PERFORMANCE EVALUATION OF VACUUM TYPE METERING MECHANISM UNDER LABORATORY AND FIELD CONDITION FOR BOLD SEEDS

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Abstract: Groundnut, pigeonpea and maize are major bold seeds crop in India. Planting of these bold seeds is a very drudgery and time consuming operation. To address this issue, vacuum type metering mechanism is done. Vacuum is created in this rod and goes down the vacuum cylinder. The metering cylinder rotates over rod and pick up the seeds through the seed hopper while passing through it. To evaluate the working of vacuum cylinder picking % & metering efficiency of metering mechanism were considered under different suction pressure i.e. for groundnut seed 4500 Pa, 5000 Pa and 5500 Pa, for maize seeds 3500 Pa, 4000 Pa and 4500 Pa while for pigeonpea seeds 1500Pa, 2000 Pa and 2500 Pa. On the basis of superior performance the optimum suction pressure inside the vacuum cylinder for groundnut seed was found to be 5000 Pa with a metering efficiency of 106.67 % and maximum picking percentage of 96%. Similarly the optimum suction pressure for maize seed was found to be 4000 Pa with a metering efficiency of 108.88 % and maximum picking percentage of 97% while for pigeonpea seed these values were found to be 2000 Pa, 110 % and 92 %.

Keywords : Vacuum type metering mechanism, Vacuum cylinder

INTRODUCTION

Vacuum metering mechanism is a relatively new concept of planting the seeds. These machines use vacuum seed metering principle. The principle offers several advantages, especially the single seed picking, no mechanical damage to the seed and their capability to deal with bolder seeds. Several researchers in India and abroad have developed tractor operated pneumatic planters. Adoption of these machines has been quite limited, due to their higher initial cost. Still considering the high accuracy and precision of the machinery, these machines have great potential for production of high value cash crops; especially requiring highly viable seeds.

Presently, among different sowing techniques, precision sowing is the preferred method since it provides more uniform seed spacing than other methods.

MATERIAL AND METHOD

Physical Characteristics of Bold Seeds

The seeds of Groundnut, Maize and Pigeonpea were procured from Department of Agronomy, Indira Gandhi Krishi Vishwavidyalaya (IGKV), Raipur. The shape and size of the groundnut, maize and pigeonpea was ascertained with three perpendicular dimensions, length (L), width (W) and thickness (T).

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Seeds</th>
<th>Length (mm)</th>
<th>Width (mm)</th>
<th>Thickness (mm)</th>
<th>Sphericity (s), %</th>
<th>1000-seed weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Groundnut</td>
<td>11.55</td>
<td>7.68</td>
<td>6.98</td>
<td>64.27</td>
<td>445</td>
</tr>
<tr>
<td>2</td>
<td>Maize</td>
<td>10.50</td>
<td>8.24</td>
<td>4.44</td>
<td>76.55</td>
<td>437.0</td>
</tr>
<tr>
<td>3</td>
<td>Pigeonpea</td>
<td>5.52</td>
<td>6.16</td>
<td>4.37</td>
<td>92.2</td>
<td>107.92</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>9.19</td>
<td>7.36</td>
<td>5.26</td>
<td>77.67</td>
<td>329.97</td>
</tr>
</tbody>
</table>

*Corresponding Author

Fig: weight and physical dimensions of seeds
Techniques of Measurement
In this section, the techniques and procedure for measurement of various parameters associated with the evaluation of the machine under laboratory and field conditions has been presented. The parameters and the methodology for their measurement are given below.

Laboratory test
Theoretical seed rate (R<sub>st</sub>)
The number of bold seeds planted per hectare was calculated by using the following relationship (Bakhtiari and Loghavi, 2009)

\[ R_{st} = \frac{10^8}{W \times X_s} \]

Where,
- \( R_{st} \) = Theoretical seeding rate, seed/ha;
- \( W \) = Row width, cm;
- \( X_s \) = Seed spacing along the row, cm.

Seeding mass rate (R<sub>sm</sub>)
The total mass of bold seeds planted per hectare expressed in Mg/ha was calculated by using the following relationship (Bakhtiari and Loghavi, 2009):

\[ R_{sm} = \frac{M}{W \times X_s} \times 100 \]

Where,
- \( R_{sm} \) = Seeding mass rate, Mg/ha;
- \( M \) = Average mass of one seed, g;
- \( W \) = Row width, cm; and
- \( X_s \) = Seed spacing along the row, cm.

Seed metering efficiency
Metering efficiency of the pneumatic planting system was calculated on the basis of percent drop of seeds for definite number of drops.

\[ \text{Metering efficiency} = \frac{\text{Total no.of seeds obtained actually}}{\text{expected no.of seeds}} \times 100 \]

Independent and dependent test variables
The study was conducted with the following independent and dependent variables:

Independent variables
Following independent test variables were recorded:
1. Suction pressure
2. Orifice size

Dependent variables
Following dependent test variables were recorded
1. Seed spacing
2. No. of seeds per hill

Theoretical Observation
1. Skip : Skip is the number of cases, where the seeds rotor fails to pick a seed.
2. Single : Single is the number of seeds (1) observed while testing.
3. Multiple : Multiple is the number of cases, where the seed plate picks more than one seed per orifice.

Measures of Accuracy of the Metering Mechanism
To analyze the performance of the mechanism, the following statistical tools were used (Kachman and Smith, 1995);
1. Mean spacing : Mean spacing is the average of the total number of measured spacing.
2. Multiple index : It is the total number of spacing, which are less than 0.5 times theoretical spacing.
3. Miss index : It is the total number of observation with spacing more than 1.5 times theoretical spacing.
4. Quality of feed index : It is the number of observations, which are 0.5 to 1.5 times theoretical spacing.
5. Precision : It is the ratio of the standard deviation of the observed spacing, between 0.5 to 1.5 times theoretical spacing to the theoretical spacing, expressed as percentage.

Field Test
The field performance was conducted in order to obtain actual data for overall machine performance, operating accuracy, work capacity, and field efficiency. After a thorough laboratory test, study on vacuum-planting system for planting bold seeds and its distribution pattern was checked in the field condition. The testing was carried out with the seed metering cylinder and vacuum rod, which was tested in the laboratory. The field trial was carried out at different travel speed (4, 4.17 and 4.13 kmph) and with seed metering cylinder with metering orifices (54) to observe the effect of travel speed and metering orifices on hill spacing.

Field capacity and field efficiency of the machine
Theoretical field capacity and effective field capacity were determined on the basis of area covered per unit time.

Theoretical field capacity
On the basis of width of furrow and speed, theoretical field capacity was calculated by following formula:

\[ \text{Theoretical field capacity (ha/h)} = \frac{W \times S}{10} \]

Where,
- \( S \) = Speed of operation, km/h
- \( W \) = Theoretical width covered,
- \( m \) = Number of furrow openers multiplied by distance between the furrow Opener, m

Effective field capacity
The seed drill was continuously operated in the field for 0.366 ha to assess its actual coverage.
Effective field capacity was calculated. Effective field capacity (ha/h) = A/T

Where,
A = Actual area covered, ha
T = Total time required to cover the area, h

Field efficiency

Field efficiency (%) = actual field capacity/theoretical field capacity × 100

RESULT AND DISCUSSION

Physical Properties of Different Bold Seeds

The average length, width and thickness of seeds varied over a wide range. Groundnut was the largest of the seeds. The average length, width and thickness of the seeds were 11.55 mm, 7.68 mm and 6.98 mm respectively. The average length, width and thickness of the maize seed were 10.58 mm, 8.24 mm and 4.44 mm and the average length, width and thickness of the pigeonpea were 5.52 mm, 6.16 mm and 4.37 mm respectively.

Bulk density of bold seeds

The bulk density of groundnut seeds, maize and pigeonpea was found to be 610 kg/m³, 720 kg/m³ and 674 kg/m³ respectively.

Moisture content of bold seeds

The moisture content of groundnut seeds, maize and pigeonpea was found to be 9.02%, 8.09% and 4.07% respectively.

Laboratory Test

Performance of the vacuum cylinder under varying suction pressure for bold seeds

| Table. Performance of the 2.5 mm circular orifice vacuum cylinder under varying suction pressure for groundnut seed. |
|---------|-----------------|-----------------|-----------------|
| S. No. | Suction pressure inside vacuum cylinder, Pa | Particulars of seeds per hill | (%) picking |
| 1      | 4500            | Skip (0)        | 15             |
|        |                 | Single (1)      | 85             |
|        |                 | Multiple (>1)   | 0              |
| 2      | 5000            | Skip (0)        | 0              |
|        |                 | Single (1)      | 96             |
|        |                 | Multiple (>1)   | 4              |
| 3      | 5500            | Skip (0)        | 0              |
|        |                 | Single (1)      | 93             |
|        |                 | Multiple (>1)   | 7              |

*desired number of seeds per hill (1).

| Table. Performance of the 2.5 mm circular orifice vacuum cylinder under varying suction pressure for maize seed. |
|---------|-----------------|-----------------|-----------------|
| S. No. | Suction pressure inside vacuum cylinder, Pa | Particulars of seeds per hill | (%) picking |
| 1      | 3500            | Skip (0)        | 14             |
|        |                 | Single (1)      | 86             |
|        |                 | Multiple (>1)   | 0              |
| 2      | 4000            | Skip (0)        | 0              |
|        |                 | Single (1)      | 97             |
|        |                 | Multiple (>1)   | 3              |
| 3      | 4500            | Skip (0)        | 0              |
|        |                 | Single (1)      | 94             |
|        |                 | Multiple (>1)   | 6              |

*desired number of seeds per hill (1).

| Table. Performance of the 2.5 mm circular orifice vacuum cylinder under varying suction pressure for pigeonpea seed. |
|---------|-----------------|-----------------|-----------------|
| S. No. | Suction pressure inside vacuum cylinder, Pa | Particulars of seed per orifice | (%) Picking |
| 1      | 1500            | Skip (0)        | 17             |
|        |                 | Single (1)      | 83             |


Table: Seed distribution under varying suction pressures for groundnut and maize seeds.

<table>
<thead>
<tr>
<th>Suction Pressure (Pa)</th>
<th>Groundnut (% Picking)</th>
<th>Maize (% Picking)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4500</td>
<td>85</td>
<td>15</td>
</tr>
<tr>
<td>5000</td>
<td>96</td>
<td>4</td>
</tr>
<tr>
<td>5500</td>
<td>93</td>
<td>7</td>
</tr>
</tbody>
</table>

*desired number of seeds per hill (1)

**Fig:** Performance of the 2.5 mm circular orifice vacuum cylinder under varying suction pressure for groundnut seed.

**Fig:** Performance of the 2.5 mm circular orifice vacuum cylinder under varying suction pressure for Maize seed.
Suction pressure inside vacuum cylinder, Pa

**Fig.** Performance of the 2.5 mm circular orifice vacuum cylinder under varying suction pressure for Pigeonpea seed

**Metering efficiency of vacuum planter**

Metering efficiency of the vacuum planting system was calculated from . At different pressure levels and is presented in it was observed that with the increase in suction pressure inside the vacuum cylinder the metering efficiency also increased from 93.33 to 111.33 percent as pressure increased from 4500 to 5500 Pa for groundnut seeds and for maize seeds metering efficiency increased from 90 to 112.22 percent as pressure increased from 3500 to 4500 Pa and for pigeonpea seeds metering efficiency increased from 91.11 to 113.33 percent as pressure increased from 1500 to 2500 Pa.

**Table:** Effect of suction pressure in the vacuum drum on the metering efficiency of metering mechanism, for groundnut maize and pigeonpea seeds

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Seeds</th>
<th>Suction pressure in vacuum rod, Pa</th>
<th>Metering efficiency of metering mechanism , (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Groundnut</td>
<td>4500</td>
<td>93.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5000</td>
<td>106.67</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5500</td>
<td>111.33</td>
</tr>
<tr>
<td>2</td>
<td>Maize</td>
<td>3500</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4000</td>
<td>108.88</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4500</td>
<td>112.22</td>
</tr>
<tr>
<td>3</td>
<td>Pigeonpea</td>
<td>1500</td>
<td>91.11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2000</td>
<td>110</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2500</td>
<td>113.33</td>
</tr>
</tbody>
</table>

**Fig.** Effect of suction pressure in the vacuum drum on the metering efficiency of metering mechanism for Groundnut
Calculation of seed rate (kg/ha)

Theoretical seed rate ($R_{st}$)

For groundnut seeds
Row width = 30 cm
$R_{st} = \frac{10^8}{30 \times 15} = 222230$ seeds/ha

For maize and pigeonpea seeds
Row width = 60 cm
$R_{st} = 83340$ seeds/ha

Seeding mass rate ($R_{sm}$)
The total mass of bold seeds planted per hectare expressed in Mg/ha was calculated by using the following relationship (Bakhtiari and Loghavi, 2009):

For groundnut seed
Average mass of one seed = 0.35g
Row width = 30 cm
$R_{sm} = \frac{0.335}{30 \times 15} \times 100 = 0.0744$ mg/ha

For maize seed
Average mass of one seed = 0.204g
Row width = 60 cm
$R_{sm} = 0.017$ mg/ha
$R_{sm} = 17.00$ kg/ha

For pigeonpea seed
Average mass of one seed = 0.131g
Row width = 60 cm
$R_{sm} = 0.01091$ mg/ha
$R_{sm} = 10.91$ kg/ha

Mechanical damage to seed by metering mechanism
Visual observations for mechanical damage due to metering mechanism were recorded and it was found that there was no visual damage to the seeds of groundnut, maize and pigeonpea. However the internal damage of seeds was measured by sowing of seeds in steel trays and found that the seed damage for groundnut, maize and pigeonpea was not significant at one per cent level of significance.
Table. Mechanical damage to seeds by planter

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Crop</th>
<th>Weight of broken seeds, g</th>
<th>Total weight of sample, g</th>
<th>Broken seeds %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Groundnut</td>
<td>09.8</td>
<td>1000</td>
<td>0.98</td>
</tr>
<tr>
<td>2</td>
<td>Maize</td>
<td>07.2</td>
<td>1000</td>
<td>0.72</td>
</tr>
<tr>
<td>3</td>
<td>pigeonpea</td>
<td>06.1</td>
<td>1000</td>
<td>0.61</td>
</tr>
</tbody>
</table>

Seed collected in 20 revolutions

Found that the seed damage for groundnut, maize and pigeonpea was 0.98%, 0.72 % and 0.16% respectively.

Measures of accuracy of the metering mechanism

Missing Index (MI)

For Groundnut Seeds

Therefore,

\[ \text{Missing Index} = \left[ \frac{3}{60} \right] \times 100 = 5\% \]

In present study values of the missing index i.e. 5 %. Hence, the machine works properly in field. These missing were perhaps due to the jerk or vibration which produced opening of seed dropping unit during operation. It may also due to the clogging/segregation motion of groundnut seeds.

For Maize Seeds

Therefore,

\[ \text{Missing Index} = \left[ \frac{3}{60} \right] \times 100 = 5\% \]

In present study values of the missing index i.e. 5 %. Hence, the machine works properly in field. These missing were perhaps due to the jerk or vibration which produced opening of seed dropping unit during operation. It may also due to the clogging/segregation motion of maize seeds.

For Pigeonpea Seeds

Therefore,

\[ \text{Missing Index} = \left[ \frac{2}{60} \right] \times 100 = 3.33\% \]

In present study values of the missing index i.e. 3.332 %. Hence, the machine works properly in field. These missing were perhaps due to the jerk or vibration which produced opening of seed dropping unit during operation. It may also due to the clogging/segregation motion of maize seeds.

Multiple Index (DI)

For Groundnut Seeds

Therefore,

\[ \text{Multiple Index} = \left[ \frac{4}{60} \right] \times 100 = 6.66\% \]

The average multiple index for the data taken along the planted rows was found to be 6.66% that means only 6.66 hills of the groundnut seeds were dropped at more than one seeds.

For Maize Seeds

Therefore,

\[ \text{Multiple Index} = \left[ \frac{4}{60} \right] \times 100 = 6.66\% \]

The average multiple index for the data taken along the planted rows was found to be 6.66 % that means only 6.66 hills of the groundnut seeds were dropped at more than one seeds.

For Pigeonpea Seeds

Therefore

\[ \text{Multiple Index} = \left[ \frac{4}{60} \right] \times 100 = 10\% \]

The average multiple index for the data taken along the planted rows was found to be 10 % that means only 10 hills of the pigeonpea seeds were dropped at more than one seeds.

Quality of Feed Index

It is the number of observations, which are 0.5 to 1.5 times theoretical spacing. Higher is the quality of feed index, better is the performance of the metering mechanism.

For Groundnut Seeds

\[ \text{Quality of feed index} = \frac{56}{60} \times 100 \]

Quality of feed index = 93.33%

For Maize Seeds

\[ \text{Quality of feed index} = \frac{56}{60} \times 100 \]

Quality of feed index = 93.33%

For Pigeonpea seeds

\[ \text{Quality of feed index} = \frac{58}{60} \times 100 \]

Quality of feed index = 96.66%

The quality of feed index for groundnut, maize and pigeonpea seeds are 93.33%, 93.33% and 96.66% respectively.

Field Test

The average moisture content and bulk density was found to be 13.88% and 1.53 g/cm³, respectively.
Cone index (penetration test)
The soil resistance was measured by a cone penetrometer. The data reveals that the cone index was found to be 234.38 kPa.

Depth of Seed Placement
The average depth of placement of Groundnut, Maize and Pigeonpea seeds in the field was 5.60, 5.57 and 4.63 cm respectively. The depth of placement of seeds was adjusted by hitching system.

Table. Depth of seed placement

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Particulars</th>
<th>Groundnut</th>
<th>Maize</th>
<th>Pigeonpea</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Average depth of seed placement</td>
<td>5.60</td>
<td>5.57</td>
<td>4.63</td>
</tr>
<tr>
<td>2</td>
<td>SD</td>
<td>0.28</td>
<td>0.32</td>
<td>0.36</td>
</tr>
<tr>
<td>3</td>
<td>CV%</td>
<td>5.00</td>
<td>5.84</td>
<td>7.77</td>
</tr>
</tbody>
</table>

Theoretical field capacity
Theoretical field capacity (ha/h) = \( \frac{W \times S}{10} \)

Where,
S = Speed of operation, km/h = 4.1 km/h
W = Theoretical width covered, m = 1.8 m

Effective field capacity
Effective field capacity (ha/h) = \( \frac{A}{T} \)

Where,
A = Actual area covered, ha = 0.366 ha
T = Total time required to cover the area, h = 0.59 h

Field efficiency
Field efficiency \( \eta (%) = \frac{\text{actual field capacity}}{\text{theoretical field capacity}} \times 100 \)

Field efficiency \( \eta (%) = \frac{0.623}{0.59} \times 100 = 84.53\% \)

Operational speed
To get optimum operational speed the machine was run at different speeds viz. 4.0 km/h, 4.17 km/h and 4.13 km/h for groundnut, maize and pigeonpea seeds respectively.

CONCLUSION
1. The optimum suction pressure of groundnut, maize and pigeonpea seed for single seed pick up through circular orifice were 5.0, 4.0 and 2.0 kPa respectively. Increase in the suction pressure increased the number of seed selected per orifice.

REFERENCES