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RESEARCH ARTICLE

Experimental study on okra planter for sowing of soaked seed

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ABSTRACT: India is one of the leading Okra-producing countries producing 66.3% of the World's okra. However, the traditional manual sowing methods result in low yield, poor quality, and high cost of cultivation. Therefore, an experimental study was designed to evaluate a tractor-operated Okra planter in the laboratory and field conditions for a locally available seed variety (Pusa A4). Laboratory experiments consisted of three independent variables; inclined plates (3 levels), inclination angles (3 levels), and speed of operations (4 levels). Dependent variables were seed spacing, a number of seeds/meter row length, and performance indices (multiple index, miss index, and quality of feed index). A 3×3×4 factorial design was applied to laboratory data analysis. The planter's best parameter combination (plate, Inclination angle, and speed) was evaluated on actual field conditions at two different locations (X and Y). The field evaluation includes; plant-plant spacing, performance indices, planter field capacity, and fuel consumption. The planter was operated at 2.17, 2.25 km/h and plant-plant spacing was observed 15.98 cm, 17.11 cm, respectively, for locations X and Y. The observed plant spacing was close to desired spacing (15 cm). The field evaluation studies validated the results of laboratory experiments and desirable plant population were observed at both locations.

1. INTRODUCTION

Punjab holds a place of pride and honor among the Indian states, owing to its outstanding achievements in the agricultural sector. Punjab witnessed tremendous increase in agricultural production during Indian green revolution era and earned a name granary of India. Punjab alone contributed around 27.33% rice and 46.22% wheat to the national pool during 2015-16 (Grover *et al.,* 2017). The water resources are on the verge of extreme crisis, and 80% of the cultivated area is facing severe groundwater depletion, which is declining at a rate of 30-50 cm/year (Singh, 2011; Gupta, 2011, Tripati *et al*., 2016). A substantial rise in groundwater utilization is observed in recent years since paddy is a water-intensive crop, pushing farmers towards heavy groundwater usage. Moreover, government policies such as free electricity for irrigation, credit facilities, and subsidies on digging wells and pumping equipment encouraged groundwater utilization (Melkani, 2014). Punjab is one of the mechanized states in the country, and overspecialized mechanical technologies (from planting to harvesting) favor the WRC pattern (Singh and Cheema, 2014).

Crop diversification has emerged as an essential alternative to attaining output growth, employment generation, and sustainability of natural resources in developing countries. Diversification of cropping patterns towards environment-friendly, high-value crops with emphasis on quality output and promotion of agro-processing industry is the need of the hour. The experts and scientists have suggested diversification of wheat-rice rotation to tackle the agricultural crisis in Punjab (Satyasai and Viswanathan 1996; Sharma 2005; Birthal*et al.*, 2007; Sidhu *et al.,* 2010; Anon., 2014; Sharma and Singh 2014). The impact of diversification would be visible when at least 20% area under WRC should be diverted to other crops (Grewal, 2013). It's often suggested that there is an urgent need to diversify into new areas like vegetables, fruits, oilseeds, pulses, and allied field crops.

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Crop diversification has been perceived as one of the alternatives to end the problems arising from WRC. Several studies have been conducted for the alternative profitable and resource-conservative cropping systems and proved effective solutions for the present crisis (Sharma, 2005; Birthal *et al*., 2007; Walia *et al.,* 2011; Sidhu *et al.,* 2009; Sidhu *et al*., 2010). Cultivation of vegetables helps in the diversification of agriculture, and these short-duration crops increased the average annual field utilization. Moreover, vegetables are cash crop with good economic returns. This follows low product quality, low yield, and high cultivation costs; results in low returns to the grower. Precision methods and the device can enhance inputs application efficiency with minimum labor and drudgery (Grewal *et al.,* 2015).

India is the second-largest producer of fruits and vegetables in the world (Anon., 2017). Okra (*Abelmoschus esculentus L.*), is an economically important vegetable crop in India with the potential to increase farm incomes. Being the leader in Okra production, India produced 6146 thousand metric ton of Okra in 528 thousand ha with average productivity of 11.6 metric ton/ha during 2016-17 (Anon., 2017). In Punjab, a total of 4.25 thousand ha area under the Okra cultivation and produced 44.37 thousand metric ton with productivity of 10.43 metric ton/ha, which was significantly lower than the state of Andhra Pradesh (17.45 metric ton/ha) during 2016-17 (Anon., 2017). It's typically grown in tropical and subtropical regions and specific varieties in moderate climates. The Okra seed coat is relatively hard compared to other vegetable seeds (Anon., 2015; Yawalkar, 1992). Hence, 24-hour water soaking is a common practice to enhance the germination percentage. These soaked seeds are more susceptible to seed damage.

Traditionally, Okra is sown with manual methods (seeding behind the plough, dibbling, and seed drills), resulting in non-uniform seed distribution, seed cluster, gap filling, and high labor costs. Moreover, conventional seeding machines do not maintain precise plant spacing and seed rate (Khambalkar *et al.,* 2014). A large number of planters are available for cotton, maize, soybean, groundnut, and pea (Sahoo and Srivastava, 2000). However, minimal information is available on the mechanical planting of soaked Okra seed. Keeping all these points in view, this study aims to evaluate the mechanized planting system for soaked Okra seed crop that could be considered as an alternative crop to WRC system and help in crop diversification of the region.

The parameters for the performance evaluation of the planter include spacing between seeds or plants (Chauhan *et al.,* 1999; Badgujar *et al.,* 2017), percent multiple, and miss (Sun *et al.,* 2012; Yasir *et al.,* 2012; Dixit *et al.,* 2011; Yadachi *et al.,* 2013; Gautam *et al.,* 2017), and precision in spacing (Dixit *et al.,* 2011; Yadachi *et al.,* 2013).

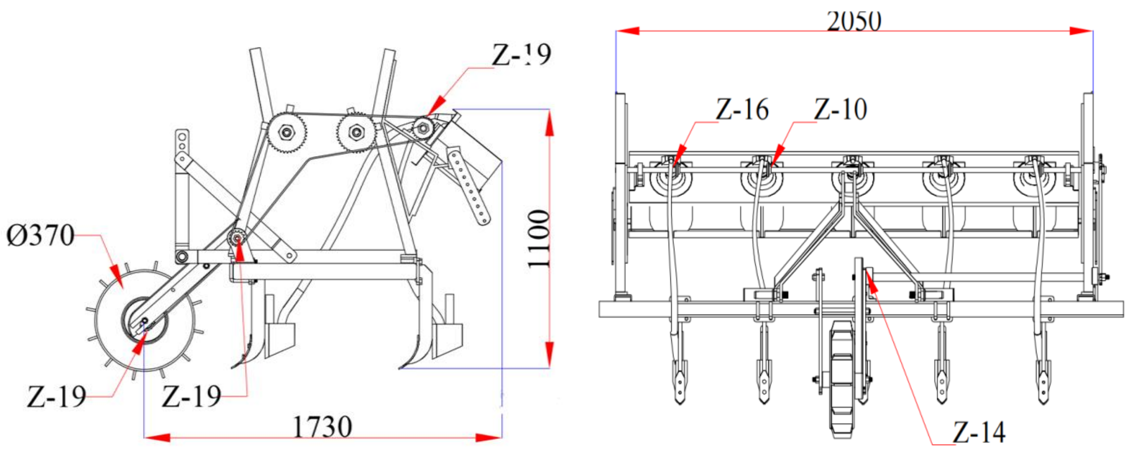
2. MATERIAL AND METHODS

A five-row-tractor-operated inclined plate Okra planter prototype used in the study (Fig. 1). It was developed at the Department of Farm Machinery & Power Engineering, Punjab Agricultural University, Ludhiana and a detailed specification of the machine were given in Table 1. Okra seeds are sown in the well-pulverized field; on both flat and ridges at a 15 cm plant spacing, 45 cm row spacing, and 3-5 cm depth. Okra is grown in two seasons; spring crop (Feb-Mar) and summer (June-July). *Pusa Sawani*, *Pusa-A4, Varsha Uphar* and *Hisar Unna* are improved Okra varieties recommended all over India (Anon., 2015).

In the present experiment, Okra seed variety *Pusa A4* was selected, recommended by the Indian Agricultural Research Institute, Delhi and Punjab Agricultural University, Ludhiana, for North-Indian plains. The seeds were water-soaked for 24 h before conducting the laboratory experiments, and there was no seed sprouting observed after soaking (Badgujar *et al.,* 2019).

Table 1.
Specification of okra planter.

Description	Specifications
Frame	Standard box section frame
Depth control mechanism	Two gauge wheels on each side of frame
Seed metering systems: Inclined plate	
Diameter of inclined plate	170 mm
Number of grooves per inclined plate	10 grooves
Number of seed hopper	5
Furrow openers: Five reversible shovel	
Seed placement depth (adjustable), mm	30 - 50
Ground wheel: lugged wheel	
Diameter, mm	400
Width, mm	70
Overall dimension of prototype, mm	2050 ×1730 ×1100
Power transmission to metering unit	Sprocket, chain, and bevel gear



Side view Front view

*all dimensions in mm. Z= number of teeth on the gear.

Fig. 1. Various views of developed okra planter

2.1. Laboratory Studies

The planter's seed distribution pattern was observed on independent variables mentioned in Table 2. Three types of inclined plates varied in cell dimension were used in the study. The cell dimension was derived from the average seed dimension of Okra seed. The cell dimension of plate A was 110% of the average seed dimension. Similarly, plate B and plate C were designed with 120% and 130% of the cell dimension, respectively. The detailed method of plate designed is explained by Badgujar *et al.,* (2017). The experiment was conducted on a sticky belt arrangement, consisted of an endless canvass belt applied with grease and power transmission unit coupled with an AC motor to vary speed. This simulated planter's ground speed in lab conditions. Each experiment was replicated three times. Seed-seed spacing was observed on the sticky belt arrangement. The observed seed-seed spacing was used to derive the number of seeds per meter row length and performance indices. The performance indices, namely multiple, miss, and quality of feed index, were calculated according to International Standard 7256/1 (ISO: 7256/1). Miss index represents how often seed skipped the desired spacing, and it is the percentage of spacing greater than 1.5 times the theoretical spacing (15 cm for Okra). Therefore, seed spacing greater than 22.5 cm was counted as miss index. Multiple index indicates more than one seed dropped within the desired spacing; percentage of spacing less than or equal to half of the desired spacing. Therefore, seed spacing less than 7.5 cm were counted as multiple index. Finally, the quality feed index measures how often spacing was close to the desired spacing. The percentage of spacing was more than half but not more than 1.5 times the theoretical spacing. Seed spacing ranged between 7.5 to 22.5 cm was considered as quality feed index.

2.2. Field Evaluation of Okra Planter

Based on the laboratory experiments, the best parameters combination of independent variables was selected for the planter field evaluation at two different locations (X and Y) and compared with manual control. Both fields were prepared, total eights plot marked, and irrigated for the summer crop (July). The soaked Okra seeds were sown with planter on a flat field. The following observations were noted during the sowing operation: sowing time, tractor turning time, and speed of operation. Theoretical field capacity and effective field capacity of the planter was calculated by the equation 1 and 2, respectively; suggested by Kepner *et al.,* (1972) and Sahoo *et al.*,

Table 2.
Variables under the study: independent and dependent variables.

Independent Variables			Dependent Variables
Types of plate	Speed, km/h	Angle of inclination	a) Average seed spacing
Plate A	1.0	45°	b) Seeds/meter row length
Plate B	2.0	50°	c) Miss index
Plate C	3.0	55°	d) Multiple index
	4.0		e) Quality of feed index

(2000). The tractor was equipped with a fuel meter; thus, the fuel meter readings were recorded before and after the completion of the plot.

$$TFC = \frac{W \times S}{10} \quad \ldots 1$$

Where,

TFC = Theoretical field capacity, ha/h
W = width of machine, m
S = speed, km/h.

$$EFC = \frac{TFC \times eff}{100} \quad \ldots 2$$

Where,

EFC = effective field capacity, ha/h
eff = efficiency of machine *i.e.* 80% (Kepner *et al.* 1972).

The plant-plant spacing was measured in each plot after 15 days and 30 days after sowing (DAS). Ten samples per plot were recorded for plant-plant spacing and germination count (2m/row length), and performance indices (miss, multiple, quality of feed) were computed.

2.3. Data Analysis

A MATLAB-R2018a software (The MathWorks, Inc, Natick, MA, USA) was used for the statistical data analysis and plotting. A 3×3×4 factorial design was applied to the laboratory experiments data analysis at a 5% significance level. Following dependent parameters, namely average seed spacing, number of seeds/meter row length, and performance indices (multiple index, miss index, and quality of feed index), were investigated, and respective F-values are reported.

3. RESULT AND DISCUSSION

3.1. Laboratory Studies

The seed distribution pattern was studied and the following dependent parameters were investigated: average seed spacing, number of seeds per meter row length, and performance indices (multiple, miss, and quality of feed index).

3.2. Average Seed Spacing

Average seed spacing was influenced by all independent variables (Plate, speed, and angle) at a 5% significance level as indicated by F-values (Table 3). Average seed spacing increased with an increase in speed and inclination angle (Fig. 2). The average spacing obtained at plate inclination of 45°, 50°, and 55° was 11.6 cm, 13.7 cm and 15.2 cm, respectively. This increase in average spacing (11.6 to 15.2 cm) with an increase in inclination angle (45° to 55°) was due to gravity; ensures complete cell filling at a lower inclination angle. Metering plate A delivered the 15.5 cm average spacing, close to the desired theoretical spacing (15 cm). In the lab study, induced vibration was observed at a higher speed (4 km/h), resulted in higher seed spacing (above 18 cm).

3.3. Number of Seed per Meter Row Length

A number of seed per meter row lengths were depicted in Fig. 2. Plate C delivered more seeds/meter row length than plates A & B. This was explained by plate cell dimension, *i.e.*, 30% bigger cell dimension than the average seed size. An increase in speed (1 km.h^{-1} to 4 km.h^{-1}) results in reduced cell-seed exposure time, further decreasing the number of seeds/meter row length for all plates. Plate A delivers ten seeds per meter row length at a 45° inclination angle and 2 km/h speed.

Table 3.
F-values of performance parameters of seed metering mechanism.

Source	Average spacing	Number of seeds/m row length	Multiple Index	Miss Index	Quality of feed index
P	69.3	112.9	96.1	15.4	12.6
θ	41.8	108.0	59.3	29.6	1.8
S	202.7	179.6	50.9	119.7	6.1
P× θ	1.6	4.4	0.5	0.5	0.3
P×S	1.8	7.0	2.6	0.6	1.6
θ×S	0.7	4.4	1.5	1.4	0.6
P×θ×S	2.0	0.7	0.2	1.5	0.6

P= Plate, S = Speed and θ= Angle of inclination

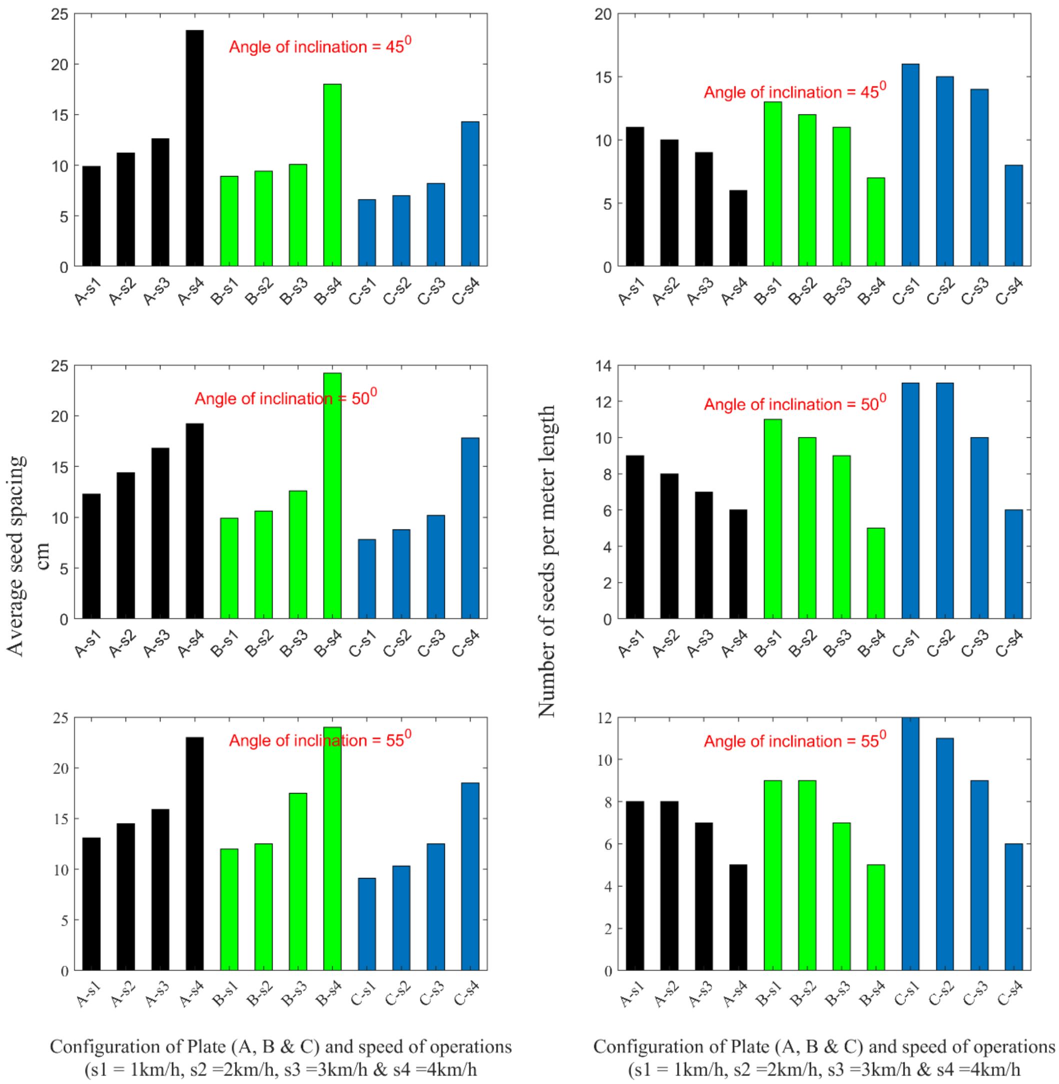


Fig. 2. Effect of metering plate & speed on seed spacing and number of seeds/m row length at a selected inclination angle

3.4. Performance Indices

Miss, multiple, and quality feed indexes are a function of seed to seed spacing which affects the plant population. Therefore, performance indices are crucial for planter performance.

3.4.1. Multiple index

Multiple index was found to be significantly influenced by the speed and plate (Table 3). Plate C picked multiple seeds compared to plate A and B, owing to 30% large cell dimension, resulting in higher multiple percentages for plate C (Fig. 3). Higher multiple percentages ensure non-uniform plant spacing, costly seed loss, and increased labour costs (thinning extra plant). Therefore, multiple percentages must be within the acceptable range. The least value of multiple (9.7%) was observed for plate A, the inclination angle of 55° and 4 km/h (Fig. 3). Also, a higher inclination angle ensured a decrease in multiple percentage (Fig. 3).

3.4.2. Miss index

In laboratory studies, miss index was ranged between 2.8% to 43.7%. Metering plate A and C at 45° inclination angle reported a miss percentage less than 5%, further increasing as speed exceeds 2 km/h (Fig. 3). Miss index percentage increased with an increase in speed. This suggests that an increase in miss percentage due to an increase in speed causes the decrease in the cell-seed exposure time and higher centrifugal force throws seed out of the cell prematurely. The average miss percentage for inclination angles of 45°, 50°, and 55° were 13.9%, 21.4%, and 25.1%, respectively. The least value of miss percentage (4.8%) was observed at the combination of inclination angle 45°, speed 2 km/h, and plate A.

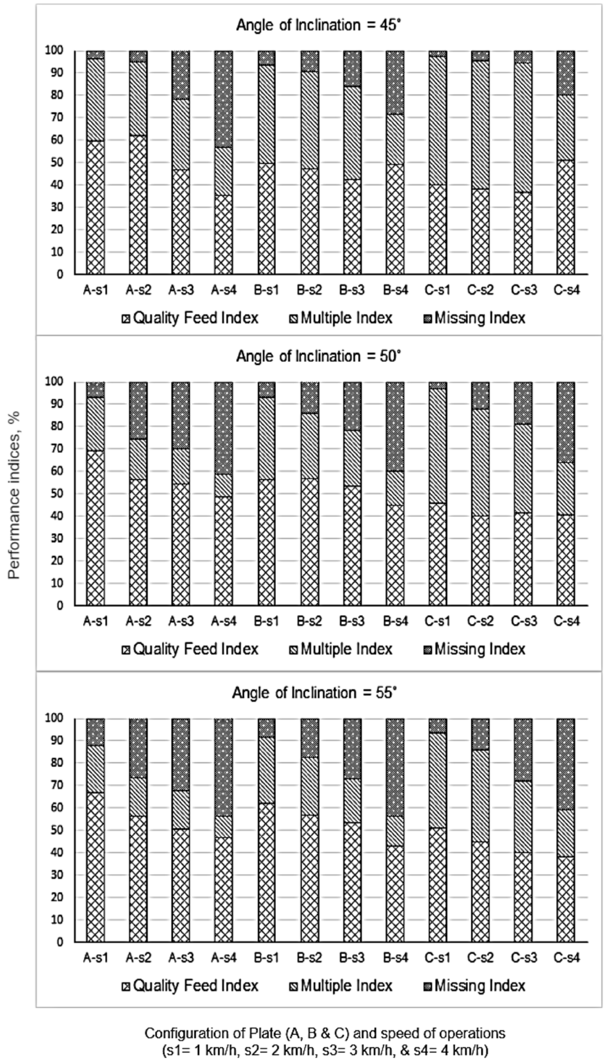


Fig. 3. Effect of metering plate & speed on performance indices at a selected inclination angle

3.2.3. Quality of feed index

The quality of the feed index was ranged between 69.2 to 35.5% (Plate A), 62 to 42.3% (Plate B), and 51 to 36.7% (Plate C). The highest percentage quality of feed index of 69.2% was observed at inclination angle 50° and plate A (Fig. 3). The average quality feed percentage was found to be increased with an increase in inclination angle from 45° to 55° (46.5% to 50.8%). The inverse relationship was observed between speed and percentage quality feed. It decreased from 55.7% to 44.2% as to speed increase from 1 km/h to 4 km/h. It was also concluded that the combined interaction of plate, inclination angle and speed had a non-significant effect on quality feed percentage.

3.3. Field Studies

The laboratory studies selected the best parameter combination (plate, inclination angle, and speed) for the field evaluation. Therefore, plate A with an inclination angle of 45° and speed of 2 km/h were selected. This combination resulted in an average spacing of 11.2 cm (close to desired spacing). Moreover, other performance indices were also in the acceptable range; quality feed (62.1%), multiples (33.1%), and miss (4.8%).

The prototype planter (working width = 2.25 m) was evaluated at two different locations (X and Y) at Punjab Agricultural University, Ludhiana. It was operated at a speed of 2.17 km/h and 2.25 km/h, and an effective field capacity of 0.39 ha/h and 0.41 ha/h was observed at locations X and Y, respectively. Fuel consumption and the draft was ranged between 3.2 l/h to 3.4 l/h and 1075.1 N to 1125.0 N (Table 4). A t-test (two samples assuming unequal variances) was performed to determine the significant differences between the planter and manual operation (Table 5).

Table 4.
Results of field evaluation of okra planter.

Observations	Location X	Location Y
Forward speed, km/h	2.17	2.25
Fuel consumption, l/h	3.2	3.4
Field capacity, ha/h	0.39	0.41
Draft, kg	109.7 (1075.1 N)	114.8 (1125.0 N)

3.3.1. Field location X

The average plant-plant spacing of 15.98 cm for the planter and control 19.08 cm for control was recorded (Table 5). Manual control leads to significantly less plant population per hectare than desired plant population per hectare. In germination count, 13.1 plants per 2 m row length were observed for the planter sowing and 11.3 plants per 2 m row length for control. Similarly, 30 DAS, 13.8, and 11.6 plants per 2 m row length were observed for planter and control, respectively. The performance index; multiple, miss, and quality of feed index, was derived from the plant to plant spacing. The multiple index of the planter was 0.21, and the control was 0.15. The following performance parameter, miss index, was 0.17 for the planter while 0.30 for the control. The quality of feed index for the planter was 0.61 (degree of variation 0.47), and control was 0.53 (degree of variation 0.60).

3.3.2. Field location Y

Plant-plant spacing of 17.11 cm and 17.95 cm was observed for planter and control, respectively. The germination count; 15 DAS was 11.9 plants per 2 m row length and 13.9 plants per 2 m row length observed for planter and control. Similarly, 30 DAS, 12.4, and 14.5

Table 5.
Performance indices for the field evaluation.

Parameters	Location X			Location Y		
	Planter	Control	P-value	Planter	Control	P-value
Plant spacing (cm)	15.98	19.08	0.02	17.11	17.95	0.42
Multiple index	0.21	0.15	0.16	0.23	0.31	0.01
Miss index	0.17	0.32	0.01	0.20	0.28	0.15
Quality of feed index	0.62	0.53	0.03	0.57	0.41	0.01
Degree of variation	0.47	0.60	-	0.53	0.91	-
Germination counts 15 DAS (Plants/2m row length)	13.1	11.3	-	11.9	13.9	-
Germination counts 30 DAS (Plants/2m row length)	13.8	12.6	-	12.4	14.5	-

plants per 2 m row length were observed for planter and control, respectively. The performance indices; multiple index of the planter, was 0.23, and the control was 0.31. Miss index for planter was 0.20 and 0.28 for the control. The quality of feed index of the planter was 0.57 with a degree of variation of 0.53, and the control was 0.41 with a degree of variation of 0.91. The statistical t-test was applied at a 5% significance level to differentiate between the planter and control observation, and the results were shown in Table 5.

4. CONCLUSIONS

The cell dimension of a plate having 10% more than the actual seed dimension resulted in desired plant spacing and optimum performance indices. In laboratory experiments, a higher speed of operation induced planter vibration and less cell-seed exposure time which resulted in higher miss indices. In an inclined plate planter, the plate inclination angle influences the seed distribution pattern, and a higher inclination angle increases miss percentage. The average plant-plant spacing of 15.98 and 17.11 cm was observed for field X and field Y, respectively. The field evaluation studies validated the laboratory results, and desirable plant populations were observed at both locations. Moreover, the performance of the planter was compared with manual control, which indicated a higher degree of variation. Besides this, the planter might offer promising benefits to crop diversification in Northern India.

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