Design and development of a vertical plate precision seed metering device with positive seed knockout mechanism

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Abstract: Planting seeds according to agronomic requirements is one of the most important and critical farm operations for crop cultivation. Placing seeds at a proper location is required to maintain the plant to plant spacing in a row. A vertical plate precision seed metering device was designed and developed for field pea. Cells with three different depths of 8.48, 8.85 and 9.22 mm and three shapes of 20^o, 30^o and 40^o left side angles were designed to obtain nine different plates. A seed metering device with different plates was fabricated and mounted on the experimental setup. The performance of the metering device was evaluated under laboratory conditions at three speeds of 37.04, 44.45 and 51.86 rpm. The results showed occurrence of stuck up seeds in the cells and higher missing hills which may be due to non-release of seeds from the seed metering device. To release seed from the metering device, a mechanism for positive seed knockout was designed and incorporated in the developed metering device of different sizes and shapes of vertical plates. The performance of vertical plate precision seed metering device with positive seed knockout mechanism was also evaluated under laboratory conditions. The results showed that cells of 8.48 mm depth and 40^o left side angle on a vertical plate seed metering device with positive seed knockout mechanism performed better with lowest average missing index of 2.67%, multiple index of 0.5% and highest uniformity of seed placement of 96.83%. Stuck up of seeds in the cells of the seed metering device was not observed after incorporating a positive seed knockout mechanism.

Keywords: precision, design, planter, missing hills, vertical plate, seed knockout.

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1 Introduction

Agricultural inputs including improved tools, implements and machinery are essential for increasing farm output. Multiple cropping also requires improved tools, implements, and machinery for land preparation and sowing of seeds for the second crop because of time limitation. Sowing is one of the most critical and important agricultural operations and requires seeds to be placed in rows at the desired depth, maintain uniform hill to hill spacing, cover the seeds with soil and provide proper compaction over the seeds. However, agronomic requirements such as row to row distance, seed to seed spacing, depth of sowing and seed rate depend on the crop, soil, and climatic conditions.

The traditional method of sowing is still widely practiced in hill agriculture in India for sowing of field crops. Seeds are usually sown manually through broadcasting or by dibbling, particularly in hill agriculture. Broadcast seeding does not maintain uniform seed spacing -and depth that causes unhealthy

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plants and lower yield. Broadcast seeding also requires a high seed rate (Maheshwari et al., 2006). Dibbling, on the other hand, maintains row to row distance and plant to plant spacing but is labor-intensive operation. Seeds sown in line is almost negligible in hill areas due to the lack of proper sowing devices. Singh et al. (2017) reported that farm machinery suitable for plain areas is not suitable in the hills due to uneven topography and smaller size of landholdings. Furthermore, animal-drawn seed drills and planters are also not suitable due to very few draught animals. Therefore, the use of seed drills and planters is negligible in the hilly regions of northeast India.

The yield of a crop is greatly affected due to delay in sowing. Precise depth of sowing of seeds and uniform hill spacing with the required seed rate is reported to increase crop yield (Tuğrul et al., 2012). Precision planting of seeds is required for high yielding variety and costly seeds. Precision planters are usually designed to place a single seed in each hill at the required spacing and uniform depth into the soil (Kepner et al., 1987). Roller type, belt type, plate type, pneumatic (air-pressure), and vacuum disk type seed metering devices are used in precision planter (Ryu and Kim, 1998). Of these, plate type and roller type are most widely used. Bamgboye and Mofolasayo (2006) evaluated the performance of a manually operated two-row okra planter and studied the effects on discharged seed weight, seed spacing, depth of seed placement and effective field capacity. Ani et al. (2016) developed a vertical plate type maize planter which sown two seeds per hill. Matin et al. (2008) evaluated maize planter having an inclined plate seed metering device and compared its performance with that of the traditional method of sowing. Grewal et al. (2015) developed a tractor operated six-row planter with three different numbers of grooves (18, 24 and 30) on an inclined plate for sowing onion seeds. The performance of the developed planter was evaluated under laboratory conditions. Liu et al. (2015) studied four plate series of vertical disc seed metering devices to develop minimum planter plate series which will cover seed sizes of all soybean varieties in China. A horizontal plate seed metering mechanism was developed by Reddy and Adake (2013) and tested in laboratory and field condition. The uniformity of seed placement were in the range of 85.0%-90.5% and 82.7%-97.0% respectively for maize and caster. Ivancan et al. (2004) outlined strong influence of speed of operation on drilling quality of a seed drill. Bakhtiari and Ahmad (2017) developed a vacuum type seed metering device for planting kenaf seeds using six plate opening diameters. The studies showed considerable variation in performance of the planters. Wankhade and Kotwal (2014) reviewed seed metering devices of planting machinery and reported large variation in miss indexes, multiple indexes and feed indexes of different metering devices. Variation in the performance of different planter may be due to different seeds and designs of the planter.

Field pea is a crop widely grown in all over the world and well adapted in different parts of India. The review of the literature shows that the existing planters may not be suitable for sowing of field pea in the hilly terrain of northeast India. Therefore a study was undertaken to design and develop a precision seed metering device for field pea. In this study, a vertical plate type seed metering device was designed and developed for precision planting of field pea. Initially, the metering device was developed without a seed knockout mechanism and the performance was evaluated under laboratory condition. Performance of the seed metering device shown clogged cells due to seeds stuck up in the cell. Therefore, a positive seed knockout mechanism was developed and performance was evaluated.

2 Theoretical considerations

2.1 Working principles

Each cell of a plate-type seed metering device picks up a seed from the hopper and delivers it into the seed tube. As the plate rotates, a seed is fed into a cell by gravity. A cut-off device wipes off excess seed from the cells thus each cell carries only a single seed. A single seed travels toward the seed tube and the spring-loaded knockout device pushes the seed from the cell for delivery in the seed tube. Figure 1 shows the schematic view of the seed delivery pattern of a vertical plate-type seed metering device. Fall of a seed from a cell depends on the angle of repose of seed and friction angle (Ryu and Kim, 1998). A seed in the cell begins to slide and fall if the sliding angle exceeds the angle of repose of the seed or the component of the seed weight in the direction tangent to the cell surface exceeds the friction force between seed and cell surface.

2.2 Requirements of a precision seed metering device

Seed metering device of a precision planter must fulfill the following requirements for satisfactory performance (Kepner et al., 1987).

1.The cells of a planter must be of proper size with respect to the seeds.

2.The seed must get sufficient time to enter the cell and therefore the plate speed and exposure distance of the cells in the hopper are the two most important design parameters. Lower plate speed is better as compared with long exposure distance.

3.A proper seed cut-off device is required to reduce seed damage (breakage).

4.Positive unloading of the seeds must be provided from the cells.

5.Germination of seed must not be affected due to damage.

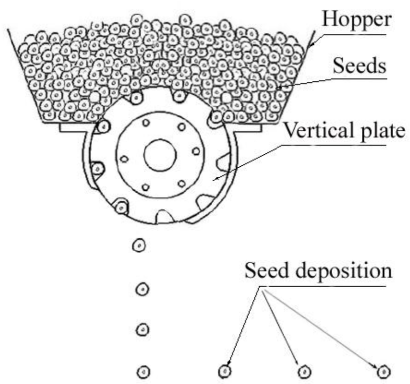


Figure 1 Seed delivery pattern of a plate-type seed metering device

2.3 Factors affecting performance of seed metering plate

The two most important design parameters for a precision seed metering device are the size and shape of the cells and, the number of cells in a plate. The shape of cell is the most critical factor which affects the dropping of the seed from a seed metering device (Ryu and Kim, 1998; Ahmadi et al., 2008). The size, shape, sphericity, true density and angle of repose of seeds affect the flow characteristics of the seeds in a planter (Jayan and Kumar, 2004).

The size of a cell should be sufficient to allow the seed to fill however large cell size increases seed damage. The percent cell fill is influenced by maximum seed size with respect to cell size, the range of seed sizes, the shape of seeds, the shape of cells, exposure time of a cell to seed in the hopper and the linear speed of the cell (Kepner et al., 1987). For precision seed metering devices, the open-angle of the cell should be small (Ryu and Kim, 1998). However, it affects the feeding of seed into the cell and the dropping of the seed from the cell. Dropping of the seed from the cell must be positive. The left side angle of the cell is an important design parameter for a seed metering device as it affects the seed holding capacity of cell and the time delay between consecutive seed dropped from the cell. The decrease in the left side cell angle increases the time delay. The right side cell angle affects the seed feeding into the cell and seed holding capacity in it (Ryu and Kim, 1998). Poor performance in feeding and dropping due to the large value of the right side cell angle as compared with the left side cell angle was also reported. It was further emphasized that the right side cell angle should not be too large.

The cell diameter or length should be nearly 10% greater than the maximum size of the seed and the cell depth should be nearly equal to the average seed diameter or thickness (Kepner et al., 1987). Seed damage is greater, if the cell is too large however, shorter depth of a cell than the length of seed also resulted in more damaged seeds (Ryu and Kim, 1998). The percentage of seed damage increases as the cell speed increases (Kepner et al., 1987).

3 Design of seed metering device

3.1 Design of seed metering plate

A plate type seed metering device with nine cells was designed for sowing field pea. The major considerations for design of the metering mechanism of the precision pea planter were:

1.The metering plate should meter one seed per cell accurately.

2.Seed to seed spacing of 10 cm should be achieved (Yadav et al., 2009).

3.The maximum permissible peripheral velocity of the plate should be 16.5 m min^{-1} (Sharma and Mukesh, 2013).

4.The maximum permissible speed of the seed metering feed shaft should be 60 rpm (Sharma and Mukesh, 2013).

5.Precision seed metering device was designed for 'Rachna' variety of field pea. The measurement of physical properties showed the mean length of the seed as 7.38±0.38 mm, however, the variation in the maximum dimension was observed in the range of 5.39 mm (height) to 8.32 mm (length). The shape and size of the cells of the metering plate were designed considering the design parameters used in Ryu and Kim (1998). Figure 2 shows the shape of the cell on the seed metering plate which was designed considering the following four variables.

d_C is the depth of the cell. It was slightly higher than the average length of the seed to feed only one seed at a time. Considering the average length of the field pea, three different cell depths of 1.15, 1.20 and 1.25 times the average length of the seeds were designed for the seed metering device. The depth of the cells was therefore obtained as 8.48, 8.85 and 9.22 mm.

β_L is the left (seed delivery) side angle of the cell. Since this angle affects time delay between consecutive dropping, therefore a compromise has to be made. It was observed that a cell depth of 9.22 mm with 50^o will allow two seeds to be filled in the cell and therefore three values of this angle, i.e. 20^o, 30^o and 40^o were used in the design of the seed metering plates.

β_R is the right side angle of the cell. The right side cell angle should be less as compared with the left side cell angle. This angle was kept zero for all the cells.

R_C is the radius of curvature of the cell bottom. The value of this radius of curvature was taken as half the depth of the cells.

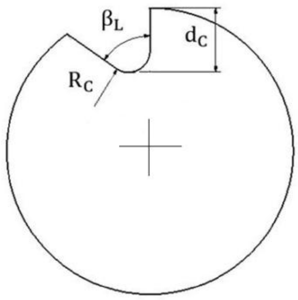


Figure 2 Cell design parameters

Considering the above four design parameters, nine different seed metering plates were designed. Profile of two seed metering plates with minimum cell depth and left side angle, and maximum cell depth and left side angle are shown in Figure 3. The width of a cell should be such that a single seed could be accommodated. Considering the largest length of field pea, the width of the cell in the seed metering device was designed to be nine millimeters. In order to accommodate a positive knockout mechanism, a spacer plate of 1.5 mm thick and 54 mm in diameter was provided in between pair of seed metering plates with cells. Figure 4 shows the exploded view of parts of the seed metering device with a positive seed knockout mechanism.

If the number of cells is more than necessary in a plate, it is difficult to keep the time interval between two consecutive seeds. Therefore a proper number of cells were determined considering the agronomic requirement. The diameter of the seed metering plates was determined using the following equation (Sharma and Mukesh, 2013):

$$dP=VR/(3.14\times1000\times N(R)) \qquad (1)$$

where,

dP = diameter of seed metering plates, mm

VR =maximum permissible peripheral velocity of seed metering plates, m min-1

NR = expected speed of seed metering feed shaft, rpm

Accordingly, seed metering plates were designed to be 86 mm in diameter.

The number of cells on the seed metering plates is the function of the speed of operation and the seed to seed spacing and therefore it was determined using the following equation (Sharma and Mukesh, 2013):

$$n = (3.14 \times Dw)/(iS \times SS) \quad (2)$$

where,

n = number of cells on the periphery of the seed metering plate;

Dw = diameter of the seed metering drive wheel, mm;

iS = speed ratio of the seed metering drive wheel shaft and seed metering feed shaft;

SS = expected seed to seed spacing, mm;

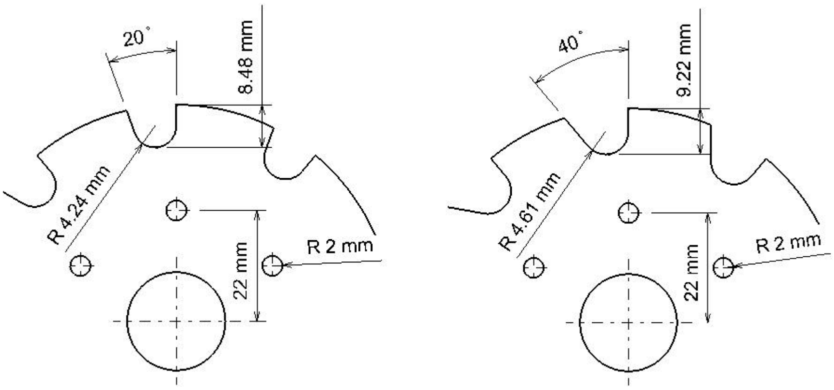


Figure 3 Cell profile with minimum and maximum depth and left side angle

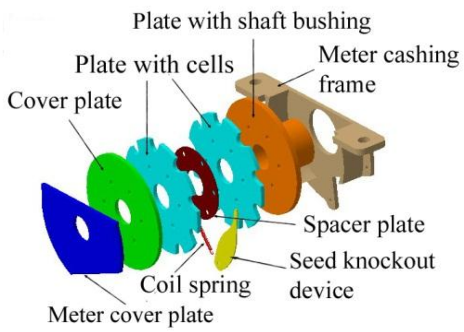


Figure 4 Exploded view of the seed metering device

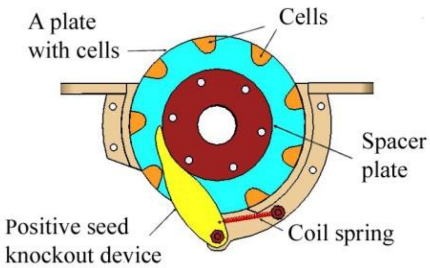


Figure 5 Seed metering device with seed knockout mechanism

Figure 6 A vertical plate seed metering device

3.2 Design of positive seed knockout mechanism

Performance evaluation of the seed metering device without the seed knockout mechanism showed considerably more missing index. Therefore, a positive seed knockout device was designed to release seed from the cells of the seed metering device. The seed knockout mechanism (Figure 5) was designed using CAD software (CATIA V5R17). One of the sides of the seed knockout mechanism was designed so that this side is in contact with the spacer plate of the seed metering device. Another side of the seed knockout mechanism pushes the seed from the cell. The seed knockout mechanism was held in its position by a coil spring.

4 Materials and methods

4.1 Experimental setup

The designed vertical plate precision seed metering device without and with seed knockout mechanism was fabricated for performance evaluation. Figure 6 shows a vertical plate seed metering device with a positive seed knockout mechanism. The experimental setup was fabricated for performance evaluation of the developed seed metering device under laboratory conditions. The developed seed metering device was mounted on a seed hopper. Power to the seed metering feed shaft was provided by an internal combustion engine. A gearbox was used to reduce the speed of the engine and to obtain different desired speeds. Figure 7 shows the experimental setup for the performance evaluation of the seed metering device.

Figure 7 Experimental setup used for performance evaluation of vertical plate precision seed metering device under laboratory condition

4.2 Experimental variables

Experiments were performed for nine different plates having three depths of cells, i.e. 8.48, 8.85 and 9.22 mm and three left-side angles of the cells, i.e. 20^o, 30^o and 40^o. The performance of the seed metering device was evaluated without and with the seed knockout mechanism. The experiments were performed at three different speeds of the seed metering device so as to obtain 0.56, 0.67 and 0.78 m s^{-1} forward speed of a planter. The speeds of the seed metering shaft were 37.04, 44.45 and 51.86 rpm. Animal and power tiller operated seed drills and planter in India are operated in this range of speeds (Bhardwaj et al., 2004). For statistical considerations, five trials were conducted for each variable and the mean value of these trials was taken as the representative value of the variable. Uniformity of seed deposition and seed breakage were used to evaluate the performance of the seed metering device. The uniformity of seed deposition was evaluated by seed spacing, missing index, multiple index and uniformity of seed placement.

4.3 Measurement methods

Two-third of the depth of hopper was filled with seeds. The engine was started and adjusted to obtain the desired speed. The trial was conducted to obtain delivery of 40 seeds on the greased belt. The distance between two consecutive seeds dropping for the trial was measured. Broken seeds delivered by the seed metering device were collected. The split seeds and damaged seeds were considered as broken seeds. The weight of the broken seeds was measured to obtain percentage seed broken. The experiment was repeated for other speed of operation and with different seed metering plates without and with a positive seed knockout mechanism. Five trials were performed for each set of variables and the order of the experiments was randomized.

4.4 Data analysis

Based on the seed spacing, missing index, multiple indexes, and uniformity of seed placement were determined.

4.4.1 Missing index

The missing indexes were calculated using the following equation (Singh et al., 2012; Bakhtiari and Ahmad, 2017).

$$I_{miss} = \frac{n_1}{N} \times 100 \quad (3)$$

where,

I_{miss} = missing index, %

N = total number of seed spacing

n_1 = number of seed spacing >1.5 times theoretical seed spacing

4.4.2 Multiple index

The multiple indexes were calculated using the following equation (Singh et al., 2012; Bakhtiari and Ahmad, 2017).

$$I_{mult} = \frac{n_2}{N} \times 100 \quad (4)$$

where,

I_{mult} = multiple index, %

n_2= number of seed spacing ≤ 0.5 times theoretical seed spacing

4.4.3 Uniformity of seed placement

The uniformity of seed placement (I_q) is the percentage of seed spacing not less than 0.5 times but not greater than 1.5 times the theoretical spacing (x_s). The uniformity of seed placement was calculated by the equation (Bakhtiari and Ahmad, 2017; Grewal et al., 2015).

$$0.5x_s \leq I_q \leq 1.5x_s \quad (5)$$

or

$$I_q = 100 - (I_{miss} + I_{mult}) \quad (6)$$

where,

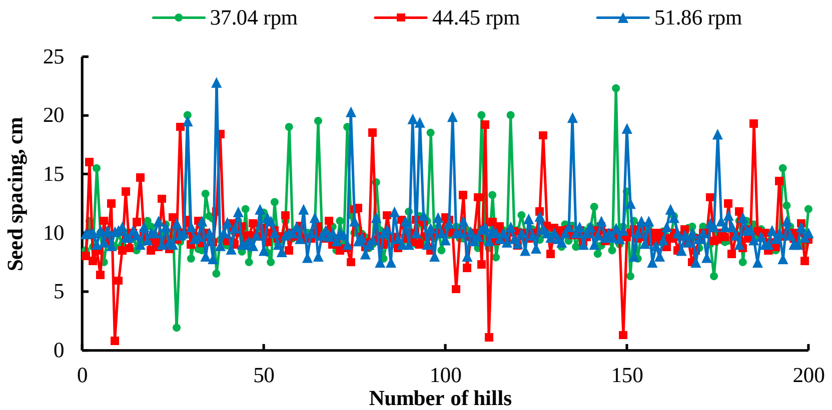
I_q = uniformity of seed placement, %

The effects of various machine and operational parameters on seed spacing were statistically analyzed using IBM SPSS Statistics 20. Three-way analysis of variance (ANOVA) was performed by seed spacing with three variables namely depth of the cell, left side angle of cell and speed of operation for both types of seed metering devices separately at 5% and 1% level of significance. Pairwise comparisons using a *t*-test were also performed on the mean of seed spacing between seed metering devices without and with seed knockout mechanism.

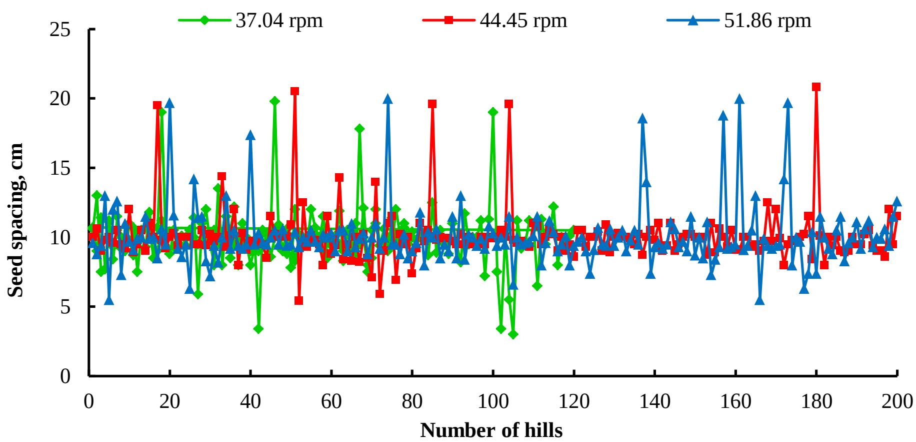
5 Results and discussion

5.1 Seed placement

Comparison of seed metering device without and with seed knockout mechanism on seed placement at three metering speeds (37.04, 44.45 and 51.86 rpm) for cell depth of 8.48 mm and left side angle of 40° is shown in Figure 8. The figure shows that seed spacing was about 10 cm for most of the seeds for without and with seed knockout mechanism however seed spacing between few seeds was about 20 cm also. Seed spacing of about 20 cm was relatively more for seed metering devices without a seed knockout mechanism as compared with the seed knockout mechanism. Seed spacing of 20 cm shows missing seed which may be due to the inability of seed to fill in the cell or seed got stuck in the cell and was not released. A similar trend of seed spacing was observed for the remaining cell depths and left side angles.



(a)Without seed knockout mechanism



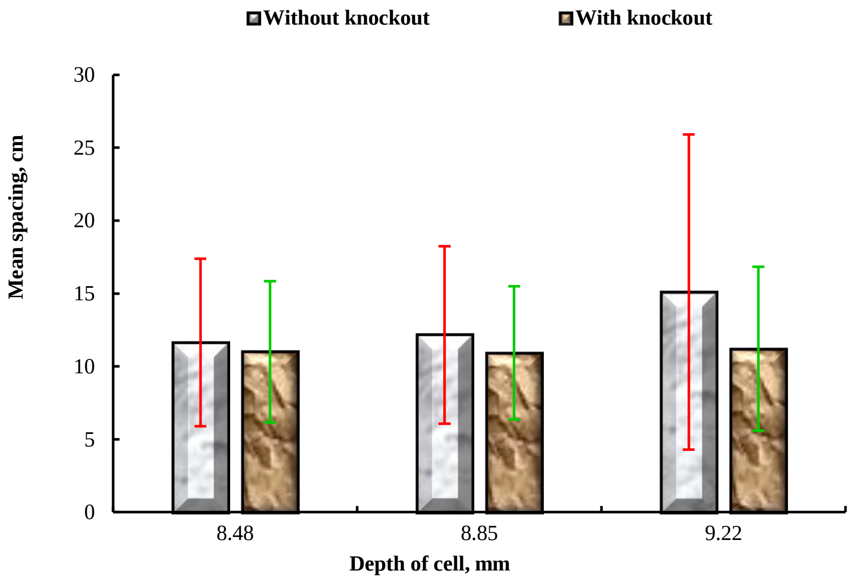
(b) With seed knockout mechanism

Figure 8 Comparison of the seed metering device on seed placement for three consecutive trials at three metering shaft speeds (37.04, 44.45 and 51.86 rpm): Cell depth, 8.48 mm and left side angle, 40°

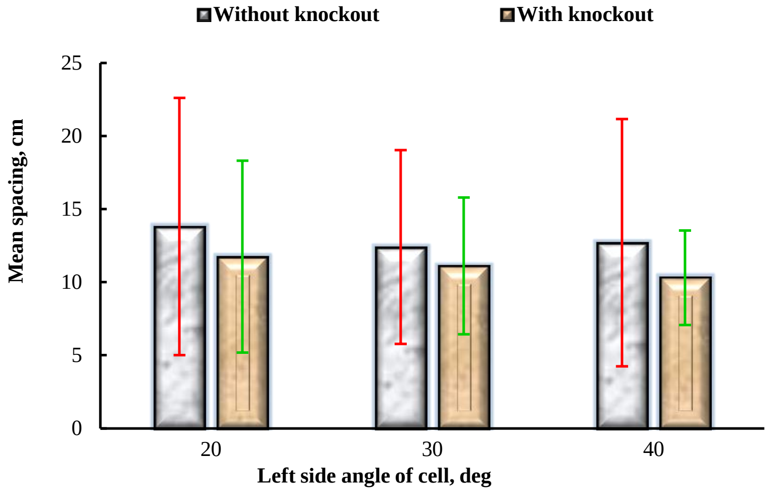
The effect of cell depths (8.48, 8.85 and 9.22 mm), left side angles (20^o, 30^o and 40^o) and speed of operation on mean seed spacing for two seed metering devices namely without and with seed knockout mechanism is shown in Figure 9. The results show that seed spacing was comparable for three cell depths for the metering device with seed knockout mechanism, however, seed spacing increased with increase in cell depth for the seed metering device without a seed knockout mechanism. Three-way ANOVA shows that depth of cell was significantly (p<0.01) different for seed metering device without seed knockout mechanism, however, the depth of cell was not significantly (p=0.21) different for seed metering device with seed knockout mechanism (Table 1).

The increase in seed spacing for the metering device without a seed knockout mechanism may be due to more missing seeds. The mean seed spacing of 10.3 cm obtained in seed metering device with seed knockout mechanism for 40^o left side angle shows better cell fill. The increase in left side angle decreased seed spacing in both types of seed metering devices. ANOVA shows that the left side angle was significantly (p<0.01) different for both seed metering devices. The interaction of depth of cell and left side angle was also significantly (p<0.01) different for both types of seed metering devices. The results show that the mean spacing of seeds increased with an increase in the speed of operation for both the seed metering devices. ANOVA shows that the speed of operation was significantly different for both the seed metering devices without and with the seed knockout mechanism at 5% and 1% level, respectively. More variation in mean seed spacing for seed metering device without seed knockout mechanism may be due to not release of seeds from the cells. Furthermore, the interaction between left side angle and speed of operation was significantly (p<0.01) different for both types of seed metering devices. Interaction between cell depth left side angle and speed of operation was significantly different for the seed metering devices without and with seed knockout mechanism at 1% and 5% level, respectively.

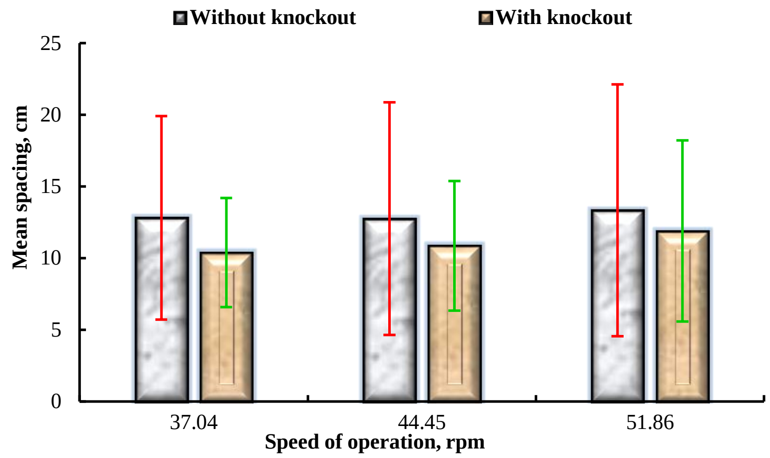
A paired t-test was performed between seed metering devices without and with seed knockout mechanism for the seed spacing and the results obtained are presented in Table 2. The results show a significant difference in uniformity of seed spacing for all the variables except in the case of 20^o and 40^o cell left side angles with 8.48 mm depth of cell. The seed metering device without and with seed knockout mechanism for 8.48 mm depth of cell showed the highest and lowest number of missing hills with cell left side angle of 20^o and 40^o respectively.



(a) cell depth



(b) cell left side angle



(c) speed of operation

Figure 9 The effect on mean seed spacing and standard deviation for the seed metering device without and with seed knockout mechanism

Table 1 Three-way ANOVA for the depth of the cell, left side angle and speed of operation on mean seed spacing

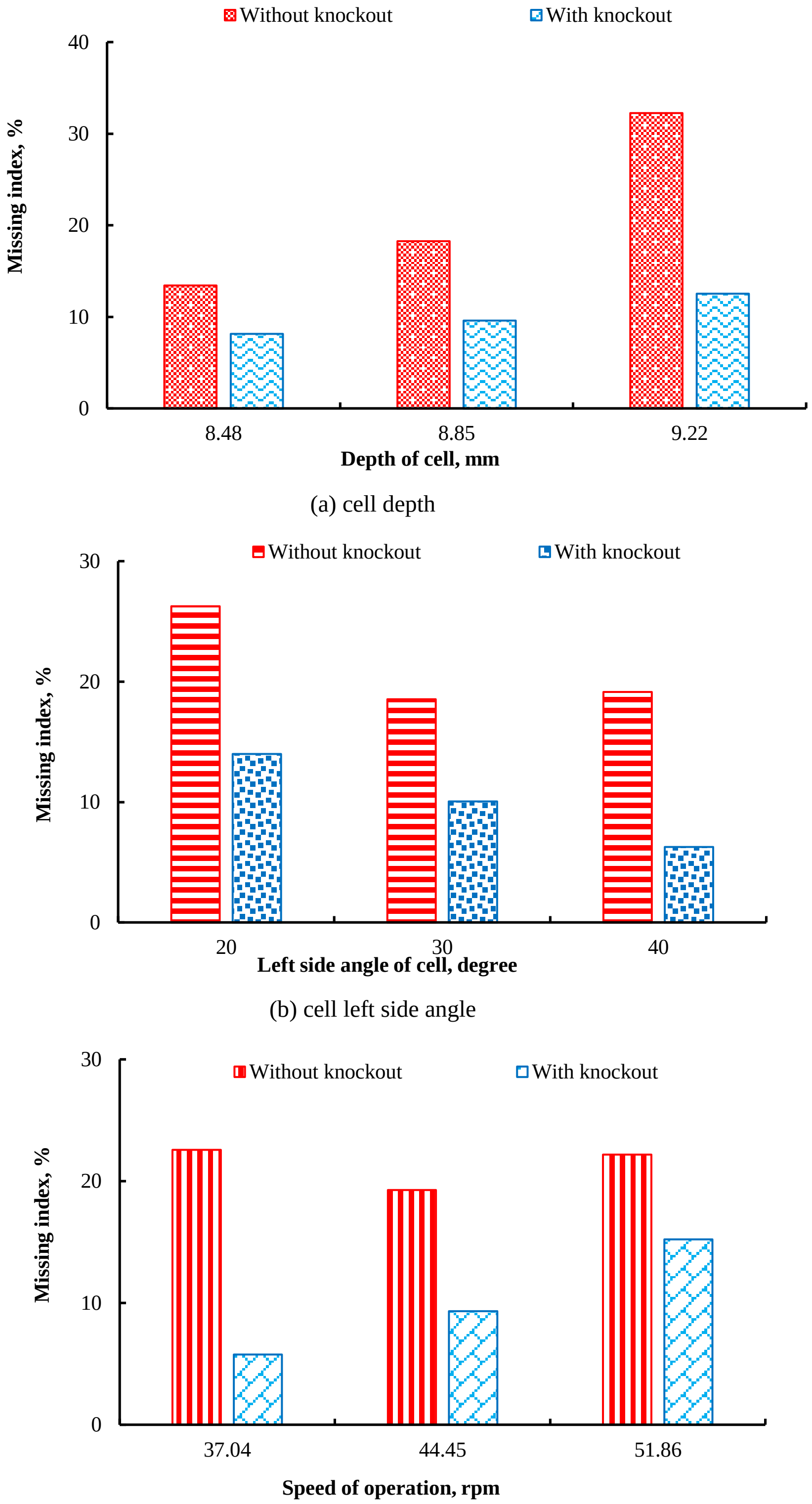
Cell variables	*p* value	
	Without seed knocking mechanism	With seed knocking mechanism
Depth, mm	< 0.01	0.21
Left side angle, degree	< 0.01	< 0.01
Speed, rpm	< 0.05	< 0.01
Depth * Angle	< 0.01	< 0.01
Depth * Speed	0.24	0.17
Angle * Speed	< 0.01	< 0.01
Depth * Angle * Speed	< 0.01	< 0.05

Table 2 *t*-values of seed spacing for seed metering device without and with seed knockout mechanism

Left side angle of cell, degree	Cell depth, mm	Mean spacing, cm		*t*-value
		Without seed knockout	With seed knockout	
	8.48	13.07	12.61	1.027
20	8.85	12.40	11.14	3.631
	9.22	15.92	11.45	6.551
	8.48	11.71	10.37	5.927
30	8.85	12.19	11.18	3.319
	9.22	13.30	11.77	3.587
	8.48	10.14	10.04	0.812
40	8.85	11.89	10.45	5.141
	9.22	16.08	10.40	10.653

5.2 Missing index

The effect of cell depth, left side angle and speed of operation on the missing index for seed metering device without and with seed knockout mechanism is shown in Figure 10. In all the experiments, the missing index for the seed metering device with the seed knockout mechanism was lower than that of the seed metering device without seed knockout mechanism (Table 3). An increase in missing index was observed with increase in depth of cells in both without and with the seed knockout mechanism.



(a) cell depth

(b) cell left side angle

(c) speed of operation

Figure 10 The effects of different parameters on missing index for the seed metering device without and with seed knockout mechanism

The results show that the increase in depth of cells increased the missing index. Furthermore, increase in the left side angle generally reduced the missing index for both types of seed metering devices. Increase in speed increased the missing index for the seed metering device with a seed knockout mechanism however no trend was observed for the seed metering device without the seed knockout mechanism. The minimum missing index of 2.0% was observed for the seed metering device with a seed knockout mechanism operated at 37.04 rpm for cell depth 8.48 mm and 40^o left side angle. The lowest missing index reported was 2.49% in Yang et al. (2015), 2.80% in Bakhtiari and Ahmad (2017), 4.07% in Matin et al. (2008) and 5.63% in Jia et al. (2007).

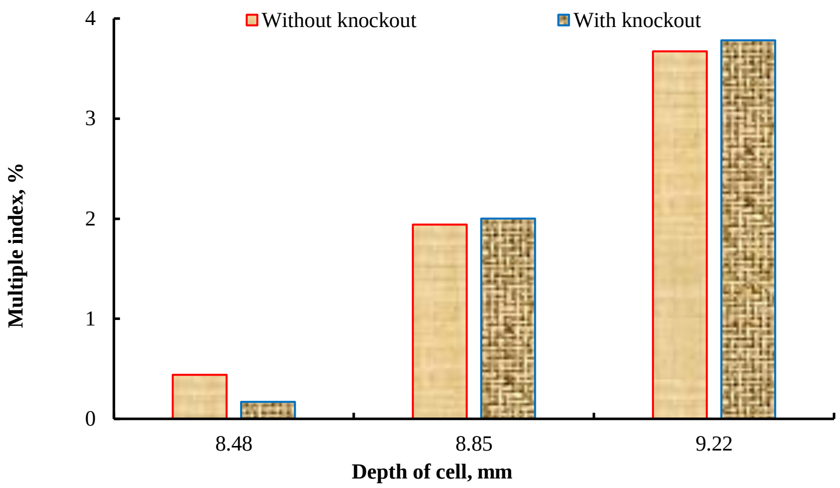
Missing of the seeds occurred because of two main reasons. First, the seed was not getting filled in the cells due to lower exposure time or cell had stuck up seed. Second, the inability of the seed metering device to release seed from the cell. Few instances of periodic missing hills were also observed. Seed stuck in the cells were not released which may be one of the reasons for periodic missing hills. The increase in missing hill caused an increase in mean seed spacing. Seed metering mechanism with positive seed knockout mechanism resulted in positive delivery of seeds and thus missing hill was considerably reduced.

Table 3 Mean performance indexes of different cell configurations without and with seed knockout mechanism

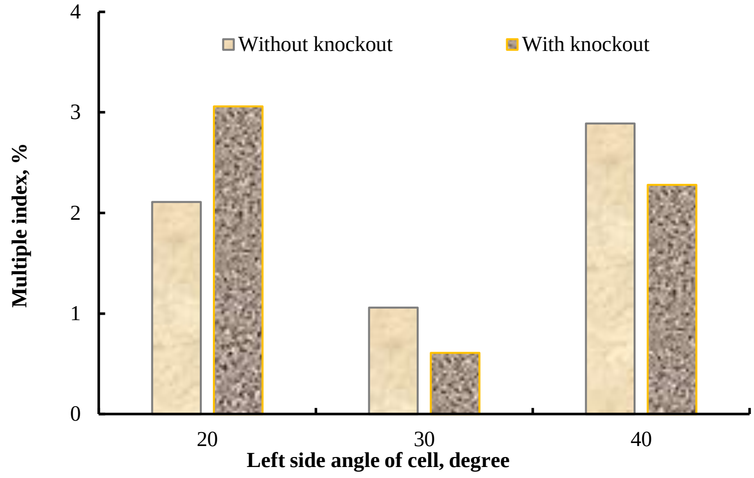
β_L, degree	d_C, mm	I_{miss}, %		I_{mult}, %		Iq,%		Broken seed, %	
		Without	With	Without	With	Without	With	Without	With
20	8.48	21.17	17.00	0.17	0.00	78.67	83.00	0.52	1.48
	8.85	20.17	10.67	2.00	3.33	77.83	86.00	4.40	6.62
	9.22	37.50	14.33	4.17	5.83	58.33	79.83	5.53	8.29
30	8.48	14.83	4.83	0.50	0.00	84.67	95.17	3.97	2.57
	8.85	17.50	10.83	1.00	0.50	81.50	88.67	3.45	1.64
	9.22	23.33	14.50	1.67	1.33	75.00	84.17	4.24	4.16
40	8.48	4.33	2.67	0.67	0.50	95.00	96.83	6.83	2.34
	8.85	17.17	7.33	2.83	2.17	80.00	90.50	3.95	3.97
	9.22	36.00	8.83	5.17	4.17	58.67	87.00	10.23	11.09

5.3 Multiple index

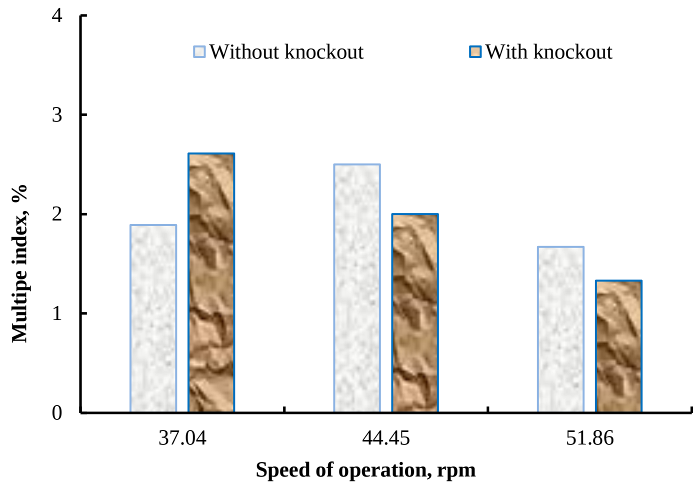
The effect of cell depth, left side angle and speed of operation on multiple index for seed metering device without and with seed knockout mechanism is shown in Figure 11. The results show an increase in multiple index with increase in depth of cells for both types of seed metering devices. Higher multiple index with increase in depth of cells may be due to the ability of the cell to accommodate two seeds. Furthermore, no trend was obtained for multiple index with different values of left side angles and speed of operation. For 8.48 mm cell depth with seed knockout mechanism, multiple index were zero except for 40^o left side angle at the operating speed of 37.04 rpm. The minimum multiple index reported were 4.35% in Dixit et al. (2011), 7.60% in Jia et al. (2007) and 11.16% in Bakhtiari and Ahmad (2017).



(a) cell depth



(b)cell left side angle

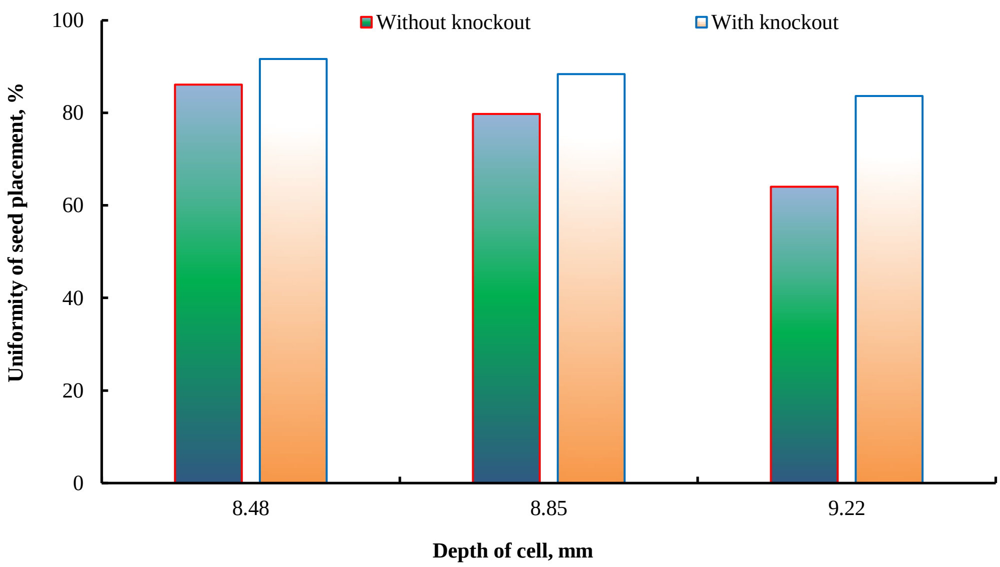


(c) speed of operation

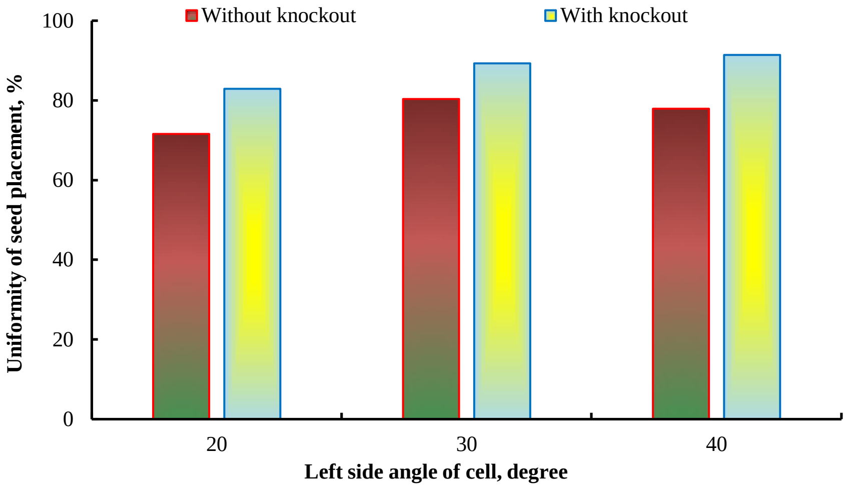
Figure 11 The effects of different parameters on multiple index for the seed metering device without and with seed knockout mechanism

5.4 Uniformity of seed placement

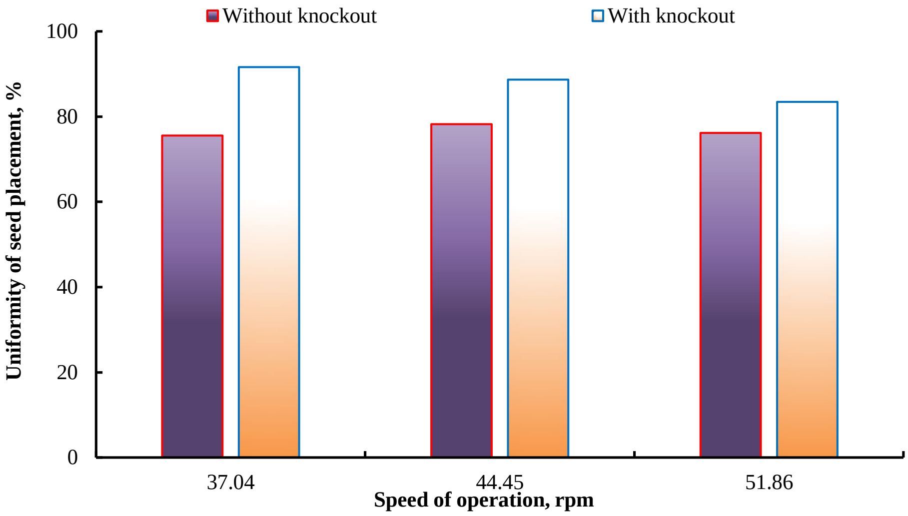
The effect of cell depth, left side angle and speed of operation on mean uniformity of seed placement for seed metering device without and with seed knockout mechanism is shown in Figure 12.



(a) cell depth



(b) cell left side angle



(c) speed of operation

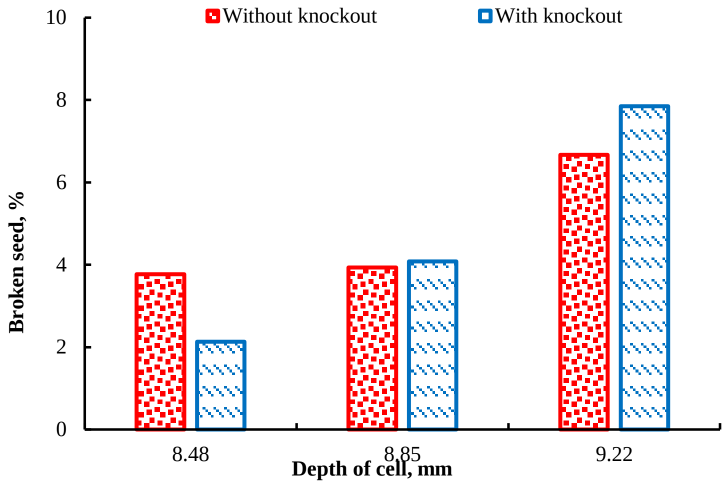
Figure 12 The effects on uniformity of seed placement for the seed metering device without and with seed knockout mechanism

The results show that the increase in depth of cells generally decreased uniformity of seed placement for both types of seed metering devices. No trend was observed for the effect of the left side angle on the uniformity of seed placement. Increase in the speed of operation decreased uniformity of seed placement for the seed metering device with seed knockout mechanism, however, no trend was seen for the seed metering device without seed knockout mechanism. The uniformity of seed placement with the seed knockout mechanism was also observed higher for all variables as compared to without knockout mechanism (Table 3). Among the different variables studied, 8.48 mm cell depth with 40^o left side angle performed best in terms of uniformity of seed placement of 96.5%, 97.5% and 96.5% at speeds of 37.04, 44.45 and 51.86 rpm respectively.

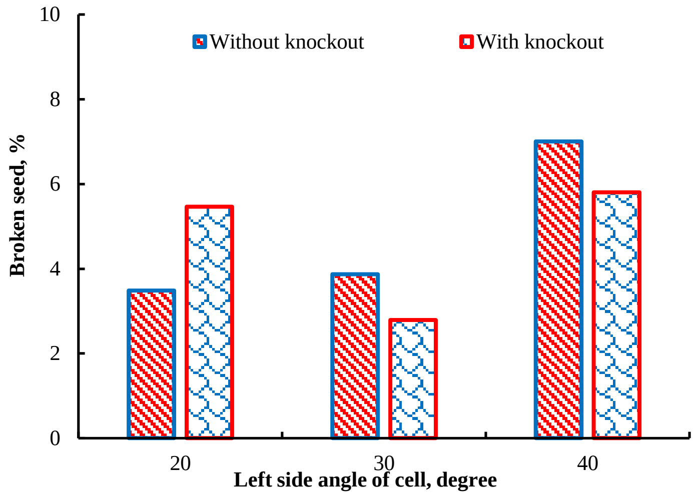
5.5 Percentage seed broken

The effect of cell depth, left side angle and speed of operation on percentage seed broken for seed metering device without and with seed knockout mechanism is shown in Figure 13.

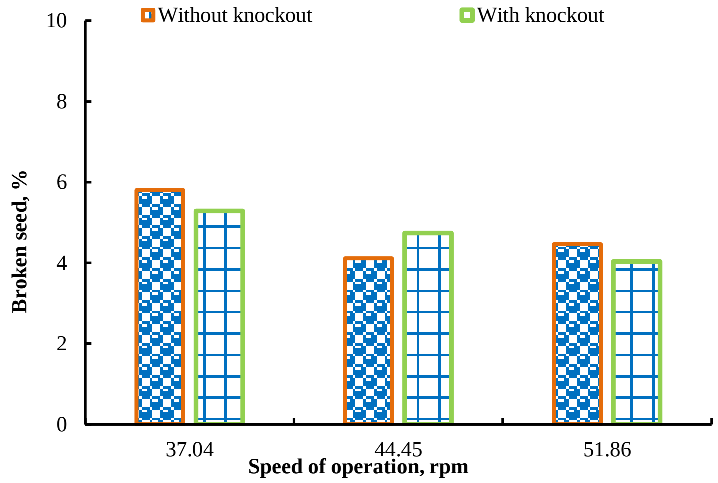
The seed broken was increased with an increase in depth of cell for the seed metering device without and with seed knockout mechanism. Minimum seed broken of 0.27% and 0.75% were observed for the seed metering device without and with seed knockout mechanism, respectively. Maximum seed broken was exorbitantly high, i.e. 12.70% and 13.44% for the seed metering device without and with seed knockout mechanism, respectively with 9.22 mm cell depth and 40^o left side angle of cell. There was no trend on broken seed percentage with other variables considered in the study.



(a) cell depth



(b) cell left side angle



(c) speed of operation

Figure 13 The effect (a) cell depth, (b) cell left side angle and (c) speed of operation on seed broken for the seed metering device without and with seed knockout mechanism

6 Conclusions

The following major conclusions can be drawn from this study:

Designed precision vertical plate seed metering device with seed knockout mechanism performed satisfactorily for field pea however considerable missing index and poor uniformity of seed deposition was observed with the seed metering device without seed knockout mechanism.

Minimum seed broken was 0.27% for the seed metering device without a seed knockout mechanism and 0.75% for seed metering device with seed knockout mechanism.

The seed metering device with a cell depth of 8.48 mm and 40^o left side angle performed relatively better in terms of mean seed spacing, uniformity of seed placement and missing index.

The cell depth has no effect on mean seed spacing for the seed metering device with the seed knockout mechanism. Increase in the speed of operation increased seed spacing however the opposite trend was observed with the left side angle for the seed metering device with a seed knockout mechanism.

The missing index increased with increase in cell depth and speed of operation however decrease in left side angle of the cell increased missing index for the seed metering device with seed knockout mechanism.

Multiple indexes increased with increase in depth of the cell, however, no trend was observed with the left side angle of cell and speed of operation.

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