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Development and Evaluation of Inclined Plate Metering Mechanism for Soaked Okra (*Abelmoschus esculentus*) Seeds

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ABSTRACT

Keywords

Okra planter, Engineering properties, Inclined plate, Average spacing, Missing index, Multiple index, Quality feed index, Seed rate.

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Soaked okra seed is recommended for a field planting for better germination percentage. Engineering properties of two seed varieties (Pusa-A4 and Punjab-8) were studied for water soaked condition for 24 hours and on the basis of these properties, an inclined plate was designed for the sowing of soaked okra seeds. Subsequently a metering mechanism of okra was developed and preliminary evaluation of the developed metering mechanism was conducted in the laboratory on following parameters: three type of inclined plates (A, B and C), three angle of inclinations (45°, 50° and 55°) and four forward speeds of operation (1.0, 2.0, 3.0 and 4.0 km/h). The performance of metering mechanism was evaluated on the basis of average spacing, multiple index, missing index, quality of feed index and seed rate. A selection of the angle of inclination and type of metering plate for the metering system was purely based on average seed spacing and index values. The best combination found in laboratory evaluation for Pusa-A4 was for plate A at 2 km/h forward speed and 45° angle of inclination were recommended for field sowing. Similarly, for Punjab-8 was plate B at 3 km/h forward speed and 50° angle of inclination was recommended.

Introduction

India is the second largest producer of vegetables in the world after China with the total production of 162.86 million tonnes and having an average productivity of 17.3 t/ha. India is the leader in the production of vegetables like pea and okra, second largest producer of onion, cabbage, cauliflower, brinjal and third in tomato, potato in the world. There is an abundant production of vegetables like potato, tomato, okra and cucurbits in India (Anon., 2014). Vegetables are an inevitable part of human diet and meal without vegetable is supposed to be incomplete. It is estimated that per capita

consumption of vegetables in India is 230 g/day as against 300 g/day recommended dietary allowance. Thus, now India has shortage of about 30 million tonnes of vegetables (Vanitha *et al.*, 2013).

The inclusion of vegetables in the daily diet is indispensable for the maintenance of good health. To feed the present population of the India, there is a need to double the total production of vegetables. Besides this, India has to produce additionally to meet the requirement of the processing industry, exports and seed industry.

India is one of the leading okra producing country in the world having 532.66 thousand hectares area under okra cultivation with a production of 6346.37 thousand tonnes okra having the productivity of 11.9 t/ha which contributes 72.9 percent of okra production followed by Nigeria 12.6 percent, Sudan 3.0 percent and Iraq 1.8 percent (Annon, 2014).

In India, sowing time of okra varies from region to region due to geographical diversity. Okra transplanting is not practiced and broadcasting leads to more seed consumption. Thus, a seed is sown directly in the soil by seeding behind the plough or dibbling, or with the seed-drills. In this seeding method, it is not possible to achieve uniformity and distributions of seed expect dibbling. Whereas, dibbling is one of the expensive sowing methods. The inter-row and intra-row distribution of seed are likely to be uneven resulting a seed cluster or gap filling requirement. The input use efficiency and plant establishment of the most vegetable crop were poor. As a result, the yield and product quality are low and cost of cultivation is high. Besides this, the seed coat of okra was very hard and it does not take up water easily after sowing in the soil, this resulted in very poor germination. Hence, to increase a germination percentage of okra generally a soaking of okra seed in water for 24 hours is very common practice in India (Anon 2015, Yawalkar, 1992).

Uniform seed spacing and depth result in better germination and emergence and increase yield by minimizing competition between plants for available light, water and nutrients. Thus single seed planters are becoming popular nowadays. Single seed planters are defined to be row crop planters or precision planting equipment that are equipped with seed metering devices that meter individual seeds at a given distance apart. Single seeds planters generally include

planter with a pneumatic plate, cell type metering mechanisms such as inclined, vertical and horizontal type metering plates and drum mechanisms (Kachman and Smith, 1995).

Under field conditions, it is often difficult to directly measure seed placement. However, an alternative method is to measure the spacing between the plants after they emerge. While measuring the spacing between the plants once they emerge, considerable variability often exists in the distances between the plants. Much of the variability in spacing could be removed by evaluating planters under laboratory conditions and thus laboratory evaluation is recommended. However, field trials are also needed to accurately evaluate how a planter will perform in the field.

Ryu and Kim (1998) developed a method to design the roller-type seed metering device for hill planter. As the roller rotates through the seed hopper, a seed is fed into the grooves by gravity and the cutoff devices (brush) removes the extra seeds above the groove so that the seeds inside the groove can only pass the brush. In the roller design, a shape of the groove and number of grooves are important design parameters. Groove shape is considered the most important factor affecting the seed dropping process from the groove.

The distance between plants within a row is influenced by a number of factors including a failure of a seed to be dropped, multiple seeds dropped at the same time, failure of seed to germinate and variability in dropping point. Kachman and Smith (1995) compared the alternative measures of accuracy in seed placement for planters using single seed metering mechanism and concluded that the mean and standard deviation spaces between seed did not offer an appropriate evaluation of planter performance on seed distribution. The

final selection of metering unit is also depended on missing and multiples during seed placement.

Sahoo and Srivastava (2008) studied the seed pattern characteristics of different metering systems such as vertical roller, horizontal plate, horizontal plate (edge drop) and inclined plate for soaked okra seed and concluded that the average spacing was close to theoretical spacing for vertical roller, horizontal plate, horizontal plate (edge drop) with cell size 10% more than the larger seed dimensions. But in case of an inclined plate, the average spacing was close to theoretical spacing with the cell size equal to larger seed dimensions. The metering system influenced the seed damage the most followed by cell speed. Considering all the performance parameters, the inclined plate metering system was selected as the more suited for metering soaked okra seed.

Yadachi *et al.*, (2013) developed an inclined plate seed metering device and evaluated its performance in a laboratory for singulation and uniform placement of carrot seeds with different treatment of coating viz. uncoated, coated with biogas slurry and thirame coated. The metering device was tested at three inclinations of 40°, 50° and 60° using plates having cells with three shapes viz. triangular, semi-circular and slant cells. The inclination of metering device statistically influenced the average spacing and performance indices, followed by cell shape and seed treatments. Overall seed damage ranged between 0.18-3.6 per cent. The selection of inclination angle of plate and shape of the metering cell for the planter was purely based on average spacing, miss index, multiple index and quality of feed index. Slant type cell plate at an inclination of 50° was recommended for the sowing of coated seed of carrot. In India, a large number of planters are available for cotton, maize, soybean, groundnut and pea (Sahoo and

Srivastava, 2000). However, very limited information is available on the mechanical planting of soaked okra seed. Keeping all these points in view the present work on development and evaluation of the metering mechanism of planter for soak okra seed was initiated to develop the prototype of okra planter.

Materials and Methods

Metering system

Metering mechanism was considered as the heart of sowing machine and its function was to separate out and drop seeds uniformly at the desired application rates. The most common type of metering devices used on planters was vertical rotor, horizontal rotor, cell type of plate and cup feed type of mechanism etc (Anon., 1991). However, the average percentage of seed damage was found to be very less in inclined plate type mechanism and for the sowing of soaked okra seed inclined plate metering mechanism was recommended by Sahoo and Shrivastava (2008). A metering plate having cell picks and drops individual seed or more than one seeds depending on the design of cell of the plate. The shape of the groove and number of grooves are important design parameters which affect the seed dropping process from the groove. The cell on the plate was designed on the basis of physical properties of seed. Hence, for different seed variety, there were different types of plate. The spacing between seeds was controlled by drive ratio (between ground wheel and plate) and a number of cells on the plate.

Engineering properties

The engineering properties of two seed varieties of okra in soaked conditions (Fig. 1) i.e., Pusa A4 which was recommended for all India sowing and Punjab-8 recommended for

Punjab state were studied to design the metering plate for inclined plate planter Table 1. The dimension of a cell is designed according to seed dimension such as length, breadth, thickness and roundness of seed.

Design of inclined plate

Design procedure adopted by Ryu and Kim (1998) and Ahmadi *et al.*, (2007) was followed to determine the shape and size of cell of the plate. The average value of geometric mean diameter (GMD) for both varieties was 5.76 mm hence the thickness of plate should be more than half of the GMD (more than 3 mm) for easy picking of seed. Therefore, a plate of having 4 mm thickness and 170 mm diameter was selected for the design of a metering system. The length of soaked seed for both varieties ranged from 4.89 to 7.52 mm with the mean value of 6.6 mm. For design consideration, a maximum dimension of the seed (length) was considered (7.5 mm). Five design variables were defined and used to determine the exact size of the groove (Table 2, Fig. 2 and 3).

The hopper bottom and plate were right angles to each other hence changing in an angle of hopper changes the angle of inclination of a plate. For easy flow ability of seed, the angle of hopper from horizontal must be more than the angle of repose of seed. Angle of repose of seed ranged from 31.24° to 33.30° hence, it must be more than 35° and hopper angle 35°, 40° and 45° w.r.t horizontal surface was selected which resulted in the angle of inclination of plate by 45°, 50° and 55° respectively.

A factorial Completely Randomized Design (CRD) was used to analyze the data obtained from laboratory experiments and to find out the interactions between the factors combination. Statistical software CPCS1 was used for the analysis of variance and comparison of means. The critical difference

was found at 5% level of significance.

Laboratory test

The performance of three types of metering plate was evaluated using a sticky belt arrangement for two varieties. The three plates were evaluated at four-speed of operation and three angles of inclination explained above. Sticky belt mechanism consisted of 4 m long endless canvass belt mounted on two endless roller. The moving canvas belt which simulated ground speed of inclined plate planter with the provision to vary the speed of operation.

Power transmission unit of belt pulley system with reduction gear and driving roller driven by a 4 kW motor. Observations were taken on the spacing between two adjacent seeds over the sticky belt applied with grease. Based upon the in-between spacing of seeds, five measures of performance parameters viz., average spacing, multiple index, missing index quality feed index and seed rate were determined (Kachman and Smith, 1995).

Performance parameters

Missing index

Missing index (M_i) was the indicator of how often the seed skipped the desired spacing. It was the percentage of spacing greater than 1.5 times the theoretical spacing, which can be given as below

$$M_i = \frac{N_1}{n} \quad (1)$$

Where,

N_1 = number of times spacing in the region is greater than 1.5 times of the theoretical spacing

n = total number of observations

Multiple index

The multiple index (M_u) was an indicator of more than one seed dropped within a desired spacing 15 cm. It was the percentage of spacing that was less than or equal to half of the theoretical spacing.

$$M_u = \frac{N_2}{n} \quad (2)$$

Where,

N_2 = number of times spacing in the region was less than or equal to half of the theoretical spacing

Quality of feed index

The quality of feed index (Q_u) was the measure of how often the spacing was close to the theoretical spacing. It was the percentage of spacing that were more than half but not more than 1.5 times the theoretical spacing. The quality of feed index was mathematically expressed as follows:

$$Q_u = \frac{N_3}{n} \quad (3)$$

Where,

N_3 = number of times spacing between 0.5 times the theoretical spacing and 1.5 times of the theoretical spacing

Seed rate

The okra planter was mounted over to the test rig and furrow openers were put with steel containers and seed were collected from the furrow openers for the twenty revolution of the ground wheel. There after the seed was weighed and the seed rate was calculated with given below formula. This was done for each speed, plate inclination angle and type of plate.

$$\text{Seed rate} = \frac{g}{a \times b \times c} \text{ kg/ha} \quad (4)$$

Where,

g = quantity of seed collected in all the seed tubes in 10 revolution of wheel in gram

a = number of furrow openers

b = spacing between the furrow openers in meters

c = circumference of wheel in meters

Results and Discussion

Average spacing

For both varieties, the average spacing was significantly influenced by all combinations of design variables taken at 5% level of significance. For Pusa A4, the inclination of metering device influenced the average spacing, followed by plate type and speed of operation whereas for Punjab-8, speed of operation only influence the average spacing as indicated by the F-values (Table 4). The average spacing increased with increase in forward speed as well as inclination angle for both varieties (Fig. 4, 5 and 6). The average spacing obtained at plate inclination of 45°, 50°, and 55° was 11.6 cm, 13.7 cm and 15.2 cm for Pusa A4 and 11.3 cm, 12.8 cm and 14.3 cm for Punjab-8 respectively. For Pusa A4, Plate A gave the average spacing of 15.5 cm which was close to the desired theoretical spacing (15 cm). Similarly, for Punjab-8, Plate B gave the average spacing (13.6 cm) that was found to be close to the desired theoretical spacing. The speed of operation of 3 km/h resulted in the average spacing of 12.8 cm and 12.9 cm for Punjab-8 and Pusa A4 respectively which was close to the recommended spacing. As the speed of operation was increased from 1 km/h to 4 km/h the average spacing found to be

increased because of vibration induced in the system that resulted in more missing of seeds. In case of an angle of inclination, the average spacing increased with increase in angle of inclination from 45° to 55° because of a force of gravity which enables the complete filling of cell at a lower angle of inclination.

Performance indices

The distance between plants within a row was influenced by a number of factors including missing index, multiple index, failure of seed to germinate and variability around the drop point. Missing, multiple and quality feed index were found statistically not influenced by all the three design variables at 5% level of significance.

Multiple index

For Punjab-8 seed variety, multiples were influenced by the angle of inclination and followed by the type of plate whereas for Pusa A4, it was influenced by the speed of operation and type of plate as indicated by the F- values (Table 4). From Figure 7, 8 and 9 showed the performance indices of various combinations of design variables.

It was found that seed metering Plate C resulted in more multiples 46.3 %, 41.6 % as compared to Plate A 28.1%, 21.3% and Plate B 34.9%, 28.8% for Punjab-8 and Pusa A4 respectively. This was because multiple seeds were picked by Plate C which having the cell depth of 130% (i.e., 30 % more than the actual dimension of seeds). More multiples of seed resulted in non-uniform plant spacing, loss of costly seed and labour requirement for thinning the extra plant population. Thus multiple seeds must be within the given acceptable range. The least multiple index 24.4% and 18.3% was observed at 4 km/h speed of operation for Punjab-8 and Pusa A4 respectively. The multiples obtained at plate

inclination of 45°, 50° and 55° were 39.6%, 27.9% and 24.1% for Pusa A4 and 43.7%, 34.8% and 30.9% for Punjab-8 respectively. From Table 4, it could be concluded that the combined interaction of type of plate, an angle of inclination and speed of operation had a non-significant effect on multiple index of seeds for both varieties.

Missing index

Missing index was found to be statistically not influenced by the angle of inclination, type of plate and speed of operation as indicated by F-values (Table 4). From Figure 7, 8 and 9 it was concluded that Plate C gave less missing index as compare to Plate A and Plate B for both varieties. For Plate C, the missing percentage was found to be 0 % from speed 1 km/h to 3 km/h at angle of inclination of 45° which later found to increase with increase in angle of inclination and speed of operation for Punjab-8 and in case of Pusa A4 it was less than 6%.

The increase in the missing index with the increase in forward speed was due to decrease in exposure time of groove to seed in the hopper and also the higher centrifugal force at higher speed was the reason which throws the seed out of the cell prematurely.

The missing obtained at plate inclination of 45°, 50° and 55° were 13.9 %, 21.4 % and 25.1 % for Pusa A4 and 8.7 %, 13.2 % and 21.3 % for Punjab-8 respectively. The percentage of the missing index was found to be 8.3 % at speed of 3 km/h and at an angle of inclination of 50° for Punjab-8 and for Pusa A4, it was 4.8 % at speed of 2 km/h and at an angle of inclination of 45° for plate A.

Quality of feed Index

Figure 7, 8 and 9 depicts the variation of quality feed index with respect to the forward

speed of operation. For Plate A, the value of quality of feed index was observed between 69.2 to 35.5 %, 62 to 42.3 % and 51 to 36.7 % for plate B and plate C respectively for various treatments of speed and angle of inclination of Plate for Punjab-8.

The highest percentage quality of feed index was found to be 62.1 % at speed of 2 km/h and at an angle of inclination of 45° for plate A. Similarly for Pusa A4, it was observed between 69.2 to 35.5%, 62 to 42.3% and 51 to 36.7% for Plate A, Plate B and Plate C respectively for various treatments of speed and angle of inclination of plate. The highest percentage of quality feed index was found to 62.1 % at speed of 2 km/h and at an angle of inclination of 45° for Plate A for Pusa A4. From Table 4 it could be concluded that the combined interaction of type of plate, angle of inclination and speed of operation had non-significant effect on quality of feed index of seeds for both varieties.

Seed rate

A seed rate of the machine was directly associated with the plant population per acre or hectare area which indicates the capability of seed metering unit to obtain the required quantity of seed which was necessary for desired plant population in particular field. For Plate A, the value of seed rate was observed 5.0 to 14.4 kg/ha, 4.7 to 14.6 kg/ha and 6.8 to 15.1 kg/ha for plate B and plate C respectively for various treatments of speed and angle of inclination of plate for Punjab-8 and similarly for Pusa A4 the value of seed rate was observed 5.5 to 14 kg/ha, 5.6 to 15.7 kg/ha and 6.5 to 17.4 kg/ha for plate B and plate C respectively. From Figure 10, 11 and 12 it was observed that seed metering plate C delivered more seed rate as compared to Plate A and Plate B for both seed varieties. This was because multiple seeds were picked by

plate C which having the cell depth of 130% that is 30 % more than the actual dimension of seeds. Combination of Plate B at speed of 3 km/h and angle of inclination of 50° gave the seed rate of 10.40 kg/ha which was close to recommended theoretical seed rate (10-12 kg/acre) for Pujab-8 and for Pusa A4 the combination of Plate A, speed of 2 km/h at angle of inclination of 45° gave the seed rate of 12.10 kg/ha. From Table 4, it could be concluded that the combined interaction of type of plate, the angle of inclination and speed of operation had a non-significant effect on seed rate for both varieties.

Final selection of optimum parameters for okra planter was based on the results of laboratory evaluation; For Punjab-8 seed variety, metering plate B with an angle of inclination 50° and speed of operation 3 km/h were selected. The average spacing between seeds at 3 km/h forward seed with metering plate B with an angle of inclination of 50° was 11.8 cm which was close to recommended spacing, multiple index 28.8 % and missing index 8.3 %.

The overall quality feed index obtained with this parameters was 62.9 % which was maximum as compared to other parameter combination and seed rate was 10.40 kg/ha (4.20 kg/acre) found which was recommended for the sowing of okra seeds. Whereas, For Pusa A4 seed variety metering plate A with an angle of inclination 45° and speed of operation 2 km/h were selected. The average spacing between seeds at 2 km/h forward seed with metering plate A with an angle of inclination of 45° was 11.2 cm, multiple index 33.1 % and missing index 4.8 %. The overall quality feed index obtained with this parameters was 62.1 % which was maximum as compared to other parameter combination and seed rate was 12.10 kg/ha (4.90 kg/acre).

Fig.1 Soaked okra seed variety used for evaluation of metering mechanism



Fig.2 Detail drawing of metering plate used for soaked okra metering

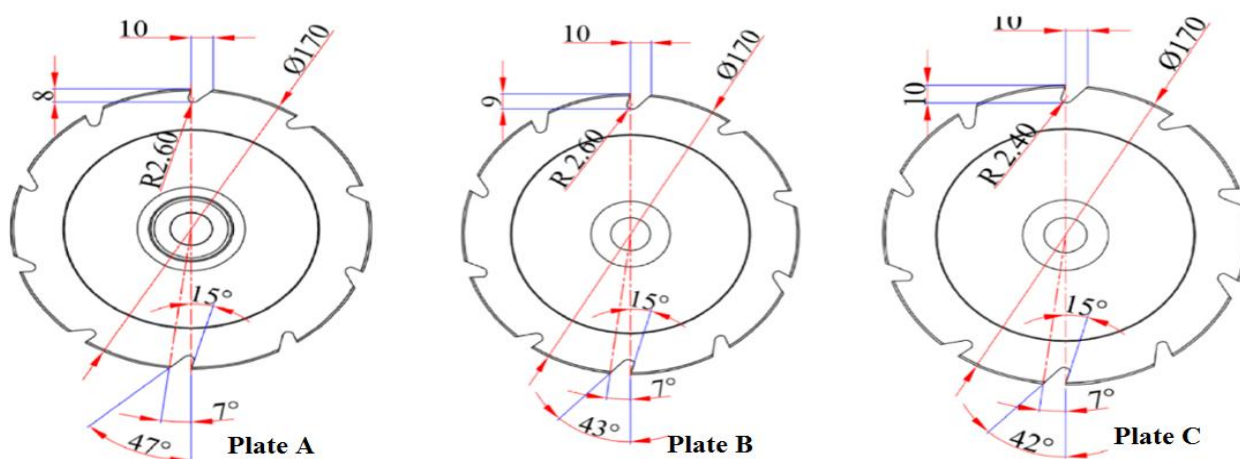


Fig.3 Metering plates used for metering of soaked okra seeds



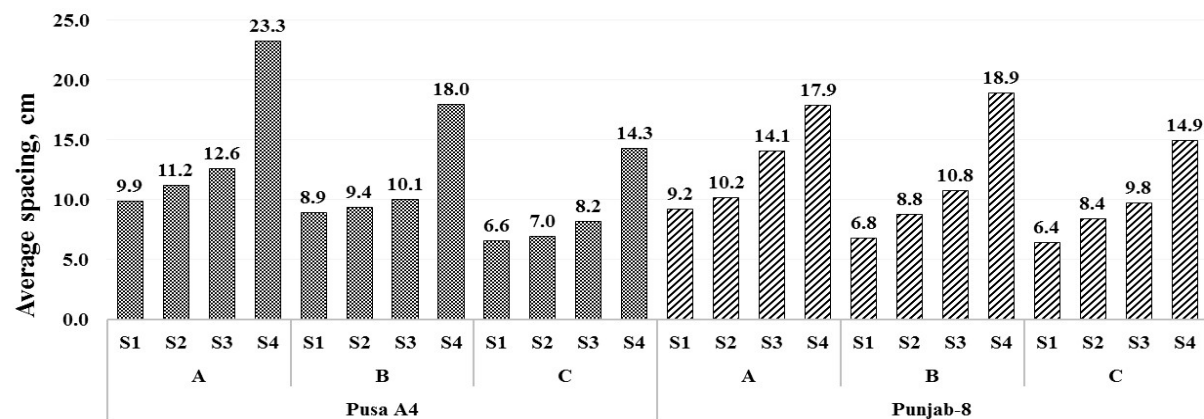


Fig 4. Effect of metering plate and speed on the average spacing of soaked okra seeds at angle of inclination of plate was 45°.

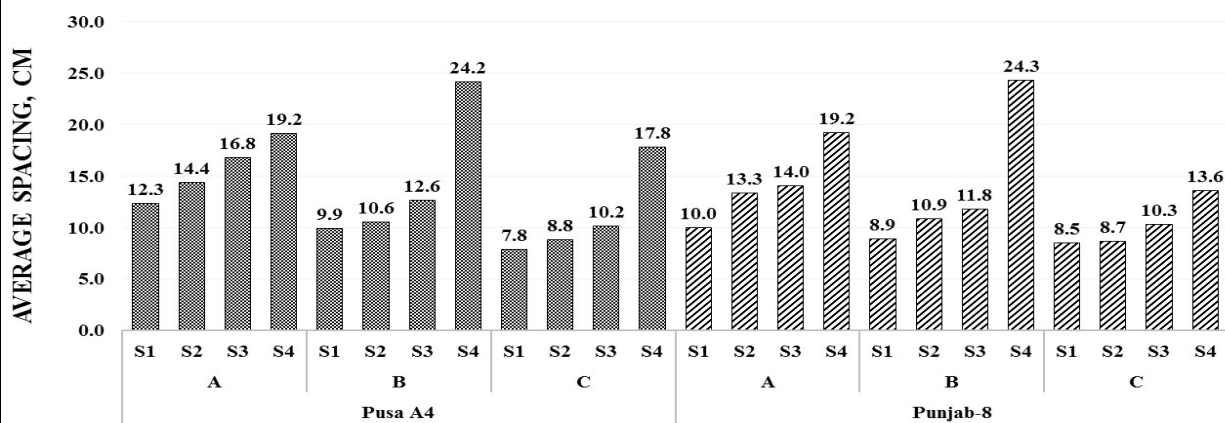


Fig 5. Effect of metering plate and speed on the average spacing of soaked okra seeds at angle of inclination of plate was 50°.

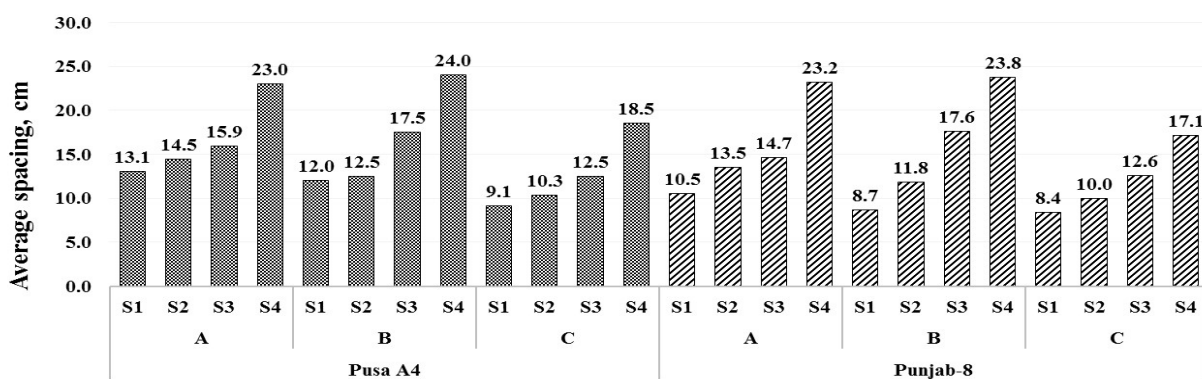


Fig 6. Effect of metering plate and speed on the average spacing of soaked okra seeds at angle of inclination of plate was 55°.

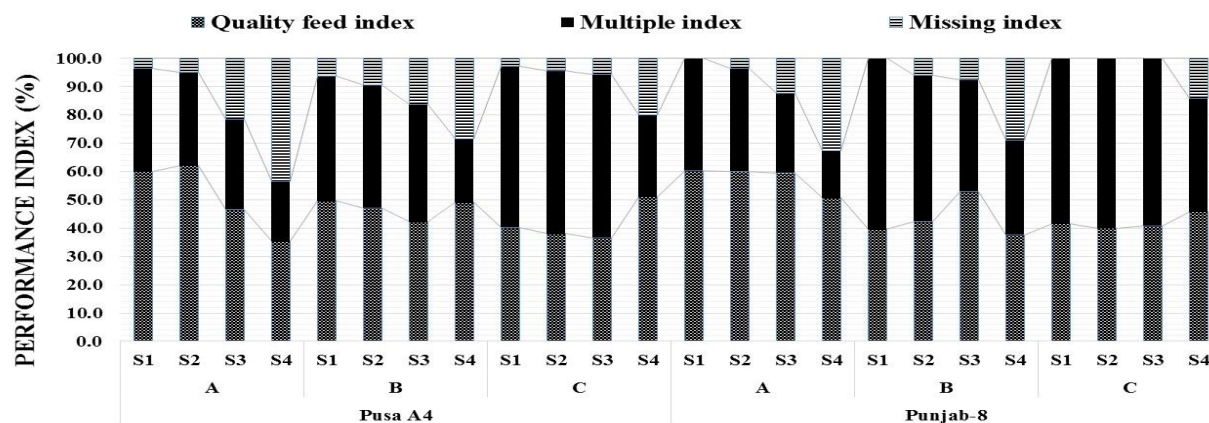


Fig 7. Effect of metering plate and speed on the performance indices of soaked okra seeds at angle of inclination of plate was 45°

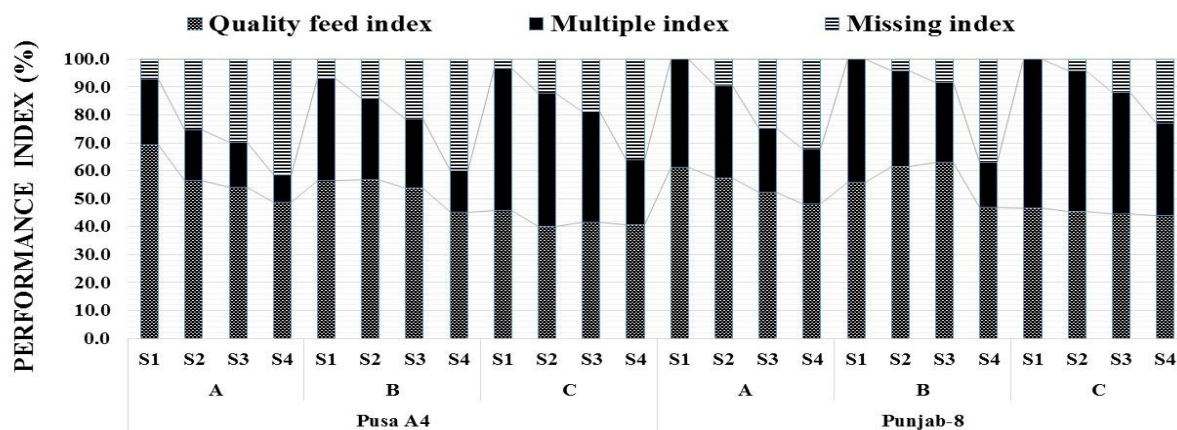


Fig 8. Effect of metering plate and speed on the performance indices of soaked okra seeds at angle of inclination of plate was 50°

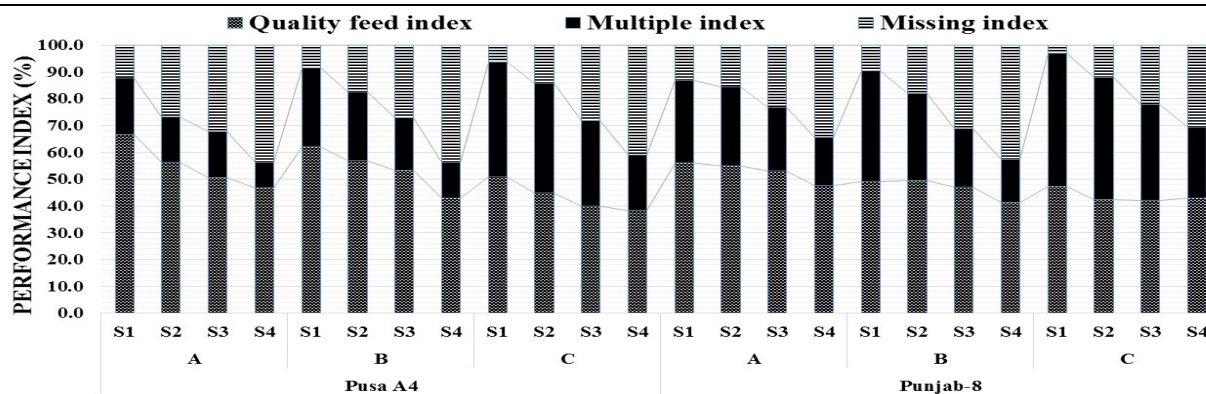


Fig 9. Effect of metering plate and speed on the performance indices of soaked okra seeds at angle of inclination of plate was 55°.

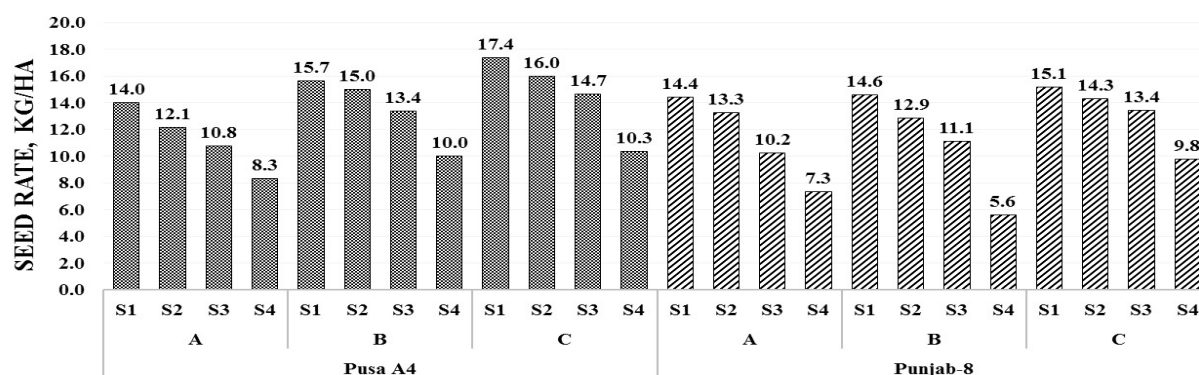


Fig 10. Effect of metering plate and speed on the seed rate of soaked okra seeds at angle of inclination of plate was 45°.

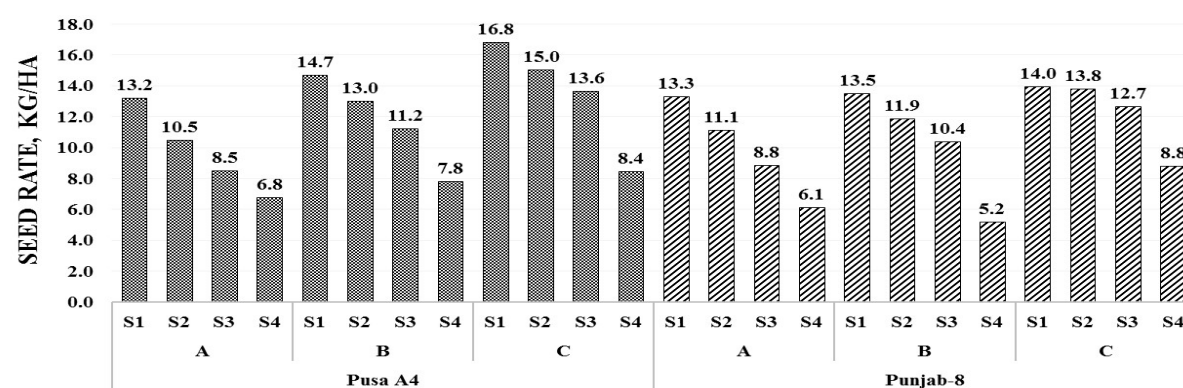


Fig 11. Effect of metering plate and speed on the seed rate of soaked okra seeds at angle of inclination of plate was 50°.

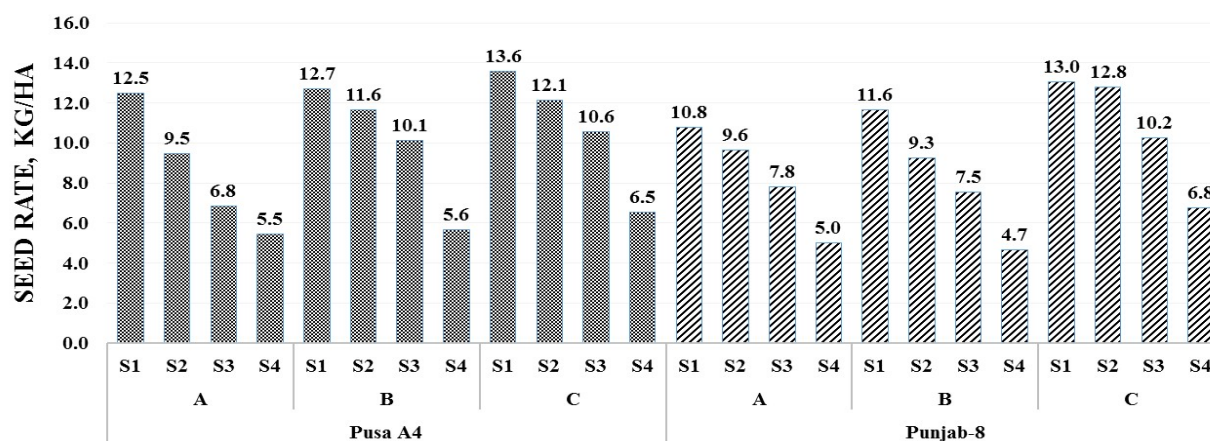


Fig 12. Effect of metering plate and speed on the seed rate of soaked okra seeds at angle of inclination of plate was 55°

Table.1 Engineering properties of soaked okra seed

Properties	Variety	
	Pusa A-4	Punjab-8
Length, mm	6.61±0.43	6.34±0.51
Breadth, mm	5.70±0.60	5.37±0.39
Thickness	5.08±0.43	4.70±0.35
Geometric Mean Diameter	5.76±0.32	5.42±0.26
Sphericity	0.87±0.05	0.85±0.06
Roundness	0.85±0.07	0.86±0.06
Angle of repose	31.24±1.25	33.30±0.78

Table.2 Design variables of inclined plate

Design variable		Purpose	Types of plate		
			Plate A	Plate B	Plate C
T _p	Thickness of plate	Should be GMD/2	4 mm	4 mm	4 mm
W _g	Width of cell	Slightly larger than length of seed so easily accommodate 1-2 seeds	10 mm	10 mm	10 mm
D _g	Depth of cell	Slightly larger than length of seed	8mm (110% of 7.5mm)	9mm (120% of 7.5mm)	10mm (130% of 7.5mm)
θ _g	Open angle of cell	Determines the loading process	7°	7°	7°
β _{ls}	Left side angle of the cell	Determines the seed holding capacity (must be β _{ls} > θ _g)	47°	43°	42°
β _{rs}	Right side angle of the cell	Determines the ease in loading process (Must be β _{rs} < β _{ls})	15°	15°	15°
R _c	Radius of the curvature	Round cell bottom prevents seeds/other substances from clinging to the bottom. (Based on the roundness of seed)	2.60 mm	2.60 mm	2.40 mm

Table.3 Plan of experiment on metering system

Independent Variables	Seed variety	Types of plates	Speed of operation, km/h	Angle of inclination
Levels of variables	Punjab-8 (P8) Pusa-A 4 (P4)	Plate A Plate B Plate C	S ₁ -1.0 S ₂ -2.0 S ₃ -3.0 S ₄ -4.0	θ ₁ -45° θ ₂ -50° θ ₃ -55°

Table.4 F-values for performance parameters of seed metering mechanism

Source	F-Value									
	Average spacing		Multiple index		Missing index		Quality feed index		Seed rate	
	PUNJA B-8	PUSA A4	PUNJA B-8	PUSA A4	PUNJA B-8	PUSA A4	PUNJA B-8	PUSA A4	PUNJA B-8	PUSA A4
P	47.90	69.37	53.46	96.10	14.30	15.43	17.68	12.64	605.69	456.80
θ	31.64	41.81	26.98	59.37	41.07	29.61	2.84	1.89	705.57	553.23
S	226.66	202.75	43.19	50.93	111.68	119.71	3.04	6.16	2418.72	1216.47
P \times θ	1.93	1.66	3.56	0.59	1.39	0.56	3.19	0.33	5.53	12.23
P \times S	8.21	1.84	1.05	2.61	1.92	0.66	1.42	1.60	34.70	20.31
$\theta \times$ S	1.95	0.72	0.25	1.58	1.68	1.45	0.65	0.67	5.34	3.71
P \times $\theta \times$ S	2.13	2.93	0.43	0.22	1.24	1.57	0.24	0.63	10.51	2.33

Where, P= Plate, S = Speed and θ = Angle of inclination

The inclination of metering device statistically influenced the average seed spacing and performance indices, followed by the type of metering Plate and speed of operation.

The average spacing of seeds was observed to be increased by increasing the speed of operation from 1km/h to 4 km/h which may be attributed to more missing.

Missing index was observed to be increased by increasing speed of operation and Plate C gave less missing index as compared to Plate A and B in both varieties.

Plate C gave the higher value of multiple index as compared to Plate A and B and which was affected by the angle of inclination of Plate for variety Punjab-8 and same in Pusa A4.

Highest feed index of 62.9 % was obtained at Plate inclination of 50°, with Plate B at speed of operation of 3 km/h for Punjab-8 which gave the 11.8 cm which was close to recommended spacing.

Highest feed index of 62.1 % was obtained at Plate inclination of 45°, with Plate A at speed of operation of 2 km/h for Pusa A4 which

gave the 11.2 cm which was close to recommended spacing.

Metering plate with Plate B at 50° inclination of metering device gave the best performance at speed of 3 km/h and thus recommended for Punjab-8.

Metering plate with Plate A at 45° inclination of metering device gave the best performance at speed of 2 km/h and thus recommended for Pusa A4.

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