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Research Article

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Development and Evaluation of Inclined Plate Metering Mechanism For Carrot (*Daucus Carota* L.) Pelleted Seeds

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Abstract

Carrot can be grown by direct seeding method which can help in saving labour. Small and irregular shaped seed lead to variation and placement of the seeds when sown using existing planters. Seed pelleting was done in the ratio of 1:1, 1:2 and 1:3 so that the physical properties of the seeds are altered to be applicable for use with an inclined plate planter. An inclined plate planter was developed for pelleted seeds. Preliminary evaluation of the developed planter was done in the laboratory for the treated seeds using different developed seed plates having 18, 24 and 30 grooves at forward speeds of 1.0, 2.0 and 3.0 km h^{-1} and inclination angle 40°, 45° and 50°. Performance was evaluated on the basis of average spacing, missing index, multiple index and quality of feed index. Average seed spacing obtained at in 1:3 seed, 45° angle in forward speed 2.0 km h^{-1}, the average spacing was observed to be 4.48, 4.29 and 4.11 cm for 18, 24 and 30 groove plate respectively. Missing index at 2.0 km h^{-1} forward speed with 24 groove seed metering plate with 45° inclination angle was 5.0% and multiple index was 14.0%. 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^{-1} was selected for the field evaluation.

Keywords: Inclined plate, quality of feed index, cell, pelleted seed, carrot

1. Introduction

Carrot (*Daucus carota* L.) is one of the major vegetable crop grown throughout the country. In Haryana and Punjab, this crop has gained the importance crop rather than as a vegetable crop because of its very high export potential. In India, Haryana is a leading carrot growing state followed by Punjab, Telangana, Karnataka, Bihar Assam and Tamilnadu. The productivity of carrot is the highest in Tamilnadu (32.88 t ha^{-1}) followed by Jammu and Kashmir, Uttar Pradesh and Punjab (24.69, 24.09 and 20.54 t ha^{-1}) (Anonymous, 2015).

Certain limitations associated with the production, processing and effective utilization of small seeds. Many vegetable seeds are small, light and irregular in shape; therefore it is difficult to plant them precisely (Dogan and Zeybek, 2009). Sowing of such tiny size, light weight and irregular shaped seeds are generally accomplished manually using broadcasting method. There is little control over the seed placement,

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spacing, line sowing, the plant stand is uneven and requires good management. A large amount of costly seed may get wasted because of uneven seed placement, thinning, damage by seed metering mechanism, damage by birds. Seed coating is an essential component of seed technology and plays vital role in making the seed bolder, safer in handling and in field emergence. The coating is designed basically to facilitate accurate precise sowing, to protect the seed against soaking injury to excess soil moisture in condition when it is spare and to give at least as good seedling emergence as does raw seed (Powell and Mathews, 1988). Thereby it enhances the farm revenue (Krishnasamy, 2003).

The most widely used measures tested and compared by Kachman and Smith (1995); mean, standard deviation, quality of feed index, multiple index, missing index and precision. These measures were based on the theoretical spacing (X ref), specified in ISO 7256-1 standard (Anonymous , 1984), and gave a good indication of spacing distribution. Concluded that the mean and the standard deviation of seed spacing did not offer an appropriate evaluation of planter performance on seed distribution (Kachman and Smith, 1995). The final selection of metering device also depends on multiple index and missing index. Developed two devices for small seed metering based on the picking action with pincette type picking unit (Shibata et al., 1990). 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. Designed a special- shaped spiral groove precision seed metering device for small grain crops (Zang and Guo, 2009). 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 (Ahmed and Gupta, 1994). 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 (Otsuka et al., 1986). Zarajczyk (2006) 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}. Based on the results of the laboratory evaluation, 30 groove seed metering plate and a forward speed of 1.5 km h^{-1} was selected for the field evaluation for tractor operated inclined plate metering device for onion seed planting (Grewal et al., 2015). A large number of planter designs are available for bolder seeds, but very little information is available on small seed like onion, carrot, particularly under Indian situations. Hence, the present study was conducted with the objective to design the metering mechanism for small sized seed like carrot and evaluate it for uniformity of seed placement.

2. Materials and Methods

The present investigation was carried out at the laboratory of Department of Farm Machinery and Power Engineering, Punjab Agricultural University, Ludhiana, India located at latitude of 30° 54' 14.4324'' N and longitude of 75° 48' 1.5192'' E, 241 m above mean sea level.

2.1. 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 (Anonymous, 1991). Since carrot 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 pelleted carrot seeds used for the study are shown in Figure 3. The average values of roundness value of carrot seed were 0.46, 0.49 and 0.52 for S_1, S_2 and S_3 pelleted seed respectively,

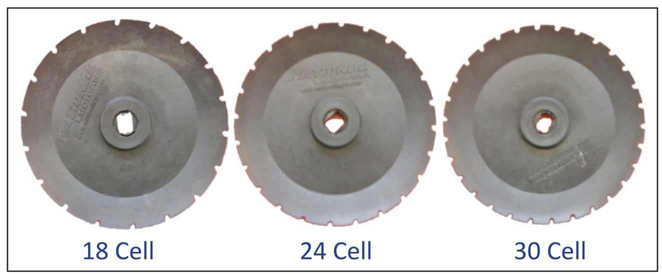

Figure 1: Metering plates used for metering of carrot seed

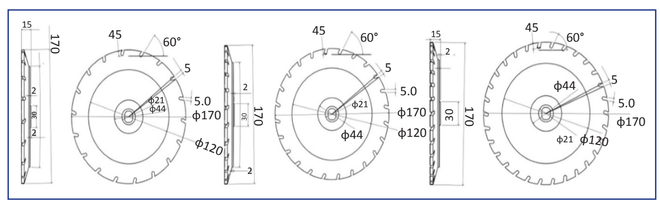

Figure 2: Details of metering plate used for carrot seed metering

Figure 3: Carrot seeds used for evaluation of metering mechanism

Table 1 (Gautam, et al. 2016, Gautam, et al. 2016, Gautam, et al. 2016, Brar et al. 2017, Badgujar, et al. 2018). 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)

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

Property	Treatment		
	S_1	S_2	S_3
Major Dimension	4.35	4.81	4.95
Intermediate Dimension	1.85	1.95	2.31
Minor Dimension	1.34	1.46	1.74
Spherecity value	0.49	0.52	0.54
Roundness value	0.46	0.49	0.52
Angle of repose (degree)	30.37°	28.87°	28.00°

Note: S_1: 1:1 Pelleted seed; S_2: 1:2 Pelleted seed; S_3: 1:3 pelleted seed

and 1:3 pelleted (S_3) seeds were 30.37 °, 28.87 °, and 28.00 ° respectively, Table 1.

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

2.2. Laboratory test

The laboratory trial was conducted during 2014-2015 with the treated seeds (S_1, S_2 and S_3) using different developed seed plates having 18, 24 and 30 grooves at forward speeds of 1.0, 2.0 and 3.0 km h^{-1}. A factorial Completely Randomized Design (CRD) was used to analysis the data obtained from laboratory experiments and to find out the interactions between the factors combination.

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, missing index, quality of feed index and precision were determined (Kachman and Smith, 1995).

Table 2: Plan of experiment on metering device

Sl. 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 km h^{-1}
		Sp_2- 2 km h^{-1}
		Sp_3- 3 km h^{-1}
4.	Cell (P)	P_1- 18 No. of grooves on Cell
		P_2- 24 No. of grooves on Cell
		P_3-30 No. of grooves on Cell

2.3. Performance parameters

2.3.1. 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 (Gautam et al., 2016, Gautam et al., 2017):

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

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.

2.4. 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 (Kachman and Smith, 1995, Gautam et al. 2016, Gautam et al., 2017). 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.

2.5. Missing index

Missing 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 (Gautam et al., 2016, Gautam et al., 2017):

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

Where,

N=Total number of observations, and

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

2.6. 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 (Gautam, et al. 2016, Gautam et al., 2017).

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

Where,

S=Sample standard deviation of the n3 observation,

X ref=Theoretical spacing

3. Results and Discussion

3.1. 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).

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^{-1}, whereas at forward speed of 2.0 km h^{-1} and 3.0 km h^{-1} and decreases with number of grooves the seed metering plate. For S_1 seed, θ_2 angle at forward speed of 2.0 km h^{-1}, the average spacing was observed to be 3.52 cm, 3.27 cm and 3.19 cm for 18, 24 and 30 groove plate respectively. For S3 seed, θ_2 angle in forward speed of 2.0 km h^{-1}, the average spacing was observed to be 4.48 cm, 4.29 cm and 4.11 cm for 18, 24 and 30 groove plate respectively.

3.2. 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.

3.3. Multiple index

Multiple index was influenced by inclination of the metering

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

Source	F-Value				
	Average spacing	Multiple index	Missing index	Quality of feed index	Degree of variation
S	1576.330	764.221	346.617	148.729	82.160
θ	109.409	57.102	151.812	88.200	76.220
Sp	28.137	119.982	38.300	142.575	1350.620
P	129.190	87.107	189.469	1.059	13.220
S×θ	6.792	0.721	8.765	3.152	0.920
S×Sp	1.487	2.164	2.863	3.693	0.920
S×P	1.898	2.692	28.276	5.203	2.450
θ×Sp	0.357	8.891	20.029	5.144	3.890
θ×P	16.126	8.838	6.209	9.251	3.440
Sp×P	0.395	2.496	12.637	6.818	1.910
S×θ×Sp	1.058	1.919	6.767	1.440	0.815
S×θ×P	1.802	2.040	4.921	1.353	1.175
S×Sp×P	0.358	2.384	4.647	3.719	0.995
θ×Sp×P	0.154	1.927	7.306	2.896	3.605
S×θ×p×P	.160	1.723	3.787	2.721	1.070

S: Seed; θ: Inclination of metering device; Sp: Speed; P: Number of cell

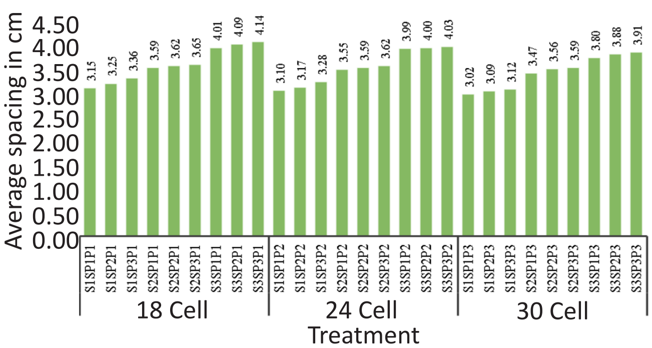

Figure 4: Effect of seed treatment, forward speed and type of seed metering plate on carrot seeds average spacing at inclination angle of plate 40°

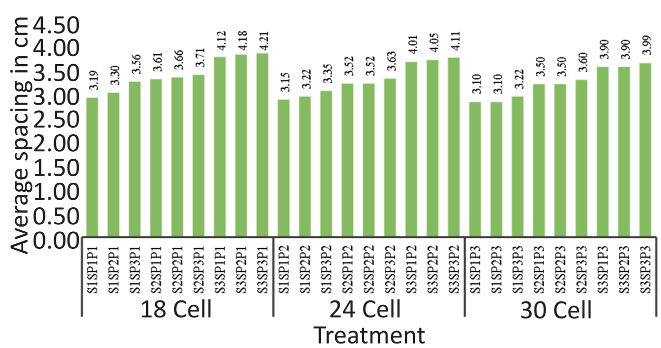

Figure 5: Effect of seed treatment, forward speed and type of seed metering plate on carrot seeds average spacing at inclination angle of plate 45°

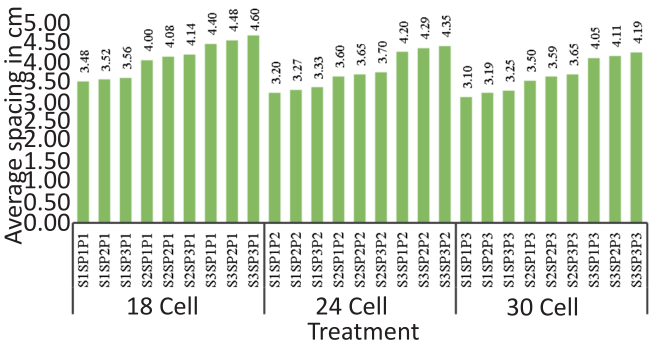

Figure 6: Effect of seed treatment, forward speed and type of seed metering plate on carrot seeds average spacing at inclination angle of plate 50°

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 Figure 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, 33.0, 31.0, 31.0 for 18 groove plate, 35.0, 29.0, 28.0 for 24 groove plate and 36.0, 34.0, 31.0 for 30 groove plate at θ2 angle and forward speed 1.0, 2.0, 3.0 km h^{-1} respectively. In S_3 seed, 21.0, 19.0, 17.0 for 18 groove plate, 21.0, 14.0, 14.0 for 24 groove plate and 28.0, 24.0, 23.0 for 30 groove plate respectively.

3.4. 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 missing index observed were at S_1 seed, 0.0, 3.0, 5.0 for 18 groove plate, 0.0, 0.0, 5.0 for 24 groove plate and 0.0, 0.0, 5.0 for 30 groove plate at θ2 angle and forward speed 1.0, 2.0, 3.0 km h^{-1} respectively. In S_3 seed, 6.0, 6.0, 12.0 for 18 groove plate, 4.0, 5.0, 12.0 for 24 groove plate and 2.0, 5.0, 9.0 for 30 groove plate respectively.

3.5. Quality of feed index

Quality of feed index was highly influenced by angle of metering plate, followed by seed and cell shape as indicated by F-values (Table 3). The data in Figures 7, 8 and 9 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

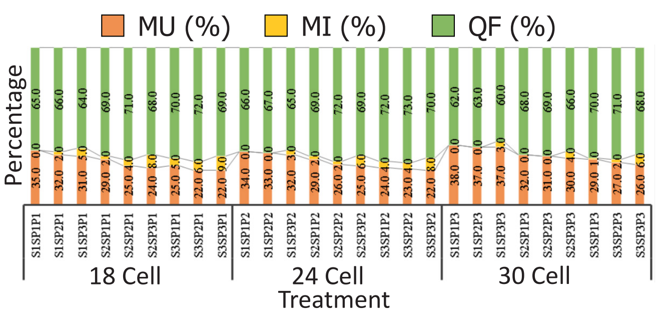

Figure 7: Effect of seed treatment, forward speed and type of seed metering plate on carrot seeds performance indices at inclination angle of plate 40°

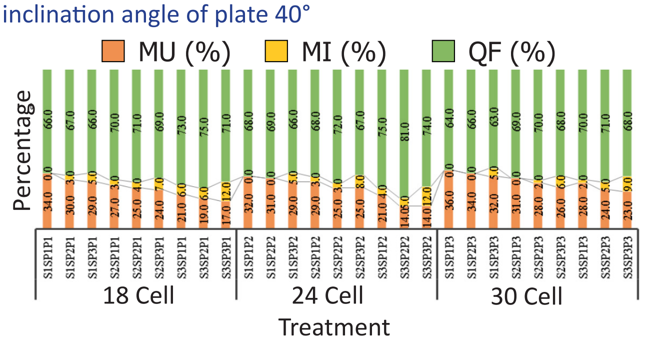

Figure 8: Effect of seed treatment, forward speed and type of seed metering plate on carrot seeds performance indices at inclination angle of plate 45°

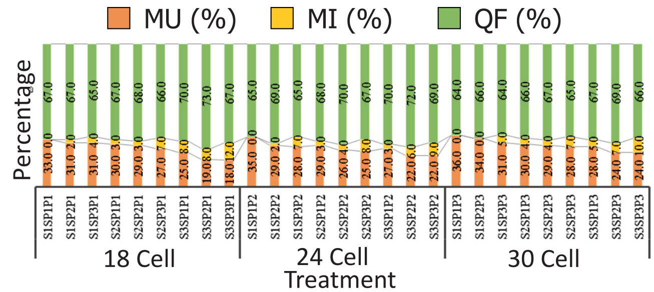

Figure 9: Effect of seed treatment, forward speed and type of seed metering plate on carrot seeds performance indices at inclination angle of plate 50°

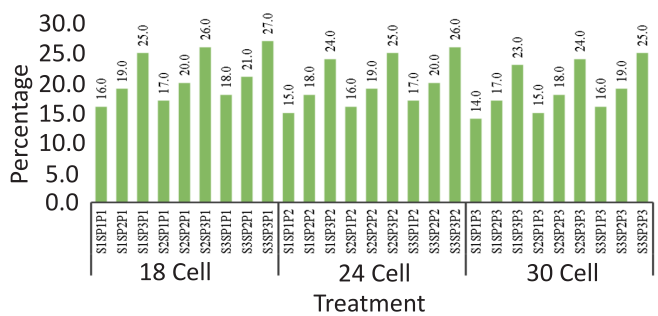

Figure 10: Effect of seed treatment, forward speed and type of seed metering plate on carrot seeds degree of variation at inclination angle of plate 40°

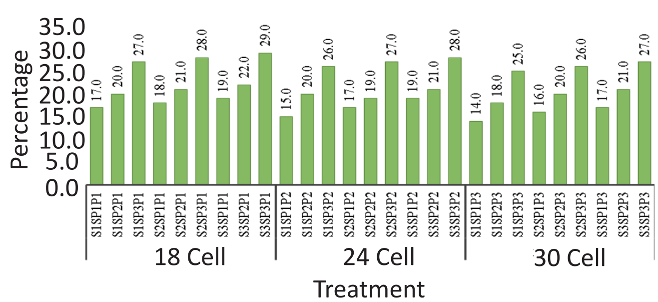

Figure 11: Effect of seed treatment, forward speed and type of seed metering plate on carrot seeds degree of variation at inclination angle of plate 45°

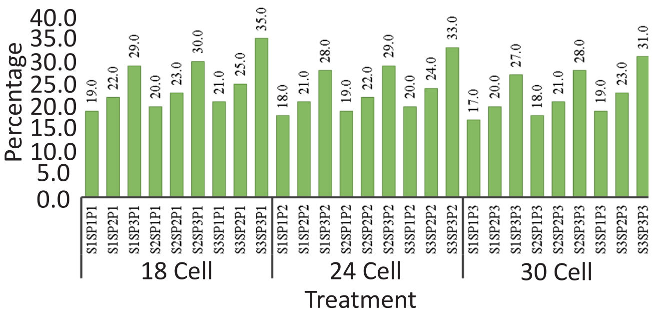

Figure 12: Effect of seed treatment, forward speed and type of seed metering plate on carrot seeds degree of variation at inclination angle of plate 50°

h^{-1} to 2.0 km h^{-1} and when the forward speed was increased from 2.0 km h^{-1} to 3.0 km h^{-1} the quality of feed index also decreased. The average quality of feed index observed were at S_1 seed, 66.0, 67.0, 66.0 for 18 groove plate, 68.0, 69.0, 66.0 for 24 groove plate and 64.0, 66.0, 63.0 for 30 groove plate at θ_2 angle and forward speed 1.0, 2.0, 3.0 km h^{-1} respectively. In S3 seed, 73.0, 75.0, 71.0 for 18 groove plate, 75.0, 81.0, 74.0 for 24 groove plate and 70.0, 71.0, 68.0 for 30 groove plate respectively.

3.6. 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 Figures 10, 11 and 12 that 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, 20.0, 27.0 for 18 groove plate, 15.0, 20.0, 26.0 for 24 groove plate and 14.0, 18.0, 25.0 for 30 groove plate at θ2 angle and forward speed 1.0, 2.0, 3.0 km h^{-1} respectively. In S_3 seed, 19.0, 22.0, 29.0 for 18 groove plate, 19.0, 21.0, 28.0 for 24 groove plate and 17.0, 21.0, 27.0 for 30 groove plate respectively.

3.7. 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.

3.8. Selection of metering mechanism

Final selection of metering system for carrot 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^{-1} was selected for the field evaluation. Missing index at 2.0 km h^{-1} forward speed with 24 groove seed metering plate with 45° inclination angle was 5.0% and multiple index was 14.0%. The overall quality of feed index obtained with these parameters was 81.0% 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.

4. Conclusion

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 quality of feed index of 81.0% was obtained at plate inclination of 45°, with 2 km h^{-1} 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^{-1} speed of metering device gave best performance with S_3 seed, and thus recommended.

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