

# Optimization of the operational parameters of an inclined plate type planter for soybean using response surface methodology

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**Abstract:** The developed planter was tested in laboratory for optimizing of the performance parameters of the newly developed tractor operated inclined plate planter having combination of forward speed (2.5 km, 3 km h<sup>-1</sup>, 3.5 km h<sup>-1</sup>, 4 km h<sup>-1</sup>) with seed plate opening (25%, 50%, 75%) for soybean crop. Performance was analysed on the basis of miss index, multiple index, quality feed index and uniformity index. Response Surface Methodology (RSM) was used to analyze output response and input variables and to find out the optimum operating condition for inclined plate planter. The optimized operational parameters were forward speed and seed plate opening and observed to be optimised at the forward speed of 3.43 km h<sup>-1</sup> with 50 per cent seed plate opening. The RSM result shows that the machine satisfactory performed at optimum operating conditions for forward speed 3.43 km h<sup>-1</sup> with 50 per cent seed plate opening to these values of output variables of 2.60 per cent, 6.69 per cent, 90.71 per cent and 76.07 per cent of miss index, multiple index, quality feed index and uniformity index were respectively for soybean.

**Keywords:** inclined plate planter, broad bed furrow, soybean, optimization

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## 1 Introduction

Seed sowing is crucial and time-sensitive among all cultural practices in crop production. Farm implements and machinery have been developed to enhance farm mechanization, save time and labor, reduce drudgery, lower production costs, minimize post-harvest losses, and increase crop yield and farm income. The percentage of agricultural workers in

India has decreased from 59.1% in 1991 to 54.6% in 2011, and further to 39.4% in 2021 (IBEF, 2023). This trend is expected to continue, with projections indicating a decline to 29.9% in 2033 and 25.7% by 2050, leading to a significant shortage of agricultural workers. The availability of farm power has increased from 0.28 kW ha<sup>-1</sup> in 1960–61 to 2.10 kW ha<sup>-1</sup> in 2013–14, and is expected to rise to 5.17 kW ha<sup>-1</sup> by 2032–33. Farm mechanization in India currently stands at approximately 40%–45%, which is lower compared to the US and Western Europe (95%), Russia (80%), Brazil (75%), and China (48%) (Tiwari et al., 2019). Recently, machinery developments such

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as the laser leveler, zero tillage equipment, happy seeder, and inclined plate planter have gained popularity.

Soybean ranks fourth among oilseed crops in terms of acreage and production. The major soybean growing states are Madhya Pradesh, Maharashtra, Rajasthan, Karnataka, and Telangana. According to the first advance estimates 2022-23, government of India soybean crop is estimated at 12.89 million tones as compared to 12.995 million tones in 2021-22. Among the states, Madhya Pradesh stood first with 50.18 lakh ha followed by Maharashtra (49.10 lakh ha), Rajasthan (11.51 lakh ha), Karnataka (4.43 lakh ha), Gujarat (2.22 lakh ha) and Telangana (1.75 lakh ha) (Agricultural Market Intelligence Centre, PJTSAU, 2022)

The primary objective of sowing operations is to place seeds and fertilizers in rows at the desired depth and spacing, cover the seeds with soil, and ensure proper compaction. Recommended row-to-row spacing, seed rate, seed-to-seed spacing, and depth of seed placement vary by crop and agro climatic conditions to achieve optimal yields. For the singulation and uniform placement of carrot seeds using an inclined plate metering mechanism, a slant-type cell plate inclined at 50° proved more effective for sowing coated carrot seeds (Yadachi et al., 2013). However, due to climate variability and insufficient soil moisture during the sowing window, farmers often operate planters at higher speeds to complete sowing of rainfed crops quickly. Various methods have evolved to assess planter metering mechanism performance. When observing plant spacing after emergence, significant variability often exists in the plant-to-plant distance. The second most common evaluation method for planter metering mechanisms is the grease belt test stand in laboratory conditions, which is unaffected by crop and soil conditions. Based on the spacing of 50 seeds, five performance parameters—average spacing, multiple index, miss index, quality of feed index, and precision—are determined (Sahu and Verma, 2016). The ultimate

goal of using improved sowing equipment is to achieve precise seed distribution within rows. Achieving the desired seed spacing largely depends on technical variables such as the type of seed pickup mechanism, machine operating speed, overall gear ratio between the drive wheel and seed rotor, and to some extent, seed quality. In light of this, the present study was conducted to evaluate the inclined plate metering mechanism for soybean.

## 2 Materials and Methods

The present investigation was carried out at the laboratory of Department of farm power and machinery, Dr. P.D.K.V., Akola, Maharashtra. The major objectives of the study were to determine the optimum values for functional components of inclined plate planter in laboratory. The variables of the study were grouped into two categories namely independent and dependent variables. All the variables have interaction among each other and their effects were analysed to determine optimized condition.

### 2.1 Parameters studied

The two independent parameters i.e., forward speed (2.5 km h<sup>-1</sup>, 3 km h<sup>-1</sup>, 3.5 km h<sup>-1</sup>, 4 km h<sup>-1</sup>) and seed plate opening (25%, 50%, 75%) were selected and the effect of these parameters on four dependent parameters viz., miss index, multiple index, quality feed index and uniformity index was studied. The dependent parameters were selected to indicate the performance of seed metering unit.

### 2.2 Experimental procedure

For optimizing the performance parameters of the newly developed inclined plate planter, laboratory tests were carried out for different settings of forward speed and seed plate opening by taking into account their effect on various performance indices such as miss index, multiple index, quality feed index and uniformity index of the seed planter. On sticky belt setup, the metering unit (Fig. 1) was tested in order to get the best travel speed and seed plate opening of developed planter. The belt was rotated at 2.5, 3, 3.5, 4 km h<sup>-1</sup> speed. Based on how the variables affect

the precision of seed placement, they were optimized. At optimized combination further field

trials of developed tractor operated inclined plate planter were conducted.



Figure 1 Seed metering plate and arrangement of seed box of BBF planter on sticky belt setup

### 2.3 Statistical analysis of data

Response surface methodology (RSM) was used to analyze output response and input variables and to find out the optimum operating condition for newly developed inclined plate planter.

### 2.4 Calibration test

The procedure of testing the planter for correct amount of seed rate is called calibration of planter. For calibration test circumference of ground cum press wheel was calculated. Number of revolutions required to cover  $1/25^{\text{th}}$  area of one hectare was calculated. The ground cum press wheel was made free to rotate by raising planter. Mark was put on the one of the lug of ground cum press wheel so that revolution can be counted easily. Seed box was filled with seeds. Fixed number of revolutions which were determined in above step, the weight of seeds collected below each furrow opener was measured.

Seed rate of planter was calculated by following formula.

$$Q = \frac{q \times 10000}{\pi \times D_e \times n \times W} \quad (1)$$

where,  $Q$  = seed rate,  $\text{kg ha}^{-1}$ ,  $q$  = weight of seeds delivered in 25 revolutions of ground wheel,  $\text{kg}$ ,  $D_e$  = effective diameter of ground cum press wheel = 0.25 m,  $n$  = number of revolution of ground wheel,  $W$  = nominal working width taken for soybean is 1.8 m

### 2.5 Seed damage test

The three randomly selected samples (1 kg) were taken from soybean seeds passed through the seed metering unit and seed tubes. The number of seeds

those were damaged mechanically including any significant bruising, skin damage or crushing were counted. Take mass of the damaged seeds in one kg of the sample and their percentage was calculated as the seed damage percentage (Bureau of Indian Standards, 1993).

### 2.6 Test methods

The performance evaluation of inclined plate metering unit for soybean seed was carried out by calculating the miss index, multiple index, quality feed index and uniformity index. Here, Optimal (Custom) design experiment was employed at two controlled conditions such as forward speed and seed plate opening for 16 experiments including 4 runs as factorial points and 5 repeated runs at the centroid. RSM, a mathematical modeling technique, was used for design experiments, statistical evaluation and optimization of process parameters. The complete design model with test results used for determining miss index, multiple index, quality feed index and uniformity index.

#### 2.6.1 Miss index

Miss index (MI) which is the percentage of spacing greater than 1.5 times the theoretical spacing. Smaller values of MI indicate better performance (Gajakos et al., 2020).

$$MI = \frac{n_1}{N} \times 100 \quad (2)$$

where,  $MI$  = miss index, %,  $n_1$  = number of spacing in the row  $> 1.5$  times of theoretical spacing,  $N$  = total number of observation.

#### 2.6.2 Multiple index

Multiple index (DI) which is the percentage of spacing that are less than or equal to half of the theoretical spacing. Smaller values of DI indicate better performance (Gajakos et al., 2020).

$$DI = \frac{n_2}{N} \quad (3)$$

where,  $DI$  =multiple Index, (%),  $n_2$ =number of spacing in the row  $\leq 0.5$  times of the theoretical spacing,  $N$  = total number of observation.

### 2.6.3 Quality feed index

The quality of feed index is an alternate way to present the performance as a result of combined effect of misses and multiples. The quality of feed index ( $A$ ) is the percentage of spacing's that are more than half but not more than 1.5 times the set spacing (Singh et al., 2012).

$$A = 100 - (MI + DI) \quad (4)$$

where,  $A$  = quality feed index, %.

### 2.6.4 Uniformity index

Uniformity of spacing is represented by an index is called uniformity index. Coefficient of variation in spacing between seeds or plants, standard deviation, mean was determined for calculating uniformity index (Gajakos et al., 2020).

$$UI = (1 - CV) \times 10 \quad (5)$$

Where,  $UI$ =uniformity index, %,  $CV$ =coefficient of variance.

## 3 Results and discussion

### 3.1 Optimization of operational parameters of inclined plate planter

Optimization of process parameters was done using Design-Expert version 11.1.2.0 software. The observed experimental values (mean of 3 experiments) and values predicted are presented in Table 1. The optimum range of input parameters (16) for the seed metering plate of planter was forward speed (2.5 to 4 km h<sup>-1</sup>) and seed plate opening (50% to 100%).

#### 3.1.1 Modelling and statistical analysis

The effect of independent parameters such as forward speed (km h<sup>-1</sup>) and seed plate opening (%) was assessed by running 16 experimental trials of Optimal (custom) design. The obtained results for

miss index, multiple index, quality feed index, and uniformity index are listed in Table 1. The obtained results of miss index and multiple index are ranged from 2% to 18.67% and 2.67% to 10%, respectively, whereas quality feed index and uniformity index were recorded in between 78.67% to 91.33% and 58.12% to 79.02%, respectively. Based on the experimental results, the optimized predictive quadratic model (in terms of coded factors) to make predictions of all responses for given levels of each factor is expressed as in Equation No. 6 to 9 whereas the relationship between actual and predicted responses is shown in Fig. 2-Fig. 4. Where A, and B represent the forward speed (%) and seed plate opening (%). The different openings of seed plate were checked to decide the level of seed plate opening of the soybean seed. A mathematical equation was obtained after fitting the results to the quadratic model. However, the obtained mathematical equations may elaborate inaccuracy in terms of results (Mostafa et al., 2021). Therefore, the statistical analysis of variance (ANOVA) was carried out for finding out the significance of the regression model, p-values, F-values, signal-noise ratio and lack of fit. The obtained ANOVA results are presented in Table 2. By using the coefficient  $R^2$  and adjusted  $R^2$ , the accuracy of model in relation to the experimental outcomes was determined. Pareto analysis was also carried out to examine the most efficient factor in responses. The effect of parameters on responses was also studied by using 3D contour plots as showed in Figure 1. The obtained p values by using F-test regression model was found very less (<0.0001) indicating that the chosen models were of high significance. The coefficient of determination ( $R^2$ ) value for miss index, multiple index, quality feed index, and uniformity index were observed as 99.68%, 97.65%, 99.37% and 93.59%, respectively; it showed that models could describe all the variations very effectively. The adjusted values of  $R^2$  as 0.9952, 0.9648, 0.9906 and 0.9038 also indicate that experimental and model predicted values are in close agreement. All the values of regression coefficients

with the significance levels are presented in Table 3. The adequate precision values determine the signal–noise ratio, and a value greater than 4 is considered acceptable. In the present experiment, the precision values were observed at 58.6130, 24.7721, 44.2852 and 15.9656 showing that the signal is adequate.

Therefore, the model can be used to navigate the design space.

$$MI=2.58-1.13A-6.66B+0.239AB+1.38^2+6.31B^2 \quad (6)$$

$$DI=6.72 + 0.412A + 2.87B + .0448AB - 0.605A^2 - 0.256B^2 \quad (7)$$

$$A=90.70+0.718A+3.79B - .0685 AB - .0775 A^2 - 6.06 B^2 \quad (8)$$

$$UI=75.99+1.73A+2.50B-1.92AB-4.74A^2-7.0B^2 \quad (9)$$

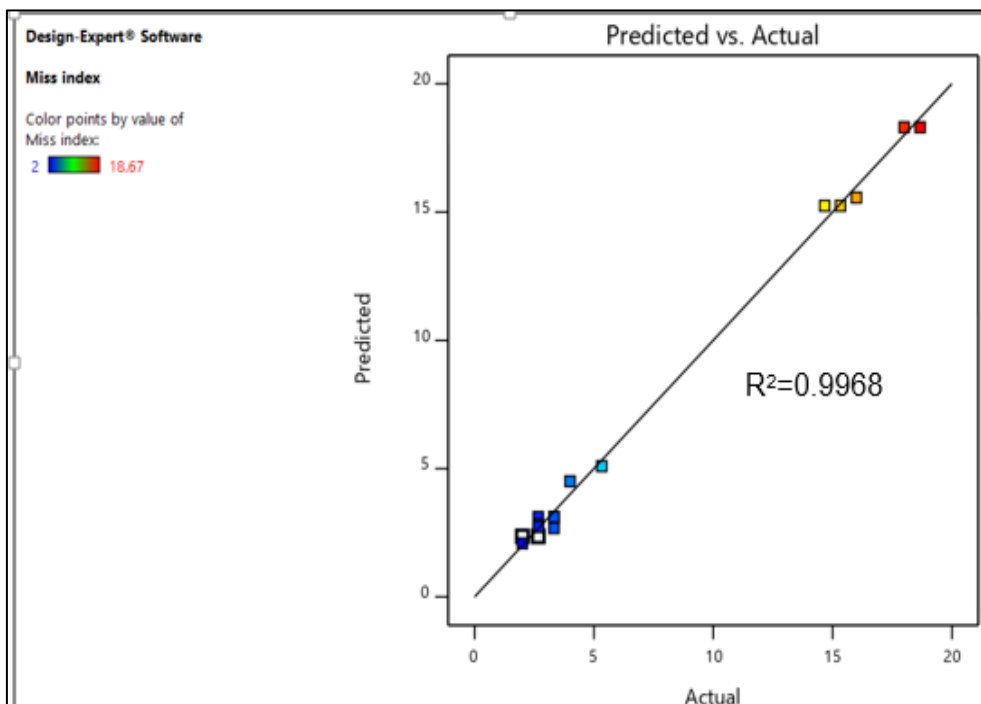


Figure 2 Relationship between actual and predicted miss index of soybean

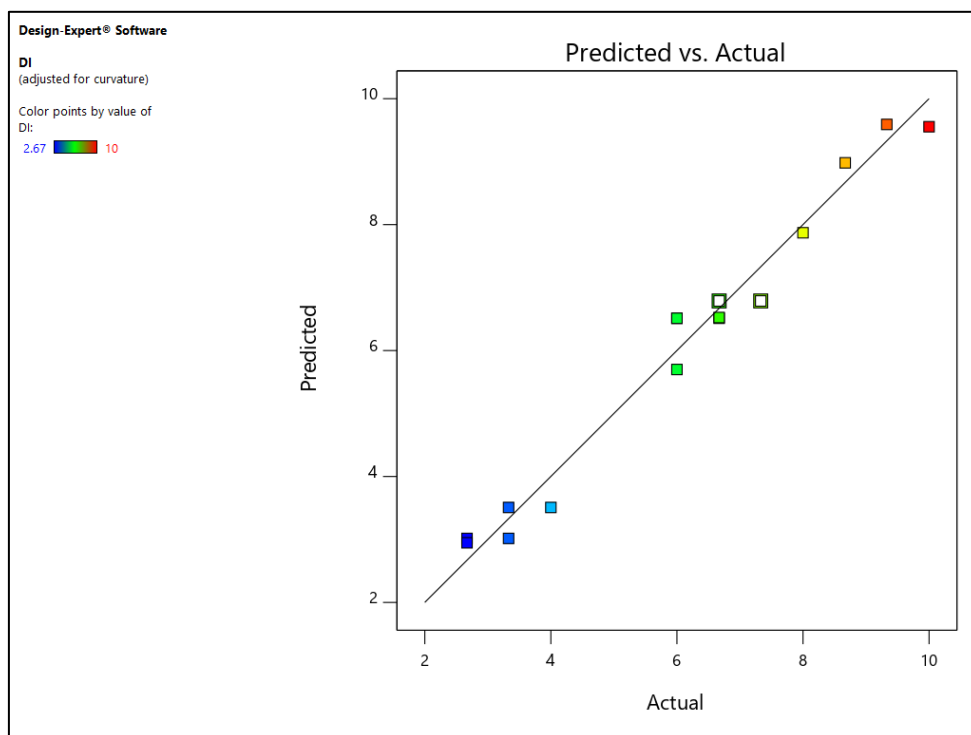


Figure 3 Relationship between actual and predicted multiple index of soybean

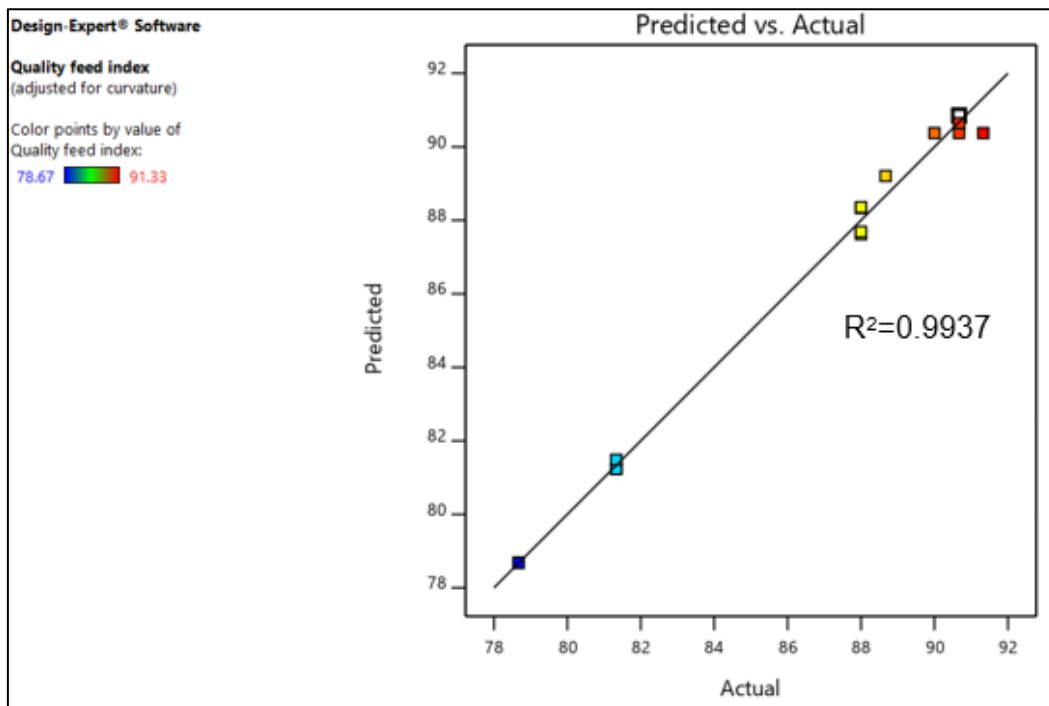


Figure 4 Relationship between actual and predicted quality feed index of soybean

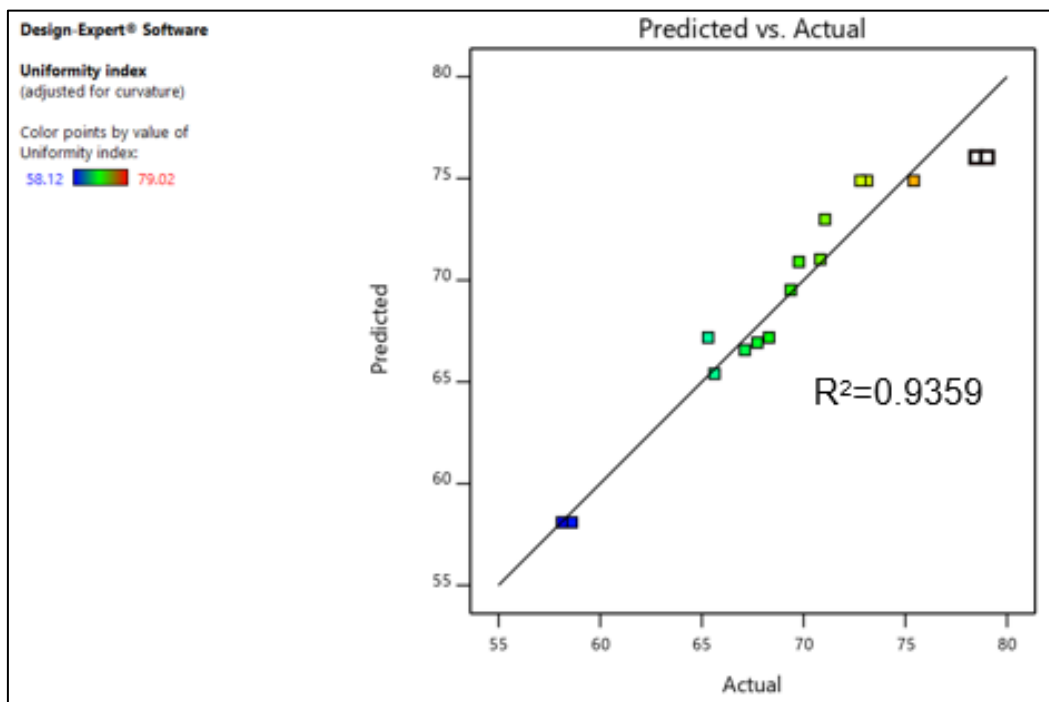


Figure 5 Relationship between actual and predicted uniformity index of soybean

### 3.1.2 Perturbation plots

The perturbation plots reveal the comparative effects of all operating parameters at a specific point in the design space. The response is plotted by changing only one factor over its range at a time while other factors are kept constant. The steepness of the curve of a factor shows that the response is more sensitive to this factor. By default, Design Expert sets the reference point at the centre of the design space

and keeping the four responses in view, four perturbation plots are obtained as shown in Fig. 6. It can be shown that seed plate opening (B) was the most influencing factor on miss index, multiple index and quality feed index followed by forward speed (A) least one. In the uniformity index, all the two factors were most influential as very high steepness of curves were observed.

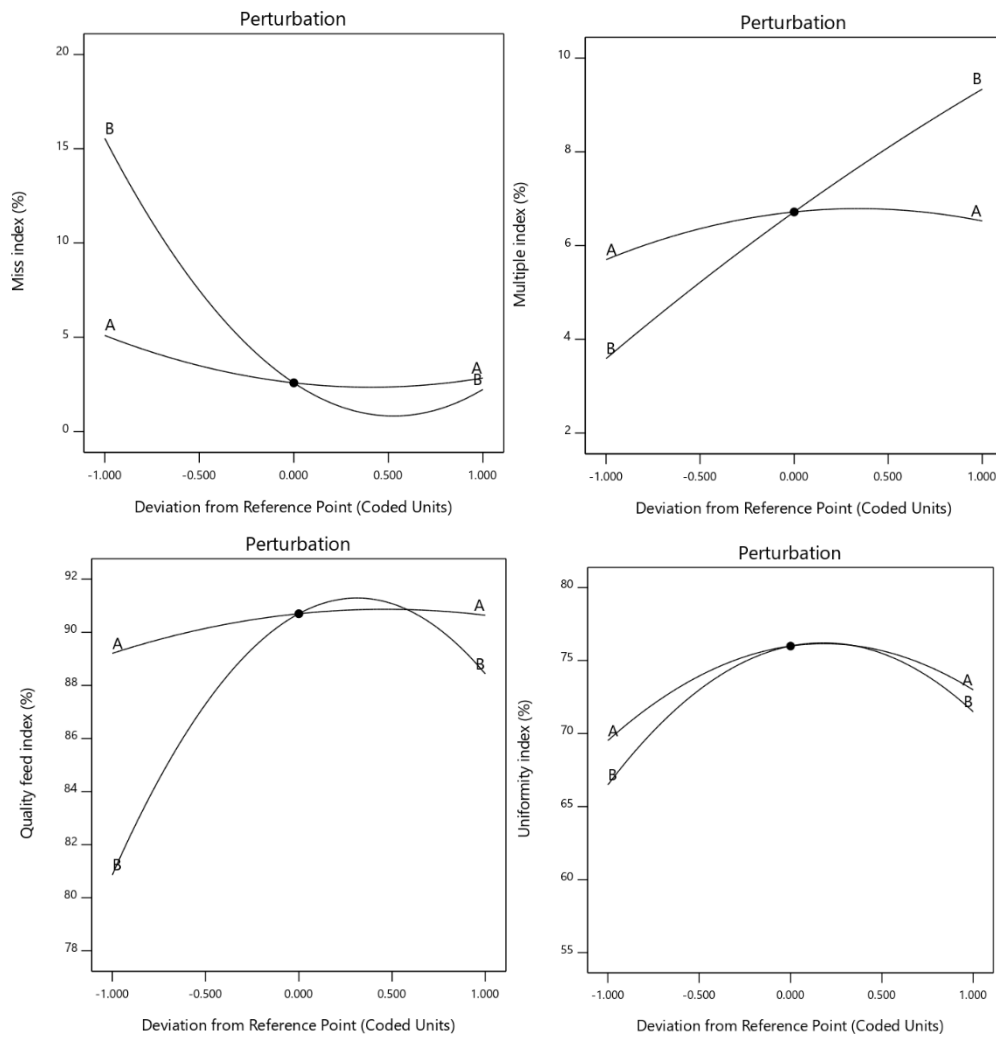


Figure 6 Perturbation plots of the soybean for miss index (a), multiple index (b), quality feed index (c), uniformity index (d)

**Table 1 Values of responses for optimization of operational parameters**

Run	Factor 1	Factor 2	Response1	Response2	Response3	Response 4
	A: forwardspeed km h <sup>-1</sup>	B: seed plate opening %	Miss index (MI) %	Multiple index (DI) %	Qualityfeed index (A) %	Uniformityindex (UI) %
1	3	50	3.33	6.67	90	72.8
2	3.5	50	2.67	6.67	90.67	78.49
3	4	25	16	2.67	81.33	65.62
4	3.5	25	14.67	4	81.33	68.3
5	2.5	25	18	3.33	78.67	58.61
6	3	50	3.33	6	90.67	73.12
7	3.5	75	2	10	88	69.77
8	3	50	2.67	6	91.33	75.42
9	3	75	3.33	8.67	88	70.82
10	4	75	2.67	9.33	88	67.11
11	2.5	75	4	8	88	67.73
12	4	50	2.67	6.67	90.67	71.05
13	2.5	50	5.33	6	88.67	69.37
14	2.5	25	18.67	2.67	78.67	58.12
15	3.5	25	15.33	3.33	81.33	65.31
16	3.5	50	2	7.33	90.67	79.02

**Table 2 Analysis of variance (ANOVA) for effect of input parameters on responses**

4	Sum of squares	Df	Mean square	F-value	p-value
Miss index					
Model	640.19	5	128.04	627.29	< 0.0001*
A-ForwardSpeed	9.83	1	9.83	48.14	< 0.0001*
B-Seed plate opening	391.34	1	391.34	1917.27	< 0.0001*
AB	0.2948	1	0.2948	1.44	0.2571
A <sup>2</sup>	5.25	1	5.25	25.74	0.0005*
B <sup>2</sup>	144.54	1	144.54	708.13	< 0.0001*
Lack of Fit	1.08	5	0.2168	1.13	0.4473 <sup>NS</sup>
Multiple index					
Model	79.74	5	15.95	83.14	< 0.0001*
A-Forward Speed	1.31	1	1.31	6.83	0.0259*
B- seed plate opening	72.89	1	72.89	380.03	< 0.0001*
AB	1.03	1	1.03	5.39	0.0427*
A <sup>2</sup>	1.00	1	1.00	5.23	0.0452*
B <sup>2</sup>	0.2378	1	0.2378	1.24	0.2916
Lack of Fit	0.9588	5	0.1918	0.9994	0.5002 <sup>NS</sup>
Quality feed index					
Model	319.38	5	63.88	317.07	< 0.0001*
A-Forward Speed	3.97	1	3.97	19.70	0.0013*
B-Seed plate opening	126.46	1	126.46	627.71	< 0.0001*
AB	2.42	1	2.42	12.00	0.0061*
A <sup>2</sup>	1.65	1	1.65	8.18	0.0170*
B <sup>2</sup>	133.22	1	133.22	661.30	< 0.0001*
Lack of Fit	1.13	5	0.2260	1.28	0.3973 <sup>NS</sup>
Uniformity index					
Model	491.91	5	98.38	29.20	< 0.0001*
A-Forward Speed	23.15	1	23.15	6.87	0.0256*
B-seed plate opening	55.16	1	55.16	16.37	0.0023*
AB	18.96	1	18.96	5.63	0.0391*
A <sup>2</sup>	61.60	1	61.60	18.28	0.0016*
B <sup>2</sup>	178.25	1	178.25	52.90	< 0.0001*
Lack of Fit	24.88	5	4.98	2.82	0.1397 <sup>NS</sup>

Note: \* = significant at 5 per cent, <sup>NS</sup>= non- significant

**Table 3 ANNOVA fit statistics**

Term	Miss index	Multiple index	Quality feed index	Uniformity index
Mean	7.29	6.08	86.63	69.42
Coefficient of determination R <sup>2</sup>	0.9968	0.9765	0.9937	0.9359
Adjusted R <sup>2</sup>	0.9952	0.9648	0.9906	0.9038
Predicted R <sup>2</sup>	0.9879	0.9392	0.9818	0.8639
C.V.	6.20	7.20	0.5181	2.64
Std. Dev.	0.4518	0.4380	0.4488	1.84
Adeq Precision	58.6130	24.7721	44.2852	15.9656

### 3.1.3 Analysis of variance (ANOVA) and modelling validation

The influence of the different operating parameters on the different responses were obtained for each factor level as forward speed and seed plate opening. The 3D surface plots of miss index, multiple

index, quality feed index and uniformity index were obtained (Fig. 7a to Fig. 7d) and the main results of these plots are represented in Table 2. The different process parameters had a prominent effect on the dependent parameters.

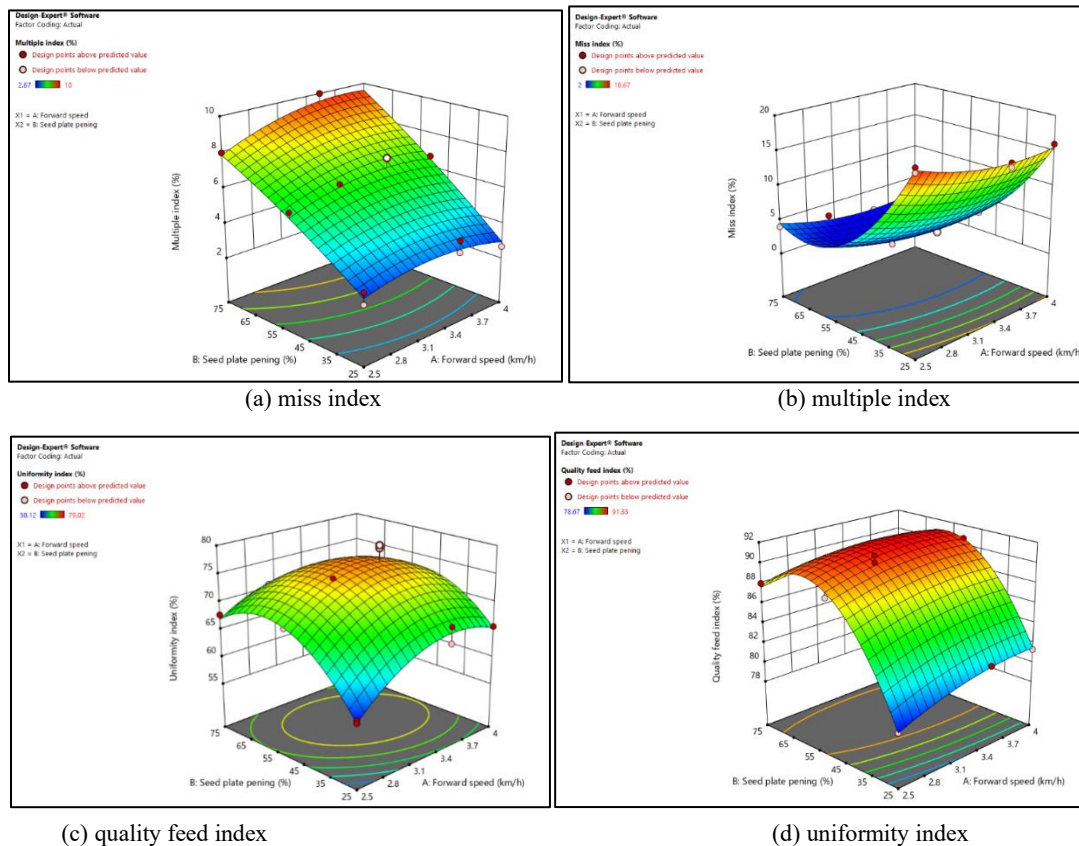


Figure 7 Surface plots for the interactive effect of process variables

### 3.2 Effect of input parameters on miss index

The miss index was ranging from 2% to 18.67% on the basis of laboratory trials. The maximum miss index was observed for the treatment combination of forward speed 2.5 km h<sup>-1</sup> with seed plate opening of 25% for soybean crop whereas the minimum miss index was found for the treatment combination of forward speed 3.5 km h<sup>-1</sup> and seed plate opening 50% and 75%. The miss index was found to be dependent on the factors such as forward speed and seed plate opening of inclined plate planter. From the Figure 2a it can be clearly seen that miss index decreases as forward speed increases from 2.5 km h<sup>-1</sup> to 3.5 km h<sup>-1</sup> and again increases as forward speed increases from 3.5 to 4 km h<sup>-1</sup>, this was might due to the metering mechanism failed to pick and drop a seed resulting in

a large spacing between seeds. It was maximum at 2.5 km h<sup>-1</sup> with 25% seed plate opening. Miss index decreases with increase in seed plate opening from 25% to 75% due to availability of adequate amount of seeds at metering mechanism for picking and dropping of seed resulting in a reduction in miss picking. It was observed adequate at 50% seed plate opening. At present there is no similar work noticed as such by using RSM whereas the findings of actual versus predicted responses quotes were observed with quite similar and dissimilar field of investigation viz., Yazgi and Degirmencioglu (2007), Sahu and Verma (2016), and Gautam et al. (2016).

### 3.3 Effect of input parameters on multiple index

The multiple index was observed to be ranging from 2.67% to 10% on the basis of laboratory trials.

The maximum multiple index was observed for the treatment combination of forward speed 3.5 km h<sup>-1</sup> and seed plate opening 75% for soybean crop whereas the minimum multiple index was found for the treatment combination of forward speed 4 km h<sup>-1</sup> and seed plate opening 25%. The multiple index was found to be dependent on the factors such as forward speed and seed plate opening of inclined plate planter. It was observed optimum at 3.5 km h<sup>-1</sup> forward speed and 50% seed plate opening. From the Figure 2b it can be clearly seen that multiple index increases as seed plate opening increases from 25 to 75 % and as forward speed increases from 2.5 km h<sup>-1</sup> to 3.5 km h<sup>-1</sup>, this was might due to multiple seeds were picked by each cell. Again multiple index decreases as forward speed increases from 3.5 to 4 km h<sup>-1</sup>. At present there is no similar work noticed by using RSM whereas the findings of actual versus predicted responses quotes were observed with quite similar and dissimilar field viz., Yazgi and Degirmencioglu (2007), Sahu and Verma, (2016), Gautam et al. (2016).

### 3.4 Effect of input parameters on quality feed index

The quality feed index was observed to be ranging from 78.67 to 91.33% on the basis of laboratory trials. The maximum quality feed index was observed for the treatment combination of forward speed 3 km h<sup>-1</sup> with seed plate opening of 50% for soybean crop. The minimum quality feed index was found for the treatment combination of forward speed 2.5 km h<sup>-1</sup> with seed plate opening of 25%. The quality feed index was found to be dependent on the factors such as forward speed and seed plate opening of inclined plate planter. From the Figure 2c it can be clearly seen that quality feed index increases from as forward speed increases from 2.5 km h<sup>-1</sup> to 3.5 km h<sup>-1</sup>, and remains same as forward speed increases from 3.5 km h<sup>-1</sup> to 4 km h<sup>-1</sup>. The similar result was obtained by Gautam et al. (2016) for onion pelleted seeds that quality feed index initially increased when the forward speed was increases from 1 km h<sup>-1</sup> to 2 km h<sup>-1</sup> and when the forward speed was increased

from 2 km h<sup>-1</sup> to 3 km h<sup>-1</sup> the quality feed index also decreased. Quality feed index increases with increase in seed plate opening from 25 to 50% and then decreases from seed plate opening of 50 to 75%. The quality feed index is the combination of miss index and multiple index.

### 3.5 Effect of input parameters on uniformity index

The uniformity index was observed to be ranging from 58.12 to 79.02% on the basis of laboratory trials. The maximum uniformity index was observed for the treatment combination of forward speed 3.5 km h<sup>-1</sup> and seed plate opening 50% for soybean crop. The minimum uniformity index was found for the treatment combination of forward speed 2.5 km h<sup>-1</sup> with seed plate opening 25%. The uniformity index was found to be dependent on the factors such as forward speed seed plate opening of inclined plate planter. From the Figure 2d, it can be clearly seen that uniformity index increases as forward speed increases from 2.5 km h<sup>-1</sup> to 4 km h<sup>-1</sup>, it is maximum at 3.5 km h<sup>-1</sup> with 50% seed plate opening. Uniformity index increases with increase in seed plate opening from 25 to 50% and then decreases with increase in seed plate opening from 50 to 75%. At present there is no similar work noticed by using RSM whereas the findings were observed with quite similar and dissimilar field viz., Gajakos et al. (2020). The uniformity index was lowest at lowest forward speed (2.5 km h<sup>-1</sup>).

### 3.6 Modelling and process optimization

The optimization of the process variable was done using the *Design- Expert software 11*. The mathematical optimization was carried out by putting the values of process parameters within the experimental range based on the instantaneous combination of all goals for responses. The optimization of goals is listed in Table 4. The quality feed index and uniformity index were set at maximum values whereas the miss and multiple index was set at a minimum value. The independent parameters were in the range of experimental results and the optimization of variables are selected based

on a combination of all goals for responses. The optimization of process parameters and predicted values were listed in Table 5. The most suitable composition of different operating parameters were forward speed and seed plate opening of 3.43 km h<sup>-1</sup>

and 49.22%≈ 50% respectively corresponding to these values of input variables, the values of miss index (MI), multiple index (DI), quality feed index (A) and uniformity index (UI) were found 2.60, 6.69, 90.71 and 76.07 percent, respectively.

**Table 4 Optimization criteria for different process variables and responses**

Name	Goal	Lower limit	Upper limit	Importance
Forward speed	is in range	2.5	4	3
Seed plate opening	is in range	50	100	3
Miss index	minimize	2.67	12.67	3
Multiple index	minimize	2	8	3
Quality feed index	maximize	84.67	92	3
Uniformity index	maximize	65.97	78.82	3

**Table 5 Optimized solution generated by the design expert software**

Forward speed (km h <sup>-1</sup> )	Seed plate opening (%)	MI (%)	DI (%)	A (%)	UI (%)	Desirability
3.43	49.22	2.60	6.69	90.71	76.07	0.772

### 3.7 Calibration test of planter

The procedure of testing of planter for correct amount of seed rate is called calibration of planter. It is necessary to calibrate the planter before putting it

in actual use to find the desired seed rate. It has been done to get the predetermined seed rate of the planter. The observed seed rate for soybean was found to be 72.78 kg ha<sup>-1</sup> as shown in Table 6.

**Table 6 Calibration of developed inclined plate planter for soybean**

Crop seed	SampleNo.	Weight of seed, g	Seed rate, kg ha <sup>-1</sup>
Soybean	I	250.32	72.78
	II	260.92	
	III	260.48	
	Average	257.24	

**Table 7 Seed damage test**

Sr. No.	Samples	Sample1	Sample2	Sample3	Average damage percentage
1.	Soybean	0.21	0.53	0.43	0.39

### 3.8 Seed damage test

The three randomly selected samples were taken from soybean seeds passed through the seed metering unit and seed tubes and visually observed for any external damage. The least seed damage (0.39%) was observed for soybean seed as shown in Table 7. This was less than the maximum allowable seed damage (0.5%) in a seed metering device of the seed drill and planter (Anonymous, 1991).

## 4 Conclusion

The operating parameters of developed planter

were optimized for planting of soybean seeds. The optimized operational parameters were forward speed and seed plate opening and observed to be optimised at the forward speed of 3.43 km h<sup>-1</sup> with 50% seed plate opening. The RSM result shows that the machine satisfactory performed at optimum operating conditions for forward speed 3.43 km h<sup>-1</sup> with 50% seed plate opening to these values of output variables of 2.60%, 6.69%, 90.71% and 76.07% of miss index, multiple index, quality feed index and uniformity index were respectively for soybean. Miss index decreases and multiple index increases as forward

speed increases from 2.5 to 3.5 km h<sup>-1</sup> again increases as speed increases from 3.5 to 4 km h<sup>-1</sup> for soybean. Quality feed index increases as forward speed increases from 2.5 to 3.5 km h<sup>-1</sup> whereas the uniformity index was lowest at forward seed of 2.5 km h<sup>-1</sup> and 25 percent opening of seed plate for soybean. From the F-value of all responses it was indicate that the seed plate opening was the most affecting parameters in a linear way followed by forward speed. The least seed damage percentage was observed of 0.39% for soybean seed.

### Competing interests

The authors declare no competing interests.

### Reference

- Agricultural Market Intelligence Centre, PJTSAU. 2022. *Soyabean October 2022*. Hyderabad: Professor Jayashankar Telangana State Agricultural University. Available at: <https://pjtsau.edu.in/files/AgriMkt/2022/Ocotber/Soyabean-Ocotber-2022> IBEF. 2023.
- Anonymous. 1991. RNAM Test Code and Procedures for Farm Machinery. Vienna, Austria: United Nations Industrial Development Organization (UNIDO).
- Bureau of Indian Standards. 1993. IS: 6316:1993. Sowing equipment-seed-cum-fertilizer drill. New Delhi, India: 1993.
- Gajakos, A. V., S. H. Thakare, A. K. Kamble, S. K. Thakare and R. D. Walke. 2020. Performance evaluation of belt type seed metering mechanism. *International Journal of Innovations in Engineering and Science*, 5(11): 43-46.
- Gautam, A., R. Khurana, G. S. Manes, A. Dixit, and A. Verma. 2016. Development and evaluation of inclined plate metering mechanism for onion pelleted seeds. *Vegetos*, 29(3): 1000144.
- Making India a Global Powerhouse in the Farm Machinery Industry*. New Delhi: India Brand Equity Foundation. Available at: <https://www.ibef.org/blogs/making-india-a-global-powerhouse-in-the-farm-machinery-industry>. Accessed 29 August 2023.
- Mostafa, M. E., Y. Zhang, S. Hu, Y. Wang, S. Su, X. Hu, S. A. Elsayed, and J. Xiang. 2021. Mechanical characteristics and energy consumption of solid and hollow biomass pellet production using a statistical analysis of operating parameters. *Waste and Biomass Valorization*, 12(12): 6635-6657.
- Sahu, M., and A. Verma, 2016. Evaluation of inclined plate metering mechanism for direct seeded rice. *International Journal of Engineering Research & Technology*, 5(5): 722-728.
- Singh, M. K., N. Kumar, P. Verma, and S. K. Garg. 2012. Performance evaluation of mechanical planters for planting of chickpea and pigeon pea. *Journal of Food Legumes*, 25(2): 131-134.
- Tiwari, P. S., K. K. Singh, R. K. Sahni, and V. Kumar. 2019. Farm mechanization – trends and policy for its promotion in India. *The Indian Journal of Agricultural Sciences*, 89(10): 1555–1562.
- Yadachi, S., I. Mani, M. S. Karla, A. Kumar, and P. K. Sahoo. 2013. Development and Evaluation of Inclined Plate Metering Mechanism for Carrot Seed. *Journal of Agricultural Engineering*, 50(2): 10-16.
- Yazgi, A., and A. Degirmencioglu. 2007. Optimisation of the seed spacing uniformity performance of a vacuum-type precision seeder using response surface methodology. *Biosystems Engineering*, 97(3): 347-356.