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Developed and performance evaluation of inclined plate metering mechanism for cowpea seeds in the laboratory condition

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Abstract
Precise metering of seed is an important performance parameter of a planter. Physical properties of cowpea seed were studied and based on their properties, an inclined plate metering mechanism was developed. Afterward, a performance evaluation of developed inclined plate metering was conducted in the laboratory condition. The metering device was tested at different variables i.e. three forward speeds (2.0, 2.5, and 3.0 km/h), at three heights of seed dropping (15, 20, and 25 cm), and at three different angles of inclination (45°, 50°, and 55°). The performance of metering was evaluated based on spacing, missing index %, multiple index %, and quality of feed index. The desired spacing obtained was 17.5 cm at 2.5 km/h speed with 20 cm height of seed dropping at 50° angle of inclination. The optimum missing and multiple index was found to be 2% at 2.5 km/h speed with 20 cm height of seed dropping at 50° angle of inclination and 1.33% at 3 km/h speed with 20 cm height of seed dropping at 50° angle of inclination respectively. The overall quality of feed index was 94.67% at 2.5 km/h speed with 20 cm height of seed dropping at 50° angle of inclination. The satisfactory result was based on spacing, missing and multiple index, and quality of feed index were found at 2.5 km/h forward speed with 20 cm height of seed dropping with 50° angle of inclination.

Keywords: Metering mechanism, inclined plate, missing index %, multiple index %, spacing, quality of feed index

1. Introduction

Cowpea (*Vigna unguiculata*) is also known as Lobia, Barbati, and Black-eyed pea. It is a warm season and semi-arid crop. It tolerates heat and dry conditions but is intolerant of frost. Cowpea is a higher drought tolerant crop. Cowpea is used for food, vegetable, feed, fodder, and green manuring.

The physical properties of cowpea seed to moisture content. The results show that the average length, width, and thickness were 9.92 mm, 6.87 mm, and 6.06 mm respectively at 12.01% d.b. moisture content. In the moisture content range from 12.01 % to 38.90% on the dry basis, the thousand of seed mass was increased from 209.23 g to 256.88 g, the projected area from 22.59 to 32.72 mm^2, the sphericity from 0.781 to 0.799, the porosity from 50.64% to 51.49 % and the terminal velocity from 9.31 ms^{-1} to 9.61 ms^{-1}. The bulk density decreased from 569.9 to 535.6 kgm^{-3} and the true density decreased from 1154.8 to 1104.1 kgm^{-3}, respectively, with the increase in moisture content from 12.01% to 39.90% db (Yalcim, 2007) [12]. Several physical and nutritional properties of cowpea seed (*Vigna sinensis* L.). The physical properties of the cowpea were used for hopper and metering plate design. The average length, width, and thickness of seeds were found to be 9.28 mm, 6.55 mm and 6.08 mm respectively. The geometric mean diameter, sphericity, and thousand of seed mass were found to be 7.16 mm, 77.2 %, and 2050 g respectively. The bulk density, true density, and porosity were 0.69 g/cm^3, 1.113 g/cm^3, and 38.88% respectively. Organic matter, protein, K, Ca, P and N amount were 90.58%, 20.31%, 0.0058%, 0.00106%, 0.142% and 3.25% respectively (Kabas *et al*., 2007) [6].
Metering mechanism is an important component of a plating machine. The aim of the metering mechanism is a uniform distribution of seeds at accurate seed spacing with recommended seed rates. For better performance, proper design of the metering mechanism is important (Ikechukwu *et al*., 2014) [5]. Seed is metered in precision planters, the accuracy of seed to seed distance in a row, called seed spacing (Korayem *et al*., 1986, Kachman and Smith, 1995) [7], and the number of seeds dropped per unit area, called seed rate (Heege, 1993) are most performances parameters.

2. Review of Literature

The design and simulation of an inclined metering mechanism. The test was conducted in the laboratory and field. According to their parameters, different forward speeds of the planter, different inclination angles, and different rotor speeds of the metering plate were tested. The results revealed that the seed rate was found to be 26.39 kg/ha, 17.26 kg/ha, and 13.35 kg/ha for 10, 15, and 20 cm spacing at the speed of 4.5 km/h and 45° inclination angle of metering plate respectively. The seed damage was 0.28 % (Sahu and Verma, 2017) [11]

An inclined plate metering device was evaluated in the laboratory for radish seeds. In this test, the different pelleting ratios like 1:1, 1:2, and 1:3 pelleted were used for testing purpose. A metering mechanism was set at three inclinations of 40°, 45°, and 50° with three different plates with 18, 24, and 30 groves on the cell. The result revealed that the average spacing was found to be 5.72, 5.66, and 5.61 cm for 18, 24, and 30 groove plates at 2.0 Km/h speed respectively. The missing index and multiple index were obtained 13 % and 12% at the forward speed of 2.0 km/h with 24 groove seed plate respectively. Whereas, they recommended the seed metering plate have 24 grooves, 45°angle of inclination, and 2.0 Km/h for better results. The overall feed index was found to be 75 %. The metering cell and plate inclination were selected in terms of average spacing, missing and multiple index, and quality of feed index (Gautam *et al*., 2017)

Determined the performance of four different types of metering namely vertical roller, horizontal plate, horizontal plate with edge drop, and inclined plate. Evaluated the performance in terms of the row-to-row spacing, plant-to-plant spacing, feed index, missing index, multiple indexes, uniformity of seed, and seed damage percentage at the three different cell speeds. The length of the span was taken to determine the average spacing of metered seeds. The quality of feed index depends on cell size and cell speed. It resulted that the inclined plate metering device was recommended and it works satisfactorily (Sahoo and Shrivastava, 2008) [10].

Studied the peripheral speed of seed metering plate on seed ratio for maize crop. The peripheral speed of the plates was tested 0.16, 0.24, 0.32, and 0.40 ms^{-1}. They found that the seed holding capacity of the metering plate decreased with the increased peripheral speed of the plate. The highest and lowest seed holding ratio was observed at the peripheral speed of 0.16 ms^{-1} and 0.40 ms^{-1} respectively (Barut and Ozmerzi, 2004) [3].

3. Material and Method

Commonly used metering mechanisms of the planter are horizontal plate, inclined plate, vertical roller, and cup over the periphery (Anon., 1991) [1]. Performance evaluation of the metering plate was evaluated as per the RNAM test code and procedure for the laboratory performance test of the seeder and planter (RNAM, 1995) [9]. An electronic test rig was developed for the performance of a metering mechanism. The mainframe was fabricated as a rectangular section of 5000 mm x 520 mm made up of 35 x 35 x 5 mm mild steel L angle. The rectangular frame was fixed at a height of 500 mm with the help of 6 legs made of 35 x 35 x 5 mm MS L angle. The two rollers were fabricated of 460 mm in length and 120 mm in diameter of made up of mild steel. A hydraulic test rig was also used. A component of the hydraulic test rig included a hydraulic platform, electric motor, shaft, and control panel. A trapezoidal seed box was used. An inclined plate metering mechanism was designed and developed for cowpea seed. The metering mechanism was fabricated with a diameter of 120 mm and was fitted on the base plate with the help of a spring and end cap. The metering plate was connected with a drive shaft using bevel gears of 18 teeth each.

3.1 Plan of experimental design of parameters

The experimental detailed plan of the test rig in the laboratory is given in table 1:-

Table 1: Experimental details

Independent variables			Dependent variable
Variables	**Levels**	**Details**	
Crop	1	Pea	➢ Missing index, % ➢ Multiple index, % ➢ Seed spacing, cm ➢ Quality of feed index,
Forward speed, Km/h	3	2, 2.5 and 3	
Angle of inclination, Degree	3	45, 50 and 55	
Seed dropping height, cm	3	15, 20,and 25	
Number of replication	3	R1, R2, and R3	

3.1.1 Spacing

The test rig was used for measuring the seed spacing by the sticky belt method. A sticky belt of 3 m length was used. A grease was applied to the belt that the seed dropped on the belt sticks to it. The grease was used to reduce the bouncing effect. The distance between seeds was measured to compute the average spacing of seeds.

3.1.2 Missing index

It is defined as the indication of skips of seed in the desired spacing. It is the percentage of spacing greater than 1.5 times the theoretical spacing (kachman and smith, 1995) [7].

$$\text{Missing index} = \frac{n_1}{N} \quad (1)$$

Where,

n_1 = number of spacing in the region greater than 1.5 times the theoretical spacing; and

N = total number of observations.

3.1.3 Multiple index

Multiple index is defined as the percentage of spacing that is less than or equal to half of the theoretical spacing. It indicates of more than one seed dropped within a recommended spacing (Kachman and Smith, 1995) [7].

$$\text{Multiple index} = \frac{n_2}{N} \quad (2)$$

Where,

n_2 = number of times spacing in the region is less than half of the theoretical spacing; and

N = total number of observations.

3.1.4 Quality of feed index
It is defined as the percentage of several events in which spacing is more than half but not more than 1.5 times the theoretical spacing. It shows, how often the seed spacing was close to the theoretical spacing (Kachman and Smith, 1995) [7]. The quality of the feed index is calculated by the equation are given below:-

$$\text{Quality of feed index} = \frac{n_3}{N} \quad (3)$$

Where,
n_3 = number of spacing between 0.5 times the theoretical spacing and 1.5 times the theoretical spacing; and
N = total number of observations.

4. Results
4.1 Spacing
Figures 1 show that the spacing increases with increased speed, the height of seed dropping, and the angle of inclination. The maximum spacing was found to be 23.5 cm at speed of 3 km/h with 25 cm of height of seed dropping at 55° angle of inclination whereas, the minimum spacing was 8.83 cm at speed of 2 km/h with 15 cm height of seed dropping at 45° angle of inclination. The value spacing at the speed of 2.5 km/h, the height of 20 cm, and the angle of inclination of 50° was very close to the desired value of spacing i.e. 17.3 cm. The increase in seed dropping height increased the spacing because the minimum seed traveling distance gives a more uniform placement of seed in a row (Kepner *et al*. 1984) [8].

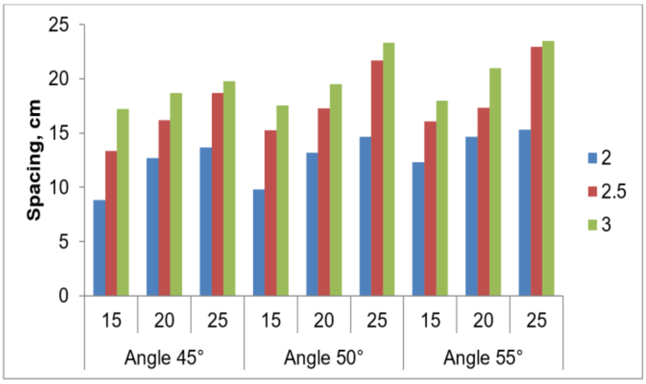

Fig 1: Effect of forward speed, height of seed drop, and angle of inclination on the spacing of cowpea

4.2 Missing index %
Figures 2 show that the missing index increased with an increased forward speed whereas the missing index decreased with increased the height of seed dropping. The maximum missing index was found to be 14.66% at speed of 3 km/h with 20 cm of height of seed dropping at 55° angle of inclination whereas, the minimum missing index % was found to be 0.6% at speed of 2.5 km/h with a height of seed dropping of 15 cm at 50° angle of inclination. The increases in the missing index with the increase in forward speed due to a decrease in the exposure time of the groove to seed in the hopper (Badgujar *et al*., 2017) [2].

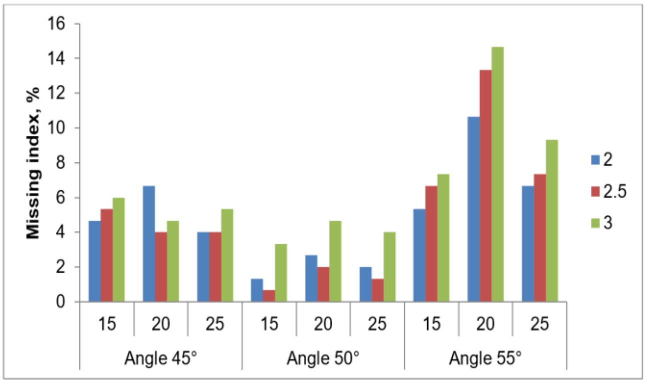

Fig 2: Effect of forward speed, height of seed drop, and angle of inclination on missing index per cent of cowpea

4.3 Multiple index %
Figure 3 shows that the multiple index decreased with increased a forward speed whereas, there was no significant effect of height of seed dropping and angle of inclination of the metering plate on multiple index per cent. The maximum multiple index was found to be 16% at speed of 2 km/h with a height of seed dropping of 15 cm at a 45° angle of inclination whereas, the minimum multiple index was found to be 1.33% at speed of 3 km/h with a height of seed dropping of 20 cm at 55° of the angle of inclination. More multiple seeds resulted in non-uniform plant spacing, loss of costly seeds, and labour requirements for thinning the extra plant population.

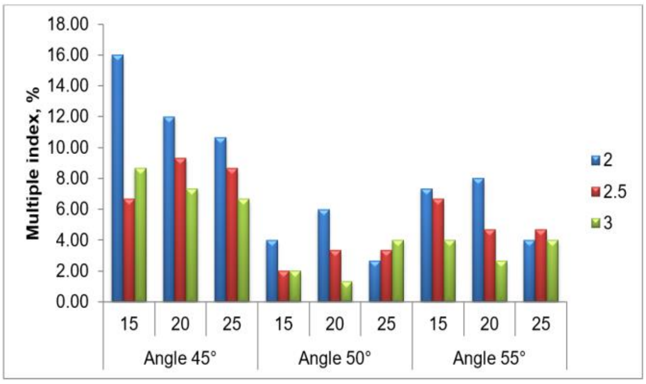

Fig 3: Effect of forward speed, height of seed drop, and angle of inclination on multiple index per cent of cowpea

4.4 Quality of feed index percent
Figure 4 shows that the maximum quality of feed index was found to be 95.33% at speed of 2 km/h with a height of seed dropping of 25 cm at a 50° angle of inclination whereas, the minimum quality of feed indeed was found to be 79.33% at speed of 2 km/h with a height of seed dropping of 15 cm at 45° angle of inclination. The decreased the quality of feed index with increased the angle of inclination. This may be due to the reason at higher speed, a seed may not get enough time to adjust in the metering plate cell, resulting in more missing and multiple hills. Similar results were also reported by Kachman and Smith (1995) [7], and Sahu and Verma (2017) [11].

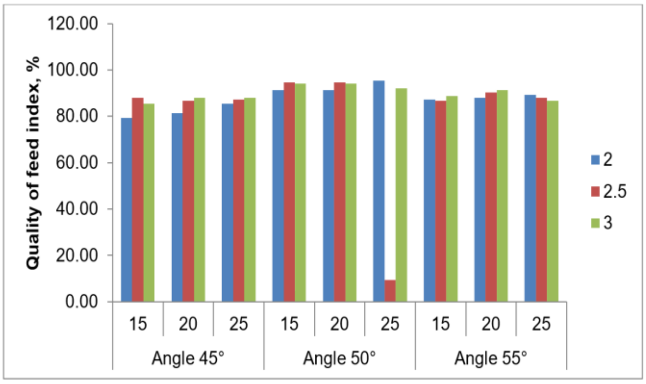

Fig 4: Effect of forward speed, height of seed drop, and angle of inclination on quality of feed index per cent of cowpea

5. Conclusion

1. Seed spacing increases with an increase in the speed and angle of inclination at all heights of seed dropping. The optimum seed spacing was found 17.3 cm at the speed of 2.5 km/h, the height of 20 cm and the angle of inclination of 50° were very close
2. Missing index is decreased with an increase in the angle of inclination. The optimum missing index was found to be 2% at speed of 2.5 km/h at a 50° angle of inclination.
3. As the forward speed increased from 2.0 km/h to 3.0 km/h, the multiple index decreased.
4. Quality of feed index was maximum (95.33%) for a speed of 2 km/h with a height of seed dropping of 25 cm at a 50° angle of inclination

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