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Laboratory investigation on seed rate for precision sowing of black gram

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Abstract

Laboratory test rig was developed with the following independent variables for achieving desired seed rate for black gram variety VBN-3. Cell geometry (S) - 3 levels -Maximum seed dimension - 4.25 mm, 10 per cent more than maximum seed dimension - 4.67 mm and 25 per cent more than maximum seed dimension - 5.31 mm. Inclination of seed metering disc (θ) - 4 levels - 30°, 35°, 40° and 45°. Peripheral speed of seed metering disc (V) - 4 levels - 0.1 ms^{-1}, 0.15 ms^{-1}, 0.2 ms^{-1} and 0.25 ms^{-1}. From the experiments it was inferred that, with the cell geometry same as that of maximum seed dimension, increase in peripheral velocity from 0.10 to 0.25 ms^{-1} resulted in 9.6, 0.5, 2.3 and 4.4 per cent increase in seed rate at 30°, 35°, 40° and 45° inclination of seed metering disc respectively. When the cell geometry was 10 per cent more than maximum seed dimension, the peripheral velocity and inclination of seed metering disc had a marginal effect on seed rate. The variation in seed rate was from 20.20 to 21.00 kg ha^{-1}. For the cell geometry having 10 per cent more than maximum seed dimension, the combination of all selected levels of peripheral velocity and inclination of seed metering disc yielded the desired seed rate of 20 kg ha^{-1}. The effect of inclination of seed metering disc on seed rate was negligible when the cell geometry is same as that of maximum seed dimension.

Keywords: Black gram, Seed geometry, Peripheral velocity and Seed rate.

1. Introduction

Among different sowing techniques, precision sowing is the preferred method at present, since it maintains more uniform seed spacing and optimum plant population than other methods. Precision planting saves seeds and utilize fertilizer to the best advantage and increases yield by enabling good cultivation practices. Precision planting technique results in uniform plant spacing, depth and aids further mechanization of intercultural farming operation that will reduce the total production cost. Shrivastava *et al*. (2003) [1] evaluated the performance of tractor drawn six row inclined plate planter for oil seeds and pulses. They reported that the use of planting equipment with inclined plate seed metering device for the precision planting of peanuts has found to increase the efficiency use of seeds and reduce the cost of production.

Jayan and Kumar (2004) [4] investigated the design of planter in relation to the physical properties of seeds. They reported that in absence of devices for the positive removal of seeds from the cells of the plate, seeds drop by gravity and as the peanut seeds are non-spherical, they move slowly leading to the variation in seed spacing. In order to achieve the uniformity in seed spacing and accuracy in seed rate, it is essential to use the metering plate with size of cells matching to the size of seeds. Aware *et al*. (2004) [5] developed an inclined plate metering mechanism for planting of peanuts. It consists of a hopper, cell plate, ground wheel, electronic circuit, and the mounting frame. The designed electronic metering mechanism was tested with a forward speed of 1 km h^{-1} in the laboratory by using grease board. They reported the average hill to hill spacing of 13.3 cm was obtained from laboratory test, which was close to hill to hill spacing value compared to the recommended plant to plant spacing of 13 cm. Anantachar *et al*. (2010) [7] reported that seed planting equipment with inclined plate seed metering devices is the most commonly used equipment for planting of peanut crop in India. For obtaining the high yield, it is very essential to drop the peanut seeds in rows maintaining accurate seed rate and seed spacing with minimum damage to seeds during metering. This mainly depends on forward speed of the planting equipment, rotary speed of the metering plate and area of cells on the plate. Sahoo and Srivastava (2008) [2] investigated the seed pattern characteristics of soaked okra seed with different metering systems *viz*., vertical roller, horizontal plate, horizontal plate (edge drop), inclined plate, cell size *viz*., (maximum seed dimension,10% more than maximum seed dimension, 25% more than maximum seed dimension and cell speed viz., 10,14,18, 24 rpm. They concluded that the average spacing was close to theoretical spacing for vertical roller, horizontal plate, horizontal plate (edge drop) with cell size 10%

10% more than the maximum seed dimensions. But in case of inclined plate the average spacing was close to theoretical spacing with the cell size equal to maximum seed dimensions. The quality of feed index was influenced highly by the metering systems, cell size and cell speed. The quality of feed index decreased with increase in speed. However, with increase in cell speed to 14 rpm only 5% decrease of quality of feed index was observed. The cell speed influenced the multiple index, miss index and degree of variation the most. The metering system influenced the seed damage the most followed by cell speed. Incline plate metering system was found the best for planting soaked okra seed. In India, a large number of planters are available for sowing cotton, maize, soybean, groundnut and pea (Sahoo and Srivastava, 2000) [3]. On the other hand, very limited research work was done on the mechanical sowing of black gram seed. Keeping above facts in view, the present work on optimizing the cell geometry of the inclined plate planter for black gram seed was investigated to develop a prototype of planter.

2. Materials and Methods

The physico-engineering properties that affect the planter design viz., seed geometry, angle of repose, bulk density and 1000 seed weight were determined by standard methods. The predominant variety VBN-3 adopted by Tamil Nadu farmers was used for the study. The major and minor axis of randomly selected 100 black gram seeds was measured by using vernier caliper. For achieving desired seed placement index a laboratory test rig was developed with the following independent variables. Cell geometry (S) - 3 levels - Maximum seed dimension - 4.25 mm, 10 per cent more than maximum seed dimension - 4.67 mm and 25 per cent more than maximum seed dimension - 5.31 mm. Inclination of seed metering disc (θ) - 4 levels - 30°, 35°, 40° and 45°. Peripheral speed of seed metering disc (V) - 4 levels - 0.1 ms^{-1}, 0.15 ms^{-1}, 0.2 ms^{-1} and 0.25 ms^{-1}.

2.1 Seed Metering Disc

Twelve numbers of seed metering disc were fabricated using 50 mm thickness and 120 mm diameter fiber sheet. The numbers of cells in the seed metering disc vary corresponding to the selected levels of peripheral speed and cell geometry. The number of cells in the seed metering disc was arrived as detailed below.

Recommended spacing between hills for black gram, m - 0.1

Ground wheel diameter of prototype pulse seeder, m (Assumed) - 0.36

Diameter of seed metering disc, m - 0.12

Forward speed of the tractor (selected), km h^{-1} - 1.5

Rotational speed of seed metering disc corresponding to 0.1 ms^{-1} peripheral velocity (V_1)

$$= \frac{\text{Peripheral velocity, } ms^{-1} \times 60}{\pi \times \text{Diameter of seed metering disc, m}}$$

$$= 0.1 \times 60 / \pi \times 0.12$$

$$= 15.91 \text{ rpm}$$

Rotational speed of ground wheel

$$= \frac{\text{Forward speed operation, } Kmh^{-1}}{60 \times \pi \times \text{Ground wheel diameter}}$$

$$= 1.5 \times 1000/60 \times \pi \times 0.36$$

$$= 22.10 \text{ rpm}$$

Speed ratio between ground wheel and seed metering disc

$$= \frac{\text{Speed of seed metering disc}}{\text{Speed of ground wheel}}$$

$$= 15.91/22.10$$

$$= 0.72$$

Revolution of ground wheel to drop one seed

$$= \frac{\text{Recommended spacing between hills, m}}{\pi \times \text{Diameter of ground wheel, m}}$$

$$= \frac{0.10}{\pi \times 0.36}$$

$$= 0.088$$

Revolution of seed metering disc to drop one seed

= Rev. of G. wheel to drop one seed x Ratio of G. wheel to seed metering disc

$$= 0.088 \times 0.72$$

$$= 0.063$$

No of cells on the seed metering disc

= 1/ Speed of seed metering disc to drop one seed

$$= 1/0.063$$

$$= 15.70 \approx 16$$

Spacing between cells on seed plate, cm

$$= \frac{\pi \times \text{Seed metering disc diameter,m} \times 100}{\text{No of cells on the seed metering disc}}$$

$$= 2.35 \text{ cm}$$

Similarly for the other three selected levels of peripheral velocity of 0.15 (V_2), 0.20 (V_3) and 0.25 (V_4) ms^{-1}, the required number of cells on the seed metering disc was arrived as 10, 8 and 6 cells respectively. For selected four levels of peripheral velocities, three discs of each maximum seed dimension (S_1), 10 percent more than maximum seed dimension (S_2) and 25 percent more than maximum seed dimension (S_3) were fabricated and the seed metering discs are shown in plate 1.

For operating the inclined plate seed metering disc at selected levels of peripheral speed, the rotational speed of the seed metering drive shaft was calculated as furnished below.

Recommended spacing between hills for pulse crop, m - 0.1

Diameter of ground wheel diameter, m - 0.36

Diameter of seed metering disc, m - 0.12

Forward speed of the tractor, km h^{-1} (Constant) - 1.5

Rotational speed of seed metering disc

$$= \frac{\text{Peripheral velocity, } m\,s^{-1} \times 60}{\pi \times \text{Diameter of seed metering disc, m}}$$

For the selected level of peripheral speed of 0.1 ms-1, the rotational speed of seed metering disc

$$= (0.1 \times 60) / (\pi \times 0.12) = 15.91 \approx 16$$

Similarly for the other three selected level of peripheral velocities of 0.15, 0.20, and 0.25 ms^{-1}, the required number of revolutions of seed metering disc per min was arrived as 24, 32 and 40 rpm respectively.

2.2 Laboratory Investigation Using Test Rig.

An experimental test rig was employed to investigate the effect of chosen levels of independent variables on seed spacing, seed rate and seed placement index (Panning *et al.*,

2000) [8]. An experimental test rig was developed in the department of farm machinery work shop, Tamil Nadu Agricultural University, Coimbatore. The test rig consists of a frame, a pair of DC motor with worm gear box (one for the seed metering disc operation and other for the operation of conveyor belt), similarly a pair of controller was employed for the supply of power for the seed metering disc and for conveyor belt.

The quantity of seeds in the metering section was maintained at constant level up to the level of sleeve with the help of sliding gate. A 75 mm diameter pulley was fitted at the other end of the seed metering drive shaft. The entire seed metering unit was mounted on the top of the main frame. A 75 mm diameter pulley fitted on one of the DC motor was connected to the pulley of the seed metering unit by "V" belt drive. For obtaining the selected levels of inclination of the seed metering disc viz., 30°, 35°, 40° and 45°, four wooden blocks with leveled base and inclined corresponding to the inclination of the disc were used in between the main frame and seed metering unit. The operational view of the test rig is shown in plate 2.

2.3 Evolutional Parameters

In crop production, the main condition for high productivity depends on seeds being in the optimum living area. In other words, it is necessary for seeds to be placed at equal intervals within rows. With uniform spacing, the roots can grow to a uniform size (Steffen *et al*., 1999; Panning *et al*., 2000) [9, 8]. Seed drill performance factors include accuracy of drop points, multiples and misses as well as seed bounces and rolls (Lan *et al*., 1999) [10]. The efficiency of planting unit usually expressed in terms of seed rate (kg ha^{-1}), spacing between hills (mm), percentage of hills with one or two seeds, percentage of hills with more than two seeds, percentage of missing hills, seed placement index (SPI) and visible seed damage as reported by earlier scientists (Karayel and Ozmerzi, 2002; Pradeeprajan and Sirohi, 2004; Staggenborg *et al*., 2004; Karayel *et al*., 2005 and Singh *et al*. 2005) [11, 12, 13, 14].

The seed rate for all the 144 treatments was arrived as detailed below. The speed of belt conveyor of 159.23 rpm corresponding to 1.5 kmph-1 forward speed of operation was achieved through a D.C. motor controller attached to the DC motor. A mark on the conveyor belt was made for identification. The conveyor belt was rotated for 20 revolutions at 160 rpm for all the treatments and the quantity of seeds collected was weighed. The seed rate (kg ha^{-1}) was calculated for all the treatments as furnished below.

Longitudinal distance covered by the conveyor belt for 20 revolutions

= Length of conveyor belt (m) x 20

= 3.87 x 20, m

= 77.4 m

Area covered for 20 revolutions of conveyor belt (m^2)

= Longitudinal distance covered by the conveyor belt for 20 revolutions (m) x width of coverage (m)

= 77.4 x 0.6 m^2

= 23.22 m^2

Weight of seeds collected for an area of 23.22 m^2 = X g

Seed rate (kg ha^{-1}) or weight of seeds collected for an area of 10000 m^2

$$= \frac{X \times 10000}{1000 \times 23.22}\ kgha^{-1}$$

Similarly for the seed rate for other three selected level of peripheral velocities of 0.15, 0.20, and 0.25 ms^{-1} was computed.

3. Results and Discussion

A total number of 144 experiments were conducted using the experimental test rig with selected levels of variables. The mean values of seed rate at selected levels of inclination of seed metering disc (θ), peripheral velocity (V) and cell geometry (S) are furnished in table 1.

Table 1: Seed rate at selected levels of peripheral velocity (V), inclination of seed metering disc (θ) and cell geometry (S)

S.No.	Inclination of seed metering disc (θ), °	Mean value of Seed rate (kg ha^{-1}) at selected level of peripheral velocity of seed metering disc, ms^{-1}			
		0.10ms^{-1} (V_1)	0.15ms^{-1} (V_2)	0.20ms^{-1} (V_3)	0.25ms^{-1} (V_4)
A	**Maximum seed dimension (S_1)**				
i	30°(θ_1)	17.10	18.70	18.20	18.75
ii	35°(θ_2)	18.30	18.32	18.15	18.40
iii	40°(θ_3)	17.90	18.48	18.40	18.32
iv	45°(θ_4)	17.78	18.65	18.68	18.56
B	**10 per cent more than maximum seed dimension (S_2)**				
i	30°(θ_1)	20.40	20.40	20.50	20.70
ii	35°(θ_2)	20.60	20.20	20.45	20.90
iii	40°(θ_3)	20.75	20.30	20.60	20.95
iv	45°(θ_4)	20.85	20.45	20.60	21.00
C	**25 per cent more than maximum seed dimension (S_3)**				
i	30°(θ_1)	22.00	22.40	22.80	22.48
ii	35°(θ_2)	22.70	22.60	22.86	22.74
iii	40°(θ_3)	22.80	22.20	22.92	22.96
iv	45°(θ_4)	22.48	22.47	22.68	22.85

a. Effect of maximum seed dimension (S_1) on seed rate (S_1)

The increase in peripheral velocity from 0.10 (V_1) to 0.25 ms^{-1} (V_4) resulted in 9.6, 0.5, 2.3 and 4.4 per cent increase in seed rate at 30° (θ_1), 35° (θ_2), 40° (θ_3) and 45° (θ_4) inclination of seed metering disc respectively. The effect of inclination of seed metering disc (θ) was negligible. The combined effect of peripheral velocity and inclination of seed metering disc resulted in variation in seed rate from 17.10 to 18.68 kg ha^{-1}. This value is lower than the recommended seed rate of 20 kg ha^{-1}.

b. Effect of 10 per cent more than maximum seed dimension (S_2) on seed rate

The peripheral velocity and inclination of seed metering disc had a marginal effect on seed rate. The variation in seed rate was from 20.20 to 21.00 kg ha^{-1}. The combination of all selected levels of peripheral velocity and inclination of seed metering disc yielded almost the recommended seed rate of 20 kg ha^{-1}.

c. Effect of 25 per cent more than maximum seed dimension (S_3) on seed rate

The same trend as that of 10 per cent more than maximum seed dimension (S2) is reflected with seed rate variation of 22.00 to 22.96 kg ha^{-1}.

Since the effect of inclination of seed metering disc (θ) on seed rate was not significant, the values of inclination of seed metering disc (θ) at each selected levels of peripheral velocity of seed metering disc (V) were pooled and the mean values are furnished in table 2 to bring out the effect of cell geometry (S).

Table 2: Mean of pooled values of seed rate for selected levels of peripheral velocity of seed metering disc

Cell geometry	Pooled values of seed rate (kg ha^{-1}) for all selected levels of inclination of seed metering disc (θ)			
	Selected levels of peripheral velocity of seed metering disc (V)			
	0.10 ms^{-1} (V_1)	0.15 ms^{-1} (V_2)	0.20 ms^{-1} (V_3)	0.25 ms^{-1} (V_4)
S_1	17.77	18.54	18.36	18.51
S_2	20.65	20.34	20.54	20.89
S_3	22.50	22.42	22.82	22.76

It is inferred that increase in cell geometry from 4.25 (S_1) to 5.31 mm (S_3) increased the seed rate by 26.6, 20.9, 24.3 and 23.0 per cent at peripheral velocity (V_1), (V_2), (V_3) and (V_4) respectively.

The seed rate obtained was the highest with cell geometry (S_3) having cell size of 5.31 mm (25 per cent more than the maximum seed dimension) followed by cell geometry (S_2) and (S_1) at all selected levels of inclination and peripheral velocity of seed metering disc. This might be due to the fact that multiple seeds occupied in the larger size of the cell S_3 leading to occurrence of higher number of hills with multiple seeds and hence increased seed rate (table 2).

The cell geometry (S_2) with combination of all selected levels of peripheral velocity (V) and inclination of seed metering disc (θ) yielded the desired seed rate of 20 kg ha^{-1}. This is due to the fact that the occurrence of number of hills with no seeds and multiple seeds was minimum with the cell size 4.67 mm (10 per cent more than the maximum seed dimension) when compared to S_1 and S_3.

4. Conclusion

Based on the analysis of the results, the following conclusions are drawn.

- With the cell geometry same as that of maximum seed dimension, increase in peripheral velocity from 0.10 to 0.25 ms^{-1} resulted in 9.6, 0.5, 2.3 and 4.4 per cent increase in seed rate at 30°, 35°, 40° and 45° inclination of seed metering disc respectively.
- The effect of inclination of seed metering disc on seed rate was negligible when the cell geometry is same as that of maximum seed dimension.
- When the cell geometry was 10 per cent more than maximum seed dimension, the peripheral velocity and inclination of seed metering disc had a marginal effect on seed rate. The variation in seed rate was from 20.20 to 21.00 kg ha^{-1}.
- For the cell geometry having 10 per cent more than maximum seed dimension, the combination of all selected levels of peripheral velocity and inclination of seed metering disc yielded the desired seed rate of 20 kg ha^{-1}.
- Increase in cell geometry from 4.25 to 5.31 mm increased the seed rate by 26.6, 20.9, 24.3 and 23.0 per cent at peripheral velocity of 0.10, 0.15, 0.20 and 0.25 ms^{-1} respectively.
- The seed rate obtained was the highest with cell geometry having cell size of 5.3 mm followed by cell geometry (4.67 mm) and (4.2 mm) at all selected levels of inclination and peripheral velocity of seed metering disc.

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