Plant Archives Vol. 25, Supplement 2, 2025 pp.3139-3148 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.supplement-2.402

DESIGN AND DEVELOPMENT OF BATTERY-OPERATED MULTI-CROP PLANTER

D.S. Karale*, Ankita Shinde and A.J. Lohar
Department of Farm Power and Machinery, Dr. PDKV Akola, Maharashtra, India
*Corresponding Author E-mail: dhirajkarale111@gmail.com
(Date of Receiving : 06-05-2025; Date of Acceptance : 02-07-2025)

ABSTRACT

To meet the needs and difficulties of small and marginal farmers a battery-operated multi-crop planter has been developed with locally available material. The multi-crop planter was propelled by using Battery Electrical Vehicle (BEV) and the power transmission from ground wheel to driver sprocket which is on the main power transmission shaft that connects to the seed metering shaft through chain and driven sprocket. In the laboratory trial calibration of planter for seed rate, miss index, multiple indices, quality feed index, uniformity index was determined. The laboratory and field trial were taken for soybean crop. The experimental optimization of parameters was done by using Design Expert 11.0 edition software by using Response Surface Methodology (RSM). Three levels of forward speed viz., 2 km/h, 2.5 km/h, 3 km/h and three level of sub-hopper opening 50 %, 75 %, 100 % were chosen to optimize the performance parameters. The RSM results shows that the planter was satisfactorily work on forward speed 2.5 km/h with 75% sub-hopper opening for all the performance parameters. During field trial the average planting depth and seed to seed spacing was found 4.96 cm and 9.81 cm respectively. The average effective field capacity of the planter was found 0.261 ha/h whereas average field efficiency was found to be 77.35%.
***Keywords* :** Planter, Soybean, Performance evaluation, field trial laboratory trial, Response Surface Methodology.

Introduction

Sowing or planting begun with the early men using the bare hands and later graduated to the use of sticks then to the use of crude implements like cutlasses and hoes for planting and the general tillage operations. Efforts have been put in place to simplify human labour overtime in sowing seeds by the innovations of seed planters. Seed planter acts as on one of the major form machineries for the use of seed sowing purpose thereby ensuring the precise use of seeds by sowing at proper spacing. The most vital constituent in seeding equipment is the metering device (Yang *et al*., 2016). Yazgi and Degirmencioglu (2007) made use of Response Surface Methodology (RSM) to look for a seed planter spacing outcome. Panning *et al.* (2000) applied an optoelectronic sensor system to examine distributed kernel locations.

The use of traditional seed drill does not maintain intra-row seed spacing, So the development of precision planter will help to place the seed in an acceptable pattern of distribution in the filed with the required accuracy and uniformity at the desired in the soil (Anantachar *et al.*, 2010).

Singh *et al.* (2019) evaluated e-powered multi-purpose two row seeder for smallholders. E-powered seeder was tested in laboratory for four forward speeds i.e., 1.45, 1.85, 1.98, 2.64 km/h for assessing the uniformity of seed metering. During field evaluation output with the seeded was1130 m2/h at speed about 2.9 km/h with 90.3% field efficiency.

Inamdar *et al.* (2020) Designed and developed electric multi-seed sowing machine with use of 750 W, 48V, 450 RPM BLDC motor for ploughing with 3 furrows the maximum torque is 44.07 Nm and the force required for the ploughing is 144 N. According to seed type and seed to seed spacing time and distance required for 1 ha is calculated.

Hijam *et al.* (2014) developed and evaluated self-propelled multi-crop planter for hill agriculture for planting maize and soybean seeds. Average depth of seed placements were 22.50 mm and 21.50 mm for maize and soybean respectively. The average field capacity of 0.11 ha/h for continuous operation of planting both maize and soybean. The average field efficiency was observed 80.98%.

Material and Method

Design and development of various components of battery operated multi-crop planter

Development of multi-crop planter was carried out on the basis of power availability, number of rows, type of seed metering mechanism, hopper size etc. Conceptual CAD view of multi-crop planter as shown in Fig. 1. The battery operated multi-crop planter consisted of frame, seed hopper, seed metering unit, seed tube, furrow opener, and ground wheel etc.

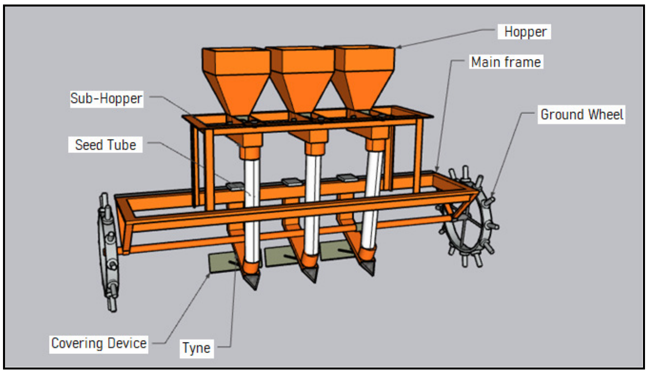


Fig. 1 : Conceptual view of multi-crop planter

Frame:

Main frame supports all components of planter. Seed hopper, furrow opener, ground wheel was mounted on main frame. Main frame of rectangular shape was made up of from mild steel C channel of size 1270 x 300 x 3 mm. fig. 2 shows fabrication stages of multi-crop planter.

Working width of multi-crop planter

The working width of planter varies with row to row according to crop. So, the working width for battery operated multi-crop planter was calculated by using equation 1

$$W = Z \times a \quad (1)$$

Where, W = working width of machine, cm;

Z = number of furrow opener in the drill;

a = row to row distance, cm

For soybean, W = 3 x 45 = 135 cm

Fig. 2 : View of fabrication stages of main frame

Metering mechanism

Metering mechanism is the heart of planter and its function is to distribute seeds uniform spacing at the desired application rates. The vertical rotor cell type seed metering was used in battery operated multi-crop planter.

Seed metering rotor:

Number of cells required on rotor was calculated as given below (Sharma and Mukesh, 2010)

$$n = \frac{\pi D}{i\,x} \quad ...(2)$$

Where, n = number of cell on rotor plate;

D = ground wheel diameter, cm;

x = required seed to seed spacing, cm; i = gear ratio

For soybean seed rotor, n = $\frac{3.142 \times 43}{1.5 \times 9}$ = 10 cells

Hence, marketely available 10 cell vertical rotor was selected for soybean seed as shown in fig. 3

Fig. 3 : Seed metering rotor selected for soybean and cotton seed

Hopper and sub-hopper

Seed hopper selected by considering the physical properties such as bulk density, angle of repose of seed, duration between refilling. Isometric view of seed hopper as shown in Fig 4. Volume of seed hopper was calculated 5687.5 cm^3 (56.875 x 10^{-4} m^3). Capacity of hopper was calculated by using equation 3 found to be 3.66 kg for soybean.

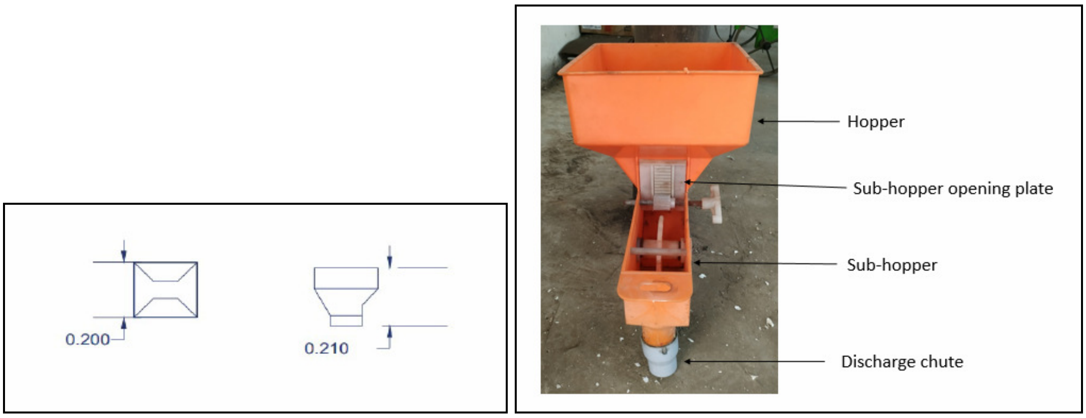


Fig. 4 : Isometric view and actual view of seed hopper

$$V = \frac{Q}{\rho} \quad ... (3)$$

Where,

V = volume of hoper, m^3;

Q = hopper capacity, kg;

ρ = bulk density of seed (soybean), kg/m^3

Seed rotor shaft

The rotor shaft was fabricated by using 16 x 16 x 2 mm M.S. square hallow bar. Length of the rotor shaft is 480 mm

Power Transmission unit

Power transmission unit of planter consist of Chain and sprocket arrangement, Ground wheel, Power transmission shaft. Seed rotor received power from the ground wheel through chain and sprocket arrangement. The driving sprocket was mounted on main shaft and driven sprocket was mounted on seed rotor shaft.

The length of chain was calculated by using following equation (Sharma and Mukesh, 2010)

$$m = \frac{2C}{P} + \frac{Z_1 + Z_2}{2} + \frac{(Z_2 - Z_1)^2}{2\pi P} \quad ...(4)$$

Where, m = number of chain links; C = centre to centre distance between two sprockets, mm; Z_1 = number of teeth on driver sprocket; Z_2 = number of teeth on driven sprocket; P = chain pitch, mm.

$$m = \frac{2 \times 460}{15} + \frac{18 + 12}{2} + \frac{(12 - 18)^2}{2 \times \pi \times 15}$$

$$m = 76.71 \approx 77 \text{ (say)}$$

Length of chain (mm) = m x P = 77 x 15 = 1155 mm

Ground wheel

For developing traction on sticky soil pegged type ground wheel is suitable where plain, lugged or pneumatic wheels fails to work. The diameter of ground wheel should range from 300 to 800 mm, the number of pegs should vary from 12 to 30 depending on size of wheel. (Data book for Agricultural Machinery Design, 2004). Therefore, peg type ground wheel was designed for battery operated multi-crop planter as shown in fig.5, for which diameter of the ground wheel was calculated as given below (Sharma and Mukesh, 2010)

$$D = \frac{niX}{\pi} \quad (5)$$

Where, D = diameter of ground wheel; n = number of cell on plate; i = gear ratio;

X = desired seed to seed spacing, cm

$$D = \frac{(3 \times 1.5 \times 30)}{\pi}$$

D = 42.96 cm ≈ 43 cm

D = 430 mm

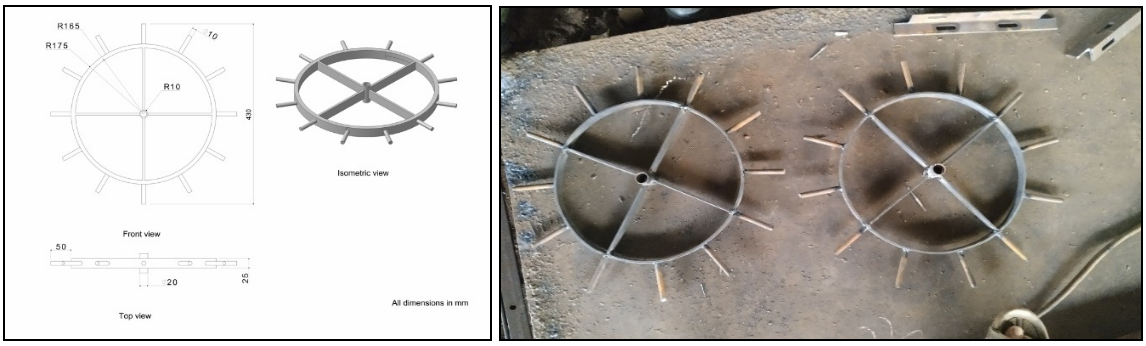
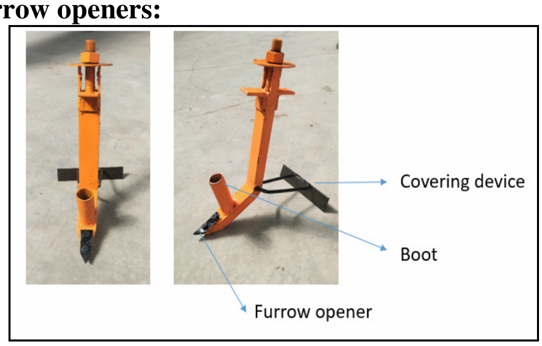


Fig. 5 : Isometric and fabricated view of ground wheel

The power transmission shaft supported by two ground wheel from both side. The shaft was made up of M.S. bar having 18 mm diameter and 1365 mm length.

Furrow openers:



Shovel type furrow openers are suitable for hard soil. Hence shovel type furrow opener was selected for multi-crop planter. Based on design consideration and material available in market width of tyne taken 40 mm and thickness taken 7 mm for furrow opener Furrow openers are provided on planter for the placement of the seeds at uniform depth and spacing i.e.4 - 5 cm.

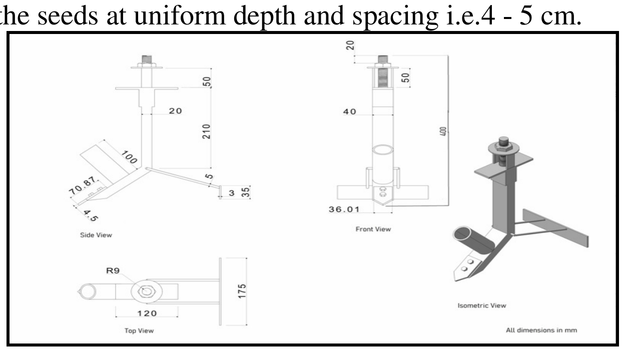


Fig. 6 : Isometric and fabricated view of furrow opener

Covering device

Seed covering device made up of mild steel having dimension (L x W x T) 175 × 35 × 3 mm which was attached behind the seed boot for covering of seed dropped in furrow as shown in fig 6.

Seed tube

Seed tube used for multi-crop planter made up of transparent plastic having the length and diameter of seed tube was taken 430 mm and 32 mm, respectively.

Prime Mover

A prime mover consisting battery electric vehicle which will help to propel developed multi-crop planter. It consists of 1000 W DC motor drive and available at Department of Farm Power and Machinery at Dr. PDKV, Akola was used to operate newly developed multi-crop planter. It has battery pack of 12 V, 120 Ah can continuously work for 6.1 h at maximum power requirement. Based on design consideration designed power requirement of planter is calculated 648.76 W.

Performance evaluation

The planter was calibrated to determine seed rate for different crop seed in laboratory. Evenness of seed spacing on sticky belt also examined. Two independent parameter. The two independent parameters each having three levels were taken i.e., forward speed (A) (3km/h, 2.5km/h and 2 km/h) and sub-hopper opening (B) (50 %, 75% and 100 %) were selected and the effect of these input parameters on four dependent parameters viz., miss index, multiple index, quality feed index and uniformity feed index was studied.

By using the Response Surface Methodology in Design Expert 11.0 version software, experimental parameter optimization was carried out. Response surface methodology has reportedly been a useful tool for operating parameter optimization when the independent variables combine together to affect the desired response. However, a number of research has been done using the response surface methodology (RSM) for optimization (Bhimani *et al*., 2014, Yazgi *et al*., 2010). The experimental design was evaluated by thirteen treatment combinations of three levels of sub-hopper opening and three forward speeds during the data analysis adopting response surface methodology.

Result and Discussion

The present study was conducted at Dept. of Farm Power and Machinery Dr. PDKV, Akola. In laboratory test calibration for seed rate, seed to seed spacing on sticky belt set up were examined at different treatment combinations. In field trial seed to seed spacing, depth of seed placement, field capacity, field efficiency was determined.

Optimization of operational parameters of battery operated multi-crop planter

A. Effect of input parameters on miss index for soybean

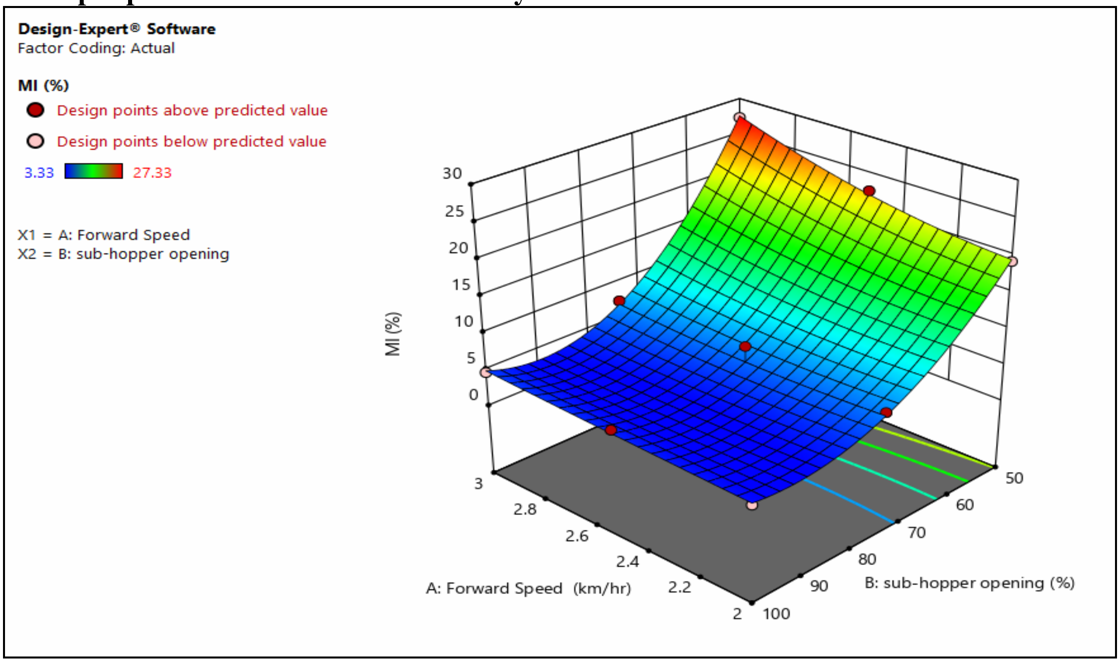


Fig. 7 : Effect of forward speed and sub-hopper opening on miss index (MI)

The Fig.7 shows combined effect of forward speed and sub-hopper opening on miss index. It can be clearly seemed that miss index increases as forward speed increases from 2 km/h to 3 km/h. it is maximum at 3 km/h with 50% sub-hopper opening. Miss index decreases with increase in sub hopper opening from 50% to 100%.it is adequate at 75% sub-hopper opening.

Final equation in terms of coded values

The response surface equation was obtained for the model of second degree in terms of coded factors as under.

Miss index = $+5.79 + 0.330\ A - 9.00\ B - 1.67\ AB + 0.723\ A^2 + 7.39\ B^2 - 0.665\ A^2B + 2.01\ AB^2$ 6

The linear positive terms in equation 6 indicated that the miss index decreased with decrease in forward speed and increase in sub-hopper opening up to certain level and then decreases. The positive value of quadratic terms indicated that high value of these variables further increases the miss index.

B. Effect of input parameters on multiple indices for soybean

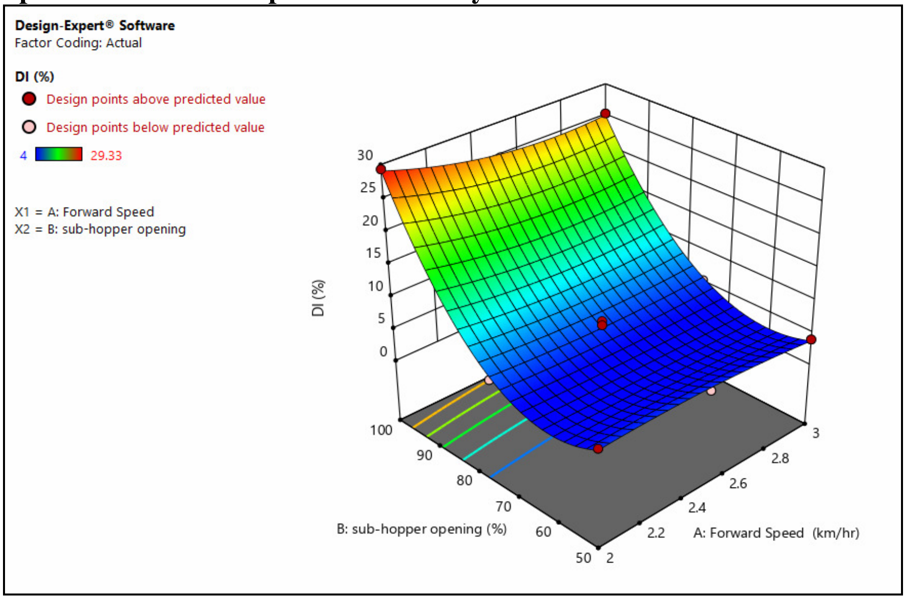


Fig. 8 : Effect of forward speed and sub-hopper opening on multiple index (DI

From the Fig. 8 it can be clearly seem that multiple index increases as sub-hopper opening increases from 50 % to 100 % and as forward speed Increases from 2 km/h to 3 km/h multiple index decreases. It was maximum at 2 km/h with 100% sub-hopper opening. It was observed minimum at forward speed 3 km/h and 50 % opening. It was optimum at 75 % sub-hopper opening with 2.5 km/h forward speed.

Final equation in terms of coded values

The response surface equation was obtained for the model of second degree in terms of coded factors as under

Multiple index = + 5.54 - 0.335 A + 10.00 B - 0.667 AB + 0.605 A^2 + 9.61B^2 + 1.33 A^2B - 0.997 AB^2 (7)

The linear positive terms in equation 7 indicated that the multiple indices increase increase in sub-hopper opening and decreases as forward speed increase. The negative value of linear terms of speed decreases the multiple index and positive quadratic terms indicated that high value of these variables further increases multiple index

C. Effect of input parameters on quality feed index for soybean

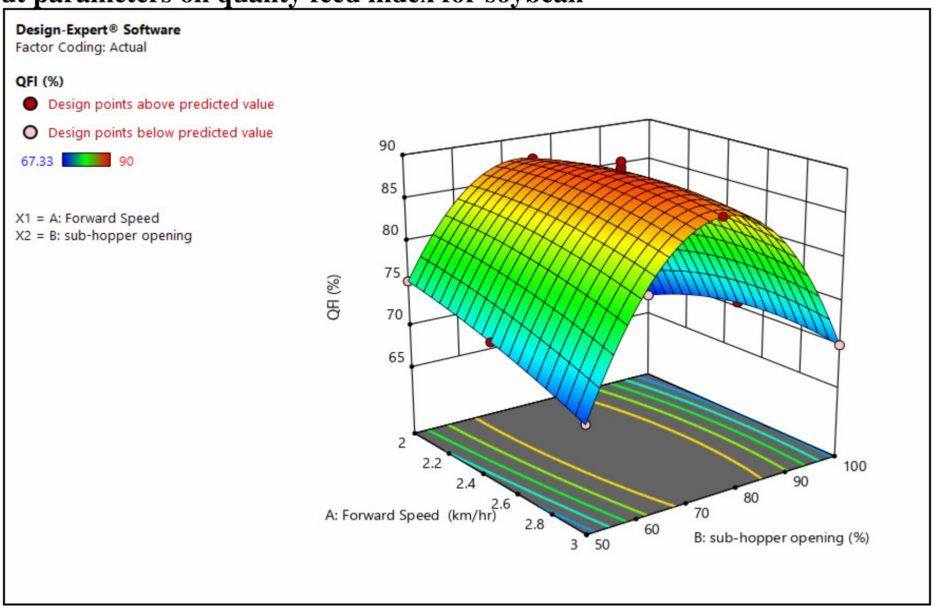


Fig. 9 : Effect of forward speed and sub-hopper opening on quality feed index (QFI)

From the Fig. 9 it can be clearly seem that quality feed index increases as forward speed increases from 2 km/h to 2.5 km/h. and decreases from 2.5 to 3 km/h forward speed. Quality feed index increases with increase in sub- hopper reopening from 50 % to 75 % sub-hopper opening. And decreases with increase in sub hoper opening from 75 % to 100%. It was observed maximum at 2.5 km/h with 75 % sub-hopper opening.

Final equation in terms of coded values

The response surface equation was obtained for the model of second degree in terms of coded factors as under.

Quality feed index = + 88.67 + 0.0000 A - 1.00 B + 2.33 AB - 1.34 A^2 - 17.00 B^2 - 0.667 A^2B- 0.997 AB^2 …8

The linear positive terms in equation 8 indicated that the quality feed index increased with increase in forward speed and increase in sub-hopper opening up to certain level and then decreases. The negative value in linear terms of speed reduced quality feed index and negative value of quadratic terms indicated that high value of these variables further reduced quality feed index.

D. Effect of input parameters on uniformity index for soybean

From the Fig. 10 it can be clearly seem that uniformity index increases as forward speed increases from 2 km/h to 2.5 km/h and then decreases as forward speed increases from 2.5 km/h to 3 km/h. it was maximum at 2.5 km/h. Uniformity index increases with increase in sub-hopper opening from 50% to 75%. It was maximum at 75 % sub-hopper opening.

Final equation in terms of coded values

The response surface equation was obtained for the model of second degree in terms of coded factors as under.

Uniformity index = +76.70 - 0.255 A - 6.36 B - 1.74 AB - 5.52 A^2 - 17.28 B^2 + 3.21 A^2B -0.892 AB^2 … 9

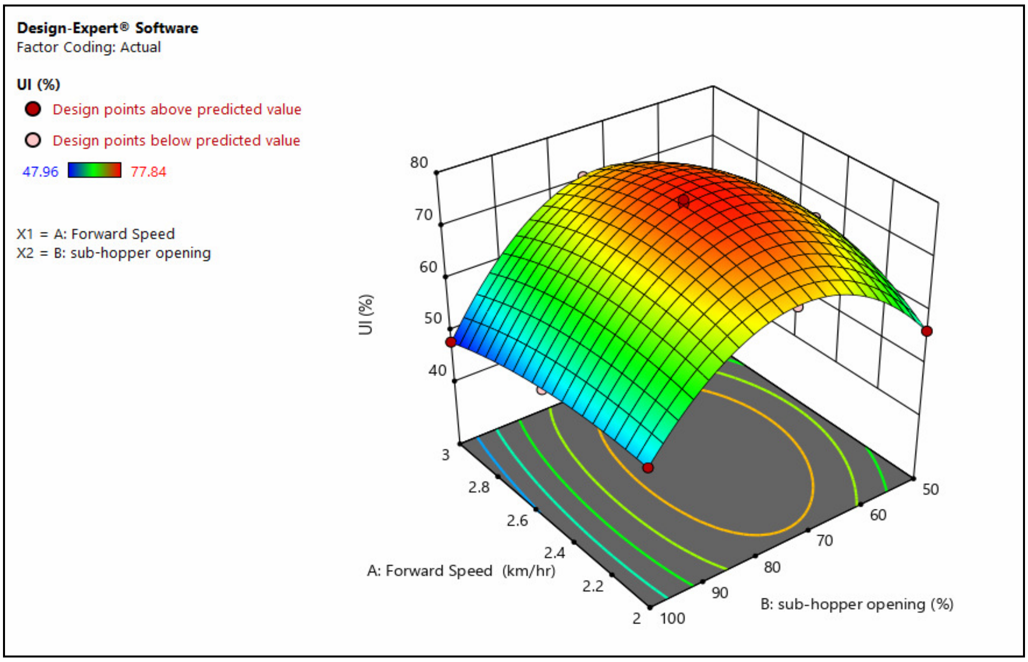


Fig. 10 : Effect of forward speed and sub-hopper opening on uniformity index (UI)

The linear negative terms in equation 9 indicated that the uniformity index increased with increase in forward speed and increase in sub-hopper opening up to certain level and then decreases. The negative value in linear terms of sub-hopper opening reduced uniformity index and positive quadratic terms indicated that high value of these variables further reduced the uniformity index.

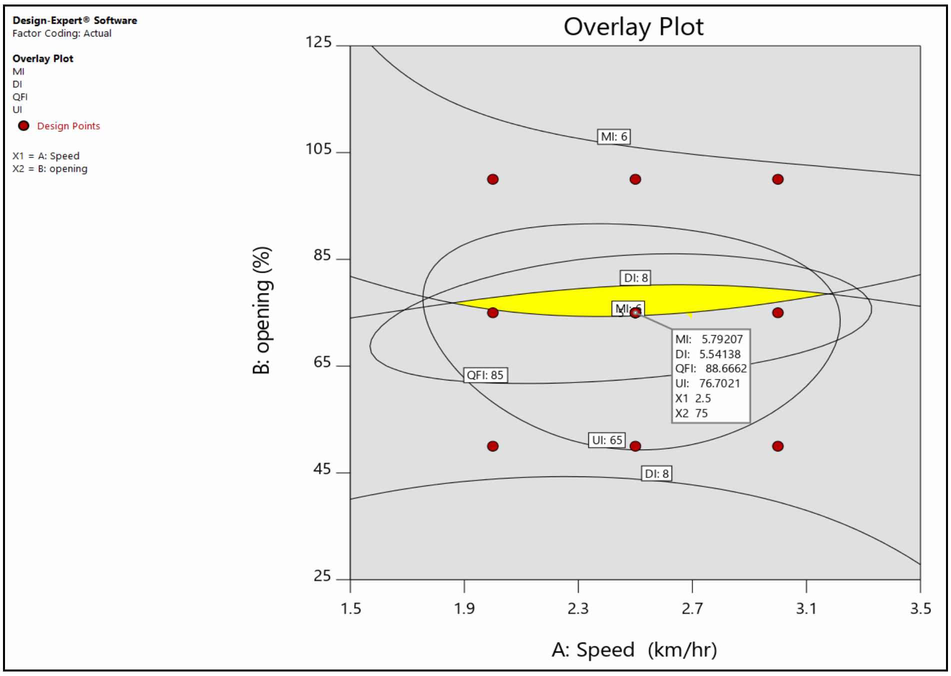


Fig. 11 : Overlay plot of forward speed and sub-hopper opening as actual factor in all responses for soybean

Fig. 11 showing overlay plot of forward speed and sub-hopper opening for all responses for cotton. The area shaded by yellow colour showing feasible zone of optimum solution obtained by superimposing contour map of all responses. The region that is not fit for optimization criteria is shown in grey colour.

Calibration of planter:

The results of calibration test are presented in table 1

Table 1: Calibration test for soybean

Crop seed	Sample No.	Row 1	Row 2	Row 3	Total	Seed rate, kg/ha
Soybean	I	71.23	68.26	69.47	208.96	
	II	70.57	67.05	71.11	208.73	
	III	70.94	69.71	68.62	209.27	
	Avg	70.91	68.34	69.73	208.98	**45.83**

Field evaluation of battery operated multi-crop planter

Field trails of developed multi-crop planter was carried out at AICRP on Weed Management, CRS, Dr. PDKV, Akola. One plot of rectangular shape was selected for conducting field trial of planter as shown in fig. 12. Field trial were conducted for soybean as per the results optimized from the laboratory trials, the travel speed of the machine was kept 2.5 km/h speed with 75 % sub-hopper opening.

The average effective working width of battery operated multi-crop planter was observed 134.53 cm. The average seed to seed spacing was found to be 9.81 cm as shown in fig.14. The average theoretical and effective field capacity of planter was found 0.377 ha/h and 0.261 ha/h respectively. The average field efficiency was observed 77.35 % which implies good performance and fall within range of values obtained by Kepner *et al.* (1978). The average depth of seed placement of soybean seed was observed 4.96 cm during field trial as shown in fig.13. The average draft required for machine was found 51.67 kg.

Fig. 12 : Field performance of multi-crop planter

Fig. 13 : Depth of seed placement

Fig. 14 : Seed to seed placement

For sowing and propelling of battery operated multi-crop planter average current requirement was 12.70 A from which power requirement was calculated as 609.6 W. The average battery voltage consumed by the machine was observed as 48.19 V. During field trial average miss and multiple indices are observed 5.56 % and 6.67 % respectively. Quality feed index and uniformity index observed 87.78 % and 70.46 % respectively during field trial.

Conclusion

Research finding concluded the following points

1. RSM results found that multi-crop planter can work satisfactorily for treatment combination of forward speed 2.5 km/h with 75% sub-hopper opening.
2. Field trial results shows that planter can work satisfactorily for forward speed 2.5km/h with 75% sub-hopper opening for sowing of soybean seed at desired spacing.
3. During field trial average miss and multiple indices observed minimum and average quality feed index and uniformity index observed maximum at forward speed 2.5 km/h with 75% sub-hopper opening.

Conflict of Interest

The authors declare that they have no conflicts of interest regarding the publication of this research paper.

Author Contribution

A.J. Lohar, M. Tech student, significantly contributed to the conception and design of the study, development of machine, performed data analysis and interpretation, and drafted the manuscript.

D. S. Karale, Assistant Professor played a crucial role in the design and development of the machine, contributed to data analysis, and provided guidance to the student throughout the research work. He also gave final approval to the manuscript.

Ankita Shinde contributed to data interpretation, data analysis, and drafting of the manuscript.

Reference

Anantachar, M., Prasanna Kumar, G.V., Guruswamy, T. (2010). Neural network prediction of performance parameters of an inclined plate seed metering device and its reverse mapping for the determination of optimum design and operational parameters. *Computers and Electronics in Agri*., **72**, 87–98.

Bhimani, J.B., Patel, S.K., Yaduvanshi, B.K., Gupta, P. (2014). Optimization of the operational parameters of a picking type pneumatic planter using response surface methodology. *Journal of AgriSearch,* **6**(1),38-43.

Hijam, J.S., De, D.P., Sahoo, K. (2014). Physical properties of soybean cultivated in NEH region of India. *Agric. Engg Int, CIGR Journal*, **16**(3), 55-59.

Inamdar A., Ansari, W., Mansabdar, P., Gujar, A., Patil, V.D. (2020). Design and Development of Electric Multiseed Sowing Machine. ISSN NO.,2347-3150

Kepner, R.A., Bainer, R. and Barger, E.L. (1978). Principles of farm machinery. 3rd Edition West port. G; AVI publishing company Inc.

Panning, J., Kocher, M., Smith, J. and Kachman, S. (2000). Laboratory and field testing of seed spacing uniformity for sugarbeet planters. *Appllied Engineering in Agriculture,* **16**(1), 7–13.

Singh, S. P., Singh, M.K., Ekka, U. (2019). E-Powered Multi-purpose two row seeder for smallholders. *Indian journal of Agricultural Science,* **89**(12).

Sharma, D.N. and Mukesh, S. (2010). Farm Machinery design principles and problems, New Delhi, Jain Brothers

Yang, L., Yan, B.X., Cui, T., Yu, Y.M., He, X.T. & Liu, Q.W. (2016). Global overview of research progress and development of precision maize planters. *International Journal of Agricultural and Biological Engineering*, **9**(1), 9-26

Yazgi, A. and Degirmencioglu, A. (2014). Measurement of seed spacing uniformity performance of a precision metering unit as a function of the number of holes on vacuum plate. *Measurement*, **56**, 128-135.