Print ISSN : 0972-8813
e-ISSN : 2582-2780

[Vol. 19(1), January-April, 2021]

Pantnagar Journal of Research

(Formerly International Journal of Basic and Applied Agricultural Research ISSN : 2349-8765)

G.B. Pant University of Agriculture & Technology, Pantnagar

PANTNAGAR JOURNAL OF RESEARCH

Vol. 19(1) January-April, 2021

CONTENTS

Performance evaluation of bullock drawn battery powered sowing machine

A. M. MONPARA, A. V. KOTHIYA and R. SWARNKAR

Department of Farm Machinery and Power Engineering, College of Agricultural Engineering and Technology, Anand Agricultural University, Godhra-389001(Gujarat)

ABSTRACT: Sowing has a dominant effect on germination of seed, plant growth, plant population in the field and ultimately on the total production. Electronic metering mechanism may be one of the options to achieve accurate seed spacing for small and marginal farmers who uses animal as a source of power. The seed rate during calibration in laboratory for three crops (soybean, pigeonpea and maize) at 3.0 km/h were recorded as 22.82 kg/ha, 12.08 kg/ha and 20.0 kg/ha, respectively. RSM analysis provided 13 different treatment combinations at three levels of angle of pull (20°, 25°, 30°) and at three levels of angle of penetration (20°, 25°, 30°). The theoretical field capacity was found between 0.504 ha/h to 0.525 ha/h. The effective field capacity was found between 0.352-0.383 ha/h. The field efficiency was found between 70.00-73.00 %. The draft and power requirement were obtained in range of 58.52 to 70.48 kgf and 0.630 hp to 0.743 hp, respectively. Depth of seed placement and uncover furrow were observed between 4.7 to 7.8 cm and 0.4 cm to 5.2 cm, respectively. After analysis of data, optimization of the design was worked out. The most desirable level of angle of pull was 30° and angle of penetration was 20°. The missing and multiple percent were recorded between 5.00 % to 8.30 % and 3.33 % to 6.67 %, respectively. Plant to plant spacing of soybean, pigeonpea, maize crop was observed 10.9, 20.9 and 20.8 cm, respectively.

Key words: Bullock drawn, electronic metering mechanism, performance evaluation, sowing machine

Sowing is one of the most important operations in raising crops. The selection of any type of sowing equipment depends upon its ability to place the seed at proper distance and depth and clusters with minimum draft and better coverage. Experiments have shown that the use of improved agricultural implements including planting machinery not only increases production but also reduce manual drudgery and improve man-machine compatibility (Singh, 2000).

The basic objective of sowing operation is to put the seed in rows at desired depth and seed to seed spacing, cover the seeds with soil and provide proper compaction over the seed. The recommended row to row spacing, seed rate, seed to seed spacing and depth of seed placement vary from crop to crop and for different agro-climatic conditions to achieve optimum yields (Kathiravan *et al.,*2019).

Under intensive cropping, timeliness of operations is one of the most important factors, which can only be achieved if appropriate use of agricultural machines is advocated. Manual method of seed sowing, results in irregular seed placement, low spacing efficiencies and serious backache for the farmer, which limits the size of field that can be seeder (Rajave *et al.,* 2018). To achieve the best performance from a seeding machine, the above limits are to be optimized by proper design and selection of the components required on the machine to suit the needs of crops

Different types of metering devices are available as per the requirement of shape and size of the seed viz., sensor based metering mechanism (Reheman and Singh, 2004), fluted wheel metering mechanism (Karayel *et al.,* 2006), inclined plate type metering mechanism (Singh *et al.,* 2012) and single raw cotton planter(Rangapara and Pandya,2014). The precision of the planter depends on how accurately the seed is metered by the metering mechanism. A ground wheel is used to drive the seed-metering device of the conventional planting machine. However, the wheel bears high resistance and easily skids. Electrical motor driven system can effectively reduce the influence of in homogeneous sowing caused by the ground wheels slipping (Shankha *et al.,* 2017, Rajaiah *et al.*, 2018 and Lende *et al.*, 2011). This metering mechanism may be one of the options to achieve accurate seed spacing with higher efficiency. By making small adjustments this metering mechanism can be used for various seeds spacing.

Since the majority of farmers are small and marginal using animal as a source of power. Agricultural productivity is linked with the availability of farm power. Draught animal power continues to be used on Indian farms due to small land holdings. More than 55 per cent of the total cultivated area is still being managed by using draught animals as against about 20 per cent by tractors (Ghule *et al.,*2016). Looking to the above fact the bullock drawn battery powered sowing machine was developed and performance evaluation was carried out.

MATERIALS AND METHODS

The bullock drawn battery powered sowing machine was developed and test evaluated at the Department of Farm Machinery and Power Engineering, College of Agricultural Engineering and Technology, AAU, Godhra, Gujarat, during the year 2017-19. This sowing machine has battery powered vertical plate type metering mechanism. It gives better performance as compare to other sowing machine having a ground wheel.

Performance Evaluation of the Developed Sowing Machine

Field preparation was done by tractor drawn cultivator with one pass followed by one pass of rotavator to get the proper seed bed for sowing soybean, pigeonpea and maize.A three level, two-factor face centered design was employed using design expert software. The results were analysed by using Response Surface Methodology (RSM).

1. Laboratory test

The experiments were carried out with three types of seeds, soybean, pigeon pea and maize. At first, the seeds were properly graded in a sieve and used for testing in the experiment. Speed levels of 2.50 km/h, 2.75 km/h and 3.00 km/h were selected for testing of above three crops (Shankha *et al.* 2017). The speed was so selected due to the fact that at higher speed the seed placement becomes non uniform. The rpm of the motor was controlled by speed regulator. The seeds were filled up in the hopper and operated for a time period. The seeds obtained were weighted at three levels of rpm.

A. Variety selection/ seed selection

The quality and variability of seed are important factors which affect germination. The popular varieties of soybean, pigeonpea and maize were selected for experiment. The variety selected for soybean was GS-335, for pigeonpea BDN-2 and for maize Gujarat-4. Seed material quality was improved by cleaning and grading. The size of cells or grooves of metering plate was selected based on seed size.

B. Calibration of sowing machine

Calibration of sowing machine was carried out for different speed of operations (2.50, 2.75, and 3.00 km/h), similar speeds were earlier taken by Shankha *et al.* (2017). Rotational speed (rpm) of the metering plate was calculated by:

$$\text{Required rpm} = \frac{\text{Forward speed of operation (m/min)}}{\text{Required seed spacing (m) x No. of cell on Plate}} \quad \text{.... (1)}$$

C. Mechanical seed damage

$$\text{Damage percentage} = \frac{\text{Mass of damaged seed}}{\text{Total mass of seeds collected}} \times 100 \quad \text{.... (2)}$$

D. Seeds germination test

$$\text{Germination percentage} = \frac{\text{Number of germinated seeds}}{\text{Total number of seeds taken for test}} \times 100 \quad \text{.... (3)}$$

2. Field testing of developed sowing machine

A. Mean mass diameter of seed bed soil

The mean mass diameter (MMD) was calculated by using following formula (Mehta *et al.*, 1995).

$$MMD = \frac{A+1.41B+2C+2.83D+4.7E+NF}{W} \quad \text{.... (4)}$$

Where,

MMD = Mean mass diameter of soil particles, mm;
A, B, C, D, E, F = Mass of soil remaining on sieve, g;
W = A+B+C+D+E+F, g; and
N = Mean of measured diameter of soil particles retained on the largest aperture sieve, mm.

B. Soil moisture content

$$M_C = \frac{W_w - W_d}{W_d} \times 100 \quad \text{.... (5)}$$

Where,

M_C = Moisture content of soil, % db
W_w = Mass of wet soil, g
W_d = Mass of oven dried soil, g

C. Bulk density of soil

$$\rho = \frac{m}{v} \quad \text{.... (6)}$$

Where,

ρ = Bulk density, g/cm^3;
m = Mass of oven dried soil, g; and
v = Volume of core sampler, cm^3

D. Soil parameters

Before conducting the experiments, soil conditions of the experimental field were studied and different parameters were calculated. The soil of the field was sandy loam. The mean mass diameter, moisture content and bulk density were obtained as 8.49 mm, 17.10 % and 1.23 g/cc, respectively.

E. Machine performance

The performance of the developed sowing machine in terms of machine parameters was assessed at different penetration angle and angle of pull. For optimization of penetration angle and pull angle, type of seed has no effect on machine parameters therefore, seed type was not considered during observations.

3. Experimental technique

After the laboratory testing of developed equipment, the field test was conducted at the farm of College of Agricultural Engineering and Technology, Godhra. The effect of two independent variables; angle of penetration and angle of pull on different dependent parameters was studied during the field performance evaluation. The experimental design was studied by thirteen treatment combinations of angle of penetration and angle of pull. The sowing length of the test plot was selected as 20 m and the width as 3.6 m for each treatment. At the starting and at the end of 20 m length of test plot, 4 m space was left for turning the equipment. The experiment was conducted on total thirteen plots.

In test plot two poles (A, B) were placed approximately 20 m apart in the middle of the test plot. The speed was calculated by the time required to cover the distance (20 m) between two poles. A stop watch was used to record the time.

$$\text{Speed (km/h)} = \frac{3.6 \text{ x Distance (m)}}{\text{Time (s)}} \quad \text{.... (7)}$$

Draft was measured by using spring dynamometer. Capacity of the dynamometer was 200 kgf. Dynamometer was attached between yoke and beam of machine. Draft was calculated by using following formula (Sahay, 2010).

$$D = P \cos\theta \quad \text{.... (8)}$$

Where,
D = Draft of machine, kgf;
P = Pull, kgf; and
θ = Angle between line of pull and horizontal surface, Degree

A. Design of experiment
Response Surface Methodology (RSM) emphasizes the modeling and analysis of the problem in which response of interest is influenced by several variables, and the objective is to optimize this response. The main advantage of RSM is to reduce number of experimental runs needed to provide sufficient information for statistically acceptable results. A three level, two-factor face centered design was employed, which pull the axial points into the faces of the cube at +/- 1 level. This is desirable because it is only a three-level design and ensures that the axial runs will not be any more extreme values than the factorial portion. The independent variables selected for the experiments were: Angle of pull X1: 20°, 25° and 30° and Angle of penetration, X2: 20°, 25° and 30°. Face-centered design in coded and un-coded levels of two variables and three levels was employed for experiments as shown in Table 1. During the analysis of the data by using RSM; the experimental design was studied by thirteen treatment combinations of three level of angle of pull and three level of angle of penetration as stated earlier. Results were analyzed using Face centered design with the help of Design Expert Software (Statease 11.0.6.0).

Table 1: Coded and un-coded levels of face centered design

Sr. No.	Coded variables		Un-coded variables	
	X1	X2	X1:Angle of pull (degree)	X2:Angle of penetration (degree)
1	-1.00	0.00	20	25
2	1.00	0.00	30	25
3	-1.00	1.00	20	30
4	1.00	1.00	30	30
5	-1.00	-1.00	20	20
6	1.00	-1.00	30	20
7	0.00	0.00	25	25
8	0.00	1.00	25	30
9	0.00	-1.00	25	20
10	0.00	0.00	25	25
11	0.00	0.00	25	25
12	0.00	0.00	25	25
13	0.00	0.00	25	25

Table 2: Performance evaluation of the developed sowing machine

Parameters	Levels	Dependent parameters
Angle of pull	20°, 25°, 30°	Theoretical field capacity (ha/h) Effective field capacity (ha/h) Field efficiency (%) Draft requirement (kgf) Power requirement (hp)
Angle of Penetration	20°, 25°, 30°	Depth of seeds placement (cm) Depth of un covered furrow (cm)

Fig. 1: Field performance of sowing machine

4. Power requirement
It was calculated from the draft and speed of operation during field test using following relationship (Sahay, 2010).

$$\text{Power (hp)} = \frac{\text{Draft (kgf) x Speed (m/s)}}{75} \quad \text{.... (9)}$$

5. Theoretical field capacity
The theoretical field capacity is the rate of field coverage that would be obtained if implements were performing its function 100 per cent of the time at the rated speed and always covering 100 per cent of its rated width. (Kepner *et al.*, 1972)

$$TFC = \frac{W \text{ x } S}{10} \quad \text{.... (10)}$$

Where,
TFC = Theoretical field capacity, ha/h;
W= Theoretical width of implement, m; and
S = Speed of operation, km/h.

6. Effective field capacity

The actual field capacity is the actual average rate of coverage by the implement. The total time required to complete the operation was recorded and effective field capacity was calculated as follows. (Kepner *et al*., 1972)

$$EFC = \frac{A}{T} \quad \text{....(11)}$$

Where,
EFC = Effective field capacity, ha/h;
A = Actual area covered, ha; and
T = Effective time, h.

7. Field efficiency

Field efficiency is the ratio of effective field capacity to theoretical field capacity. It is expressed in per cent.

$$\text{Field efficiency (\%)} = \frac{\text{Effective field capacity}}{\text{Theoretical field capacity}} \times 100 \quad \text{...(12)}$$

8. Depth of seed placement

The machine was operated in the field under normal seedbed conditions. Then the soil was removed carefully without disturbing the seeds. The depth of the seeds below the soil surfaces was measured vertically.

9. Depth of uncovered furrow

Depth of the uncovered was measured from the top to bottom of the uncovered furrow after the field operation.

10. Quality Parameter

Numbers of quality parameters of sowing machine taken are as below for the comparison of developed sowing machine.

A. Mean spacing

Mean spacing of the plant to plant is the average of the total number of measured spacing and calculated by following formula.

$$X = \frac{\Sigma X}{n} \quad \text{....(13)}$$

Where,
X = Mean spacing of the seed, cm;
ΣX = Sum of the number of observations; and
N = 1, 2, 3…n number of observations

B. Miss Index

The miss percentage is represented by an index called the miss index (I_{miss}) which is the percentage of spacing's greater than 1.5 times the theoretical set spacing (X) (Bracy *et al.,* 1999).

$$I_{miss} = n1/N \quad \text{....(14)}$$

Where, n1 is number of spacing > 1.5 X; and N is total number of measured spacing.

C. Multiple Index

Multiples index is created when more than one seed is delivered by a cell. The multiples percentage of multiple seeds are represented by an index called multiple index (Bakhtiari and Loghavi, 2009) which is the percentage of spacing that are less than or equal to half of the theoretical spacing. Smaller values of multiple index indicate better performance.

$$I_{mult} = \frac{\Psi}{N} \times 100 \quad \text{....(15)}$$

Where,
I_{mult} = Multiple index, %;
ψ = Total number of observations with spacing, which are less than 0.5 times theoretical spacing; and
N = Total number of observations.

D. Quality feed index

The quality feed index I_{qf} is the percentage of spacing that are more than half but not more than 1.5 times the set planting distance S in mm. The quality of feed index is an alternate way of presenting the performance of misses and multiples.

$$I_{qf} = 100 - (I_{miss} + I_{mult}) \quad \text{.....(16)}$$

E. Plant population

The number of plants per 5 m length was determined by taking observation at five randomly selected spots by using 5 m length and by counting number of plant within the length.

RESULTS AND DISCUSSION

1. Laboratory Test

A. Calibration of the developed sowing machine

Calibration is most important process for any sowing equipment for the desired seed rate and spacing. The developed sowing machine was calibrated for soybean, pigeonpea and maize at three speeds (2.50, 2.75, 3.00 km/h),

Table 2: Data obtained from calibration test of the sowing machine

Crops	Speed (km/h)	Rpm	Seeds spacing (cm)	Seed rate (kg/ha)
Soybean	2.50	42	10.49	23.19
	2.75	46	10.65	22.86
	3.00	50	10.66	22.82
Pigeonpea	2.50	21	19.73	13.01
	2.75	23	21.16	12.11
	3.00	25	21.25	12.08
Maize	2.50	21	19.74	24.72
	2.75	23	20.19	22.22
	3.00	25	20.55	20.00

Seed damage was not found during calibration test due to hard texture of seeds.

B. Mechanical seed damage

Seed damage of the sowing machine was calculated by measuring mass of the damaged seed from the dropped seed during the calibration of the sowing machine. But no seed breakage was observed while testing the metering mechanisms with soybean, pigeonpea and maize seed due to the hard structure of the seed. Magar *et al.* (2009) found negligible (0.61 percent) damage in groundnut.

C. Seed germination test

It was observed that the average germination of the soybean, pigeonpea and maize for un-metered seeds were found as 91.22, 93.10 and 95.41 % respectively and for metered seeds average germination were 91.14, 92.58 and 95.02 % respectively. These results are matches with Rakesh *et al.* (2018).

Table 3: Seeds germination test

Crops	Unmetered seed germination (%)	Metered seed germination (%)
Soybean	91.22	91.14
Pigeonpea	93.10	92.58
Maize	95.41	95.02

D. Miss, multiple and quality feed index of the sowing machine

The average miss index for different speed of operation is presented in Table 4. Miss index increased with increasing of rpm of metering plate because of the less exposure time of metering plate to pick up the seed. Similar results were also found by Singh *et al.* (2012) for chickpea and pigeon pea.

Table 4: Miss, multiple and quality of feed index of the developed machine

Crops	Speed (km/h)	Rpm (%)	Miss Index (%)	Multiple Index (%)	Quality feed index (%)
Soybean	2.50	42	4.25	2.85	92.9
	2.75	46	4.85	2.65	92.5
	3.00	50	5.36	2.30	92.3
Pigeonpea	2.50	21	5.23	5.24	89.5
	2.75	23	5.40	4.86	89.7
	3.00	25	5.90	3.84	90.3
Maize	2.50	21	6.25	6.36	87.4
	2.75	23	6.31	5.96	87.7
	3.00	25	6.78	5.24	88.0

2. Field performance results

C. Speed of operations

Speed of operations of the developed sowing machine ranged from 2.80 to 2.93 km/h. The highest speed of operations was observed at 20° penetration angle because the soil resistance also increased with increasing penetration angle which reduced the speed. Speed of operations decreased with increasing penetration angle.

D. Effect of angle of pull and angle of penetration on theoretical field capacity

Theoretical field capacity of the developed sowing machine was in the rangeof0.504 to 0.525 ha/h. The highest TFC was observed at 20° penetration angle. Theoretical field capacity is dependent on speed of operation and width of operation. As speed of operation of the machine increased the value of TFC also increased as more area was covered at higher speed. Angle of penetration had significant effect on TFC.

The model F-value of 94.46 implies that the model is significant ($P<0.05$). In this case X1, X2 and $X2^2$ are significant model terms. R^2 and adjusted R^2 values of the model are 0.98 and 0.97 respectively.

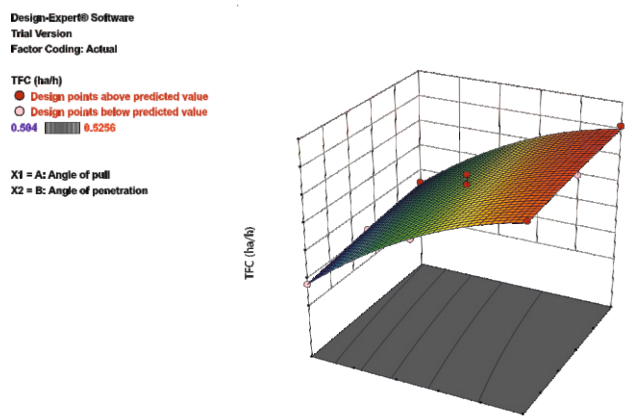

Fig. 3: Effect of angle of pull and angle of penetration on theoretical field capacity

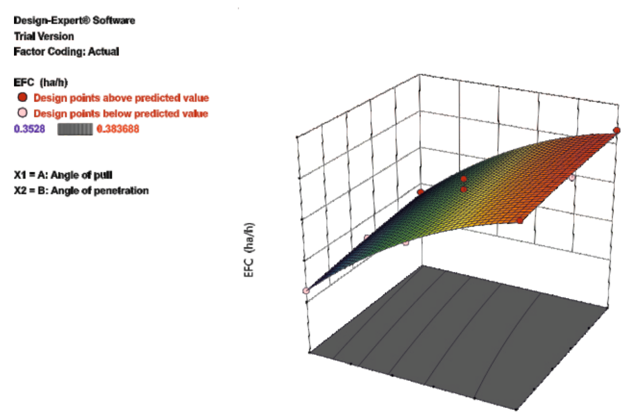

Fig. 4: Effect of angle of pull and angle of penetration on effective field capacity

E. Effect of angle of pull and angle of penetration on effective field capacity

Effective field capacity of the developed sowing machine ranged from 0.352 to 0.383 ha/h with an average value of

0.371 ha/h. The maximum effective field capacity of developed sowing machine at coded point (20°, 30°) was about 0.383 ha/h. EFC increased as more area was covered. Angle of penetration had significant on EFC as angle of penetration increased. Effective field capacity is higher than bullock drawn planter which was found by Kulkarni and Deshpande (2004).

The model F-value of 92.99 implies that the model is significant ($P<0.05$). In this case X1, X2 and $X2^2$ are significant model terms. R^2 and adjusted R^2 values of the model are 0.98 and 0.97, respectively.

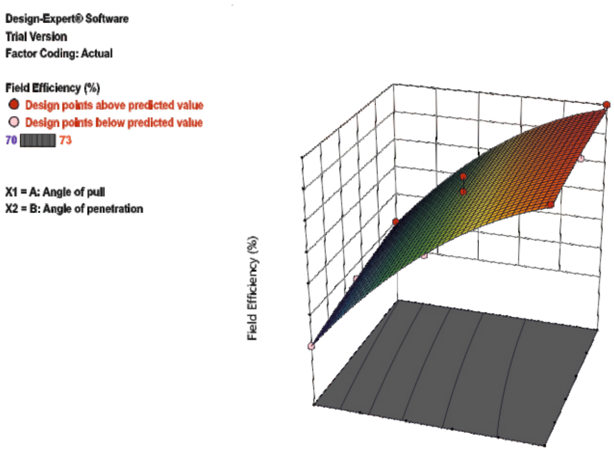

Fig. 5: Effect of angle of pull and angle of penetration on field efficiency

F. Effect of angle of pull and angle of penetration on field efficiency

The field efficiency of the developed sowing machine ranged from 70.00 % to 73.00 %. The highest field efficiency received at coded point (20°, 30°) which indicated that the maximum field efficiency received at lowest angle of penetration. However, effect of angle of pull and angel of penetration was significant on field efficiency. The model F-value of 94.46 implies that the model is significant ($P<0.05$). In this case X1, X2, and $X2^2$ are significant model terms. R^2 and adjusted R^2 values of the model are 0.98 and 0.97, respectively.

G. Effect of angle of pull and angle of penetration on draft requirement

The draft requirement of the developed sowing machine ranged from 58.52 to 70.48 kgf. The minimum draft was observed at coded point (20°, 30°) which indicated that the minimum draft received at minimum angle of penetration. These results are closely matches with animal drawn seed drill developed by Dhok *et al.* (2015), Jena and Khandai (2017), Singh and Yadaw (2014).

The model F-value of 468.55 implies that the model is significant ($P<0.05$). In this case X2 and $X2^2$ are significant model terms. R^2 and adjusted R^2 values of the model are 0.99 and 0.99, respectively.

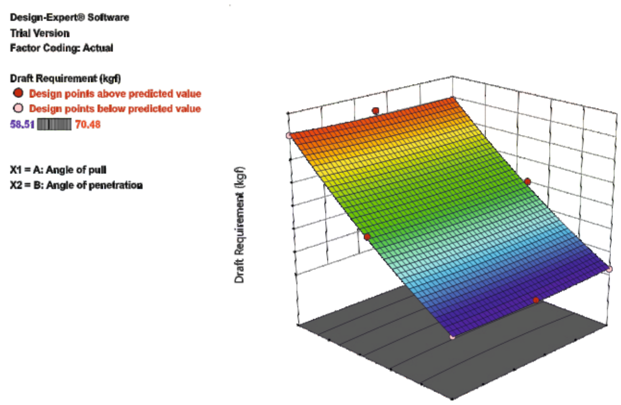

Fig. 6: Effect of angle of pull and angle of penetration on draft requirement

The general trend of the graph (Fig. 6) indicates that the draft increased with the increasing penetration angle. The maximum draft (70.48 kgf) was obtained at 30° angle of penetration. As angle of penetration increased more volume of the soil mass through the machine was increased and therefore soil resistance was also increased which resulted into more draft value.

H. Effect of angle of pull and angle of penetration on power requirement

The power requirement ranged from 0.630 hp to 0.743 hp. The Fig. 7 shows that the power requirement increased

Table 5: ANOVA for response surface reduced quadratic model for desirability

Name	Goal	Lower	Upper	Importance
A: Angle of Pull (Degree)	is in range	20	30	3
B: Angle of Penetration (Degree)	is in range	20	30	3
TFC (ha/h)	maximize	0.504	0.526	3
EFC (ha/h)	maximize	0.353	0.384	3
Field efficiency (%)	maximize	70.00	73.00	3
Draft requirement (kgf)	minimize	58.520	70.480	3
Power requirement (hp)	minimize	0.631	0.744	3
Depth of seed placement (cm)	is in range	4.700	7.800	3
Depth of uncovered furrow (cm)	is in range	0.400	5.200	3

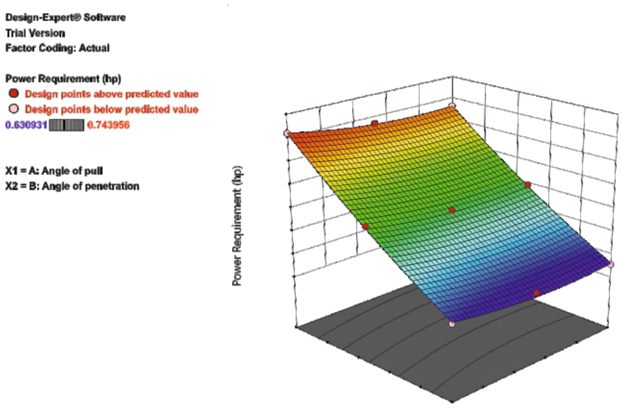

Fig. 7: Effect of angle of pull and angle of penetration on power requirement

with increase in penetration angle. The maximum power recorded at 30° angle of penetration.

The model F-value of 753.81 implies that the model is significant. Values of P less than 0.0500 indicate model terms are significant. In this case X1, X2, X1^2 and X2^{2}are significant model terms. R^2 and adjusted R^2 values of the model are 0.9981 and 0.9968, respectively.

I. Effect of angle of pull and angle of penetration on depth of seed placement

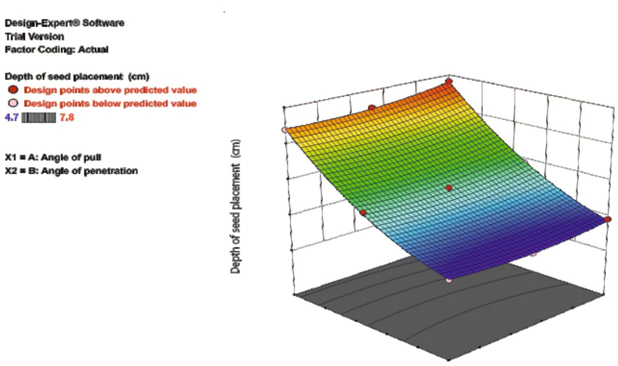

Fig. 8: Effect of angle of pull and angle of penetration on depth of seed placement

The depth of seed placement ranged from 4.7 cm to 7.8 cm. The Fig. 8 shows that the depth of seed placement increased with increase in penetration angle.Angle of pull has no more effect on depth of seed placement.

The model F-value of 351.51 implies that the model is significant. Values of P less than 0.0500 indicate model terms are significant. In this case X1, X2, X1^2 and X2^{2}are significant model terms. $R^2$and adjusted R^2 values of the model are 0.9981 and 0.9968, respectively.

J. Effect of angle of pull and angle of penetration on depth of uncovered furrow

The depth of uncovered furrow ranged from 0.4 cm to 5.2

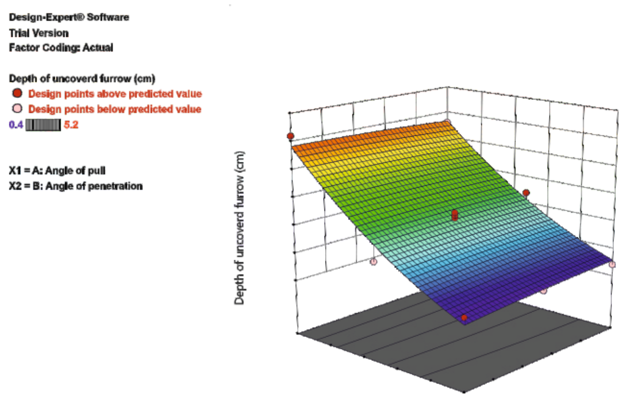

Fig. 9: Effect of angle of pull and angle of penetration on depth of uncovered furrow

cm. The Fig. 9 shows that the depth of uncovered furrow increased with increase in penetration angle.

The model F-value of 48.27 implies that the model is significant. Values of P less than 0.0500 indicate model terms are significant. In this case X2 are significant model terms. R^2 and adjusted R^2 values of the model are 0.97 and 0.95, respectively.

K. Effect of angle of pull and angle of penetration on desirability of the model

The data obtained from the 13 runs of experiments were analyzed using Face Centered Design. The optimization with different independent (factors) and dependent parameters (responses) was carried out using manual regression quadratic and linear model with the help of Design Expert (Statease 11.0.6.0) software. The analyzed data of developed sowing machine in graphical form are shown in Fig. 3 to 9. The angle of pull was varied from 20° to 30° and angle of pull varied from 20° to 30°.

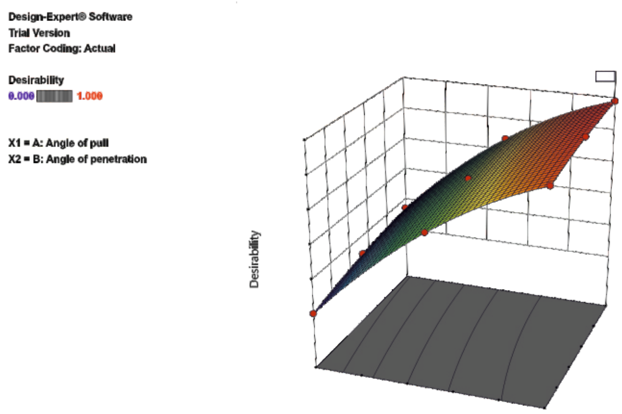

Fig 10: Desirability with respect to the angle of pull and angle of penetration

The optimized values for the best performance of developed sowing machine was assessed at different treatment and it was found that 20° penetration angle at 30° angle of pull was the best desirability achieved as shown in Table 10

The graph (Fig. 10) indicates that the maximum desirability (0.978) was observed at angle of pull 30° and angle of penetration 20°. The data of max desirability were taken for further testing.

CONCLUSION

The developed bullock drawn battery powered sowing machine was evaluated in the laboratory as well as in field for its performance and fulfilled all the functional requirements satisfactorily. The sowing machine can be used for sowing the different seeds in the field. The performance of the seed metering mechanism was found satisfactory. It provided a desired seed rate at different speeds i.e. the seed rate at 3.0 km/h speeds was obtained for soybean, pigeonpea and maize as 22.82kg/ha, 12.08kg/ha and 20.0kg/ha, respectively.Maximum EFC was found as 0.38 ha/h. Minimum draft requirement was found as 58.54 kgf at 30° angle of pull and 20° angle of penetration. The power requirement developed seed drill was obtained as 0.630 to 0.743 hp. Plant to plant spacing of soybean, pigeonpea, maize crop was observed 10.9, 20.9 and 20.8 cm respectively. The missing percent of soybean, pigeonpea, maize crop was observed 8.30, 5.00 and 5.00 %, respectively. The multiple percent of soybean, pigeonpea, maize crop was observed 6.67, 3.33 and 3.33 %, respectively. Quality of feed index was observed for soybean, pigeonpea pea and maize as 85.00, 91.67 and 91.67, respectively. Depth of seed placement was observed for soybean, pigeonpea pea and maize as 4.9, 4.8 and 5.1 cm, respectively. Average plant population per 5-meter length for soybean, pigeonpeaand maize were 45.8, 23.6 and 23.6, respectively. For the developed machine angle of pull 30° and angle of penetration 20° was found best. At this combination draft was found minimum (58.54 kgf) and maximum EFC (0.38 ha/h). Depth of seed placement was found as 4.9 cm.

REFERENCES

Bakhtiari, M. R. and Loghavi, M. (2009). Development and evaluation of innovative garlic clove precision planter. *J. Agric. Sci. Tech.*, 11: 125-136.

Bracy, R.P., Parish R.L. and Joe. E. McCoy. (1999). Precession seeder uniformity varies with theoretical spacing. *Hort. Technology*,9(1): 47-50.

Dhok, A. S., Biwal, V. D., Ghadge, S. B. and Sutkar, P. D. (2015). Performance evaluation of bullock drawn planter with low cost metering device. *International Journal of Agriculture Engineering*, 8(1):136-139.

Ghule, A. B., Gholap, B. S., Waghmode, A., Gavhane, R. and Bhutada, S. H. (2016).Status of draught animal power (DAP) and dapbased technology of Chandrapur, Nashik, Satara and Solapur districts of Maharshtra. *International Journal ofResearch in Engineering and Technology*, 5(8):388-392.

Jena, P. P. and Khandai, S. (2017). Performance evaluation of bullock drawn three-row inclined plate planter. *International Journal of Current Microbiology and Applied Sciences* 6(11):1545-1553. doi: https://doi.org/10.20546/ijcmas.2017.611.184

Karayel, D., Wiesehoff, M., Ozmerzi, M. andMuller, J. (2006). Laboratory measurement seed drill seed spacing and velocity of fall of seeds using high-speed camera system. *Computers and Electronics in Agriculture,* 50 (2):89-96.

Kathiravan, R. and Balashanmugam, P. (2019). Design and fabrication of manually operated seed sowing machine. *International Research Journal of Engineering and Technology (IRJET),* 6(6): 3767-3774. irjet.net/archives/V6/i6/IRJET-V6I6755.pdf

Kepner, R. A., Bainer, R. and Barger E. L. (1972). Principles of farm machinery 2[nd] d. xi, 486 p: illus.; 24 cm. Westport, Conn.: Avi Pub. Co.

Kulkarni, P. S. andDeshpande, S. S. (2004). Performance evaluation of lightweight, bullock drawn Jyoti multicrop planter. (Master Thesis, department of farm machinery and power MPKV, Rahuri.) Call No.631.3/KUL.

Lende, A. B., Sanglikar, R.V., Nalawade, S. M. andKadam, P. B. (2011). Electronic metering mechanism for bullock drawn planter. *Green Farming,* 2 (6):739-741.

Magar, A. P., Bhutada, S. H. and Aubj, M. D. (2009) Performance evaluation of bullock drawn seed drill for groundnut. *International Journal of Agricultural Engineering*, 2 (2):338-341.

Mehta M. L., Verma S. R., Misra S. K. and Sharma, V. K. (1995). Testing and Evaluation of Agricultural Machinery. National Agricultural Technology Information Centre, New Delhi, Pp 56-79.

Rajaiah P., Indra Mani, Adarsh Kumar, Satish D. Lande, Roaf A. Parray, Ashok Kumar Singh and CiniVergese. (2018). Comparative Study of Mechanical and Electronic Paddy Planter for Direct Seeding. *International Journal of Current Microbiology and Applied Sciences,* 7(09):1284-1294.

Rajave, S., Rajeshkumar. R., Pramjin. P., Ramu. P. and Rajasekaran. K. (2018). Design and Fabrication of Seed in Planter by Conversion of Energy. *International Journal of Engineering Research & Technology (IJERT)*, 6(4):1-4.https://www.ijert.org/research/design-and-fabrication-of-seed-in-planter-by-conversion-of-energy-IJERTCONV6IS04085.pdf

Rakesh, N., Prasad, G. V., Sarma, A. and Hema Kumar, H.V. (2018). Development and Evaluation of Small Tractor Drawn Seed Planter with Battery Operated Seed Metering Mechanism. *International Journal of Current Microbiology and Applied Sciences,* 7(03): 1879-1886.

Rangapara, D. K. and Pandya, J. (2014). Performance evaluation of manually operated single row cotton planter. *International Journal of Engineering Sciences and Research Technology*, 3(9):40-44.

Sahay, J. (2010). Elements of Agricultural Engineering (4th ed., Reprint,2010). Delhi: Standard Publishers Distributors.

Shankha, K., Bhatt, Y.C., Singh, G., Joshi, S. and Jain, H.K. (2017). Development of Electronic Metering Mechanism for Precision Planting of Seeds. *International Journal of Current Microbiology and Applied Sciences*, 6(8): 3481-3487.

Singh, G. (2000). Modernization of Agricultural in India Part I Farm mechanization. Agricultural Situation in India, January.

Singh, J. and Yadaw, M. (2014). Performance evaluation of animal drawn multi-purpose tool seed cum fertilizer drill for paddy crop. *International Journal of Innovative Research in Engineering andScience*, 4(3): 44-49.

Singh, M. K., Kumar, N., Verma, P. and Garg, S. K. (2012). Performance evaluation of mechanical planters for planting of chickpea and pigeon pea. *Journal of Food Legumes*, 25(2):131-134.

Received: February 20, 2021
Accepted: April 11, 2021