Development and Evaluation of Inclined Plate Metering Mechanism for the Sowing of Maize (Zea mays L) Seed

Inderpal Singh¹, Anand Gautam²*, Anoop Kumar Dixit¹, Gursahib Singh Manes¹ and Arshdeep Singh¹

¹Department of Farm Machinery and Power Engineering, Punjab Agricultural University, Ludhiana-141004, India.
²Krishi Vigyan Kendra, Ferozepur-152001, India.

Authors’ contributions

This experimental work was carried out in collaboration among all authors and this work was accomplished with the joint efforts and contributions of the authors. Authors IS and AKD designed and evaluated the metering mechanism, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AG, GSM and AS managed the analyses of the study. Author AG managed the literature searches. All authors read and approved the final manuscript.

ABSTRACT

Maize (Zea mays L) is the third most imperative food cash crop after wheat and rice in India. Inclined plate seed metering mechanism was developed and evaluated in the laboratory for singulation and uniform placement of maize seeds with three varieties (PMH-1, PIONEER-3396, PMH-10). Metering device was tested at three inclinations of 45°, 50° and 55° using three types of metering plates (P1, P2, P3) having 24 groove number cells. The average spacing between seeds at 3 km/h forward speed with metering plate P1, with angle of inclination 50° was 18.35 cm, 17.67 cm and 17.98 cm for PMH-1, PIONEER-3396 and PMH-10 seeds, respectively. The overall quality of feed index obtained with the parameters are 83.38%, 87.20% and 85.40% for PMH-1.
PIONEER-3396 and PMH-10 seeds, respectively, which was higher than other parameters and seed rate of (6.70, 6.75 and 6.70) kg/acre for PMH-1, PIONEER-3396 and PMH-10 seeds, respectively.

**Keywords:** Maize; inclined plate; quality of feed index; missing index; multiple index.

1. INTRODUCTION

Maize (*Zea mays* L) is the third most imperative food cash crop after wheat and rice in India. During the year 2014-15, the area under cultivation of maize in both the seasons *kharif* and *rabi* was 9185.40 thousand hectare with a production of 24.17 million tonne and productivity of 2632 kg ha\(^{-1}\) [1] and it is cultivated throughout the year in all states of the country. Maize can be grown in all four seasons viz; *kharif* (monsoon), post monsoon, *rabi* (winter) and spring. It is beneficial to complete the sowing operation 13-15 days before the advent of monsoon during *kharif* season. However, in rain-fed areas, the time of sowing should be coincided with starting of monsoon [2], 3-5 cm deep in lines, 60 cm of row-to-row distance and 20 cm of the plant to plant distance is appropriate for seed sowing [3].

Mostly, maize is sown manually for small scale farming. However, horizontal and inclined plate planters are generally used by large farmers. Mechanical drilling methods or planters for the sowing of seeds affects mainly the depth, precise placement of seeds and uniformity of seed placement. It results in a higher yield as compared to the manual planting operations [4]. Uniform spacing of seeds boosts the crop yield, on the other hand, non-uniform spacing declines the production of crop [5].

The ultimate objective of the planting using improved sowing equipment is to achieve precise seed distribution within the row for its proper growth. The seeds must achieve proper plant-to-plant spacing. Various planters and seed drills with different metering mechanisms have been developed, evaluated and reported by various researchers in the literature [6,7,8,9,10,11]. Seeding with conventional practice increases the non-uniform plant population which adversely affect yield [8]. The seed-to-seed spacing mostly depends upon the technical variables of the machine such as seed pickup mechanism type, operating speed of the machine and overall gear ratio (between the drive wheel and seed plate). Small spacing between seeds results from the pick and drop of multiple seeds [12].

Horizontal seed metering mechanism devices were well accepted and broadly acquired in India but they result in more damage to seeds, missing and multiple seed drops. To diminish these losses, the inclined plate and vertical plate metering devices were developed [13].

Hence, there is a need for precise and economical specialized equipment in India for direct planting of maize crop to reduce labour requirement and input costs. In order to overcome this problem, the development of a precise metering mechanism for sowing of maize seed was needed which could provide higher seed singulation and minimum seed missing in the field. There are many planters having different seed metering mechanisms, the application of single seed metered plate mechanism (inclined plate) has increased rapidly due to better seeding performance than that of other metering units [8,9].

2. MATERIALS AND METHODS

2.1 Metering Mechanism

The metering mechanism was considered as the crux of planter and its main aim was too discrete out and drop seeds uniformly at the desired application rates. Horizontal rotor, vertical rotor, cell type plate and cup feed type plate mechanisms are the most usual type of metering mechanism used on planters. However, developed a two-row self-propelled multi-crop planter having inclined plate type seed metering mechanism and operated it for maize seeds and the average seed placement depth and average field efficiency was found to be apt [8,9].

Metering plates consist of grooves or a cell which picks and drops the seed at an appropriate distance depending upon the rotating speed of plate. Moreover, the number and shape of grooves (cell) are also vital design parameters which play a crucial role in seed dropping process from groove. In addition to this, the grooves on the plates were designed by taking in consideration of physical or engineering properties of the seed. Hence different types of plates are preferred for different maize varieties and the spacing between the seeds was adjusted by the number of grooves on the plates and drive ratio (Fig. 1).
2.2 Engineering Properties

Three varieties (PMH-1, PMH-10 and PIONEER-3396) of the maize were selected for the study. Firstly, calculated their physical properties and then metering mechanism was designed on the basis of observed parameters. The dimensions of the groove were drafted by considering seed dimensions such as length, breadth, thickness and roundness of maize seed. PMH-1 and PMH-10 were recommended by Punjab Agricultural University, Ludhiana because these two varieties cover major area under maize in Punjab region and PIONEER-3396 is a commercially available variety which cover more area compared to other non-recommended varities in Punjab (Table 1).

2.3 Development of Metering Plates for Inclined Plate Maize Planter

Three inclined plates (P1, P2 and P3) with different groove shape were developed based on the design procedure adopted by [5] and [14].

Seven design variables defined below were used to determine the exact size and shape of different plate grooves (Fig. 1).

\[
\begin{align*}
D_g &= \text{Depth of groove of plate.} \\
W_g &= \text{Opening of the groove periphery of the inclined plate can be somewhat larger than length of the seed} \\
R_c &= \text{The radius of curvature of grooves bottom} \\
D_1 &= \text{Inner diameter of the groove in plate P3} \\
\theta_g &= \text{The opening angle of the groove is defined as the angle between two straight lines connecting the starting and final point of groove and the center of the plate. It determines the loading process of the groove} \\
\beta_r &= \text{It is the angle of the groove at its right side which determines the easy loading of seeds} \\
\beta_l &= \text{It is the angle of groove at its left side which determines holding capacity of groove.}
\end{align*}
\]

Three plates of same 172 mm diameter (24 grooves in each plate) were fabricated to perform
inclined plate metering mechanism of maize seed. Depth of the cell or groove was adjusted on the basis of largest intermediate dimension measured from seeds. Based on the intermediate dimension of the depth of the groove was selected 11 mm. The opening of groove periphery was selected on the basis of largest major dimension from the seeds [15,16,17]. The groove opening of the periphery of plate was kept as 13 mm such that only one are loaded when the groove passes through the seed mass depending upon orientation of seed the right side angle 47° (In plate P2) such that easy loading of the groove should be done as well as the seed in the groove should be related upon the release point. The different value and front and side view of inclined plate P1, P2 and P3 shown in Fig. 1.

2.4 Laboratory Evaluation

The evaluation metering mechanism was done in the laboratory for the seed distribution pattern at four forward speeds (2.0, 3.0, 4.0 and 5.0 km/h). A sticky canvas belt arrangement was operated for the evaluation of various parameters being studied. The speed of the moving canvas belt of test rig simulated ground speed of planter with the provision to vary the speed of operation. The metering mechanism was mounted on the universal mounting frame of the test rig. The power to operate the planter was given from a 4 KW motor through gearbox, variable drive and set of pulleys. Hence, based upon the in-between spacing of the seeds five measures of performance parameters were calculated such as seed rate average seed spacing, missing index, multiple index and quality feed index [18].

2.5 Performance Parameters

Seed rate: Seeds were collected from each furrow openers by the 20 revolutions of the ground wheel in the polythene bags kept under furrow openers then seed rate was calculated for each treatment, inclination angle, plate and speed by weighing the seed collected in the polythene bags.

Average seed spacing: A wooden board of 0.35 m width and 2 m length was used for the determination of seed spacing then the white chart sheet was pasted on the board. After that whiteboard was treated with white grease.

| Treatments                  | PMH-1   | PMH-10  | PIONEER-3396 |
|-----------------------------|---------|---------|--------------|
| Major dimension (length)    | Range(mm) | 8.18-10.90 | 7.93-9.98 | 9.03-11.86 |
|                            | Mean(mm)   | 9.32     | 8.86        | 10.28      |
|                             | CV        | 0.06     | 0.06        | 0.07       |
|                             | ±SD       | 0.60     | 0.54        | 0.75       |
| Intermediate dimension (Width) | Range(mm) | 5.67-8.87 | 5.98-9.94 | 6.89-10.02 |
|                            | Mean(mm)   | 7.22     | 7.15        | 8.23       |
|                             | CV        | 0.06     | 0.10        | 0.09       |
|                             | ±SD       | 0.45     | 0.71        | 0.70       |
| Minor dimension (Thickness) | Range(mm) | 4.45-6.98 | 4.56-6.79 | 4.28-7.78 |
|                            | Mean(mm)   | 5.89     | 5.60        | 5.42       |
|                             | CV        | 0.9      | 0.11        | 0.17       |
|                             | ±SD       | 0.53     | 0.63        | 0.97       |
| Geometric mean diameter (GMD) | Range(mm) | 6.32-8.20 | 6.46-8.48 | 7.07-8.51 |
|                            | Mean(mm)   | 7.33     | 7.06        | 7.68       |
|                             | CV        | 0.05     | 0.06        | 0.05       |
|                             | ±SD       | 0.35     | 0.39        | 0.39       |
| Sphericity                  | Range     | 0.61-0.86 | 0.66-0.87 | 0.65-0.86 |
|                            | Mean      | 0.78     | 0.79        | 0.75       |
|                            | CV        | 0.05     | 0.06        | 0.09       |
|                            | ±SD       | 0.03     | 0.04        | 0.06       |
| Roundness                   | Range     | 0.57-0.83 | 0.59-0.84 | 0.57-0.87 |
|                            | Mean      | 0.74     | 0.74        | 0.66       |
|                            | CV        | 0.06     | 0.08        | 0.13       |
|                             | ±SD       | 0.04     | 0.05        | 0.08       |
As a result, the seed dropped to surface of board was stuck to the board because the grease on board was eliminating the effect of bouncing of seed. Then the board was passed through the furrow openers and distance between the seeds was noted to calculate value of average spacing of seed [19,20,21].

**Missing index:** It is the total number of observation with spacing more than 1.5 times the theoretical spacing. Its high value is mainly due to the failure of the seed picking system or, due to lack of positive release of the seeds [15,20,21].

\[ M_{s1} = \frac{n_1}{N} \times 100 \]

Where,

- \( M_{s1} \) = Missing index,
- \( n_1 \) = The total number of observation with spacing more than 1.5 times of the theoretical spacing
- \( N \) = Total observations.

**Multiple index:** Multiple index is the total number of spacing, which are less than 0.5 times the theoretical spacing. It is the number of cases, where the plate picks more than one seed per groove which results in wastage of the costly seeds and input of the operations of planting [19,20,21].

\[ M_{p1} = \psi \frac{n_2}{N} \times 100 \]

Where,

- \( M_{p1} \) = Multiple index, %
- \( n_2 \) = Total number of observations with spacing, which are less than 0.5 times of the theoretical spacing
- \( N \) = Total observations.

**Quality of feed index:** It is the number of observations, which are 0.5 to 1.5 times the theoretical spacing. Higher is the quality of feed index, better is the performance of the metering mechanism [19,20,21].

\[ Ql = \frac{n_3}{N} \times 100 \]

Where,

- \( Ql \) = Quality of feed Index, %
- \( n_3 \) = Number of observation, which are 0.5 to 1.5 times of the theoretical spacing
- \( N \) = Total observations

### 3. RESULTS AND DISCUSSION

#### 3.1 Average Spacing

For all three varieties, the average spacing was influenced by all combinations of design variable taken at 5% level of significance. The increase in average spacing with an increase in angle and speed is due to more vibration of the machine with speed and availability of less retention time to pick up seed whereas, as the angle of inclination increases there is more sliding of grain resulting in more miss.

In case of PMH-1, the mean average spacing was found to be minimum at speed S1 (18.38 cm) and maximum at speed S4 (20.90 cm) in respective of angle and type of plate. Average spacing was found to be maximum (24.64 cm) at the combination of P3 \( \Theta \) S4 and minimum (16.35 cm) at the combination of P2 \( \Theta \) S1 (Table 3). Moreover, in case of PIONEER-3396, The mean average spacing was found to be minimum in plate P2 (17.80 cm) and maximum in plate P3 (19.76 cm) is respective of angle and forward speed and the mean average spacing was found to be minimum at speed S1 (16.50 cm) and maximum at speed S4 (20.71 cm) is respective of angle and type of plate. Average spacing was found to be maximum (23.94 cm) in the combination of P3 \( \Theta \) S4 and minimum (14.97 cm) at the combination of P2 \( \Theta \) S1 (Table 4). Then the mean average spacing for PMH-10 was found to be minimum in plate P2 (17.80 cm) and maximum in plate P3 (20.28 cm) is respective of angle and forward speed and the mean average spacing was found to be minimum at speed S1 (17.06 cm) and maximum at speed S4 (21.03 cm) is respective of angle and type of plate. Average spacing was found to be Maximum (25.37 cm) at the combination of P3 \( \Theta \) S4 and minimum (15.12 cm) at the combination of P2 \( \Theta \) S1 (Table 5).

#### 3.2 Multiple Index

The multiple index of maize seed deceased with increase in forward speed and angle of inclination. The effect of type of plate was found at 5% level of significance.

The mean multiple index was found minimum for PMH-1 at speed S4 (9.22%) and maximum at speed S1 (25.15%) is respective of angle and type of plate. The decrease in multiple index with an increase in angle and speed is due to lesser number of grains accumulated in the cell due to vibrations and sliding of seed from the plate.
Multiple index was found to be maximum (35.45%) at a combination of P2 Ø1 S1 and minimum (0%) at a combination of P3 Ø3 S4 (Table 3). The mean multiple index for PIONEER-3396 was found minimum at speed S4 (10.29%) and maximum at speed S1 (22.52%) is respective of angle and type of plate. Multiple index was found to be maximum (31.67%) at the

Table 2. Plan of experiment on metering system

| Independent Variable | Seed variety | Types of plates | Speed of operation, km/h | Angle of inclination |
|----------------------|--------------|-----------------|--------------------------|---------------------|
| Levels of variables  | PMH-1        | PLATE P1        | S1-2.0                   | 0-45°               |
|                      | PMH-10       | PLATE P2        | S2-3.0                   | 0-50°               |
|                      |              | PLATE P3        | S3-4.0                   | 0-55°               |

Table 3. Effect of forward speed, angle of inclination and type of seed metering plate on the dependent variables in PMH-1 variety seeds

| Treatment | Average spacing (cm) | Multiple index (%) | Missing index (%) | Quality of feed index (%) | Seed rate (kg/acre) |
|-----------|----------------------|--------------------|-------------------|--------------------------|---------------------|
| P1 Ø1     | S1 17.18             | 28.56              | 0.00              | 71.44                    | 7.75                |
|           | S2 18.05             | 23.33              | 0.00              | 76.67                    | 6.84                |
|           | S3 18.86             | 20.63              | 5.56              | 73.81                    | 6.46                |
|           | S4 19.67             | 12.50              | 6.67              | 80.83                    | 5.59                |
| Ø2 S1     | 17.30                | 23.33              | 0.00              | 76.67                    | 7.66                |
|           | S2 18.35             | 13.56              | 2.56              | 83.88                    | 6.70                |
|           | S3 19.10             | 13.56              | 5.56              | 80.88                    | 6.38                |
|           | S4 19.89             | 12.00              | 8.33              | 79.67                    | 5.76                |
| Ø3 S1     | 17.62                | 19.84              | 0.00              | 80.16                    | 7.42                |
|           | S2 18.55             | 13.28              | 8.33              | 73.81                    | 6.65                |
|           | S3 19.66             | 11.11              | 8.33              | 80.56                    | 6.27                |
|           | S4 19.65             | 8.56               | 13.33             | 78.11                    | 5.76                |
| P2 Ø1     | S1 16.35             | 35.45              | 0.00              | 64.55                    | 8.39                |
|           | S2 16.61             | 31.73              | 0.00              | 68.27                    | 7.86                |
|           | S3 17.72             | 26.19              | 0.00              | 73.81                    | 7.42                |
|           | S4 19.02             | 15.08              | 10.50             | 74.42                    | 6.46                |
| Ø2 S1     | 17.15                | 31.67              | 0.00              | 68.33                    | 8.28                |
|           | S2 17.22             | 29.17              | 4.46              | 66.37                    | 7.88                |
|           | S3 18.99             | 22.82              | 11.11             | 66.07                    | 7.34                |
|           | S4 20.11             | 12.05              | 13.33             | 74.62                    | 6.94                |
| Ø3 S1     | 20.14                | 29.17              | 0.00              | 70.83                    | 7.93                |
|           | S2 20.26             | 19.84              | 8.33              | 71.83                    | 7.80                |
|           | S3 20.29             | 17.86              | 12.22             | 69.92                    | 7.23                |
|           | S4 21.93             | 11.11              | 20.56             | 68.33                    | 6.46                |
| P3 Ø1     | S1 18.67             | 20.63              | 0.00              | 79.37                    | 7.48                |
|           | S2 19.23             | 18.89              | 5.56              | 75.55                    | 6.94                |
|           | S3 19.88             | 12.50              | 6.67              | 80.83                    | 6.81                |
|           | S4 21.21             | 11.11              | 12.22             | 76.67                    | 4.50                |
| Ø2 S1     | 18.81                | 19.84              | 6.67              | 73.49                    | 7.47                |
|           | S2 19.86             | 15.08              | 12.22             | 72.70                    | 6.87                |
|           | S3 20.33             | 11.11              | 13.33             | 75.56                    | 6.49                |
|           | S4 21.72             | 5.56               | 18.89             | 75.55                    | 4.48                |
| Ø3 S1     | 22.21                | 17.78              | 20.00             | 62.22                    | 7.07                |
|           | S2 22.92             | 11.11              | 20.56             | 68.33                    | 6.86                |
|           | S3 23.32             | 5.56               | 24.44             | 70.00                    | 4.59                |
|           | S4 24.64             | 0.00               | 27.78             | 72.22                    | 4.14                |

Where, P=Plate, S=Speed, Ø=Angle of Inclination
combination of P2 Θ1 S1 and minimum (0%) at the combination of P3 Θ3 S4 and P1 Θ3 S4 (Table 4). The mean multiple index or PMH-10 was found minimum at angle Θ1 (15.18%) and maximum at Θ1 (23.38%) respective of speed and type of plate. Multiple index was found to be maximum (35.45%) at the combination of P2 Θ1 S1 and minimum (5.56%) at the combination of P3 Θ3 S4 and P1 Θ3 S4 (Table 5).

3.3 Missing Index

The missing index of seeds was found to be increase with increase in forward speed and angle of inclination. The effect of type of plate was found significant at 5% level of significance.

The mean missing index for PMH-1 was found to be minimum at speed S1 (2.96%) and maximum at speed S4 (13.10%) respective of angle and type of plate. The seed get dislodged from the cell due to vibrations. It also could be that the time for plate to pick the seed get reduced. The missing index was found to be maximum (27.78%) at a combination of P2 Θ1 S1 and minimum (0%) at a various combination in plate P1, P2 and P3. Minimum (0%) missing index was

| Treatments | Average spacing (cm) | Multiple index (%) | Missing index (%) | Quality of feed index (%) | Seed rate (kg/acre) |
|------------|----------------------|--------------------|------------------|--------------------------|---------------------|
| P1 Θ1      |                      |                    |                  |                          |                     |
| S1         | 15.81                | 28.88              | 0.00             | 71.12                    | 7.24                |
| S2         | 16.34                | 23.33              | 0.00             | 76.67                    | 7.07                |
| S3         | 18.53                | 19.84              | 0.00             | 80.16                    | 6.36                |
| S4         | 19.48                | 16.67              | 8.33             | 75.00                    | 5.84                |
| Θ2         |                      |                    |                  |                          |                     |
| S1         | 16.36                | 23.33              | 0.00             | 76.67                    | 7.15                |
| S2         | 17.67                | 12.98              | 0.00             | 87.20                    | 6.75                |
| S3         | 18.00                | 11.11              | 5.56             | 83.33                    | 6.32                |
| S4         | 19.82                | 11.11              | 10.50            | 78.39                    | 5.42                |
| Θ3         |                      |                    |                  |                          |                     |
| S1         | 17.50                | 15.08              | 4.47             | 80.45                    | 7.08                |
| S2         | 17.75                | 12.50              | 5.56             | 81.94                    | 6.48                |
| S3         | 19.20                | 10.05              | 11.11            | 78.84                    | 6.03                |
| S4         | 20.50                | 0.00               | 15.00            | 85.00                    | 5.23                |
| P2 Θ1      |                      |                    |                  |                          |                     |
| S1         | 14.97                | 31.67              | 0.00             | 68.33                    | 8.18                |
| S2         | 16.10                | 26.79              | 0.00             | 73.21                    | 7.93                |
| S3         | 17.78                | 26.19              | 4.47             | 69.34                    | 7.39                |
| S4         | 18.28                | 22.22              | 12.22            | 65.56                    | 6.70                |
| Θ2         |                      |                    |                  |                          |                     |
| S1         | 16.32                | 28.59              | 0.00             | 71.41                    | 8.15                |
| S2         | 16.57                | 26.83              | 4.47             | 74.90                    | 7.64                |
| S3         | 18.53                | 19.84              | 6.67             | 73.49                    | 7.13                |
| S4         | 18.56                | 15.87              | 18.89            | 65.24                    | 6.27                |
| Θ3         |                      |                    |                  |                          |                     |
| S1         | 16.36                | 24.44              | 4.47             | 71.09                    | 8.02                |
| S2         | 16.74                | 20.00              | 10.50            | 69.50                    | 7.51                |
| S3         | 19.48                | 13.10              | 17.78            | 69.12                    | 6.94                |
| S4         | 23.57                | 11.11              | 24.44            | 64.45                    | 6.03                |
| P3 Θ1      |                      |                    |                  |                          |                     |
| S1         | 16.08                | 20.63              | 4.47             | 74.90                    | 7.61                |
| S2         | 17.78                | 16.67              | 10.50            | 72.83                    | 7.27                |
| S3         | 18.53                | 11.11              | 13.30            | 75.99                    | 6.41                |
| S4         | 20.50                | 10.05              | 24.44            | 65.51                    | 4.35                |
| Θ2         |                      |                    |                  |                          |                     |
| S1         | 16.57                | 16.67              | 6.67             | 76.66                    | 7.42                |
| S2         | 18.72                | 13.10              | 15.00            | 71.90                    | 7.23                |
| S3         | 19.18                | 10.05              | 24.44            | 65.51                    | 6.32                |
| S4         | 21.78                | 5.56               | 30.00            | 64.44                    | 4.02                |
| Θ3         |                      |                    |                  |                          |                     |
| S1         | 18.53                | 13.33              | 17.78            | 68.89                    | 7.37                |
| S2         | 21.92                | 11.11              | 27.78            | 61.11                    | 6.97                |
| S3         | 23.57                | 5.56               | 30.00            | 64.44                    | 4.72                |
| S4         | 23.94                | 0.00               | 35.50            | 64.50                    | 3.92                |

Where, P=Plate, S=Speed, Θ= Angle of Inclination
found in plate P2 is from speed S1 to S3 at angle \( \Theta_1 \), in plate P2 from S1 to S2 at angle \( \Theta_1 \) (Table 3). The mean missing index for PIONEER-3396 was found to be minimum at speed S1 (4.21%) and maximum at speed S4 (19.92%) is respective of angle and type of plate. Mean missing index was maximum in case of plate P3 (19.99%) compare to plate P1 (5.04%) and P2 (8.66%) respective of angle and type of plate. Mean missing index was maximum in case of PIONEER-3396 was found to be minimum at speed S1 (4.21%) and maximum at speed S4 (19.92%) is respective of angle and type of plate. Mean missing index was maximum in case of plate P3 (19.99%) compare to plate P1 (5.04%) and P2 (8.66%) respective of angle and type of plate. Mean missing index was maximum in case of plate P3 (19.99%) compare to plate P1 (5.04%) and P2 (8.66%) respective of angle and speed. Meaning index was found to be maximum at the combination of P2 \( \Theta_1 \) S1 and minimum (0%) at various combinations in plate P1, P2 and P3. Minimum (0%) missing index was found in plate P1 is from speed S1 to S3 at angle \( \Theta_1 \), in plate P2 from S1 to S2 at angle \( \Theta_1 \) (Table 4). The mean missing index for PMH-10 was found to be minimum at speed S1 (1.08%) and maximum at speed S4 (11.26%) is respective of angle and type of plate. Mean missing index was maximum in case of plate P3 (10.00%) compare to plate P2 (5.72%) and P1 (3.73%) is respective of angle and speed. Missing index was found to be maximum (20.56%) at the combination of P2 \( \Theta_1 \) S1 and minimum (0%) at various combinations in plate P1, P2 and P3. Minimum (0%) missing index was found in plate P1 is from speed S1 to S3 at angle \( \Theta_1 \), in plate P2 from S1 to S2 at angle \( \Theta_1 \) (Table 5).

Table 5. Effect of forward speed, angle of inclination and type of seed metering plate on the dependent variables in PMH-10 variety seeds

| Treatments | Average spacing (cm) | Multiple index (%) | Missing index (%) | Quality of feed index (%) | Seed rate (kg/acre) |
|------------|----------------------|--------------------|------------------|--------------------------|---------------------|
| P1 \( \Theta_1 \) | | | | | |
| S1 15.42 | 29.37 | 0.00 | 70.63 | 7.66 |
| S2 16.92 | 36.12 | 0.00 | 73.81 | 7.13 |
| S3 17.02 | 24.44 | 0.00 | 75.56 | 6.32 |
| S4 19.67 | 13.10 | 4.76 | 82.14 | 6.05 |
| \( \Theta_2 \) | | | | | |
| S1 16.14 | 25.56 | 0.00 | 74.44 | 7.61 |
| S2 16.98 | 13.10 | 4.76 | 82.14 | 6.22 |
| S3 18.79 | 13.10 | 8.33 | 80.56 | 5.45 |
| S4 20.03 | 11.11 | 8.33 | 80.56 | 5.45 |
| \( \Theta_3 \) | | | | | |
| S1 18.10 | 19.84 | 0.00 | 80.56 | 7.47 |
| S2 18.95 | 14.89 | 6.67 | 78.57 | 6.65 |
| S3 20.32 | 12.22 | 6.67 | 81.11 | 5.74 |
| S4 21.49 | 5.56 | 12.12 | 82.32 | 5.31 |
| P2 \( \Theta_1 \) | | | | | |
| S1 15.12 | 35.45 | 0.00 | 64.55 | 8.04 |
| S2 15.81 | 31.67 | 0.00 | 68.33 | 7.56 |
| S3 16.21 | 28.59 | 4.76 | 66.65 | 6.99 |
| S4 18.26 | 16.67 | 6.67 | 76.66 | 6.51 |
| \( \Theta_2 \) | | | | | |
| S1 15.77 | 31.67 | 0.00 | 68.33 | 7.10 |
| S2 16.12 | 28.89 | 4.76 | 66.64 | 7.36 |
| S3 18.90 | 19.84 | 6.67 | 73.49 | 6.94 |
| S4 20.03 | 11.11 | 8.33 | 80.56 | 5.45 |
| \( \Theta_3 \) | | | | | |
| S1 17.67 | 29.37 | 0.00 | 70.63 | 7.66 |
| S2 19.64 | 22.22 | 6.67 | 71.11 | 7.27 |
| S3 20.13 | 15.87 | 13.33 | 70.80 | 6.59 |
| S4 20.98 | 12.22 | 17.78 | 70.00 | 6.36 |
| P3 \( \Theta_1 \) | | | | | |
| S1 16.73 | 25.56 | 0.00 | 74.44 | 7.23 |
| S2 17.17 | 20.63 | 4.17 | 75.20 | 6.89 |
| S3 17.67 | 16.67 | 10.50 | 72.83 | 6.41 |
| S4 20.04 | 12.22 | 12.22 | 75.56 | 4.35 |
| \( \Theta_2 \) | | | | | |
| S1 18.90 | 20.63 | 4.17 | 75.20 | 7.13 |
| S2 19.67 | 15.00 | 8.33 | 76.67 | 6.75 |
| S3 21.71 | 12.22 | 11.11 | 76.67 | 6.22 |
| S4 24.44 | 10.50 | 13.33 | 76.17 | 4.40 |
| \( \Theta_3 \) | | | | | |
| S1 19.71 | 19.84 | 5.56 | 74.60 | 6.94 |
| S2 20.04 | 13.10 | 12.22 | 74.68 | 6.60 |
| S3 21.93 | 10.50 | 17.78 | 71.72 | 4.59 |
| S4 25.37 | 5.56 | 20.56 | 73.88 | 4.07 |

Where, \( P=\text{Plate} \), \( S=\text{Speed} \), \( \Theta=\text{Angle of Inclination} \)
3.4 Quality Feed Index

The effect of angle and speed was found to be non-significant in quality in feed index, whereas the effect of the type of plate was significant.

The mean quality of feed index for PMH-10 was found minimum at angle \( \Theta 3 \) (72.67\%) and maximum at \( \Theta 1 \) (76.08\%) is respective of speed and type of plate. The mean quality of feed index was found minimum at plate P2 (69.79\%) and maximum in P1 (78.42\%) is respective of angle and type of plate. Quality of feed index was found to be maximum (83.38\%) at a combination of P1 \( \Theta 2 \) S2 and minimum (62.22\%) at a combination of P3 \( \Theta 3 \) S1 (Table 3). The mean quality of feed index for PIONEER-3396 was found minimum in plate P3 (68.86\%) and maximum in P1 (79.56\%) is respective of speed and angle. The mean quality of feed index was found minimum at speed S4 (69.79\%) and maximum at S2 (74.02\%) respective of angle and type of plate. Quality in feed index was found to be maximum (87.20\%) at the combination of P1 \( \Theta 2 \) S2 and minimum (61.11\%) at the combination of P3 \( \Theta 3 \) S2 (Table 4). The mean quality of feed index for PMH-10 was found minimum in plate P3 (35.45\%) and maximum in P1 (79.04\%) is respective of speed and angle. The mean quality feed index was found minimum at speed S1 (72.55\%) and maximum at S4 (75.88\%) respective of angle and type of plate. Quality of feed index was found to be maximum (85.40\%) at the combination of P1 \( \Theta 2 \) S2 and minimum (64.55\%) at the combination of P2 \( \Theta 1 \) S1 (Table 5).

3.5 Seed Rate

The seed rate of seeds deceased with increase in forward speed and angle of inclination. At 5\% level of significance the effect of the plate was also found to be significant is respective to speed and angle.

The mean seed rate for PMH-1 was found minimum at speed S4 (5.65 kg/acre) and maximum at speed S1 (7.72 kg/acre) respective of angle and type of plate. Decrease in seed rate with increase in missing index and increase in seed rate with increase in multiple index. Seed rate was found to be maximum (8.39 kg/acre) at a combination of P2 \( \Theta 1 \) S1 and minimum (4.14 kg/acre) at a combination of P3 \( \Theta 3 \) S4 (Table 3). The mean seed rate for PIONEER-3396 was found minimum at speed S4 (5.30 kg/acre) and maximum at speed S1 (7.58 kg/acre) respective of angle and type of plate. Decrease in seed rate with increase in missing index and increase in seed rate with increase in multiple index. Seed rate was found to be maximum (8.18 kg/acre) at the combination of P2 \( \Theta 1 \) S1 and minimum (3.92 kg/acre) at the combination of P3 \( \Theta 3 \) S4 (Table 4). The mean seed rate for PMH-10 was found minimum at speed S4 (5.41 kg/acre) and maximum at speed S1 (7.49 kg/acre) respective of angle and type of plate. Decrease in seed rate with increase in missing index and increase in seed rate with increase in multiple index. Seed rate was found to be maximum (8.04 kg/acre) at the combination of P2 \( \Theta 1 \) S1 and minimum (4.07 kg/acre) at the combination of P3 \( \Theta 3 \) S4 (Table 5).

Experiments conducted in the laboratory proves that there is significant effect of forward speed (2 km/h, 3 km/h, 4 km/h and 5 km/h) and angles of inclination (45°, 50° and 55°) on the average seed spacing, multiple index, missing index, quality feed index and seed rate of all three varieties for three different kind of metering mechanism plates (P1, P2 and P3).

The angle of inclination of metering mechanism influenced average speed spacing and performance indicis, followed by the type of metering plate and speed of operation. It is observed that the average spacing of seeds was increased by increasing operation speed from 2 km/hr to 5 km/hr which results more missing.

Multiple index was found to be decrease with increase in the forward speed of operation from 2 km/h to 5 km/h and angle of inclination of metering plate. Multiple index (35.45\%) was highest in case of P2 plate at the speed of 2 km/h. Moreover, Missing index was found to be increase with increase in the forward speed of operation from 2 km/h to 5 km/h and angle of inclination of metering plate. Missing index (35.50\%) was highest in case of P3 plate at the speed of 5 km/h and The average quality feed index was maximum for P1 Plate in all three maize varieties.

At the end, Parameter combination (P1S2\( \Theta 2 \)) Plate P1 at the angle of inclination of 50° at the forward speed of 3 km/h for PMH-1, PIONEER-3396 and PMH-10 varieties was the observed as the appropriate parameter from all the combinations.
3.6 Selection of Metering Mechanism

Final selection of metering system for inclined plate maize planter based on the results of laboratory evaluation, for all the three varieties (PMH-1, PIONEER-3396 and PMH-10) seeds metering plate P1 with angle of 50° (ϴ2) and forward speed of 3 km/h (S3) were selected. The average spacing between seeds at 3 km/h forward speed with metering plate P1, with angle of inclination 50° was 18.35 cm, 17.67 cm and 17.98 cm for PMH-1, PIONEER-3396 and PMH-10 seeds, respectively. Multiple index 13.56%, 12.98% and 13.1% for PMH-1, PIONEER-3396 and PMH-10 seeds, respectively. Missing index of 2.56%, 0%, and 1.56% for PMH-1, PIONEER-3396 and PMH-10 seeds respectively. The overall quality of feed index obtained with the parameters are 83.38%, 87.20% and 85.40% for PMH-1, PIONEER-3396 and PMH-10 seeds, respectively which was maximum as compared to other parameters and seed rate of (6.70, 6.75 and 6.70) kg/acre for PMH-1, PIONEER-3396 and PMH-10 seeds, respectively.

4. 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 obtained with the parameters are 83.38%, 87.20% and 85.40% for PMH-1, PIONEER-3396 and PMH-10 seeds, respectively which was maximum as compared to other parameters at plate inclination of 50°, with 3 km/h speed of operation and recommended. The angle of inclination of metering mechanism influenced average speed spacing and performance indices, followed by the type of metering plate and speed of operation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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