RESEARCH ARTICLE

# 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 pickling % & 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.** Dimensions and test weight of the seeds considered for study

| Seed dimensions, mm (average) | | | | | | |
|---|---|---|---|---|---|---|
| S. No. | Seeds | Length (mm) | Width (mm) | Thickness (mm) | Sphericity (s), % | 1000-seed weight (g) |
| 1 | Groundnut | 11.55 | 7.68 | 6.98 | 64.27 | 445 |
| 2 | Maize | 10.50 | 8.24 | 4.44 | 76.55 | 437.0 |
| 3 | Pigeonpea | 5.52 | 6.16 | 4.37 | 92.2 | 107.92 |
| | Average | 9.19 | 7.36 | 5.26 | 77.67 | 329.97 |

**Fig:** weight and physical dimensions of seeds

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**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 ($R_{st}$)**

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,

**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):

$$R_{sm} = \left[\frac{M}{w \times x_s}\right] \times 100$$

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.

$$\text{Metering efficiency} = \frac{Total\ no.of\ seeds\ obtained\ acctuly}{ecpected\ \ no.of\ seeds} \times 100$$

**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 :

Theoretical field capacity (ha/h) = W ×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. The time required for complete sowing was recorded and 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, 7.68mm 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/$m^3$, 720 kg/$m^3$ and 674 kg/$m^3$ 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 vaccume 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 vaccume 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** |

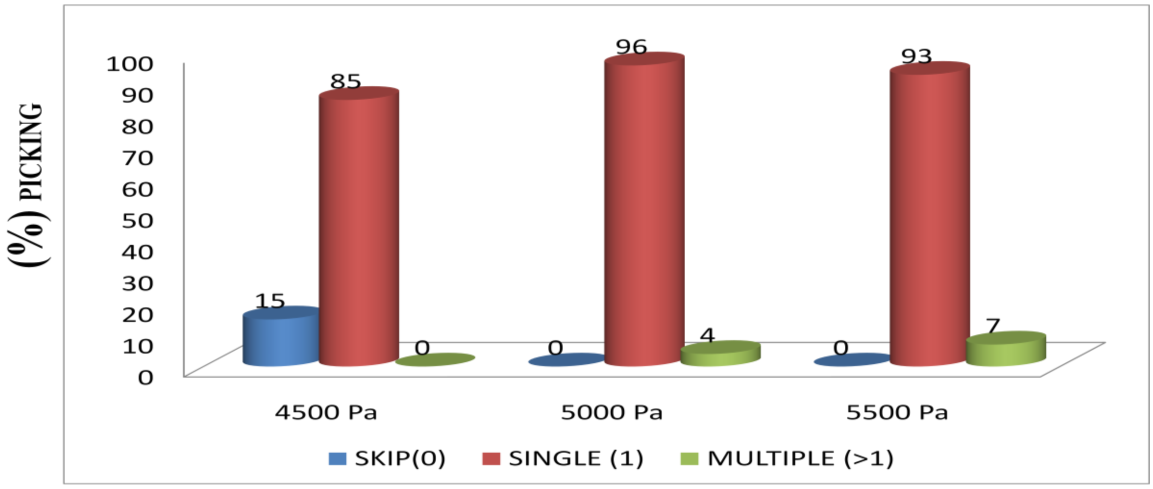
*desired number of seeds per hill (1).

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

| S. No. | Suction pressure inside vaccume cylinder, Pa | Particulars of seed per orifice | (%) Picking |
|---|---|---|---|
| **1** | **1500** | Skip (0) | **17** |
| | | Single (1) | **83** |

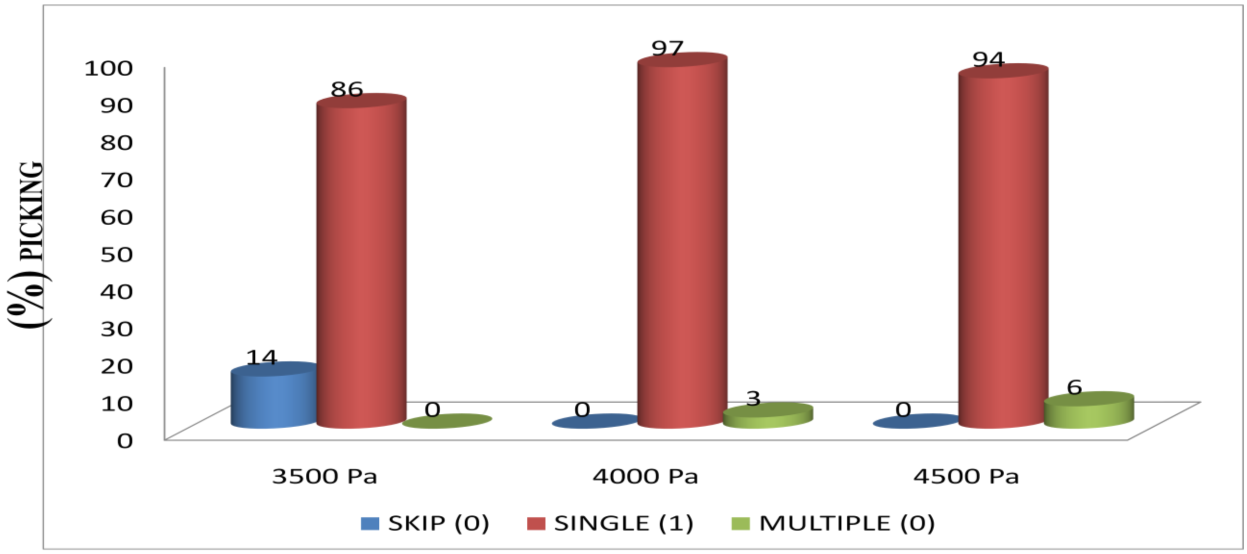
| | | | |
|---|---|---|---|
| | | Multiple (>1) | **0** |
| **2** | **2000** | Skip (0) | **0** |
| | | Single (1) | **95** |
| | | Multiple (>1) | **5** |
| **3** | **2500** | Skip (0) | **0** |
| | | Single (1) | **92** |
| | | Multiple (>1) | **8** |

*desired number of seeds per hill (1)




**Suction pressure inside vaccume cylinder, Pa**

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




**Suction pressure inside vaccume cylinder, Pa**

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

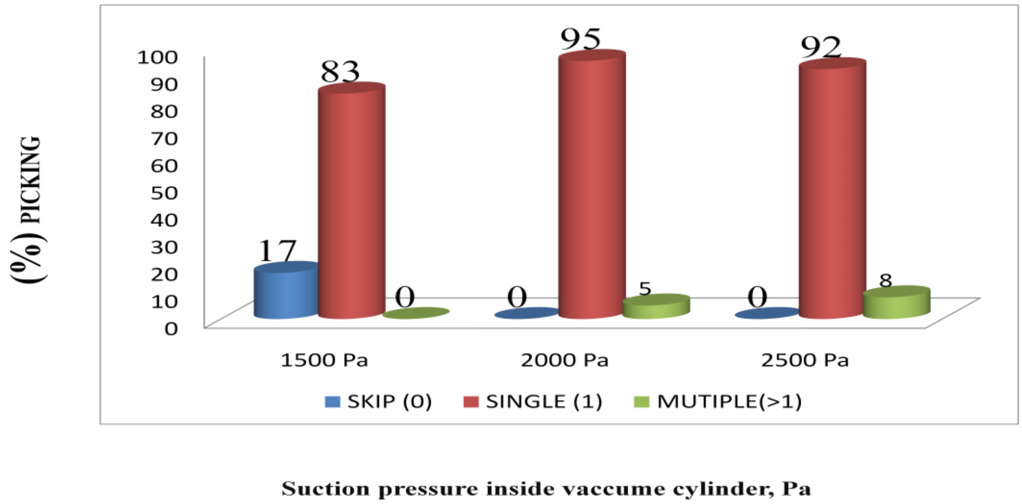



**Fig:** Performance of the 2.5 mm circular orifice vacuum cylinder under varying suction pressure for Pigeonpea seed

**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 vaccume cylinder the metering efficiency also increased from 93.33 to 111.33 percent as pressure increased from 4500 to5500 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

| S. No. | Seeds | Suction pressure in vacuum rod, Pa | Metering efficiency of metering mechanism ,(%) |
|---|---|---|---|
| 1 | Groundnut | **4500** | **93.33** |
| | | **5000** | **106.67** |
| | | **5500** | **111.33** |
| 2 | Maize | **3500** | **90** |
| | | **4000** | **108.88** |
| | | **4500** | **112.22** |
| 3 | Pigeonpea | **1500** | **91.11** |
| | | **2000** | **110** |
| | | **2500** | **113.33** |

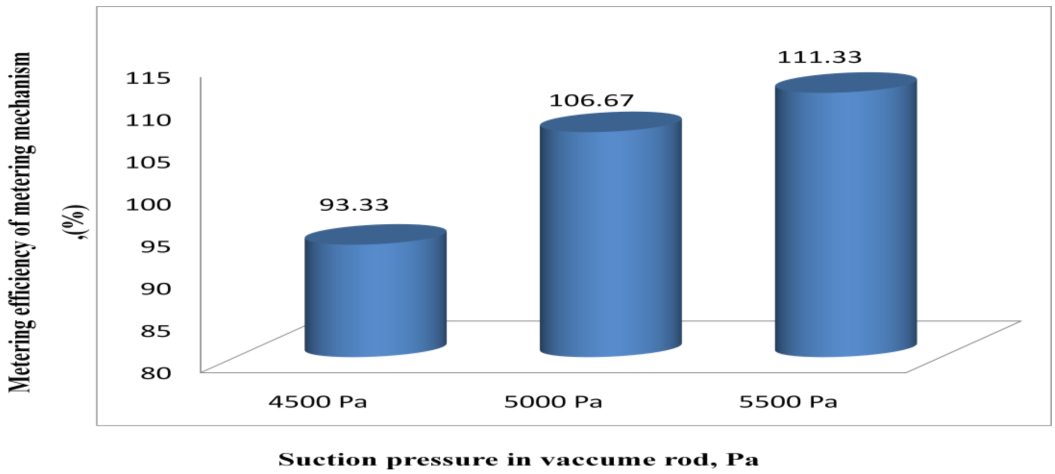



**Fig.** Effect of suction pressure in the vacuum drum on the metering efficiency of metering mechanism for Groundnut

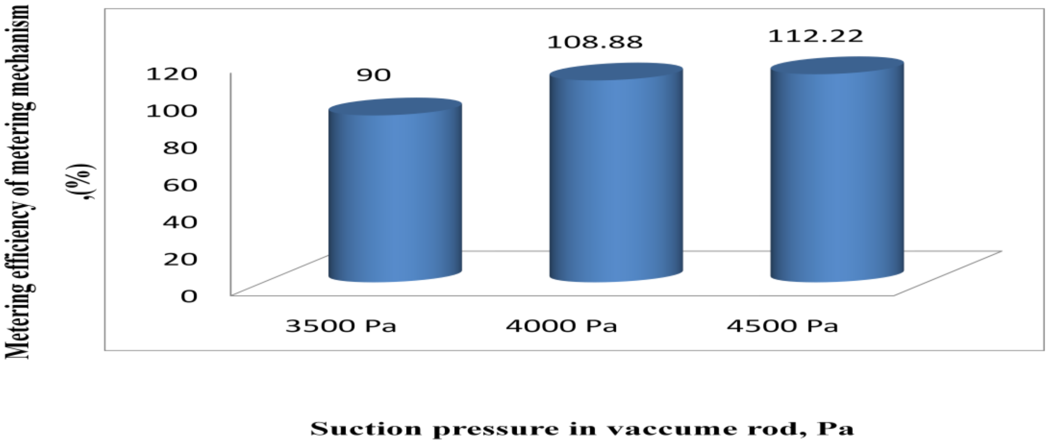



**Fig.** Effect of suction pressure in the vacuum drum on the metering efficiency of metering mechanism for Maize

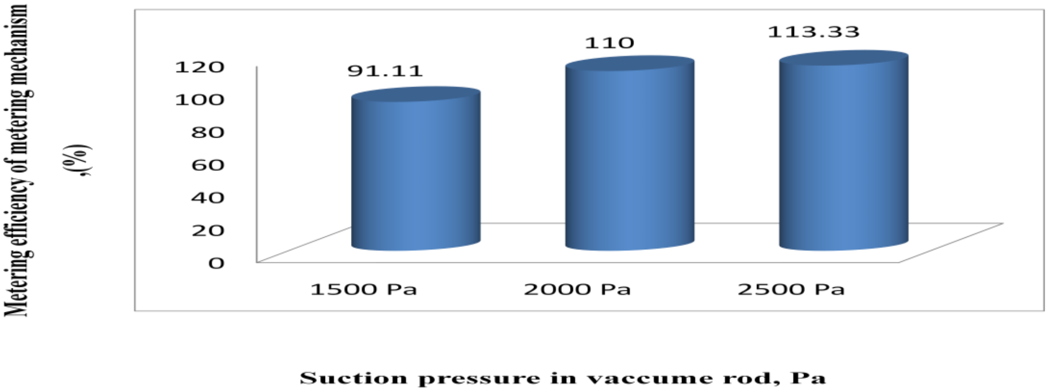



**Fig.** Effect of suction pressure in the vacuum drum on the metering efficiency of metering mechanism for pigeonpea

**Calculation of seed rate (kg/ha)**
**Theoretical seed rate ($R_{st}$)**
**For groundnut seeds**

Row width = 30 cm

$$R_{st} = \frac{10^8}{30 \times 15} = 222230 \text{ seeds/ha}$$

**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

$$R_{sm} = \left[\frac{0.335}{30 \times 15}\right] \times 100$$

= 0.0744 mg/ha

= 74.44 kg/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

| Sr. No | Crop | Weight of broken seeds, g | Total weight of sample, g | Broken seeds % |
|---|---|---|---|---|
| 1 | Groundnut | 09.8 | 1000 | 0.98 |
| 2 | Maize | 07.2 | 1000 | 0.72 |
| 3 | pigeonpea | 06.1 | 1000 | 0.61 |

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,

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

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,

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

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,

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

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

$$\text{Multiple Index} = \left[\frac{6}{60}\right] \times 100 = 10\ \%$$

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**

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

$$\text{Quality of feed index} = 96.66\ \%$$

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/cm$^3$. 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

| Depth of seed placement, cm | | | | |
|---|---|---|---|---|
| S. No. | Particulars | Groundnut | Maize | Pigeonpea |
| 1 | Average depth of seed placement | 5.60 | 5.57 | 4.63 |
| 2 | SD | 0.28 | 0.32 | 0.36 |
| 3 | CV% | 5.00 | 5.84 | 7.77 |

**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

= Number of furrow openers multiplied by distance between the furrow Opener, m

Theoretical field capacity (ha/h) = $\frac{1.8 \times 4.1}{10}$

**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

Effective field capacity (ha/h) = $\frac{0.366}{0.59}$ = 0.623

**Field efficiency**

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

Field efficiency η (%) = $\frac{0.623}{0.738} \times 100$ = 84.5%

**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 .

**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.
2. The seed rate varies with the vacuum pressure, and forward speed of travel. Seed rate is increased with increase in vacuum pressure of vacuum rod. The seed rate of groundnut, maize and pigeonpea was found 74.44 kg/ha, 17.00 kg/ha and 10.91 respectively.
3. To get optimum operational speed of the machine was 4.1 km/hfor groundnut, maize and pigeonpea seeds respectively.
4. The implement is capable of planting groundnut, maize and pigeonpea at the rate of 1.60 h/ha.
5. The average field efficiency was found 84.53%.

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