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Performance evaluation of the battery operated drum seeder

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Abstract
The battery operated drum seeder was developed for the direct sowing of the pre-germinated paddy seeds in the puddled field. The main aim of this study was to reduce the drudgery of the farmers. The developed drum seeder was evaluated in both laboratory and field conditions. During the field evaluation, drum was filled with seeds up to three-fourth of its volume. This drum seeder was evaluated by operating it at the combination of three different forward speeds of 1 km/h, 1.5 km/h and 2 km/h with three different ground wheel diameters of 50 cm, 55 cm and 60 cm at two different lug inclination angles of 45° and 90°. The maximum effective field capacity and field efficiency of the drum seeder were 0.128 ha/h and 79.94% respectively, for 55 cm ground wheel at 2 km/h speed with lug inclination angle of 90°.

Keywords: Drum seeder, pre-germination, lug inclination angle, forward speed, effective field capacity, field efficiency

Introduction
Paddy is the one of the main food crop in the world. The scientific name of paddy is *Oriza sativa* L. Rice has one of the biggest consumption levels all across the world. It has 63.52% of carbohydrates, 10.37% of fiber and 5.80% of protein as major nutrients by mass (Khin and Then, 2019) [3]. Paddy grows in temperate, tropical as well as subtropical climates. In India rice is grown under three major ecosystems: rainfed upland (16%), irrigated land (45%) and rainfed lowland (39%), with the productivity of 0.87, 2.24 and 1.55 t/ha, respectively. It contributes 20 to 25 percent of agricultural GDP (Mali *et al*. 2018) [7]. It can be sown in a dry seedbed, wet seedbed or can be transplanted in puddled field. Paddy is grown either by direct seeding like broadcasting or by transplanting (Goel and Verma, 2000) [2]. Asian countries produce more than 90% of the overall paddy production in the world. China and India are the two major producers of rice. Asia is regarded as the home for all the species of paddy. Total production of paddy in the year 2019-20 was 118.43 million tonnes on an area of 43.78 million ha with the yield of 2705 kg/ha (Agricultural Statistics at a Glance, 2020) [1]. In India West Bengal was the highest producer of paddy with the production of 15.57 million tonnes on area of 5.46 million ha. Total production of paddy in Gujarat state was 1.87 million tonnes with yield of 2143 kg/ha in 2019-20 (Agricultural Statistics at a Glance, 2020) [1].

In traditional method of sowing, paddy is grown in a small plot called nursery and after sometime, it is transplanted to main field. The transplanting of paddy to the main field requires more number of labours, takes much time to complete the work and it is a highly drudgery work. Agriculture in recent days has faced many problems, one of the prominent among them is migration. Around 25 to 30% of the rural population is shifting from villages to urban areas resulting in an acute shortage of farm labours. Therefore, direct seeding of the pre-germinated paddy seeds by drum seeder is becoming more popular now days in India. A drum seeder is an implement consisting of a seed drum used for sowing the germinated paddy seeds. These are operated manually by pulling. Power from ground wheels is transmitted to the drum through the shaft (Mahilang *et al*., 2017) [6]. The gear ratio of ground wheel and drum will be 1:1. But these drum seeders are manually pulled by the farmer, which is again a drudgery work. Therefore, battery operated drum seeder was developed, in order to reduce the drudgery of pulling. It is simple in construction and environmental friendly. Therefore the study was undertaken to evaluate the performance of the developed battery operated drum seeder in puddled fields.

Materials and Methods

The laboratory evaluation of the developed battery operated drum seeder was conducted at the Implement shed of the Department of Farm Machinery and Power Engineering, CAET, Godhra. Field evaluation of the seeder was done in the Instructional farm, Kankanpur, CAET, Godhra. Gurjari variety of paddy seeds was chosen for the evaluation of this seeder. The sowing holes of the drum were covered and drum of the seeder was filled up to the three fourth level of its volume. During laboratory evaluation of the drum seeder, a polythene sheet with grease applied on it was spread on the ground for 10 m length and 1 m width. Drum seeder was operated on the sheet with different combinations of diameter of ground wheel, forward speeds and lug inclination angles.

During the field evaluation size of the experimental plot was measured. The soil of the experimental plot was sandy loam with the bulk density of 1.3 g/cc (before puddling). The land was prepared by puddling and leveling. The puddling index of the field was 33.90%. Paddy seeds were soaked in water for 24 h and incubated for another 24 h for pre-germination. Length of 1 mm to 2 mm sprout is expected (Kumar *et al.* 2017) [4]. These pre-germinated seeds were sown in puddled soils after 1-2 days of puddling using the drum seeder. The seed rate adopted for direct sowing of Gurjari variety of paddy was 25 kg/ha.

The different independent and dependant parameters considered during the both laboratory as well as field evaluation of the drum seeder were given in the table below:

Table 1: Different variables

Independent Variables	Levels	Values	Dependent Variables
Ground wheel diameters	3	50 cm	Hill to hill spacing (cm)
		55 cm	Number of seeds/hill
		60 cm	Missing index (%)
Forward speeds	3	1.0 km/h	Seed rate (kg/ha)
		1.5 km/h	Wheel slip (%)
		2.0 km/h	Effective field capacity (ha/h)
Lug inclination angles	2	45°	Field efficiency (%)
		90°	

Determination of Hill to Hill Spacing

Spacing between the two consecutive seed hills were measured by a steel scale of 30 cm length after sowing by drum seeder. Ten randomly selected observations were taken and the mean was determined to find out the hill to hill spacing.

Determination of Number of Seeds per Hill

This indicates the number of seeds dropped at one point. It was counted manually after the seeds dropped from the drum seeder. Ten randomly selected observations were taken and the mean was determined to find out the number of seeds per hill.

Missing Index (%)

The recommended seed spacing for direct seeding of paddy is 15 cm. If the actual distance between two consecutive hills is more than 1.5 times the theoretical (recommended) spacing, it is considered as a missing hill. The data was recorded for all the treatments, and each treatment was replicated three times. The missing index (%) was calculated using the below equation (Kumar *et al.*, 2021) [5];

$$\text{Missing Index} = \frac{N_m}{N_t} \times 100$$

Where,
N_m = Number of missing hills
N_t = Total number of hills

Seed rate (Kg/ha)

Seed rate is the amount of seeds in kg required to sow the one hectare of land. It was determined by collecting and weighing the seeds after each trial of the drum seeder in case of laboratory evaluation. During field evaluation, it was evaluated based on the number of seeds dropped per m^2 of area.

Effective Field Capacity

The effective field capacity is the actual rate of coverage by the machine, based upon the total time used in the field considering the time losses. Effective field capacity will be calculated by the following formula:

$$\text{Effective field capacity (ha/h)} = \frac{\text{Total area covered (ha)}}{\text{Time required to cover the field (h)}}$$

Field Efficiency

It is the ratio of effective field capacity to the theoretical field capacity and it is expressed in percentage. Field efficiency will be calculated by the following formula:

$$\text{Field efficiency (\%)} = \frac{\text{Effective field capacity}}{\text{Theoretical field capacity}}$$

Results and Discussion

The developed battery operated drum seeder was evaluated in both laboratory and field conditions.

- Laboratory Evaluation
- Field Evaluation

Laboratory Evaluation

The laboratory evaluation of the developed battery operated drum seeder was conducted at the Implement shed of the Department of Farm Machinery and Power Engineering, CAET, Godhra. During laboratory evaluation, dependant parameters such as hill to hill spacing, number of seeds/hill, missing index and seed rate were determined. The effect of different independent variables on each dependent parameters are discussed as below:

Effect of independent parameters on hill to hill spacing

Maximum hill to hill spacing obtained was 16.82 cm for 60 cm ground wheel diameter at 2.0 km/h speed with lug inclination of 45°, while 14.16 cm is the minimum hill to hill spacing obtained for 50 cm ground wheel diameter at 1.0 km/h with the lug inclination of 90°.

Effect of independent parameters on number of seeds/hill

Maximum number of seeds/hill obtained was 3.67 for 50 cm ground wheel diameter at 2.0 km/h speed with lug inclination of 90°, while 3.13 seeds are the minimum number of seeds/hill obtained for 60 cm ground wheel diameter at 1.0 km/h with the lug inclination of 45°. Number of seeds/hill was increasing with increase in speed and it was more in case of 90° lug inclination angle.

Effect of independent parameters on missing index

Maximum missing index obtained was 9.56% for 60 cm ground wheel diameter at 2.0 km/h speed with lug inclination of 45°, while 4.26% was the minimum missing index obtained for 50 cm ground wheel diameter at 1.0 km/h with the lug inclination of 90°. Missing index was increasing with increase in speed, increase in ground wheel diameter and it was more in case of 45° lug inclination angle.

Effect of independent parameters on seed rate

Maximum seed rate obtained was 25.92 kg/ha for 50 cm ground wheel diameter at 2.0 km/h speed with lug inclination of 90°, while 19.28 kg/ha was the minimum seed rate obtained for 50 cm ground wheel diameter at 1.0 km/h with the lug inclination of 45°. Seed rate was increasing with increase in speed, decrease in ground wheel diameter and it was more in case of 90° lug inclination angle.

Field Evaluation

To assess the performance of developed battery operated drum seeder, field experiments were carried out by varying forward speed, diameter of ground wheel and lug inclination angle. Area of the experimental plot was 1000 m^2. The performance of the developed drum seeder was evaluated in terms of hill to hill spacing, number of seeds/hill, missing index, seed rate, wheel slip, effective field capacity and field efficiency. To analyze the data, Design Expert Software (State ase 13.0) was used. The effect of different independent variables on each dependent parameters are discussed as below:

Effect of independent parameters on hill to hill spacing

During the field evaluation of drum seeder, the variation of hill to hill spacing was measured with the three different ground wheel diameters of 50 cm, 55 cm & 60 cm, at three forward speeds of 1.0 km/h, 1.5 km/h and 2.0 km/h with the lug inclinations angles of 45° & 90° were measured.

The variation of hill to hill spacing for 45°& 90° lug inclination are shown graphically as below;

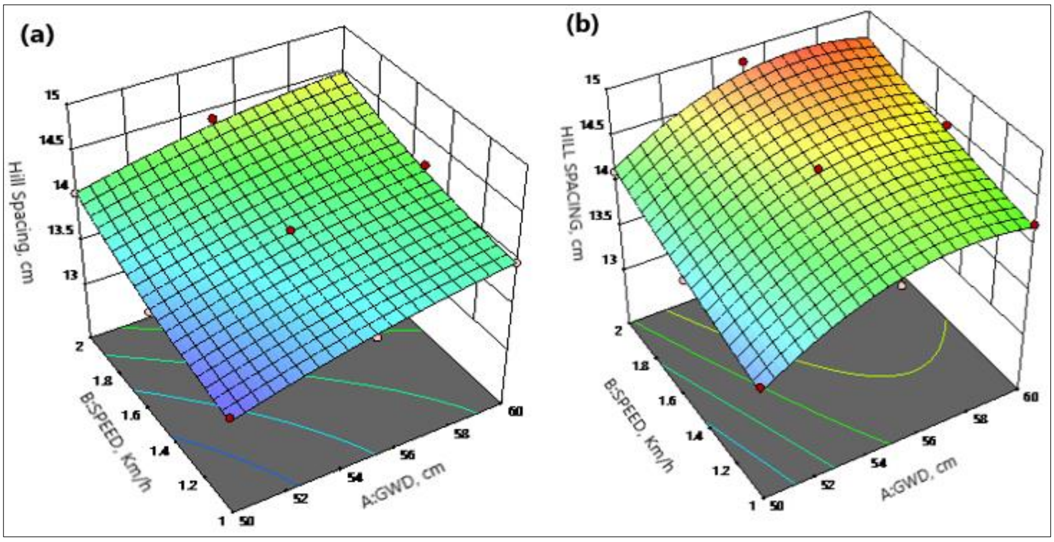

Fig 3: Variation of hill to hill spacing, (a) 45° lug inclination angle, (b) 90° lug inclination angle

Maximum hill to hill spacing obtained was 14.72 cm for 60 cm ground wheel diameter at 2.0 km/h forward speed with the lug inclination of 90° and minimum was 13.44 cm for 50 cm ground wheel diameter obtained at 1.0 km/h with the lug inclination of 45°. Hill to hill spacing increased with increase in speed and increase in diameter of the ground wheel.

The Model F-value of 19.76 for hill to hill spacing implies the model is significant. P-values less than 0.0500 indicate model terms are significant. In this case A, B, C, AB, A^2, A^2C are significant model terms. R^2 and adjusted R^2 values of the model are 0.9731and 0.9239, respectively. Where A is ground wheel diameters, B is forward speeds and C is lug inclination angles.

Effect of independent parameters on number of seeds/hill

The variation of number of seeds/hill with the three different ground wheel diameters of 50 cm, 55 cm & 60 cm, at three forward speeds of 1.0 km/h, 1.5 km/h and 2.0 km/h with the lug inclinations angles of 45° & 90° were measured:

The variation of number of seeds/hill for 45°& 90° lug inclination are shown graphically as below;

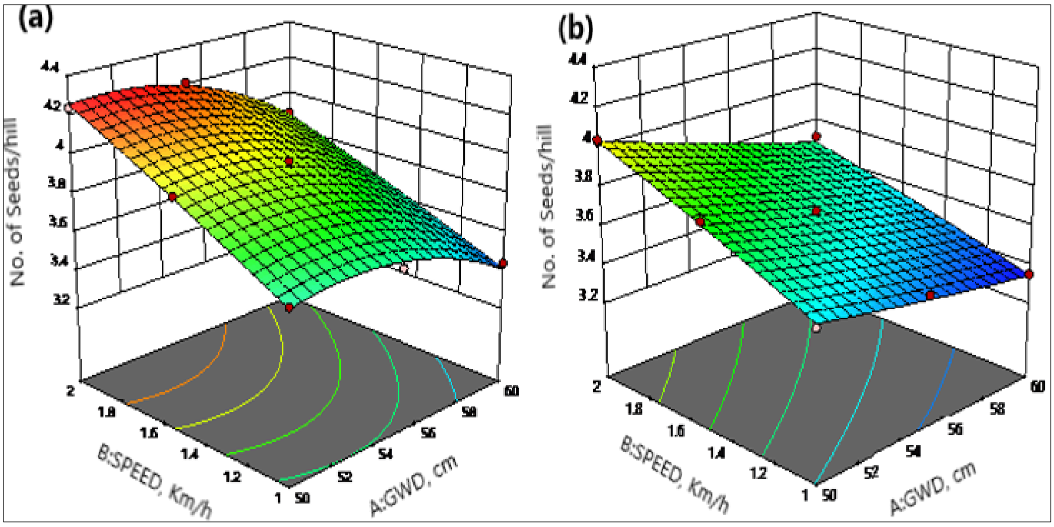

Fig 4: Variation of number of seeds/hill (a) 45° lug inclination angle (b) 90° lug inclination angle

Maximum no. of seeds/hill obtained were 4.24 seeds for 50 cm ground wheel diameter at 2.0 km/h forward speed with the lug inclination of 45° and minimum was 3.36 seeds for 60 cm ground wheel diameter obtained at 1.0 km/h with the lug inclination of 90°. Number of seeds/hill increased with increase in speed and it nearly remained constant with increase in diameter of the ground wheel.

The Model F-value of 67.17 implies the model is significant. P-values less than 0.0500 indicate model terms are significant. In this case A, B, C, BC, A^2, A^2C are significant model terms. R^2 and adjusted R^2 values of the model are 0.9919 and 0.9772, respectively.

Effect of independent parameters on missing index

The variation of missing index with the three different ground wheel diameters of 50 cm, 55 cm & 60 cm, at three forward speeds of 1.0 km/h, 1.5 km/h and 2.0 km/h with the lug inclinations angles of 45° & 90° were measured:

This variation of missing index for 45° & 90° lug inclination are shown graphically as below:

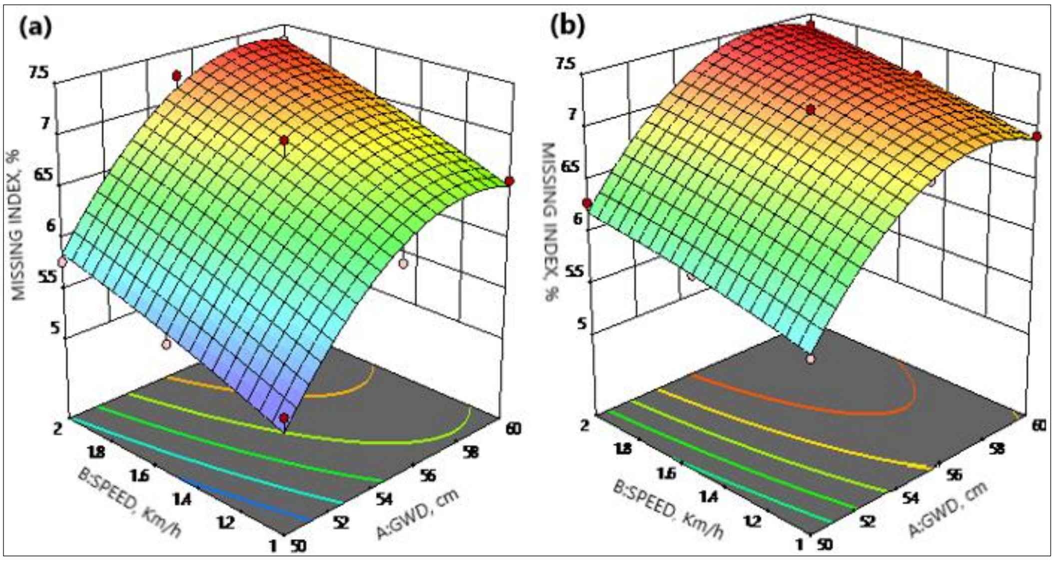

Fig 5: Variation of missing index (a) 45° lug inclination angle (b) 90° lug inclination angle

Maximum missing index obtained was 7.44% for 60 cm ground wheel diameter at 2.0 km/h forward speed with the lug inclination of 90° and minimum was 5.26% for 50 cm ground wheel diameter obtained at 1.0 km/h with the lug inclination of 45°. Missing index increased with increase in speed as well as increase in diameter of the ground wheel.

The Model F-value of 62.48 implies the model is significant. P-values less than 0.0500 indicate model terms are significant. In this case A, B, C, BC, A^2 are significant model terms. R^2 and adjusted R^2 values of the model are 0.9823 and 0.9666, respectively.

Effect of independent parameters on seed rate

The variation of seed rate with the three different ground wheel diameters of 50 cm, 55 cm & 60 cm, at three forward speeds of 1.0 km/h, 1.5 km/h and 2.0 km/h with the lug inclinations angles of 45° & 90° were measured:

This variation of seed rate for 45° & 90° lug inclination are shown graphically as below:

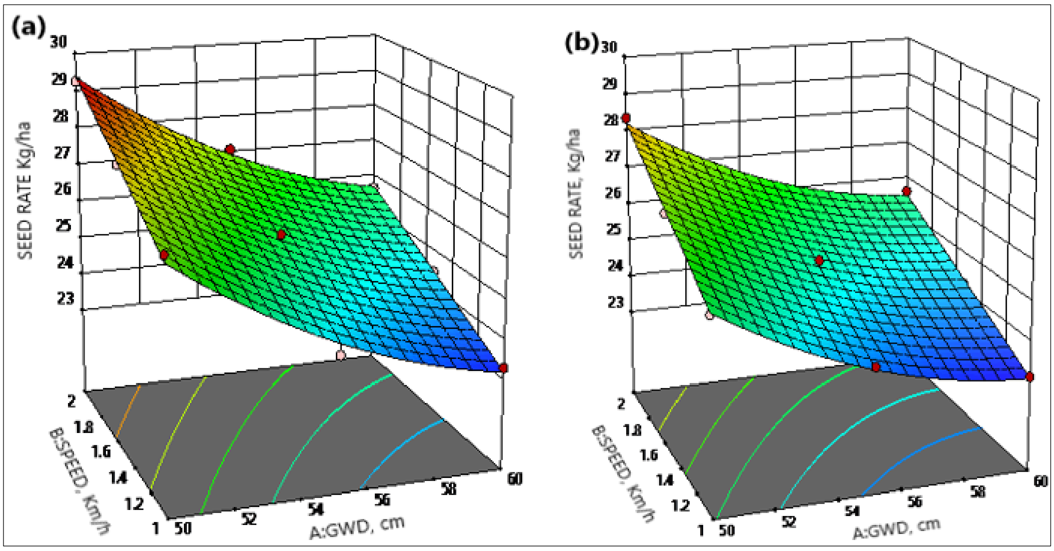

Fig 6: Variation of seed rate (a) 45° lug inclination angle (b) 90° lug inclination angle

Maximum seed rate obtained was 28.36 kg/ha for 50 cm ground wheel diameter at 2.0 km/h forward speed with the lug inclination of 90° and minimum was 23.36 kg/ha for 60 cm ground wheel diameter obtained at 1.0 km/h with the lug inclination of 45°. Seed rate increased with increase in speed and decreased with increase in diameter.

The Model F-value of 186.86 implies the model is significant. P-values less than 0.0500 indicate model terms are significant. In this case A, B, C, AC, A^2 are significant model terms. R^2 and adjusted R^2 values of the model are 0.9940 and 0.9887, respectively.

Effect of independent parameters on wheel slippage (%)

The variation of wheel slippage with the three different ground wheel diameters of 50 cm, 55 cm & 60 cm, at three forward speeds of 1.0 km/h, 1.5 km/h and 2.0 km/h with the lug inclinations angles of 45° & 90° were measured:

This variation of wheel slip for 45° & 90° lug inclination are shown graphically as below:

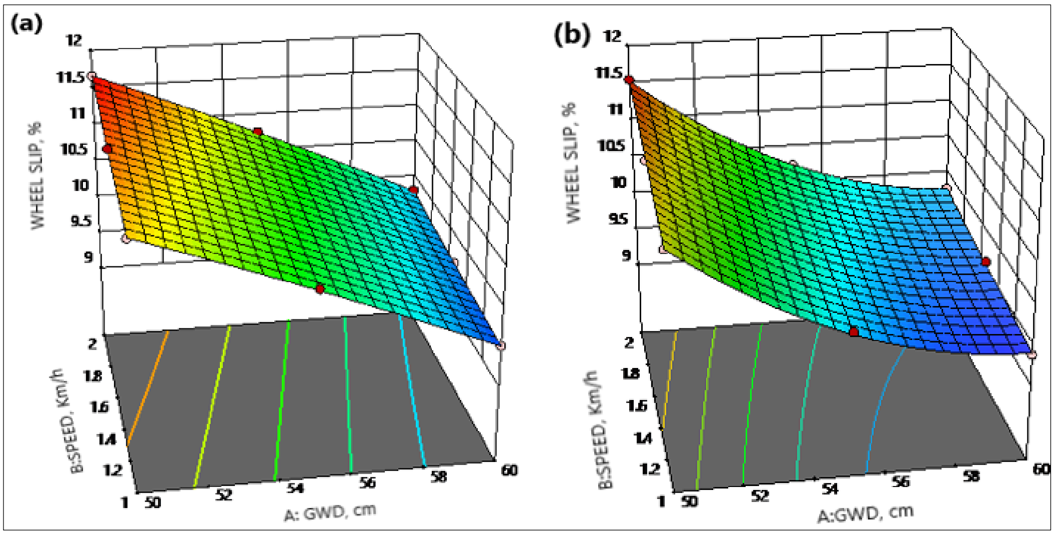

Fig 7: Variation of Wheel slip (a) 45° lug inclination angle (b) 90° lug inclination angle

Maximum wheel slip obtained was 11.68% for 50 cm ground wheel diameter at 2.0 km/h forward speed with the lug inclination of 45° and minimum was 9.42% for 60 cm ground wheel diameter obtained at 1.0 km/h with the lug inclination of 90°.

Wheel slip increased with the increase in speed and decreased with increase in diameter of the ground wheel. When the speed is increased, the force applied on the ground wheel increased which in turn caused more wheel slip. With the increase in diameter of the ground wheel, contact area with the ground is increased, hence the wheel slip reduced.

The Model F-value of 892.73 implies the model is significant. P-values less than 0.0500 indicate model terms are significant. In this case A, B, C, AB, A^2, A^2C are significant model terms. R^2 and adjusted R^2 values of the model are 0.9994 and 0.9983, respectively.

Effect of independent parameters on effective field capacity (EFC)

The variation of effective field capacity with the three different ground wheel diameters of 50 cm, 55 cm & 60 cm, at three forward speeds of 1.0 km/h, 1.5 km/h and 2.0 km/h with the lug inclinations angles of 45° & 90° were measured:

This variation of effective field capacity for 45° & 90° lug inclination are shown graphically as below:

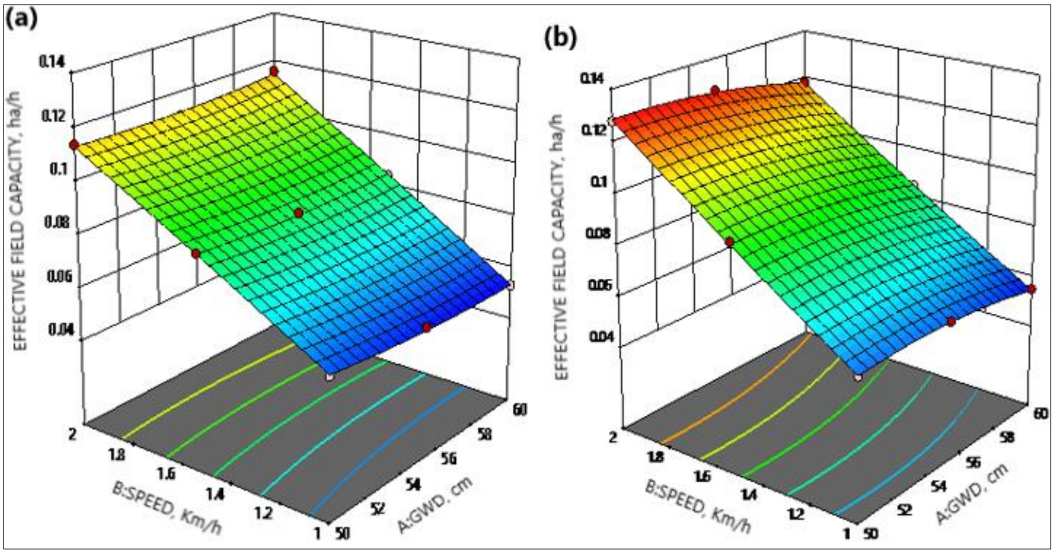

Fig 7: Variation of effective field capacity (a) 45° lug inclination angle (b) 90° lug inclination angle

Maximum effective field capacity obtained was 0.128 ha/h for 50 cm ground wheel diameter at 2.0 km/h forward speed with the lug inclination of 90° and minimum was 0.054 ha/h for 60 cm ground wheel diameter obtained at 1.0 km/h with the lug inclination of 45°. Effective field capacity increased with increase in forward speed and remained nearly constant with the increase in diameter of the ground wheel diameter.

The Model F-value of 685.94 implies the model is significant. P-values less than 0.0500 indicate model terms are significant. In this case A, B, C, AC, BC, ABC, A^2C are significant model terms. R^2 and adjusted R^2 values of the model are 0.9992 and 0.9977, respectively.

Effect of independent parameters on field efficiency

The variation of field efficiency with the three different ground wheel diameters of 50 cm, 55 cm & 60 cm, at three forward speeds of 1.0 km/h, 1.5 km/h and 2.0 km/h with the lug inclinations angles of 45° & 90° were measured:

This variation of field efficiency for 45° & 90° lug inclination are shown graphically as below:

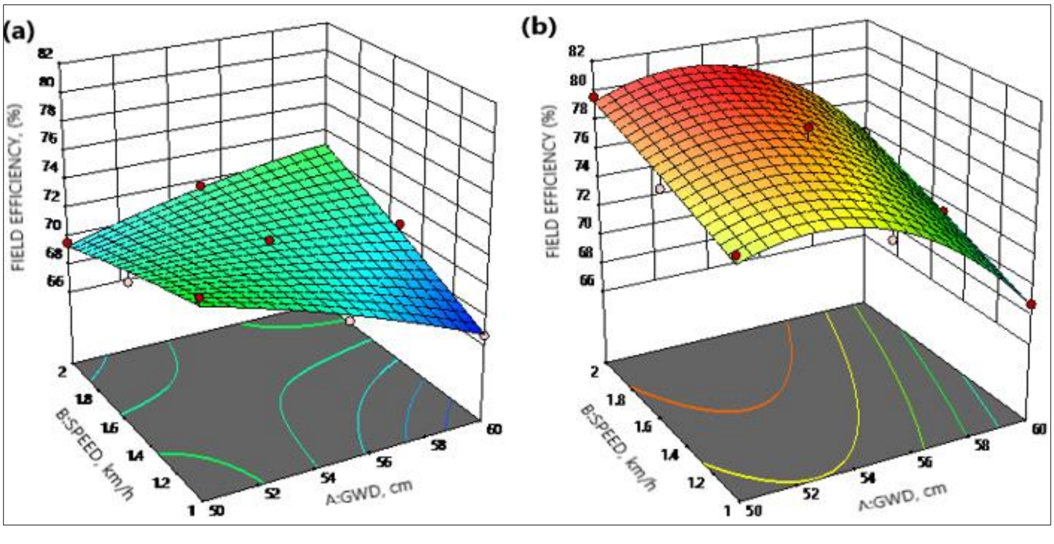

Fig 8: Variation of field efficiency (a) 45° lug inclination angle (b) 90° lug inclination angle

Maximum field efficiency obtained was 79.94% for 55 cm ground wheel diameter at 2.0 km/h forward speed with the lug inclination of 90° and minimum was 67.50% for 60 cm ground wheel diameter obtained at 1.0 km/h with the lug inclination of 45°. Field efficiency increased with the increase in speed and remained nearly constant with the increase in diameter of the ground wheel.

The Model F-value of 35.41 implies the model is significant. P-values less than 0.0500 indicate model terms are significant. In this case A, B, C, AB, AC, BC, A^2, ABC, A^2C are significant model terms. R^2 and adjusted R^2 values of the model are 0.9848 and 0.9570, respectively.

Optimization of the results

Results obtained after the experiment were optimized using the design expert software for obtaining the overall best combination of ground wheel diameter, forward speed and lug inclination angle.

Table 1: Optimization of dependant parameters

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
A	is in range	50	60	1	1	3
B	is in range	1	2	1	1	3
C	is in range	45	90	1	1	3
Hill spacing	is in range	14	15	1	1	3
No of seeds/ hill	is in range	3.5	4	1	1	3
Missing index	none	5.26	7.38	1	1	3
seed rate	is in range	23	27	1	1	3
Wheel slip	minimize	9.38	11.66	1	1	3
Field efficiency	maximize	66.66	79.94	1	1	3

Total 12 results were obtained after the optimization. Maximum desirability of 0.858 was obtained for the ground wheel diameter of 56.15 cm, forward speed of 2.0 km/hr and lug inclination angle of 90°. During this combination of independent variables, dependent variables such as hill to hill spacing of 14.58 cm, number of seeds/hill of 3.8, missing index of 7.43%, seed rate of 26.03 kg/ha, wheel slip of 10.08%, effective field capacity of 0.125 ha/h and field efficiency of 79.33% were obtained by optimization.

Conclusions

Based on the results obtained from the evaluation of the battery operated drum seeder, it can be concluded that drum seeder with 55 cm ground wheel diameter at forward speed of 2.0 km/h with lug inclination of 90° has given the best results. During this combination, hill to hill spacing of 14.66 cm, number of seeds/hill of 3.81, missing index of 7.21%, seed rate of 26.11 kg/ha, wheel slip of 10.26%, effective field capacity of 0.127 ha/h and field efficiency of 79.94% were obtained.

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