 14.83 mm, 11.71 mm, 9.48 mm, 7.84 mm and 6.58 mm depths with diameters of 8 mm, 9 mm, 10 mm, 11 mm and 12 mm respectively were prepared keeping the volume constant and were used for the study. The five different peripheral speeds of the cup discs i.e. 6.28 m/min, 9.42 m/min, 12.55 m/min, 18.84 m/min and 23.56 m/min were chosen. The belt speed was calculated and maintained to study the seed rate deviation, seed distribution and seed damage.

Table 4 Sample calculation for dimension of cup and hill spacing for paddy variety pathara

A. Assumptions	
Seed rate	85 kg/ha
Spacing	20 cm × 10 cm
B. Calculation for dimension of cup	
No of hills per ha	1000000 / 20 × 10 = 500000
Amount of seeds to fall in each hill	85000 / 500000 = 0.17 gm
Thousand grain weight	33.73 gm
No. of seeds in each hill	0.17 / 0.03373 = 5.04, or say 5
Bulk density of seeds	0.456
Volume of seeds in each hill	0.3728 c.c.
Additional 20% volume	0.07456 c.c.
Total volume	0.44736 c.c.
Cylinder volume, 1/3 of total volume	0.14912 c.c.
Height of cylinder taking diameter 8 mm	5.93 mm
Height of cone	8.9 mm
Total height of cup	14.83 mm
So for 8 mm diameter of cup, the cup height has been taken as 14.83 mm and with this cup dimensions 5 seeds are to fall in each hill.	
C. Calculations for hill spacing	
Diameter of cup disc	10 cm
Cup disc, rpm	20
Peripheral speed of cup disc	6.28 m/min
No. of cups in cup disc	8
Belt speed	0.97 km/hr
Hill spacing	0.97 × 100000 / 60 × 20 × 8 = 10.10 cm, or say 10
So with a belt speed of 0.97 km/hr hill spacing to be maintained is 10 cm	

Designs of Ground Wheel Diameter, Number of Cups and Cup Disc Diameter

The ground wheel diameter of the seed drill was taken as 32 cm. The ground wheel of existing commercially available manually operated seed drill is only 25 cm. The larger diameter has been taken to rotate the ground wheel smoothly even if the seed bed was not prepared well. The ground wheel was fabricated from 2.5 cm M.S. flat and 18 pegs were provided on the periphery with the height of the pegs being 2.5 cm.

The number of cups can be calculated using the following formula:

$Z = \pi D / X.S$; where,

Z = number of cups in the cup disc;

D = ground wheel diameter;

S =spacing in between the plants;

N = seed metering shaft, r.p.m.;

n = ground wheel, r.p.m.;

X = gear ratio ; Assuming,

D = 32 cm

X = 1 and

S = 10 cm;

$Z = \pi D / XS = 10.05 \approx 10$

Therefore the number of cups to be used in the cup disc was 10. In case of slow speed, the seeds were discharged from the cup by gravity. Under this condition, the guide plate was provided so that the seeds were directed to the seed funnel. In order to provide the guide plate, the peripheral distance between two cups should be at least 3.25 cm. So the cup disc dia = 32.5 / π = 10.34

Sample calculation for dimension of cup and hill spacing for paddy variety pathara has been mentioned in **Table 4**.

Results and Discussion

The results of the different experiments conducted during the course of the studies are presented in this section. The experimental data collected from the test rig are presented in **Table 5**.

The seed rate deviation varied from 2.08 to 6.22 %. The results indicated that the minimum seed rate deviation occurred with cup No.3 having 10 mm diameter with a peripheral speed of 6.28 m/min. This may be due to improper filling of cup when the cup diameter was less than 10 mm and when the cup diameter was more than 10 mm seed retention was difficult because of the slippage. It was also found that the seed rate deviation was increasing with the increasing of peripheral speed. This may be due to improper filling at higher speed and scattering of seeds during centrifugal discharge due to the increase in kinetic energy of seeds.

The seed distribution efficiency varied from 82.76 to 85.46 %. It was found that the maximum seed distribution efficiency was found with cup No.3 with a peripheral speed of 6.28 m/min. It was also found that the seed distribution efficiency was decreasing with the increase in the peripheral speed. This may be due to scattering of seeds during centrifugal discharge as the seeds posses more kinetic energy.

The seed damage varied from 0.43 to 2.41 %. It was found that the minimum seed damage was attributed with cup No.3 with a peripheral speed of 6.28 m/min. It was found that the seed damage was increasing as the peripheral speed increased. This may be due to higher impact of the seeds. From the analysis of results it was found that the dimension of cup of 10 mm × 9.48 mm was found best with a permissible peripheral velocity up to 23.56 m/min. with an overall efficiency of 80.94 %. But the seed pattern observed for hill dropping was up to peripheral speed of 12.55 m/min and from 18.84 m/min to 23.56 m/min the seed pattern was of drilling the seeds.

Conclusions

The dimensions of the cup i.e. 10 mm × 9.48 mm was found to be best and was used successfully up to a peripheral speed of 23.56 m/min with the desired seed rate deviation, seed distribution and seed damage. The seed pattern observed for hill dropping was up to peripheral speed of 12.55m/min and from 18.84 m/min to 23.56 m/min that was of drilling the seeds. These research findings would help in developing a multicrop seed drill using the cup feed metering device for the sowing of other major crops like groundnut, green gram, black gram etc. to promote line sowing to the benefit of the farmers.

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Table 5 Evaluation of cup feed metering mechanism of paddy variety pathara

Cup Dimensions	Peripheral speed of cup disc (m/min)	Seed rate deviations (%)				Seed distribution (%)				Breakage of seeds (%)			
		R1	R2	R3	Mean	R1	R2	R3	Mean	R1	R2	R3	Mean
8 mm diameter and 14.83 mm depth	6.28	4.61	4.32	4.16	4.36	83.82	83.62	83.54	83.66	0.8	1	0.7	0.83
	9.42	4.82	5.01	4.46	4.76	83.61	83.36	83.26	83.41	0.86	0.92	0.99	0.92
	12.55	5.12	5.1	4.82	5.01	83.42	83.16	83.02	83.2	0.89	0.98	1.11	0.99
	18.84	5.14	5.12	4.91	5.05	83.19	83.02	82.86	83.03	0.92	1.02	1.12	1.02
	23.56	5.21	5.16	5.11	5.16	83.01	82.83	82.53	82.79	1.61	0.82	1.29	1.29
9 mm diameter and 11.71 mm depth	6.28	4.81	4.43	5.6	4.61	84.28	84.12	84.02	84.14	0.88	0.98	0.84	0.9
	9.42	4.91	4.98	4.8	4.89	84.09	83.92	83.76	83.93	0.9	0.89	1.15	0.98
	12.55	5.16	5.16	4.91	5.07	83.86	83.68	83.32	83.62	1.1	0.78	1.48	1.12
	18.84	5.26	5.21	4.98	5.15	83.64	83.49	83.13	83.42	1.12	0.99	1.43	1.18
	23.56	5.61	5.34	5.28	5.14	83.38	83.18	82.94	83.15	1.16	1.12	1.56	1.28
10mm diameter and 9.48 mm depth	6.28	2.01	2.06	2.02	2.03	85.31	85.43	85.46	85.4	0.56	0.42	0.81	0.59
	9.42	2.24	2.16	2.2	2.2	85.02	85.13	85.18	85.11	0.48	0.92	0.59	0.66
	12.55	2.57	2.96	2.64	2.55	84.72	84.83	84.86	84.83	0.74	0.82	0.54	0.7
	18.84	2.96	2.81	2.74	2.83	84.41	84.52	84.53	84.43	0.82	0.88	0.98	0.89
	23.56	2.99	2.92	2.87	2.92	84.14	84.21	84.26	84.23	0.9	0.89	1.24	1.01
11 mm diameter and 7.84 mm depth	6.28	5.1	5.01	4.92	5.01	84.26	84.36	84.28	84.3	0.9	1	0.92	0.94
	9.42	5.16	5.24	5.01	5.13	84.03	84.14	84.16	84.11	0.98	1.08	0.94	1
	12.55	5.28	5.42	5.71	5.29	83.78	83.96	83.98	83.93	1.04	1.09	0.97	1.03
	18.84	5.38	5.48	5.8	5.55	83.52	83.69	83.7	83.63	1.22	1.27	1.08	1.19
	23.56	5.82	5.79	5.98	5.86	83.3	83.46	83.53	83.43	1.28	1.86	1.84	1.66
12 mm diameter and 6.58 mm depth	6.28	5.2	5.12	5.1	5.14	83.92	83.86	83.66	83.81	1.23	1.17	1.05	1.15
	9.42	5.28	5.21	5.24	5.24	83.71	83.58	83.42	83.57	1.24	1.23	1.21	1.22
	12.55	5.5	5.61	5.49	5.38	83.5	83.36	83.21	83.35	1.31	1.28	1.3	1.29
	18.84	5.81	5.89	5.89	5.86	83.26	83.16	83.01	83.11	1.84	1.98	1.92	1.91
	23.56	6.24	6.12	6.22	6.19	83.02	83	82.76	82.92	2.02	2.41	1.99	2.14

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