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Development and Evaluation of Inclined Plate Metering Mechanism for Onion Pelleted Seeds

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Abstract

The ability to place seeds at a given distance apart in a row is an important performance factor of a planter with single seed metering mechanism. Inclined plate seed metering device was developed and evaluated in laboratory for singulation and uniform placement of onion seeds with different pelleting ratio viz. 1:1, 1:2 and 1:3 pelleted. Metering device was tested at three inclinations of 40°, 45°and 50° using plates having three different groove number 18, 24 and 30 on cells. Average seed spacing obtained at in S_3 seed, θ_2 angle in forward speed 2.0 km/h, the average spacing was observed to be 5.90, 5.35 and 5.15 cm for 18, 24 and 30 groove plate respectively. Missing index at 2.0 km/h forward speed with 24 groove seed metering plate with 45° inclination angle was 5.0% and multiple index was 11.0%. The overall quality of feed index obtained with these parameters was 84.0% which is maximum when compared with other seed treatments, forward speeds and types of seed metering plate combinations with different angle of inclination of plates. The selection of plate inclination and type of metering cell for the planter was purely based on average spacing, missing index, multiple index and quality of feed index. With 24 groove seed metering plate with 45° inclination angle and forward speed of 2.0 km/h was selected for the field evaluation.

Keywords

Inclined plate; Miss index; Multiple index; Quality index; Cell; Pelleted seed

Introduction

Onion (Allium cepa L.) is one of the major vegetable crop grown throughout the country. Onion is one of those versatile crops that can be stored for a longer period under ambient conditions and safely withstands the hazards of rough handling and transportation. It is widely grown in different parts of the country mainly by small and marginal farmers. In Punjab onion is sown over an area in 2013-14 of about 8.3 thousand hectare having production of 185.4 thousand tonne [1]. Generally, the onion seeds are sown in nursery and transplanted with row to row spacing of 15 cm and plant to plant spacing of 7.5 cm to get optimum yield. During onion cultivation, transplanting of seedlings, weeding and harvesting are the most labour intensive operations that are presently done manually in India. The labour requirement in manual transplanting of onion seedlings is as high as 100-120 man- days/ha as 8.9 lakh seedlings per hectare are to be transplanted [2]. Because of high requirement and shortage of labour, the area under onion cultivation is low and can be increased by mechanization of this crop.

Performance of single seed planter mainly depends on its ability to place seeds at a given distance apart. Under field conditions, it is often impossible to directly measure seed placement. An alternative is to measure the spacing between plants after they emerge. When examining the spacing between the plants once they emerge, considerable variability often exists in the plant-to-plant distance. Much of the variability in spacing could be removed by evaluating planters under laboratory conditions. However, field trails are also needed to accurately evaluate how planters perform in field. The main aim is to quantify the observed variability in a way that will allow one to make meaningful comparisons between single seed metering devices. A number of factors affect the spacing of plants. The seed selection mechanism may fail to select or drop a seed resulting in large spacing between the seeds. The device may pick and drop multiple seeds resulting in small spacing between seeds. Seed tube design and soil conditions along with other factors determine the final placement of seed. As all seeds may not germinate, the distribution of plant spacing will differ from the intended seed spacing.

Kachman and Smith [3] tested and compared the most widely used measures; mean, standard deviation, quality of feed index, multiple index, miss index and precision. These measures were based on the theoretical spacing (X ref), specified in ISO 7256-1 standard [4], and gave a good indication of spacing distribution. Kachman and Smith [3] concluded that the mean and the standard deviation of seed spacing did not offer an appropriate evaluation of planter performance on seed distribution. The final selection of metering device also depends on multiple index and miss index. Shibata et al. [5] developed two devices for small seed metering based on the picking action with pincette type picking unit. One device was designed with a spring pick up unit and other device with electromagnetic pick-up type. Lower misses were observed for spring pickup type at low peripheral speed of 13.4 cm.s^{-1} with 71% seeding efficiency. In case of electromagnetic pickup device, no misses were observed even at high peripheral speeds with 80% seeding efficiency. Zang and Guo [6] designed a special- shaped spiral groove precision seed metering device for small grain crops. The spiral groove sections with rectangular bottom, V-shaped bottom and U-shaped bottom were used for seed metering. V-shaped bottom was chosen, because of its stability for seeding. Development of manually operated electrostatic planter for small seed was reported by Ahmed and Gupta [7]. There was no damage to seeds passing through metering device, but number of seeds picked up by electrostatic charge varied from 2-6 seed per hill. Study on feasibility of precision planting by cell type metering device for radish seed was reported by Otsuka et al. [8]. Kowalczuk and Zarajczyk [9] examined the quality of carrot sowing with belt type seeder at 3 working speeds of 0.7, 1.0 and 1.4 m.s^{-1}, and found the best working speed as 0.7 m.s^{-1}. A large number of planter designs are available for bolder seeds, but very little information is available on small seed like onion, particularly under Indian situations. Hence,

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the present study was conducted with the objective to design the metering mechanism for small sized seed like onion and evaluate it for uniformity of seed placement.

Materials and Methods

Metering system

Mechanical seed metering devices in planter usually have cells on a moving member to have positive seed metering. Commonly recommended metering systems on planters are horizontal plate, inclined plate, vertical rollers with cells, and cups over the periphery [4]. Since onion seeds are small in size and very susceptible to mechanical damages, metering with vertical and horizontal plate metering mechanism were not considered. Laboratory experiment was thus conducted with inclined plate cell type metering mechanism having different cell numbers (Figure 1). Details of the metering plates are shown in Figure 2. The types of onion seeds used for the study are shown in Figure 3. The average values of roundness value of onion seed were 0.75, 0.78 and 0.82 for 1:1, 1:2 and 1:3 pelleted seed respectively (Table 1). This gave clue to use slant shape of cells over plate periphery. The values of angle of repose for 1:1 pelleted (S_1), 1:2 pelleted (S_2) and 1:3 pelleted (S_3) seeds were 31.61°, 29.50°, 24.78°, and 23.70° respectively (Table 1).

The hopper slope was thus decided at 45 ° by the values of angle of repose of the seeds.

Laboratory test

The performance of cells of different shapes was evaluated using a sticky belt and by varying inclination of the metering device for both coated and uncoated seeds (Table 2). The sticky belt mechanism consisted of 4 m long endless canvass belt mounted on two endless rollers spaced 100 cm apart along with a seed hopper and 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 greased belt. Based upon the in-between spacing of 50 seeds, five measures of performance parameters viz. average spacing, multiple index, miss index, quality of feed index and precision were determined [1].

Performance parameters

Multiple index: Multiple index (D) is an indicator of more than one seed dropped within a desired spacing. It is the percentage of spacing's that are less than or equal to half of the theoretical spacing:

$$D = n1/N \tag{1}$$

Where,

N = Total number of observations, and

n1 = Number of spacing's in the region less than or equal to 0.5 times of the theoretical spacing.

Quality of feed index: Quality of feed index (A) is the measure of how often the seed spacing's were close to the theoretical spacing [4]. It is the percentage of spacing's that are more than half, but not more than 1.5 times the theoretical spacing. The quality of feed index is mathematically expressed as follows:

$$A = n2/N \tag{2}$$

Where,

N = Total number of observations, and

n2 = Number of spacing's between 0.5 times the theoretical spacing and 1.5 times of the theoretical spacing.

Miss index: Miss index is an indicator of how often a seed skips the desired spacing. It is the percentage of spacing greater than 1.5 times the theoretical spacing, and expressed as:

$$M = n3/N \tag{3}$$

Where,

N = Total number of observations, and

n3 = Number of spacing's in the region > 1.5 times of the theoretical spacing.

Degree of variation: Degree of variation (c) is a measure of the variability in spacing after accounting for variability due to both multiples and skips. The degree of the variation is the coefficient of variation of the spacing that are classified as singles.

$$C = {}^{S}\!/_{X_{ref}} \tag{4}$$

Where,

S = Sample standard deviation of the n3 observation,

X ref = Theoretical spacing

Results and Discussion

Average spacing

The average spacing was significantly influenced by all combinations of design variables of the study at 5% level of significance. Inclination of metering device influenced the average spacing, followed by cell number as indicated by the F-values (Table 3).

Figure 1: Metering plates used for metering of onion seed.

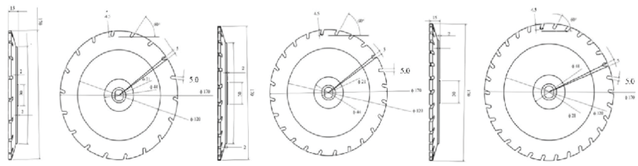

Figure 2: Details of metering plate used for onion seed metering.

Figure 3: Onion seeds used for evaluation of metering mechanism.

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Table 1: Physical and engineering properties of onion seeds under different seed treatments.

Property	Treatment		
	S_1	S_2	S_3
Major Dimension	3.16	3.45	3.71
Intermediate Dimension	2.32	2.76	2.88
Minor Dimension	2.01	2.35	2.71
Spherecity value	0.77	0.81	0.82
Roundness value	0.75	0.78	0.82
Angle of repose (degree)	29.50	24.78	23.70

Table 2: Plan of experiment on metering device.

S. No.	System Variable	Level of Variable
1.	Seed Treatment (S)	S_1-1:1 Pelleted Seed
		S_2-1:2 Pelleted Seed
		S_3-1:3 Pelleted Seed
2.	Inclination of metering mechanism(θ)	θ_1- 40°
		θ_2- 45°
		θ_3- 50°
3.	Speed of operation (Sp)	Sp_1- 1 kmh^{-1}
		Sp_2- 2 kmh^{-1}
		Sp_3- 3 kmh^{-1}
4.	Cell (P)	P_1- 18 Number of grooves on Cell
		P_2- 24 Number of grooves on Cell
		P_3-30 Number of grooves on Cell

Table 3: F-values for performance parameters of seed metering mechanism.

Source	F-Value				
	Average Spacing	Multiple Index	Miss Index	Quality Feed Index	Degree of Variation
S	6668.486	811.685	212.839	239.651	60.089
θ	168.743	31.510	97.090	7.705	2.213
Sp	47.410	65.053	60.260	16.017	973.483
P	696.377	117.435	46.917	23.161	44.110
S * θ	22.272	5.848	12.759	.917	0.649
S * Sp	32.042	0.450	2.259	1.195	1.608
S * P	75.332	0.352	8.198	2.570	0.703
θ * Sp	2.782	2.253	19.345	7.566	3.927
θ * P	41.509	2.602	8.849	6.052	0.215
Sp * P	5.771	0.651	2.605	1.083	0.092
S * θ * Sp	7.155	0.808	1.540	1.756	1.418
S * θ * P	5.858	1.550	2.967	1.889	0.141
S * Sp * P	3.280	0.399	2.775	1.319	0.101
θ * Sp * P	1.441	1.354	5.579	3.223	0.208
S * θ * Sp * P	0.631	0.396	1.531	1.255	0.272

The data presented in Figures 4, 5 and 6 depicts that average spacing varied slightly with the change in type of treatments of seed, inclination angle of plate and type of seed metering plate. The average spacing increased with the increase in the ratio of seed treatment at forward speed of 1.0 km/h, whereas at forward speed of 2.0 km/h and 3.0 km/h and decreases with number of grooves the seed metering plate. For S_1 seed, θ_2 angle in forward speed 2.0 km/h, the average seed spacing was observed to be 3.460 cm, 3.400 cm and 3.290 cm for 18, 24 and 30 groove plate respectively. In S_3 seed, θ_2 angle in forward speed 2.0 km/h, the average spacing was observed to be 5.90, 5.35 and 5.15 cm for 18, 24 and 30 groove plate respectively.

Performance indices

The distance between plants within a row is influenced by a number of factors including multiple index, missing index, failure of a seed to emerge, and variability around the drop point. Missing, multiple and quality of feed index were highly influenced by all the three design variables at 5% level of significance.

Multiple index

Multiple index was influenced by inclination of the metering device, followed by cell shape and type of seed as indicated by the F-values (Table 3). The experimental multiple index for independent parameters are given in Figures 7, 8 and 9. It is apparent that the multiple index was affected by the parameters studied i.e. treatment of seed, inclination angle of planter, forward speed and types of seed metering plate. The average multiple index observed were at S_1 seed 30.0, 28.0, 27.0 for 18 groove plate, 32.0, 31.0, 29.0 for 24 groove plate and 35.0, 33.0, 32.0 for 30 groove plate at θ_2 angle and forward speed 1.0, 2.0, 3.0 km/h respectively. In S_3 seed, 19.0, 13.0, 12.0 for 18 groove plate, 20.0, 11.0, 10.0 for 24 groove plate and 24.0, 18.0, 17.0 for 30 groove plate respectively.

Missing index

Missing index was influenced most by plate angle, followed by cell shape, as indicated by the F-values (Table 3). Missing index increased with the increase in forward speed as shown in Figures 10, 11 and 12. The average miss index observed at S_1 seed were, 6.0, 6.0, 10.0 for 18 groove plate, 5.0, 5.0, 10.0 for 24 groove plate and 2.0, 3.0, 6.0 for 30 groove plate at θ_2 angle and forward speed 1.0, 2.0, 3.0 km/h respectively. For S_3 seed, 10.0, 12.0, 18.0 for 18 groove plate, 3.0, 5.0, 14.0 for 24 groove plate and 8.0, 11.0, 16.0 for 30 groove plate respectively.

Quality of feed index

Quality of feed index was highly influenced by angle of metering

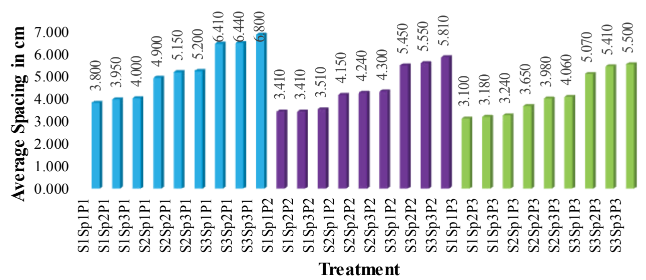

Figure 4: Effect of seed treatment, forward speed and type of seed metering plate on onion seeds average spacing at inclination angle of plate 50°.

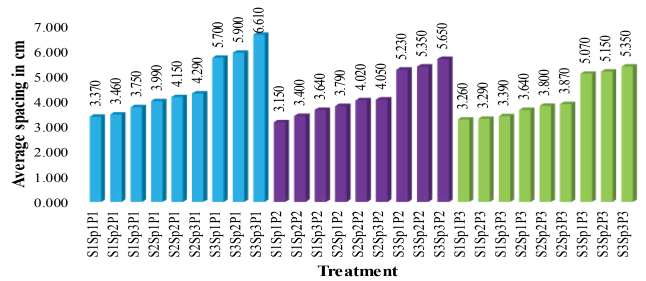

Figure 5: Effect of seed treatment, forward speed and type of seed metering plate on onion seeds average spacing at inclination angle of plate 45°.

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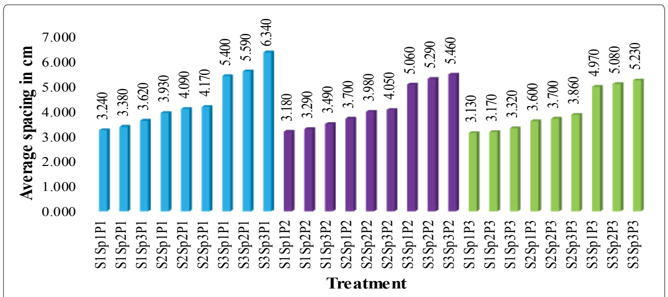

Figure 6: Effect of seed treatment, forward speed and type of seed metering plate on onion seeds average spacing at inclination angle of plate 40°

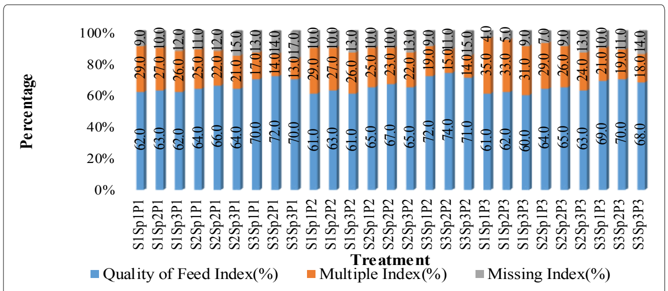

Figure 7: Effect of seed treatment, forward speed and type of seed metering plate on onion seeds performance indices at inclination angle of plate 50°.

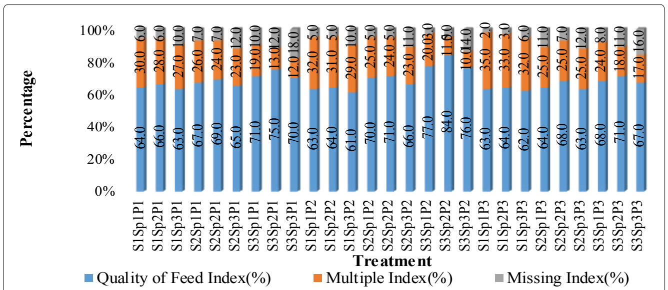

Figure 8: Effect of seed treatment, forward speed and type of seed metering plate on onion seeds performance indices at inclination angle of plate 45°.

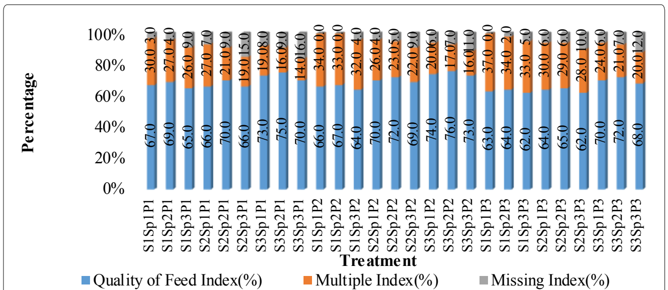

Figure 9: Effect of seed treatment, forward speed and type of seed metering plate on onion seeds performance indices at inclination angle of plate 40°.

plate, followed by seed and cell shape as indicated by F-values (Table 3). The data in depicts the variation of quality of feed index with respect to the forward speed. It can be seen that the quality of feed index initially increased when the forward speed was increased from 1.0 km/h to 2.0 km/h and when the forward speed was increased from 2.0 km/h to 3.0 km/h the quality of feed index also decreased.

Degree of variation

The coefficient of variation of spacing's is classified as singles. Lower the value of coefficient of variation in single's, better is the performance of a metering mechanism. It is evident from the degree of variation increases with the increase in speed for all types of seed metering plates. The average degree of variation observed were at S_1 seed, 17.0, 19.0, 26.0 for 18 groove plate, 16.0, 18.0, 25.0 for 24 groove plate and 15.0, 17.0, 24.0 for 30 groove plate at θ_2 angle and forward speed 1.0, 2.0, 3.0 km/h respectively. In S_3 seed, 19.0, 22.0, 30.0 for 18 groove plate, 18.0, 21.0, 29.0 for 24 groove plate and 17.0, 20.0, 28.0

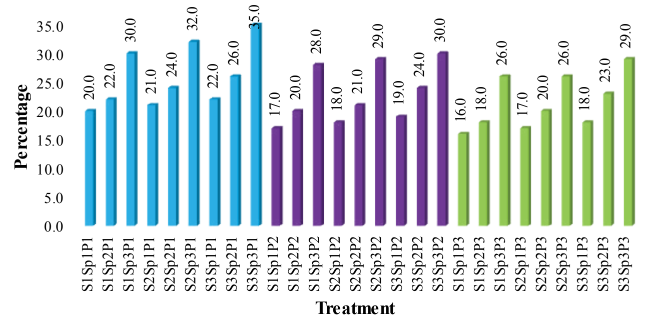

Figure 10: Effect of seed treatment, forward speed and type of seed metering plate on onion seeds degree of variation at inclination angle of plate 50°.

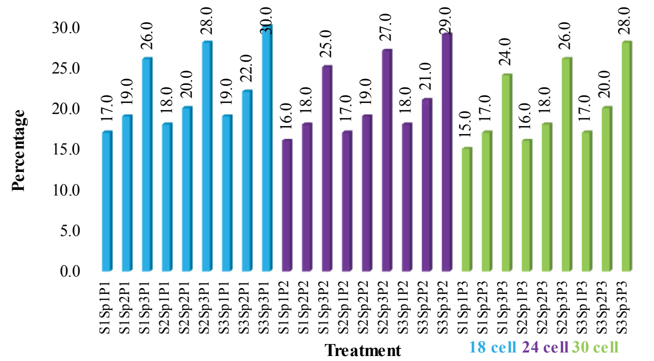

Figure 11: Effect of seed treatment, forward speed and type of seed metering plate on onion seeds degree of variation at inclination angle of plate 45°.

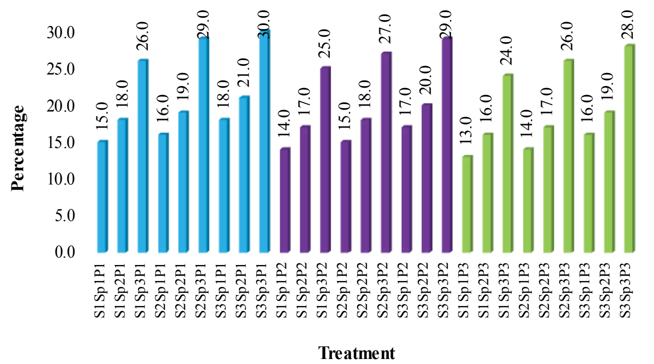

Figure 12: Effect of seed treatment, forward speed and type of seed metering plate on onion seeds degree of variation at inclination angle of plate 40°.

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for 30 groove plate respectively.

Seed damage

The seed damage was estimated based on germination and visual damage and bruising. Bruising of pelleted seeds can be observed by visual observation of the samples used in the laboratory experiments on visual observation of the samples of S_1, S_2, and S_3 no prominent bruises were observed. There can be no damage to the seeds which are encapsulated within the outer coating in case of pelletized seeds.

Selection of metering mechanism

Final selection of metering system for onion planter based on the results of laboratory evaluation, with 24 groove seed metering plate with 45° inclination angle and a forward speed of 2.0 km/h was selected for the field evaluation. Missing index at 2.0 km/h forward speed with 24 groove seed metering plate with 45° inclination angle was 5.0% and multiple index was 11.0%. The overall quality of feed index obtained with these parameters was 84.0% which is maximum when compared with other seed treatments, forward speeds and types of seed metering plate combinations with different angle of inclination of plates.

Conclusions

The inclination of metering device statistically influenced the average seed spacing and performance indices, followed by cell number, inclination angle, speed of operation and seed treatment. Highest feed index of 84.0% was obtained at plate inclination of 45°, with 2 km/h speed of operation and 24 groove cell number when tested for S_3 seed. Metering plate with 24 groove cells at 45° inclination at 2 km/h speed of metering device gave best performance with S_3 seed, and thus recommended.

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