Performance evaluation of triangular cell sunflower seed metering roller under field condition using power tiller

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Abstract: Presently, the triangular cell sunflower seed metering roller has not been evaluated in field conditions using a power tiller. This study was undertaken to evaluate its working performance in the field conditions. Randomized complete block design with three replications and three level of forward speed and a quantity of seeds in hopper was used to evaluate performance of the triangular cell sunflower seed metering roller. Performance indices namely mean spacing; miss index, multiple indexes, quality of feed index, precision index, and coefficient of variation were used to describe the performance of the triangular cell sunflower seed metering roller. Results were analysed statistically to determine the effect of forward speed, quantity of seed in the hopper and their interaction on the performance indices. Best performance was at a combination of forward speed 1.3 km h^{-1} and a quantity of seeds in the hopper of 2.392 kg, which gave a mean spacing of 226.16 cm, a miss index of 25%, multiple indexes of 0.43%, a quality of feed index of 97.33% and a precision index of 16.58%. Based on agronomical recommendations for sunflower planting and performance comparison with other sunflower metering device, it is concluded that triangular cell sunflower seed metering roller can perform efficiently and economically and can be adopted by the small and medium farmers.

Keywords: metering roller; power tillers; sunflower seed; performance indices.

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1 Introduction

Seed metering system is the bottommost part in row crop planter, its performance affects seed rate, miss index, multiple indices, quality of feed index, precision index and uniformity of seed spacing (Singh et al., 2006). Field and laboratory methods have been developed and used for evaluation of seed meter performance, each methods having its own advantage and shortcoming (Navid et al., 2011; Singh et al., 2014; Nardon and Botta, 2022).

Currently, available seed metering devices for sunflower planting include studded roller seed meter, air assisted vertical plate seed meter, horizontal plate seed meter, vacuum disc seed meter, pressurised drum seed meter and finger pick – up seed meter. According to Murray et al. (2006) and Sureka et al., (2023) those technologies have different degrees of sophistication which leads to technical, financial, economic and social consequences. This may be a limitation when are considered for use in an environment like Tanzania.

Singh et al. (2006), developed and evaluated

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mechanical metering devices which are rectangular with slope (teak wood), circular (teak wood), triangular large cell (aluminium casting) and triangular small cell (aluminium casting) for development of sunflower planter under simulated conditions (test rig) and recommended a triangular small cell type seed metering device, since it gave an optimum seed quantity, maximum seed germination and minimum seed damage. Singh et al. (2006) investigated the technical feasibility of the mechanical planting of sunflower seeds. Four different types of rollers were fabricated and evaluated under laboratory condition, a triangular small cell seed meter gave optimum performance and used to develop prototype of a single row manually operated sunflower planter as shown in Figure 1. The field performance results were; field capacity 0.10 ha h^{-1}, labour requirement 19.34-man h ha^{-1}, draft 14.96 kg, seed rate 4.32 kg ha^{-1}, number of plant/m row 11.66, number of plant m^{-2} 22.66, average hill distance 18.53 cm, number of seed germinated/hill 2.83. In that regard, to date a triangular cell sunflower seed metering device has not been evaluated under field conditions using tractor powered planter. Therefore, this study evaluates the performance of a triangular cell sunflower seed metering roller under field conditions using a power tiller – drawn planter.

2 Material and methods

The experiment was conducted at centre for agricultural mechanization and rural technology (CAMARTEC) in Arusha, Tanzania which is at a latitude of 3°20'S and longitude of 36°37'E and an altitude of 1400 m. Power tiller drawn sunflower planter as shown in Figure 1, was used for the performance evaluation of triangular cell sunflower seed metering roller.

Figure 1 Developed power tiller drawn sunflower planter

2.1 Performance evaluation

Performance evaluation was conducted for three combinations of forward speeds and three levels of quantity of seed in hopper with three replications, using randomized complete block design (RCBD). Crop and machine variables used for performance evaluation of power tiller operated sunflower seed planter is prescribed in the following section.

2.2 Variables and measurements

The functional dimensions of the three common varieties of sunflower seed, namely length, width, height, bulk density and moisture content were measured as shown in Table 1. From that record variety was selected for further measurement and used for the development of power tiller operated sunflower seed planter including adapting triangular cell sunflower seed metering roller, since it is the one used by majority of local farmers in Tanzania.

Table 1 Common variety of sunflower seed

Particulars	Variety		
	Record	Kenya seed	Hysun 33
Length (mm)	12.298	10.88	10.9616
Width (mm)	6.540	5.01	5.583
Thickness (mm)	4.413	4.28	3.6518
Bulk density (g cm^{-3})	0.455	0.386	0.554
Moisture content (%)	11	12	12

2.2.1 Crop variables

Crop variables such as seed variety, weight of 1000 sunflower seeds, moisture content, size or linear dimensions of the sunflower seeds and bulk density was considered and discussed as follows:

2.2.1.1 Seed variety

Record variety of sunflower seed was selected and used during the experiment.

2.2.1.2Mass of 1000 sunflower seeds

Eight samples each with 100 seeds were randomly selected from the bulk and weighed on an electronic balance to an accuracy of 0.01 g and their mass was recorded. The result was used to determine the equivalent mass for 1000 sunflower seeds.

2.2.1.3 Moisture content of sunflower seeds

Three samples of sunflower seeds taken from the bulk were measured for moisture content using a digital grain moisture meter in a dry basis.

2.2.1.4 Seed size

The size (length, *L*, width, *W* and thickness, *T*) of the sunflower seeds was measured using digital Vernier caliper. The sample of 50 sunflower seeds was taken for measurement. Length of the sunflower seed was measured by positioning exterior jaws of the digital Vernier caliper along the major axis of the sunflower seed; width of the sunflower seed was measured by positioning exterior jaws of digital Vernier caliper along the intermediate axis of the sunflower seed and thickness of the sunflower seed was measured by positioning exterior jaws of digital Vernier caliper along the minor axis of the sunflower seed.

2.2.1.5 Bulk density

A cylindrical container was filled by sunflower seeds and the weight of the sunflower seeds was measured and experiment was repeated 3 times. The bulk density was determined by using Equation 1 provided by Smith et al (1994).

$$Bulk\ density, (kg\ m^{-3}) = \frac{Weight\ of\ the\ sunflower\ seeds\ \ (\mathrm{kg})}{Volume\ of\ the\ container\ \ (\mathrm{m}^3)} \tag{1}$$

2.2.1.6 Percentage of purity of the seed

A sample sunflower seed was taken from the bulk and its mass was measured on digital balance and recorded. The sample was allowed to pass through the 2 mm round sieve. The quantity of the seeds passed through the 2 mm round sieve was collected and its weight was measured on the digital balance and recorded. The process was repeated three times. The purity of the sunflower seeds was determined using Equation 2 given by Baalbaki et al., (2012).

$$P(\%)=\frac{Wp}{Ws}\times 100\% \tag{2}$$

Where, P = percentage of purity of sunflower seeds (%); W_p = mass of sunflower seed passed through 2 mm circular sieve (g); and W_s = total mass of the sample of sunflower seed (g).

2.2.2 Soil variables

The following soil variables; soil moisture content, soil bulk density and textural class were considered and measured as explained here under:

2.2.2.1 Soil moisture content

A normal sampling of soil was done and soil sample was placed in a sealed bag and transferred into the soil laboratory. The bag and soil sample were weighed on a digital balance and recorded. The mass of the bag and wet soil sample was the difference between the mass of the wet soil sample. The soil sample was then dried at 105°C in an oven for 24 hours. The mass of the dried sample was measured and recorded. The moisture content of the soil was calculated using Equation 3 provided by Smith et al., (1994).

$$\Theta_d=\left(\frac{Wt - Wd}{Wd}\right)\times 100\% \tag{3}$$

Where, Θ_d = soil moisture content (%); W_t = mass of the soil sample (g); and W_d = mass of dried sample of soil (g).

2.2.2.2 Soil bulk density

Mild steel cylindrical core of diameter 10 cm and height 10 cm was used. The core was inserted into the soil on the field to take the sample. The collected soil sample was taken into a sealed bag and its weight was measured and recorded. Mass of empty sealed bag was measured and recorded too. The mass of the soil sample was the difference between the mass of the soil sample in a sealed bag and the weight of the empty sealed bag. The sample of soil was dried in an oven at 105°C for 24 hours. The mass of the dried sample was measured and recorded. The bulk density of the soil was determined by using Equation 4 provided by Smith et al., (1994).

$$\rho = \frac{Wd}{V} \quad (4)$$

Where, ρ = bulk density of the soil (g cm^{-3}); W_d = mass of dried soil sample (g); and V = volume of the soil sample (core volume).

2.2.3 Machine variables

Machine variables under test were forward speed (S) and quantity of seeds in the hopper (H). Machine variables were selected before the field test so that the test was run in a controlled manner with consistency. These variables were established as explained below;

2.2.3.1 Quantity of seeds in a hopper

According to ISO 7256/1 (ISO Standards, 1984) and Testing codes and procedures for the evaluation of agricultural machinery and equipment (Smith et al., 1994), there should be a minimum variation in to seed rate (kg ha^{-1}) with respect to the quantity of seed in hopper. With that regard, hopper was kept at three levels which are full, half full and one over eight full and used for the experiment.

2.2.3.2 Forward speed

Three forward speeds (km h^{-1}) for planting sunflower were established on the field, according to ISO 7256/1 (ISO Standards, 1984) and Panning et al. (2000) that most uniform seed spacing for each planter configuration occurred at lowest speed of 3.2 km h^{-1} and according to Al-Gaadi and Marey (2011), forward speed of 2.25 km h^{-1} had maximum efficiency and does not affect seed uniformity. Forward speed was established on the test plot of 20 m length and 10 m wide. The time it took to cover 20 m length of run was recorded and procedures were repeated three times for different gear ratio of the power tiller. Forward speed was calculated using Equation 5.

$$S = \frac{3.6 \times D}{T} \quad (5)$$

Where, S = forward speed (km h^{-1}), D = linear distance (m) covered by the power tiller, and T = time (s) spent by a power tiller to travel the specified linear distance.

2.3 Field testing of the planter

Performance evaluation of triangular cell sunflower seed metering roller was conducted on ploughed field with 20 m effective length and 3 meter wide, for a combination of forward speeds (S) and quantity of seed in hopper (H) by using RCBD with three replications. Field evaluation on uniformity of spacing and seeds distribution pattern were used to describe field performance of triangular cell sunflower metering roller.

2.4 Performance indices

Performance indices of a planter in terms of uniformity of spacing and seed distribution pattern were evaluated as per ISO 7256/1 (ISO Standards, 1984) and similar formula used by Kachman and Smith (1995) and Al-Gaadi (2011) as described hereunder;

2.4.1 Multiple index

All spacing less than 0.5 times theoretical seed spacing were considered to be multiples. Multiple indexes were calculated using Equation 6 as provided by the ISO 7256/1 (ISO Standards, 1984).

$$I_{mult}, \% = \frac{Nmult}{N} \times 100 \quad (6)$$

Where, I_{mult} = multiple indexes (%); N_{mul} = number of occasions where seed spacing was less than or equal to half of the theoretical spacing; and N = total number of observations.

2.4.2 Miss index

All space larger than 1.5 times theoretical seed spacing was considered to be misses and calculated using the Equation 7 as provided by the ISO 7256/1 (ISO Standards, 1984).

$$I_{miss}, \% = \frac{Nmiss}{N} \times 100 \quad (7)$$

Where, I_{miss} = miss index; N_{miss} = number of occasions where sunflower seeds spacing was greater than 1.5 times the theoretical spacing; and N = total number of observations.

2.4.3 Quality of feed index

The quality of the feed index is the measure of how often the spacing was close to the theoretical spacing. It is the percentage of spacing that are more than half but not more than 1.5 times the theoretical spacing in mm, the quality of feed index was calculated using Equation 8 as provided by the ISO 7256/1 (ISO Standards, 1984).

$$I_{qf} = 100\% - (I_{miss} + I_{mult}) \tag{8}$$

Where, I_{qf} = quality of feed index (%); I_{miss} = miss index (%); and I_{mult} = multiple indices (%).

2.4.4 Precision index

Precision in spacing is a measure of the variability (coefficient of variation) in spacing, between sunflower seeds after accounting variability due to both multiples and misses. The precision index was calculated using Equation 9 as provided by the ISO 7256/1 (ISO Standards, 1984).

$$Ip = \frac{Sd}{S} \times 100 \tag{9}$$

Where, I_p = precision index; S_d = standard deviation of spacing more than half the theoretical spacing but not more than 1.5 times the theoretical spacing (mm).

2.4.5 Standard deviation and coefficient of variation

Spacing between seeds and the number of plants per hill was measured to analyze the uniformity of plant spacing. The standard deviation and coefficient of variation were calculated by using Equations 10 and 11 as provided by the ISO 7256/1 (ISO Standards, 1984).

$$S.D = \frac{\sqrt{((Xi-X)^2}}{N} \tag{10}$$

$$CV = \frac{SD}{X} \times 100 \tag{11}$$

Where, SD = the standard deviation; CV = the coefficient of variation; N = the total number of observations; Xi = the spacing; X = the mean spacing.

2.4.6 Number of seeds dropped

Number of seeds dropped was observed by counting total number of seeding actions done by the developed power tiller operated sunflower seed planter in a 20 m run.

2.4.7 Mean number of seed dropped per hill

Mean number of seeds dropped per hill was observed and calculated using Equation 12 provided by Kachman and Smith (1995) and Al – Gaadi (2011).

$$N_{sd} = \frac{Ts}{Ns} \tag{12}$$

Where, N_{sd} = mean number of seed dropped per hill; Ts = observed total number of seeds dropped per hill in 20 m run; and Ns = total number of seeding in 20 m run.

2.4.8 Percentage of dropping single seed per hill

The occurrence of single seed per hill for a given length of run was measured and given in terms of percentage. Percentage of dropping single seed per hill was calculated using Equation 13 provided by Kachman and Smith (1995) and Al – Gaadi (2011).

$$S_1(\%) = \frac{ns}{NS} \times 100\% \tag{13}$$

Where, S_1 = percentage of single (%); ns = observed total number of hills with single seed; and Ns = total number of seeds.

2.4.9 Percentage of dropping double seeds per hill

The occurrence of two seeds per hill for a given run length was measured and given in percentage. The percentage of dropping double seeds per hill, was calculated using Equation 14 provided by Kachman and Smith (1995) and Al – Gaadi (2011).

$$S_2(\%) = \frac{nd}{NS} \times 100\% \tag{14}$$

Where; S_2 = percentage of double (%); nd = observed total number of hills with two seeds; and Ns = total number of seeding.

2.4.10 Percentage of dropping triple seeds per hill

The occurrence of three seeds per hill for a given run length was measured and given in percentage. Percentage of dropping triple seeds per hill, was calculated using Equation 15 provided by Kachman and Smith (1995) and Al – Gaadi (2011).

$$S_3(\%) = \frac{nt}{NS} \times 100\% \tag{15}$$

Where, S_3 = percentage of triple (%); nt = observed total number of hills with three seeds; and Ns = total number of seeding.

2.4.11 Percentage of dropping multiple seeds per hill

The occurrence of four or more seeds per hill for a given length of run was measured and given in terms of percentage. Percentage of multiple was calculated using Equation 16 provided by Kachman and Smith (1995) and Al – Gaadi (2011).

$$S_m(\%) = \frac{nm}{NS} \times 100\% \quad (16)$$

Where, S_m = percentage of multiple (%); nm = observed total number of hills with more than seeds; and Ns = total number of seeding.

2.4.12 Seed rate

Number of seed in terms of mass (g) expressed per unit area (ha) was termed as seed rate. Seed rate was calculated using Equation 17 provided by Smith et al., (1994);

$$S_r(kg\ ha^{-1}) = \frac{W \times 10}{A} \times 100\% \quad (17)$$

Where, Sr = seed rate (kg ha^{-1}); W = measured weight (g) of seed dropped per area covered by the planter; and A = area (m^2) covered by the planter.

2.4.13 Seed damage

Number of broken seeds measured in (g) out of total amount of seed measured in (g) for a given length of run was measured and given in terms of percentage. Seed damage was calculated using Equation 18 provided by Smith et al., (1994).

$$S_d(\%) = \frac{q}{Q} \times 100 \quad (18)$$

Where; S_d = seed damage (%); q = amount of broken seed in (g) collected for given length of run; and Q = Total amount of seeds in (g) collected for a given length of run.

2.6 Field evaluation of planter

The plot for test was ploughed by the disc plough and pulverized by harrowing to obtain fine seedbed for sunflower planting. Greaves power tiller of 14.6 hp was used for the field test. One power tiller operator and three data collector personnel were involved for the field experiment. The output parameters were measured and the results recorded.

2.6.1 Spacing

Spacing between two seeds in a row was measured by using tape measure.

2.6.2 Seed rate

The amount of collected seed during the field experiment was measured to calculate seed rate.

2.6.3 Seed damage

During the field experiment, visible seed damage was sorted out and its mass measured to establish the percentage of seed damage.

2.6.4 Seed distribution pattern

Number of seeds dropped per hill for a given length of run was considered to be seed distribution. Therefore, seed distribution was counted as single seed per hill, double seed per hill, triple seed per hill and multiple seed per hill.

2.7 Statistical analysis

In this study, RCBD was used to test the equality of the treatment against the nuisance factors that affect the response. The mean table for different parameters was tabulated and level of significance was reported.

3 Results and discussion

3.1 Crop variables

3.1.1 Crop variety

Sunflower seed, Record variety with length of 12.298 mm, width 6.540 mm, thickness 4.413 mm, bulk density 0.455 g/cm^3 and moisture content of 11% was used to evaluate the working performance of the triangular cell sunflower metering roller as per the considerations provided in section 2.2.

3.1.2 A Thousand grain mass

It was observed that thousand grain mass was 58.78 g±3.54 g at 10% moisture content. This mass classifies the seed as a medium seed which is acceptable for the size of seed to be used for planting (Serafin and Thompson, 2014).

3.1.3 Moisture content

The measured moisture content is 10%±0.00%wb, which is the recommended moisture for sunflower planting (Singh and Sharma, 2006).

3.1.4 Seed size

Results are given in Table 2. It was observed that seed size met recommendations for sunflower planting (Deevani, 1991; Singh and Singh, 2011).

3.1.5 Bulk density

Bulk density was found to be 411±2.49 kg m^{-3}. Similar trends were reported by Singh and Sharma (2006) on technical feasibility of mechanical planting of sunflower.

Table 2 Linear dimensions of seed

S/n	Seed dimensions (mm)	Mean±SD
1	Length	11±0.87
2	Width	6.4±6.90
3	Thickness	3.3±0.44
4	Bulk density (g cm^{-3})	0.411
5	Moisture content (%)	10

3.3 Machine variables

3.3.1 Quantity of seed in hopper (H)

The levels are full, half full and one eight full. This is according to ISO 7256/1 (ISO Standards, 1984) and Testing and Evaluation of Agricultural Machinery and Equipment (Smith et al., 1994). With that regard, the developed hopper is of a capacity of 2.392 kg, hence at highest level (H_1), the hopper was provided with 2.392 kg of seed. At the intermediate level (H_2), the hopper was provided with 1.191 kg of seed and at the lowest level (H_3), hopper was provided with 0. 298 kg equal to (298 gm) of seed.

3.3.2 Forward speed (S)

The peripheral speed varies with respect to the changes in forward speed, as the forward speed increased, peripheral speed also increased. Variation in peripheral speed with respect to forward speed is given in Table 3.

Table 3 Peripheral speed of metering roller with respect to forward speed

S/n	Forward speed	Peripheral speed on metering roller	
	Km h^{-1}	m min^{-1}	rpm
1	1.3	3.6	11
2	2.2	6.0	18
3	3.5	9.6	29

3.4 Performance results of field experiment

3.4.1 Uniformity of spacing

Field Performance of triangular cell sunflower metering roller was conducted as discussed in section 3.4 and field observations on uniformity of spacing and seed distribution pattern was done. Uniformity of spacing in terms of mean spacing, mean longitudinal displacement/shift, miss index (%), multiple index (%), quality of feed index (%) and precision index (%) as shown in Table 4 was used to designate uniformity of spacing and results were analyzed statistically to determine effect of forward speed (S), quantity of seed in hopper (H) and their interaction on uniformity of spacing.

Table 4 Summarized results of field performance on uniformity of spacing

Output variable for 20 m length of run	Experiment run								
	S_1H_1	S_1H_2	S_1H_3	S_2H_1	S_2H_2	S_2H_3	S_3H_1	S_3H_2	S_3H_3
Mean spacing (cm)	26.16	26.21	26.84	27.78	26.47	27.00	27.58	27.89	27.45
Mean longitudinal displacement from desired spacing (25 cm)	3.65	3.91	4.01	3.85	4.05	3.80	4.31	4.69	4.47
Number of missing hills	2	2	3	3	5	2	3	6	5
Number of multiple hills	66	47	66	63	63	67	65	61	66
Miss index (%)	2.25	2.63	4.19	4.61	6.22	3.26	3.69	8.95	6.99
Multiple indexes (%)	0.43	0.43	1.28	0.00	0.43	0.00	0.00	0.00	1.30
Quality of feed index (%)	97.33	96.94	94.53	95.39	93.34	96.74	96.31	91.05	91.71
Precision index (%)	16.58	18.74	18.29	16.61	19.70	16.81	19.39	22.72	20.45

Note: ***** The values denote average values from three replications

3.4.1.1 Mean spacing

The effect of forward speed (S) and quantity of seed in hopper (H) is presented in Table 5. It observed that mean spacing ranged from 26.16 cm to 27.89 cm for all combination of forward speed (S) and quantity of seed in hopper (H). The highest mean spacing of 27.89 cm was observed for the highest level (H_3) of forward speed 3.5 km h^{-1} and intermediate level (H_2) of quantity of seed in hopper 1.191 kg, while the lowest mean spacing of 26.16 cm was observed for the lowest level (S_1) of forward speed 1.3 km h^{-1} and highest level (H_1) of quantity of seed in hopper 2.382 kg. Mean spacing increased from 26.16 cm to 27.89 cm with an increase in forward speed from 1.3 km h^{-1}(S_1) to 3.5 km h^{-1} (S_3) as shown in Figure 2. It was observed that mean spacing is influenced by longitudinal displacement/shift which ranges from 1.16 cm to 2.89 cm from the desired spacing of 25cm and variability around the drop point.

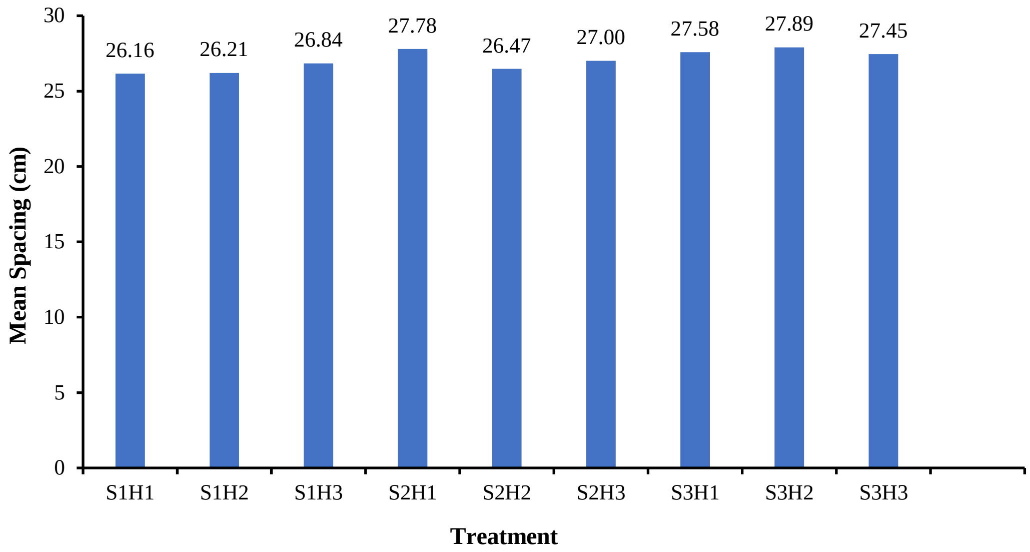

Figure 2 Effect of forward speed and quantity of seed on mean spacing

Analysis of variance (ANOVA) showed that effect of forward speed (S), quantity of seeds in the hopper (H) and their interaction (SH) were not significant (p > 0.05) on mean spacing for the selected range of forward speed from 1.3 km h^{-1} to 3.5 km h^{-1}. Similar trends were reported by Panning et al. (2000) and Al-Gaadi and Marey (2011).

Coefficient of variation (CV) on mean spacing for the observed spacing 26.23 cm, 26.17 cm, 26.50 cm, 27.16 cm, 25.75, 26.81 cm, 27.16 cm 26.56 cm and 26.89 cm with respect to the desired spacing of 25cm is given in Table 5.

The lowest value of coefficient of variation (CV) observed was 15.3% for an intermediate level (S_2) of forward speed 2.2 km h^{-1} and highest level (H_1) of quantity of seeds in hopper 2.392 kg. The lower value of coefficient of variation indicates the accuracy and uniformity in spacing (Brown, 2012).

Table 5 Coefficient of variation in mean spacing

Experiment run	S_1H_1	S_1H_2	S_1H_3	S_2H_1	S_2H_2	S_2H_3	S_3H_1	S_3H_2	S_3H_3
CV (%)	15.81	17.97	17.34	15.3	19.13	15.63	17.84	21.42	18.99
Standard Deviation (cm)	4.15	4.69	4.57	4.15	4.93	4.20	4.85	5.68	5.11
Mean normally sown spacing (cm)	26.23	26.17	26.50	27.16	25.75	26.81	27.16	26.56	26.89

3.4.1.2 Miss index

The effect of forward speed (S) and quantity of seed in hopper (H) is presented in Table 5. It observed that the miss index ranged from 2.25% to 8.95% for all combinations of forward speed (S) and quantity of seed in hopper (H). The highest miss index of 8.95% was observed for the highest level (S_3) of forward speed 3.5 km h^{-1} and intermediate level (H_2) of quantity of seed in hopper 1.191 kg, while the lowest miss index of 2.25% was observed for the lowest level (S_1) of forward speed 1.3 km h^{-1} and highest level (H_1) of quantity of seed in hopper 2.382 kg. Miss index increased from 2.25% to 8.95% with increase in forward speed from 1.3 km h^{-1} (S_1) to 3.5 km h^{-1} (S_3) as shown in Figure 3. It observed that miss index is influenced by a failure of seed to be dropped and packaging nature of seed in the cell which may be affected by seed feed cutting – off device.

Analysis of variance (ANOVA) showed that forward speed (S) was significant ($p \leq 0.05$) on miss index, the quantity of seeds in the hopper (H) and their interaction (SH) were not significant (p > 0.05). A similar trend was observed by Pal et al., (2020) during performance evaluation of a vertical plate seed metering mechanism for potato planter.

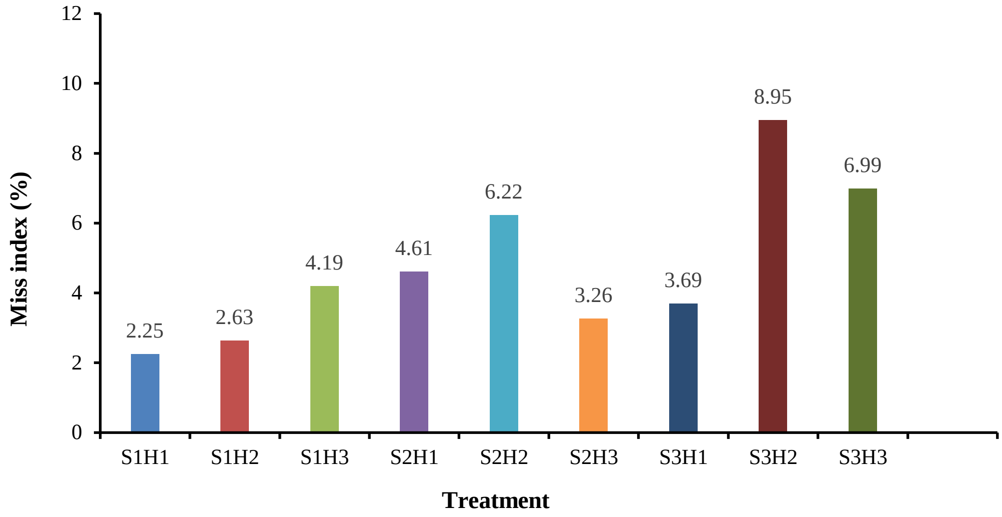

Figure 3 Effect of forward speed and quantity of seeds on missing index

3.4.1.3 Multiple indexes

The effect of forward speed (S) and quantity of seed in the hopper (H) is presented in Table 5. It observed that multiple indexes ranged from 0.00% to 1.30% for all combination of forward speed (S) and quantity of seed in hopper (H). The highest multiple indexes of 1.30% was observed for the highest level (S_3) of forward speed 3.5 km h^{-1} and lowest level (H_3) of the quantity of seed in hopper 0.298 kg, while the lowest miss index of 0.00% was observed for the range of forward speed from 2.2 km h^{-1} (S_2) to 3.5 km h^{-1} (S_3) and range of quantity of seed in hopper from 2.382 kg (H_1) to 0.298 kg (H_3) respectively. Multiple indexes increased from 0.00% to 1.30% when forward speed increased from 2.2 km h^{-1} (S_2) to 3.5 km h^{-1} (S_3) as shown in Figure 4. Multiple indexes are influenced by multiple seeds dropped simultaneously due to the packaging nature of seed and seed sizes.

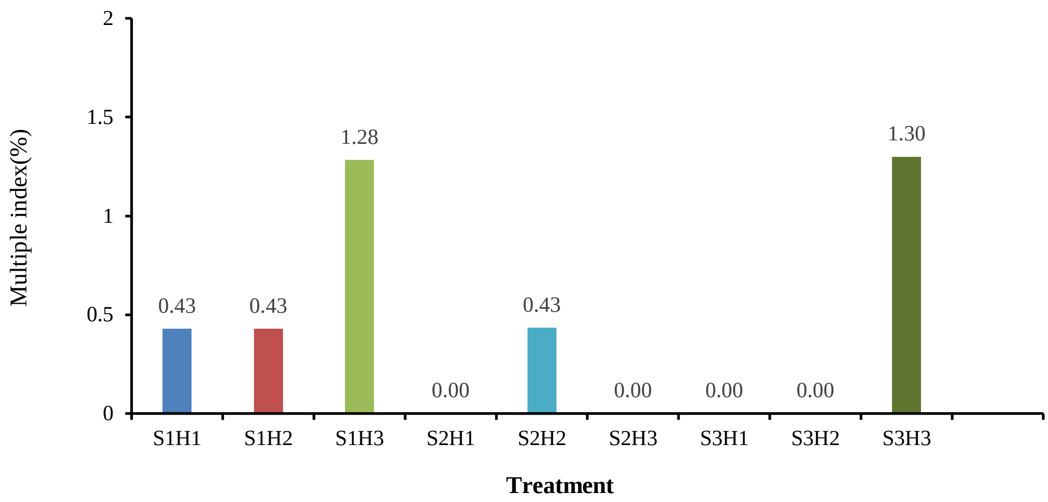

Figure 4 Effect of forward speed and quantity of seed on multiple indexes

Analysis of variance (ANOVA) showed that none of the forward speed (*S*), quantity of seeds in the hopper (*H*) and their interaction (SH) was significant ($p > 0.05$) on multiple indexes.

3.4.1.4 Quality of feed index

The effect of forward speed (*S*) and quantity of seed in hopper (*H*) is presented in Table 5. It observed that quality of feed index ranged from 91.05% to 97.33% for all combinations of forward speed (S) and quantity of seed in hopper (H). The highest quality of feed index of 97.33% was observed for the lowest level (S_1) of forward speed 1.3 km h^{-1} and highest level (H_1) of quantity of seed in hopper 2.382 kg, while the lowest quality of feed index of 91.05% was observed for the highest level (S_3) of forward speed 3.5 km $h^{-1}$and intermediate level (H_2) of quantity of seed in hopper 1.191kg. Quality of feed index decreased from 97.33% to 91.05% when the forward speed increase from 1.3 km h^{-1} (S_1) to 3.5 km h^{-1} (S_3) and decrease of quantity of seed in hopper from 2.382 kg (H_1) to 1.191kg (H_2) as shown in Figure 5. In addition, it was observed that quality of feed index is influenced by multiple indexes and miss index.

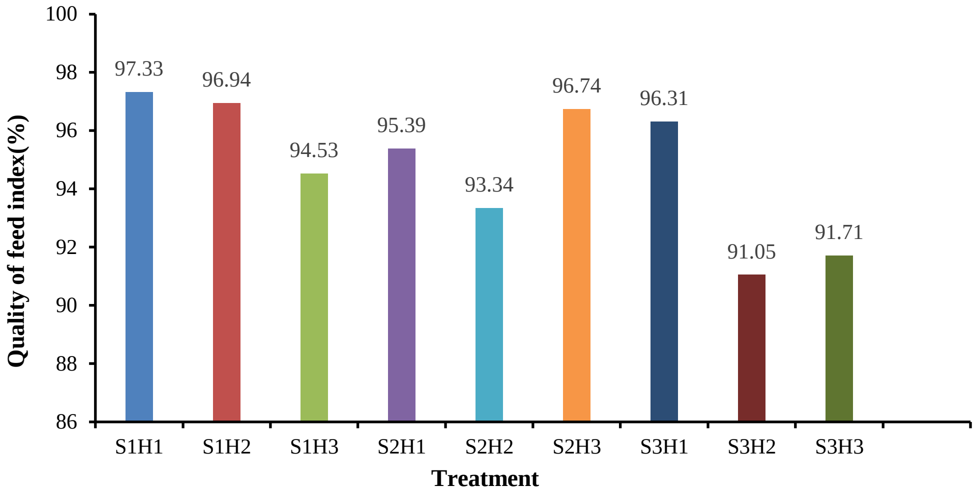

Figure 5 Effect of forward speed and quantity of seeds on quality of feed index

Analysis of variance (ANOVA) showed that forward speed (S), quantity of seeds in the hopper (H) and their interaction (SH) were not significant (p > 0.05) on quality of feed index. A similar result was reported by Al-Gaadi and Marey (2011) for potato planter with high quality of feed index at a lower forward speed.

3.4.1.5 Quality of feed index

The effect of forward speed (S) and quantity of seed in hopper (H) is presented in Table 5 and Figure 6. It was observed that precision index ranged from 16.58% to 20.45% for all combinations of forward speed (S) and quantity of seed in hopper (H). The highest precision index of 20.45% was observed for the highest level (S_3) of forward speed 3.5 km h^{-1} and the lowest level of quantity of seed in hopper (H_3) 0.298 kg, while the lowest precision index of 16.58% was obtained for lowest level (S_1) of forward speed 1.3 km h^{-1} and highest level (H_1) of quantity of seed in hopper 2.382 kg. Precision index decreased from 16.58% to 20.45% when the forward speed increased from 1.3 km h^{-1} (S_1) to 3.5 km h^{-1} (S_3) and decrease of quantity of seed from 2.382 kg (H_1) to 0.298 kg (H_3). Lower values of the precision index indicate better performance than higher values of the precision index as reported by Kachman and Smith (1995) and Celik et al. (2007).

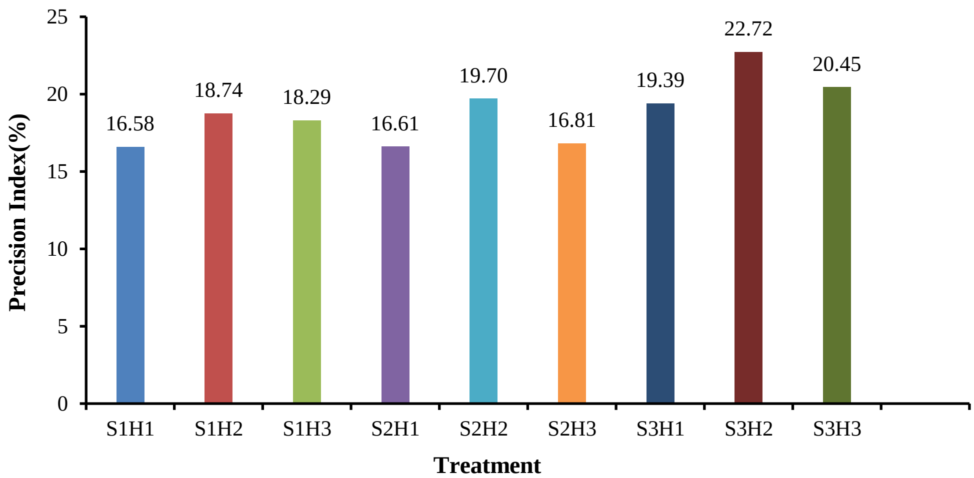

Figure 6 Effect of forward speed and quantity of seeds on Precision index

Analysis of variance (ANOVA) showed that forward speed (S) was significant ($P<0.05$) on the precision index, the quantity of seeds in the hopper (H) and their interaction (SH) is not significant ($P>0.05$) on the precision index.

3.4.2 Seed distribution pattern

Seed distributions pattern in terms of number of seeing for a given length of run, percentage of dropping single seed per hill, percentage of dropping double seed per hill, percentage of dropping triple seed per hill, percentage of dropping multiple seed per hill, seed rate (kg ha^{-1}) and seed damage in percentage caused by metering roller are shown in Table 6 and Figure 7. In addition, the results were analyzed statistically to determine the effect of the forward speed (S), quantity of seed in hopper (H) and their interaction (SH).

Table 6 Summarized result of seed distribution pattern

Output variable for 20 m length of run	Experiment run								
	S_1H_1	S_1H_2	S_1H_3	S_2H_1	S_2H_2	S_2H_3	S_3H_1	S_3H_2	S_3H_3
Number of seeding per 20 m run	73	76	74	72	75	74	73	72	76
Mean number of seed per hills	2.7	2.8	2.6	2.7	2.5	2.6	2.7	2.6	2.7
Percentage of dropping single seed per 20 m run	9.6	11.7	10.7	12.3	15.9	9.4	11.0	15.2	12.7
Percentage of dropping double seed per 20 m run	36.5	26.4	36.1	32.5	31.9	40.9	28.7	30.3	36.2
Percentage of dropping triple seed per 20 m run	34.8	36.0	36.7	34.3	30.6	32.5	32.6	29.0	27.8
Percentage of dropping multiple seed per 20 m run	19.1	25.9	16.5	20.9	17.2	17.2	18.7	22.7	23.2
Seed rate (kg ha^{-1})	8.83	8.64	8.18	8.23	8.37	8.22	7.74	7.93	7.37
Seed rate (kg $acre^{-1}$)	3.53	3.46	3.27	3.29	3.35	3.29	3.10	3.17	2.95
Seed damage (%)	1.14	1.93	1.26	1.35	1.21	2.17	3.08	1.86	2.09

Note: * The values denote average values from three replications

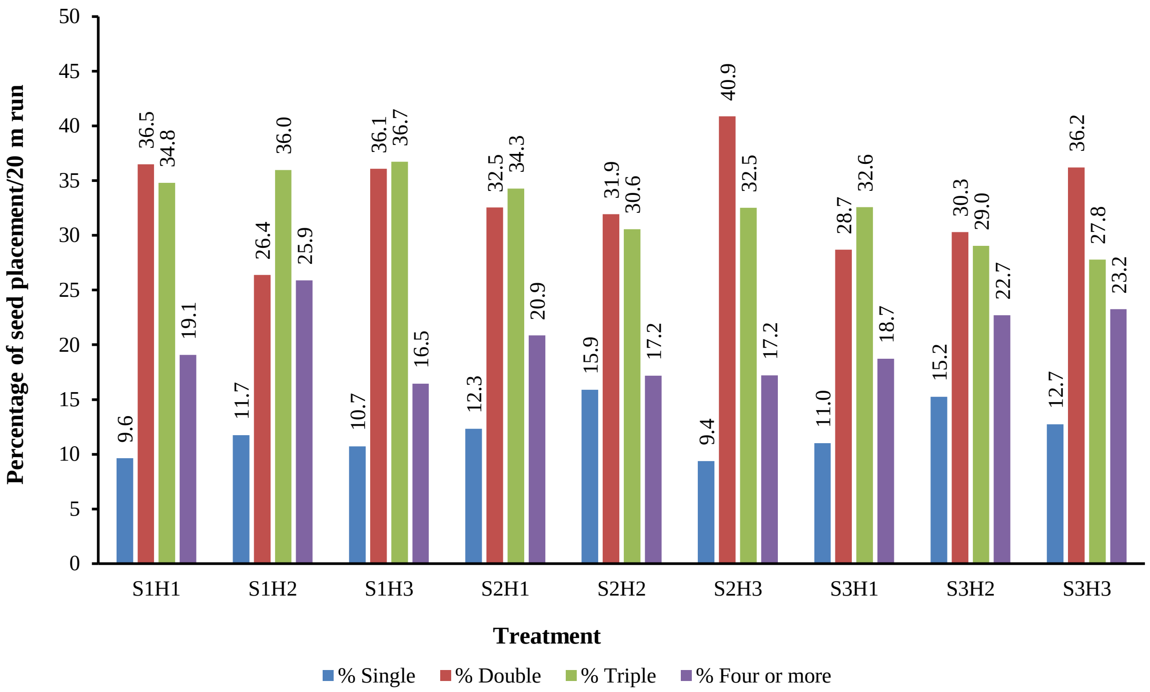

Figure 7 Effect of forward speed and quantity of seed-on-seed distribution pattern

The results were analyzed statistically to determine the effect of the forward speed (S), quantity of seed in hopper (H) and their interaction (SH) as describe hereunder.

3.4.2.1 Percentage of dropping single seed per hill

The effect of planter forward speed (S) and quantity of seed in hopper (H) is presented in Table 7 and Figure 12. It observed that percentage of dropping single seed per 20 meter running length ranged from 9.4% to 15.9% for all combinations of forward speed (S) and quantity of seed in hopper (H). The highest percent of 15.9% was observed for the intermediate level (S_2) of forward speed 2.2 km h^{-1} and intermediate level (H_2) of quantity of seed in hopper 1.191 kg, while the lowest percent of 9.4% was observed for the intermediate level (S_2) of forward speed 2.2 km h^{-1} and lowest level (H_3) of quantity of seed in hopper 0.298 kg. Percentage of dropping single seed per 20-meter run decreased from 15.9% to 9.4% when quantity of seed in hopper decreased from 1.191 kg to 0.298 kg with no change in forward speed of 2.2 km h^{-1} (S_2). To some extent, this is not a desirable feature for a planter, it provides a chance to have missed hill when seed failure to germinate, however, it was observed that seed size and packaging nature of seed in the cell had some influence on number of seed dropped. Similar trends of 14% of dropping single seed per hill for a 6-meter running length was reported by Abebe (2017) for maize.

Analysis of variance (ANOVA) showed that none of the planter forward speed, quantity of seeds in the hopper and their interaction was significant ($p > 0.05$) on percentage of dropping single seed.

3.4.2.2 Percentage of dropping double seeds per hill

The effect of planter forward speed (S) and quantity of seed in hopper (H is presented in Table 7 and Figure 12. It was observed that percentage of dropping two seed per 20 meter running length ranged from 26.4% to 40.9% for all combinations of forward speed (S) and quantity of seed in hopper (H). The highest percent of 40.9% was observed for the intermediate level (S_2) of forward speed 2.2 km h^{-1} and lowest level (H_3) of quantity of seed in hopper 0.298 kg, while lowest percent of 26.4% was observed for the lowest level (S_1) of forward speed 1.3 km h^{-1} and intermediate level (H_2) of quantity of seed in hopper 1.191kg. Percentage of dropping two seed per 20 meter run increased from 26.4% to 40.9% when forward speed (S) increased from 1.3 km h^{-1} (S_1) to 2.2 km h^{-1} (S_2) with decrease of quantity of seed in hopper from 1.191 kg (H_2) to 0.298 kg (H_3). It is observed that dropping two seeds per hill is the desirable feature for a planter (Singh and Sharma, 2006). Similar results were reported by Abebe (2017) for maize, Singh and Sharma (2006) for sunflower and Singh et al. (2006) for sunflower.

Analysis of variance (ANOVA) showed that, quantity of seeds in the hopper was significant ($p \leq 0.05$) while forward speed and their interaction were not significant ($p > 0.05$) on percentage of dropping single seed.

3.4.2.3 Percentage of dropping triple seeds per hill

The effect of planter forward speed (S) and quantity of seed in hopper (H) is presented in Table 7 and Figure 12. It was observed that percentage of dropping three seed per 20 meter running length ranged from 27.8% to 34.8% for all combinations of forward speed (S) and quantity of seed in hopper (H). The highest percent of 34.8% was observed for the lowest level (S_1) of forward speed 1.3 km h^{-1} and the highest level (H_1) of quantity of seed in hopper 2.382 kg, while the lowest percent of 27.8% was observed for the highest level (S_3) of forward speed 3.5 km h^{-1} and lowest level (H_3) of quantity of seed in hopper 0.298 kg. Percentage of dropping three seed per hill decreased from 34.8% to 27.8% when forward speed increased from 1.3 km h^{-1} (S_1) to 3.5 km h^{-1} (S_3) with a decrease of quantity of seed in hopper from 2.392 kg (H_1) to 0.298 kg (H_3). It was observed that dropping three seeds per hill is the desirable feature for a planter (Singh and Sharma, 2006). Similar results reported by Singh et al. (2006) for sunflower.

Analysis of variance (ANOVA) showed that none of the planter forward speed (S), quantity of seeds in the hopper (H) and their interaction (SH) were not significant ($p > 0.05$) on percentage of dropping three seed per hill.

3.4.2.4 Percentage of dropping multiple seed per hill

The effect of planter forward speed (S) and quantity of seed in hopper (H) is presented in Table 7 and Figure 12. It was observed that percentage of dropping multiple seed (four seeds and above) per 20 meter running length ranged from 16.5% to 25.9% for all combinations of forward speed (S) and quantity of seed in hopper (H). The highest percent of 25.9% was observed for the lowest level (S_1) of forward speed 1.3 km h^{-1} and intermediate level (H_2)

of quantity of seed in hopper 1.191 kg, while lowest percent of 16.5% was observed for the lowest level (S_1) of forward speed 1.3 km h^{-1} and lowest level (H_3) of quantity of seed in hopper 0.298 kg. Percentage of dropping multiple seed per hill decreased from 25.9% to 16.5% when quantity of seed in hopper decreased from 1.191 kg (H_2) to 0.298 kg (H_3). It was observed that multiple seed are influenced by seed size, clearance between seed metering roller and seed meter housing and the packaging nature of seed in the cell. Dropping four or more seeds per hill is a desirable feature for a planter (Singh and Sharma, 2006). However, it involved thinning to avoid competition and to maintain single seed per hill. Similar results were reported by Abebe (2017) for maize.

Analysis of variance (ANOVA) showed that planter forward speed (S), quantity of seeds in the hopper (H) and their interaction (SH) were significant ($p \leq 0.05$) on percentage of dropping multiple seed per hill.

3.4.2.5 Mean number of seeding

The effect of planter forward speed (S) and quantity of seed in hopper (H) is presented in Table 7 and Figure 8. It was observed that number of seeds per 20 meter running length ranged from 72 to 76 for all combinations of forward speed (S) and quantity of seed in hopper (H). The highest number of seeding 76 was observed at forward speed of 1.3 km h^{-1} (S1) and 3.5 km h^{-1} (S_3) with quantity of seed in hopper 1.191 kg (H_2) and 0.298 kg (H_3) respectively, while lowest number of seeding 72 was observed at forward speed of 2.2 km h^{-1} and 3.5 km h^{-1} with quantity of seed in hopper 2.382 kg (H_1) and 1.191 gm (H_2). Values of mean number of seeding indicate number of points where seed will be dropped for a 20-meter running length with respect to the desired number of seeding which ranged from 66 to 80 for a desired spacing of 25 cm to 30 cm respectively. It is observed that number of seeding is influenced by a failure of a seed to be dropped and slippage from ground wheel.

In the analysis of variance (ANOVA), the results showed that, none of the planter forward speed (S), quantity of seeds in the hopper (H) and their interaction (SH) were not significant ($p > 0.05$) on the mean number of seeding.

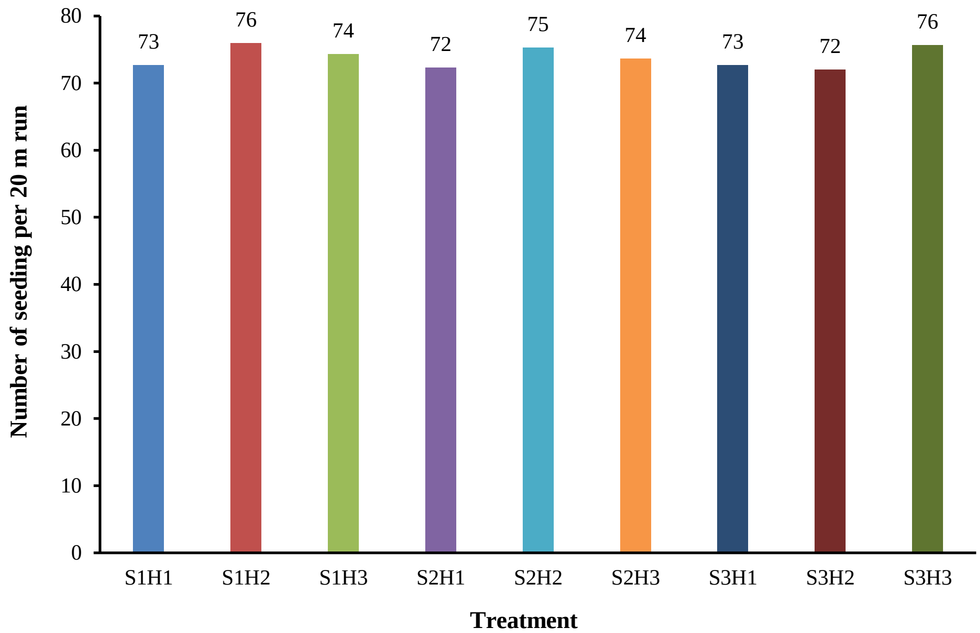

Figure 8 Effect of forward speed and quantity of seeds on number of seeds

3.4.2.6 Seed rate

The effect of planter forward speed (S) and quantity of seed in hopper (H) is presented in Table 7. It was observed that seed rate ranged from 7.37 kg ha^{-1} (2.95 kg $acre^{-1}$) to 8.83 kg ha^{-1} (3.53 kg $acre^{-1}$) for all combination of forward speed (S) and quantity of seed in hopper (H). The highest seed rate of 8.83 kg ha^{-1} was observed for the lowest level (S_1) of forward speed 1.3 km h^{-1} and highest level (H_1) of quantity of seed in hopper 2.382 kg, while the lowest seed rate of 7.37 kg ha^{-1} was observed for highest level (S_3) of forward speed 3.5 km h^{-1} and lowest level (H_3) of quantity of seed in hopper 0.298 kg. Seed rate decreased from 8.83 kg ha^{-1} to 7.37 kg ha^{-1} when forward speed increased from 1.3 km h^{-1} (S_1) to 3.5 km h^{-1} (S_3) and the decrease of quantity of seed from 2.382 kg (H_1) to 0.298 kg (H_3) as shown in Figure 9. It was observed that seed rate is influenced by failure of seed to be dropped, that increase of forward speed leads to having short time for the cell to pick up the seed and the seed itself fails to position into the cell.

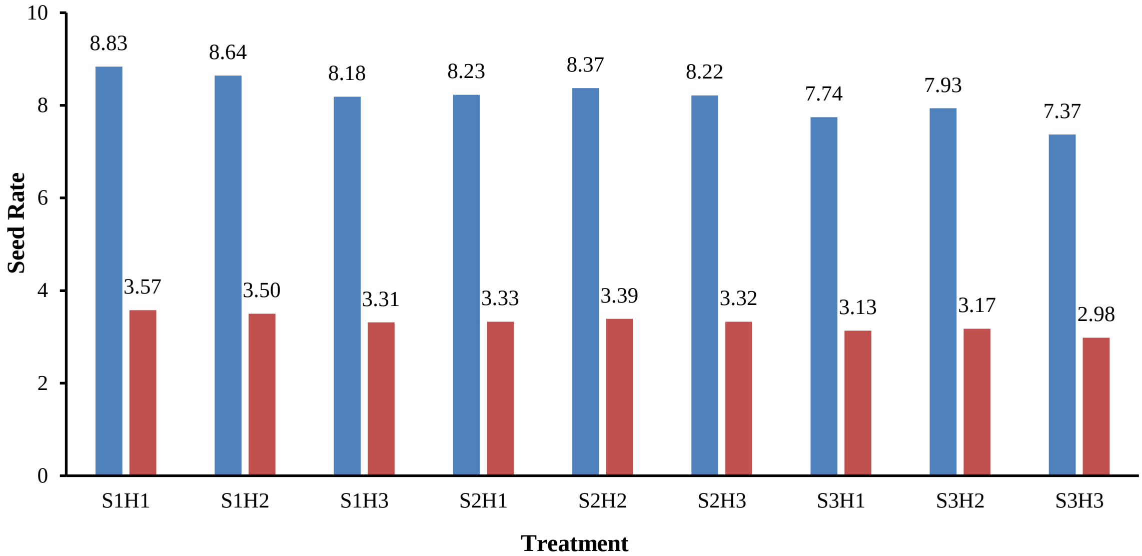

Figure 9 Effect of forward speed and quantity of seeds on seed rate

Analysis of variance (ANOVA) showed that forward speed (S) was significant ($p \leq 0.05$) on the seed rate, quantity of seeds in the hopper (H) and their interaction (SH) were not significant ($p > 0.05$) on the seed rate. The similar result was reported by Sahoo and Srivastava (2000 for the evaluation of inclined plate metering mechanism for direct seeded rice.

3.4.2.7 Seed damage

The effect of planter forward speed (S) and quantity of seed in hopper (H) is presented in Table 7. It was observed that seed damage ranged from 1.14% to 3.08% for all combination of forward speed (S) and quantity of seed in hopper (H). The highest seed damage of 3.08% was observed for the highest level (S_3) of forward speed 3.5 km h^{-1} and highest level (H_1) of quantity of seed in hopper 2.382 kg, while the lowest seed damage of 1.14% was observed for lowest level (S_1) of forward speed 1.3 km h^{-1} and highest level (H_1) of quantity of seed in hopper 2.382 kg. Seed damage increased from 1.14% to 3.08% when forward speed increased from 1.3 km h-1(S_1) to 3.5 km h^{-1} (S_3) as shown in Figure 10`. It observed that seed damage is influenced the workmanship and good geometry of the seed feed cutting–off device. Similar results were reported by Shiddanagouda et al., (2013) for carrot, Anantachar et al., (2010) for peanuts, Ani et al., (2016) for maize, Oduma et al., (2014) for cowpea, Sahoo and Srivastava (2000) for okra seed, Gupta and Herwanto (1992) for paddy, Ashoka et al., (2012) for groundnut.

Analysis of variance (ANOVA) showed that forward speed (S), quantity of seeds in the hopper (H) and their interaction (SH) were not significant (p >0.05) on seed damage from metering roller.

3.4.3 Mean comparison on different types of sunflowers planter

Performance results of the developed power tiller-drawn sunflower planter were compared with other planters used for sunflower planting as shown in Appendix I and the results showed that under normal field conditions and operations, the developed power tiller-drawn sunflower planter with triangular cell metering roller perform satisfactory in terms of mean spacing, coefficient of variation, miss index, multiple indexes, quality of feed index, precision index, seed damage and seed rate.

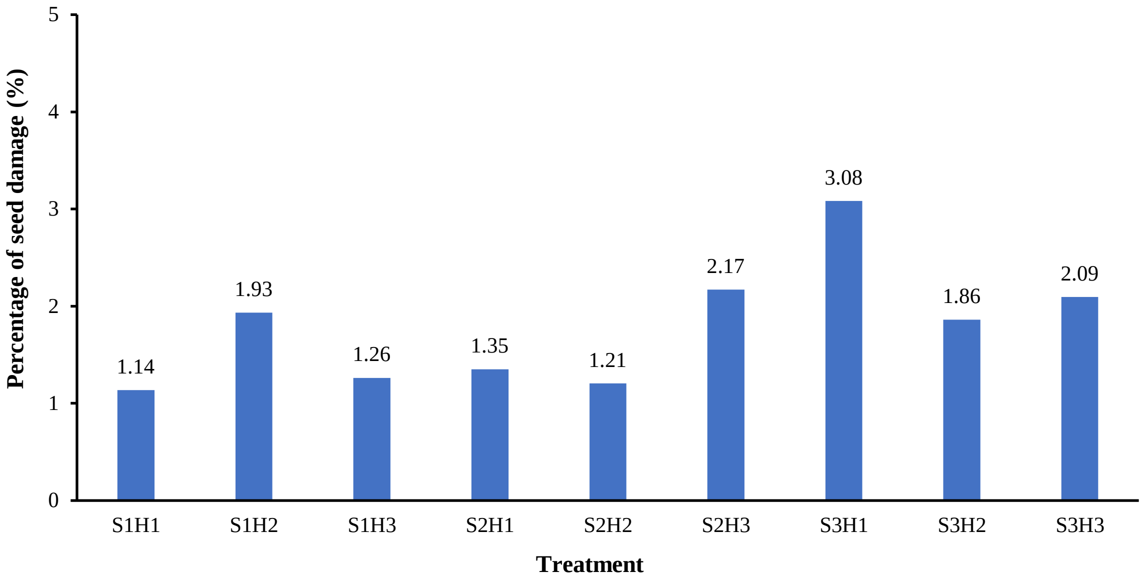

Figure 10 Effect of forward speed and quantity of seeds on seed damage

4 Conclusions

Triangular cell sunflower metering roller was adopted and adapted to the developed power tiller-drawn planter to form power tiller drawn sunflower planter. The developed planter consists of metering unit, furrow openers, seed covering device, frame and draw bar, provisional were made to adjust depth of furrow openers, seed covering device and hill distance. Planter performs all planting operations in a single pass excluding hopper feeding. Specifications of the planter include its nominal working width of 1.5 meter, hoppers capacities 4.6 kg and seed rate 8.83 kg ha^{-1}. Performance of the power tiller drawn sunflower planter under field conditions in terms of uniformity of spacing and seed distribution pattern were used to describe its working performance of the triangular cell sunflower metering roller.

The minimum values of miss index 2.25%, multiple indexes 0.00%, precision index 16.58%, mean longitudinal displacement 3.65 cm, mean spacing 26.16 cm, coefficient of variation in spacing 15.3% and maximum values of quality of feed index 97.33% were used to describe uniformity of spacing , and minimum percentage of dropping single seed per hill 9.6%, multiple seeds per hill 16.5%, seed damage 1.14% and maximum percentage of dropping double seed per hill 40.9%, triple seed per hill 34.8%, number of seedling 76, seed rate 8.83 kg ha^{-1} were used to describe seed distribution pattern.

The best performance of the developed power tiller drawn sunflower planter was at the forward speed of 1.3 km h^{-1} and quantity of seed in the hopper of 2.382kg which provides a 2.25% miss index, 0.43% multiple index, 97.33% quality of feed index, 16.58% precision index, 26.16 cm mean spacing, 15.81% coefficient of variation on spacing, 8.83 kg ha^{-1} seed rate, 73 number of seedling per 20 meters run, 1.14% seed damage, 90.36% of dropping multiple seeds per hill and 9.64% of dropping single seed per hill. Based on agronomical recommendations for sunflower planting and performance comparison with other sunflower metering device under field conditions, it is concluded that the developed power tiller-drawn sunflower seed planter can perform efficiently and may be adopted by small and medium farmers.

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Conflict of Interest

The authors declare that there is no any conflict of interest in this manuscript.

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APPENDIX I Mean Comparison on Types of Sunflowers Planter

Table 1 Mean comparison on spacing

S/N	Types of Planters	Metering Device	Speed of Operation m/min (Metering device)	Speed of Operation Km/h (Forward speed)	Mean Spacing (cm)
1	Performance of triangular cell sunflower seed meter under field conditions using power tiller	Triangular cell seed metering roller	3.6 – 9.6	1.3 – 3.5	26.16 – 27.89
2	Precision vacuum planter (Celik et al., 2007)	Seed cell wheel		3.6 – 7.2	50.57
3	No-till planter (Celik et al., 2007)	Studded seed roller		3.6 – 7.2	38.12
4	Universal planter (Celik et al., 2007)	Studded seed roller		3.6 – 7.2	37.96
5	Semi-automatic Potato planter (Celik et al., 2007)	Horizontal spacing wheel		3.6 – 7.2	40.76
6	Technical feasibility of mechanical planting of sunflower planter (Singh and Sharma, 2006)	Uniformly shaped triangular small cell type roller	4.11 – 16.04	-	18.53
7	Development and testing of power tiller operated multi-crop seed cum fertilizer drill (Verma and Gupta, 2016)	Nylon roller	-	2.88	-

Table 2 Mean comparison on coefficient of variation

S/N	Types of Planters	Metering Device	Speed of Operation m/min (Metering device)	Speed of Operation Km/h (Forward speed)	CV (%)
1	Performance of triangular cell sunflower seed meter under field conditions using power tiller	Triangular cell seed metering roller	3.6 – 9.6	1.3 – 3.5	15.3 – 21.42
2	Precision vacuum planter (Celik et al., 2007)	Seed cell wheel	-	3.6 – 7.2	52.6
3	No-till planter (Celik et al., 2007)	Studded seed roller	-	3.6 – 7.2	45.6
4	Universal planter (Celik et al., 2007)	Studded seed roller	-	3.6 – 7.2	55.1
5	Semi-automatic Potato planter (Celik et al., 2007)	Horizontal spacing wheel	-	3.6 – 7.2	64.0
6	Technical feasibility of mechanical planting of sunflower planter (Singh & Sharma, 2006)	Uniformly shaped triangular small cell type roller	4.11 – 16.04	-	-
7	Development and testing of power tiller operated multi-crop seed cum fertilizer drill (Verma & Gupta, 2016)	Nylon roller	-	2.88	-

Table 3 Mean comparison on miss index

S/N	Types of Planters	Metering Device	Speed of Operation m/min (Metering device)	Speed of Operation Km/h (Forward speed)	Miss index (%)
1	Performance of triangular cell sunflower seed meter under field conditions using power tiller	Triangular cell seed metering roller	3.6 – 9.6	1.3 – 3.5	2.25 – 8.95
2	Precision vacuum planter (Celik et al., 2007)	Seed cell wheel	-	3.6 – 7.2	27.2
3	No-till planter (Celik et al., 2007)	Studded seed roller	-	3.6 – 7.2	5.1
4	Universal planter (Celik, Ozturk & Way, 2007)	Studded seed roller	-	3.6 – 7.2	10.2
5	Semi-automatic Potato planter (Celik, Ozturk & Way, 2007)	Horizontal spacing wheel	-	3.6 – 7.2	14.2
6	Technical feasibility of mechanical planting of sunflower planter (Singh & Sharma, 2006)	Uniformly shaped triangular small cell type roller	4.11 – 16.04	-	-
7	Development and testing of power tiller operated multi-crop seed cum fertilizer drill (Verma & Gupta, 2016)	Nylon roller		2.88	-

Table 4 Mean comparison on multiple indexes

S/N	Types of Planters	Metering Device	Speed of Operation m/min (Metering device)	Speed of Operation Km/h (Forward speed)	Multiple index (%)
1	Performance of triangular cell sunflower seed meter under field conditions using power tiller	Triangular cell seed metering roller	3.6 – 9.6	1.3 – 3.5	0.0 – 1.28
2	Precision vacuum planter (Celik et al., 2007)	Seed cell wheel		3.6 – 7.2	11.9
3	No-till planter (Celik et al., 2007)	Studded seed roller		3.6 – 7.2	11.9
4	Universal planter (Celik et al., 2007)	Studded seed roller		3.6 – 7.2	18.7
5	Semi-automatic Potato planter (Celik et al., 2007)	Horizontal spacing wheel		3.6 – 7.2	19.3
6	Technical feasibility of mechanical planting of sunflower planter (Sukhbir & Sharma, 2006)	Uniformly shaped triangular small cell type roller	4.11 – 16.04	-	-
7	Development and testing of power tiller operated multi-crop seed cum fertilizer drill (Verma & Gupta, 2016)	Nylon roller		2.88	-

Table 5 Mean comparison on quality of feed index

S/N	Types of Planters	Metering Device	Speed of Operation m/min (Metering device)	Speed of Operation Km/h (Forward speed)	Quality of feed index (%)
1	Performance of triangular cell sunflower seed meter under field conditions using power tiller	Triangular cell seed metering roller	3.6 – 9.6	1.3 – 3.5	91.05 – 97.33
2	Precision vacuum planter (Celik et al., 2007)	Seed cell wheel	-	3.6 – 7.2	60.9
3	No-till planter (Celik et al., 2007)	Studded seed roller	-	3.6 – 7.2	83.0
4	Universal planter (Celik et al., 2007)	Studded seed roller	-	3.6 – 7.2	71.1
5	Semi-automatic Potato planter (Celik et al., 2007)	Horizontal spacing wheel	-	3.6 – 7.2	66.6
6	Technical feasibility of mechanical planting of sunflower planter (Singh and Sharma, 2006)	Uniformly shaped triangular small cell type roller	4.11 – 16.04	-	
7	Development and testing of power tiller operated multi-crop seed cum fertilizer drill (Verma and Gupta, 2016)	Nylon roller		2.88	-

Table 6 Mean comparison on precision index

S/N	Types of Planters	Metering Device	Speed of Operation m/min (Metering device)	Speed of Operation Km/h (Forward speed)	Precision index (%)
1	Performance of triangular cell sunflower seed meter under field conditions using power tiller	Triangular cell seed metering roller	3.6 – 9.6	1.3 – 3.5	16.58 – 22.72
2	Precision vacuum planter (Celik et al., 2007)	Seed cell wheel		3.6 – 7.2	32.9
3	No-till planter (Celik et al., 2007)	Studded seed roller		3.6 – 7.2	29.7
4	Universal planter (Celik, Ozturk & Way, 2007)	Studded seed roller		3.6 – 7.2	31.4
5	Semi-automatic Potato planter (Celik, Ozturk & Way, 2007)	Horizontal spacing wheel		3.6 – 7.2	31.9
6	Technical feasibility of mechanical planting of sunflower planter (Singh & Sharma, 2006)	Uniformly shaped triangular small cell type roller	4.11 – 16.04	-	
7	Development and testing of power tiller operated multi-crop seed cum fertilizer drill (Verma & Gupta, 2016)	Nylon roller		2.88	

Table 7 Mean Comparison on number of seeds dropped per hill

S/N	Types of Planters	Metering Device	Speed of Operation		Seed Range
			m/min (Metering device)	Km/h (Forward speed)	
1	Performance of triangular cell sunflower seed meter under field conditions using power tiller	Triangular cell seed metering roller	3.6 – 9.6	1.3 – 3.5	2 – 3
2	Precision vacuum planter (Celik et al., 2007)	Seed cell wheel	-	3.6 – 7.2	-
3	No-till planter (Celik et al., 2007)	Studded seed roller	-	3.6 – 7.2	-
4	Universal planter (Celik et al., 2007)	Studded seed roller	-	3.6 – 7.2	-
5	Semi-automatic Potato planter (Celik et al., 2007)	Horizontal spacing wheel	-	3.6 – 7.2	-
6	Technical feasibility of mechanical planting of sunflower planter (Singh & Sharma, 2006)	Uniformly shaped triangular small cell type roller	4.11 – 16.04	-	2 - 3
7	Development and testing of power tiller operated multi-crop seed cum fertilizer drill (Verma & Gupta, 2016)	Nylon roller		2.88	-

Table 8 Mean comparison on percentage of seed damage

S/N	Types of Planters	Metering Device	Speed of Operation		Percentage of seed damage (%)
			m/min (Metering device)	Km/h (Forward speed)	
1	Performance of triangular cell sunflower seed meter under field conditions using power tiller	Triangular cell seed metering roller	3.6 – 9.6	1.3 – 3.5	1.14 – 3.08
2	Precision vacuum planter (Celik, Ozturk & Way, 2007)	Seed cell wheel	-	3.6 – 7.2	-
3	No-till planter (Celik, Ozturk & Way, 2007)	Studded seed roller	-	3.6 – 7.2	-
4	Universal planter (Celik, Ozturk & Way, 2007)	Studded seed roller	-	3.6 – 7.2	-
5	Semi-automatic Potato planter (Celik, Ozturk & Way, 2007)	Horizontal spacing wheel	-	3.6 – 7.2	-
6	Technical feasibility of mechanical planting of sunflower planter (Singh & Sharma, 2006)	Uniformly shaped triangular small cell type roller	4.11 – 16.04	-	3.96 – 9.11
7	Development and testing of power tiller operated multi-crop seed cum fertilizer drill (Verma & Gupta, 2016)	Nylon roller		2.88	Nil

Table 9 Mean comparison on seed rate

S/N	Types of Planters	Metering Device	Speed of Operation		Seed Rate (kg/ha)
			m/min (Metering device)	Km/h (Forward speed)	
1	Performance of triangular cell sunflower seed meter under field conditions using power tiller	Triangular cell seed metering roller	3.6 – 9.6	1.3 – 3.5	7.37 – 8.83
2	Precision vacuum planter (Celik et al., 2007)	Seed cell wheel	-	3.6 – 7.2	-
3	No-till planter (Celik et al., 2007)	Studded seed roller	-	3.6 – 7.2	-
4	Universal planter (Celik et al., 2007)	Studded seed roller	-	3.6 – 7.2	-
5	Semi-automatic Potato planter (Celik et al., 2007)	Horizontal spacing wheel	-	3.6 – 7.2	-
6	Technical feasibility of mechanical planting of sunflower planter (Singh & Sharma, 2006)	Uniformly shaped triangular small cell type roller	4.11 – 16.04	-	4.32
7	Development and testing of power tiller operated multi-crop seed cum fertilizer drill (Verma & Gupta, 2016)	Nylon roller		2.88	3.53 – 14.15