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ORIGINAL CONTRIBUTION

Optimization of Performance Parameters of Onion Digger with Cutter Bar Topping Unit

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Abstract A tractor-operated onion digger with cutter bar topping unit was developed for multiple operations, i.e., topping, digging, soil separation and windrowing of onions in a single pass. The physical and agronomical properties of onions are computed such as equatorial diameter, polar diameter, shape index, bulk density, plant height and number of tillers per plant which were measured and found to be 44.75 mm, 43.34 mm, 1.01, 561 kg/m^3, 28.76 mm, 5 number, respectively. Field evaluation of the developed machine was conducted to optimize the independent parameters such as moisture content (9.5, 11.65 and 13.0%) (d.b.), rake angle (10°, 15°, 20°) and speed of operation (2.5, 3.25, 4.0 km/h) on three responses, i.e., digging efficiency, damage percentage and topping efficiency in response surface methodology by using central composite design in Design Expert software. The optimum conditions for highest digging efficiency (93.76%), minimum damage percentage (6.44%) and maximum topping efficiency (78.46%) were found at 11.39% (d.b.) moisture content, 15.12° rake angle and 3.11 km/h speed of operation, respectively. For optimum values of independent parameters, the field efficiency, actual field capacity and theoretical field capacities were found to be 85%, 0.17 ha/h and 0.20 ha/h, respectively.

Keywords Onion · CCD · RSM · Design Expert software

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Introduction

India has witnessed a remarkable growth in horticultural production in the past few years. Significant improvement has been made in area enlargement resulting in greater production. India shares about 21% of the world output of vegetables from about 4.6% of the cropped area in the country [1].

Onion (*Allium* cepa L.) is considered to be major important crop among vegetable crops. In the world context in onion production India is the second leading onion producer next to China along with a yielding of 23.262 million tonnes, from the region of 1.285 million hectares. However, productivity is around 18.10 MT/ha which was lower as observed with many countries like USA Egypt and Turkey [2]. Onion contributes 7.4% in total vegetable production as it plays a big role among all vegetables. The five major onion-producing states in India are as follows: Maharashtra which is a leading producer of onion with the production of 8.85 MT with a cultivation area of 0.507 million hectares, followed by Madhya Pradesh, Karnataka, Bihar, Rajasthan and Andhra Pradesh [3]. However, there is a lot of scope for of Indian onion in the world market, during the year of 2018–2019 the country has exported nearly 2,182,826.23 MT of fresh onion to the different places of the world for the value of Rs. 3467.06 crores. Major export destinations during 2018–2019 are Bangladesh Pr, Malaysia Arab Emts, Sri Lanka and Nepal [4].

The major constraints and drawbacks to improve the high yield and high standard grade of vegetable crops in India are due to the absence of suitable technological development and ascribed to peculiar pedo-climatic conditions of the areas and diffusion of hybrid varieties coming from other environments [5]. To increase the onion crop-growing area and its productivity, the major limitation is due to low availability of machinery suitable for particular crop. Timeliness is the key requirement in onion production. Introduction of harvesting machine to perform all the operations required to the market needs in a single pass reduces the time and price and also avoid the excessive loses due to unfavorable climatic conditions during harvesting. The remaining time span available in harvesting may take advantage of utilizing for post-harvest processes. Onions are highly sensitive in nature; thus, they require attentive and meticulous harvesting and storage ahead of processing or consumptions. So, in this research, we focused to find a technically and economically viable option of onion harvesting which was onion digger with cutter bar topping unit, which is the most suitable solution.

The best performance of the developed machine depends on the influence of suitable operating condition. Hence, it is mattering much to decide the optimum operating parameters at which responses reach their maximum. Further, there is no reported study on optimization of soil and design variables of onion digger with topping unit, not many investigations have utilized central composite design (CCD) in response surface methodology (RSM), with the use of response surface methodology a wide range of variables can be investigated with minimum number of test runs. So, in this research the optimization of process parameters was done using RSM.

Materials and Methods

Experimental Design for Performance Evaluation of Developed Machine

To study the field performance evaluation of developed machine, the effect of three independent variables such as soil moisture content (*A*), rake angle (*B*) and speed of operation (*C*) is investigated. Digging efficiency (*R1*), damage percentage (*R2*) and topping efficiency (*R3*) were the three responses analyzed in the Design Expert software using central composite design (CCD) in response surface methodology (RSM). The range of levels of the factors used in the study is shown in Table 1. These ranges of levels of factors differing correspondingly to experimental design are shown in Table 2.

The lower level of rake angle, i.e., 10°, 15° and 20°, was selected for the study, since higher rake angles are accentuated upheaval of soil around the tool which will cause increase in draft drastically [6]. The speed of operation affects the draft of the tillage tool, by the accelerating component of the soil particles. Hence, the operating speeds 2.5, 3.25 and 4.0 km/h were selected for the study. The higher and lower moisture contents of soil during field operation will also cause the higher slip, draft, and more damage of bulbs. Hence, the moisture contents 9.5, 11.65, 13.8% (d.b.) were selected for the study.

The number of experimental test runs in central composite design (CCD) includes the standard 2^n factorial points with its starting point at the center, and 2n axial points (n = number of independent variables), with (n_c) of the number of central points, for estimating of experimental error. Then the total number of runs is (N) calculated by using Eq. 1.

$$N = 2^n + 2n + n_c = 2^3 + 2 \times 3 + 6 = 20 \qquad (1)$$

The total number of experimental runs needed for the desired three levels of independent variables is found to be (N = 20). After fixing the desired variables in the experimental test run, then the values are coded into ± α for the axial points, 0 for middle points and ± 1 for the factorial points.

The empirical model was developed for each response from dependent and independent parameters used in the study by using a second-degree polynomial [7] equation Eq. 2.

$$Y = \beta_0 + \sum_{i=1}^{n} \beta_i X_i + \sum_{i=1}^{n} \beta_{ii} X_i^2 + \sum_{i=1}^{n} \sum_{j=i+1}^{n} \beta_{ij} X_i X_j + \varepsilon \qquad (2)$$

where Y = resultant response variables (%); β_0 is the intercept coefficient; β_i, β_{ii}, β_{ij} are the linear, quadratic, interaction coefficient, respectively; n is number of factors studied in experiment; X_i, X_j are the coded independent parameters, and ε is the standard error.

Table 1 Independent parameters and their actual and coded levels of CCM in RSM

Variables	Units	Levels of independent variables				
		− α	Low valve	Medium value	High value	+ α
A: moisture content	% (d.b.)	8.03 (− α)	9.5 (− 1)	11.65 (0)	13.8 (1)	15.26 (α)
B: rake angle	(°)	6.59 (− α)	10 (− 1)	15 (0)	20 (1)	23.40 (α)
C: speed of operation	km/h	1.98 (− α)	2.5 (− 1)	3.25 (0)	4.0 (1)	4.51 (α)

*Values within enclosure indicate the coded values of CCD in RSM

Table 2 Experimental responses for designed variable factors of coded and actual units

Std	Run	Codes values			Actual values			Response 1	Response 2	Response 3
		A: moisture content% (d.b.)	*B*: rake angle (°)	*C*: speed of operation (km/h)	*A*: moisture content% (d.b.)	*B*: rake angle (°)	*C*: speed of operation (km/h)	Digging efficiency (%)	Damage percentage (%)	Topping efficiency (%)
14	1	0	0	+ α	11.65	15	4.51	87.94	8.17	72.91
19	2	0	0	0	11.65	15	3.25	93.45	6.45	77.9
2	3	1	− 1	− 1	13.8	10	2.5	85.81*	8.11	75.01
6	4	1	− 1	1	13.8	10	4	88.25	8.69	73.27
4	5	1	1	− 1	13.8	20	2.5	87.91	8.21	74.73
11	6	0	− α	0	11.65	6.59	3.25	87.31	7.73	76.91
10	7	+ α	0	0	15.26	15	3.25	86.89	8.58	72.95
15	8	0	0	0	11.65	15	3.25	93.85	6.39	78.31
9	9	− α	0	0	8.03	15	3.25	88.01	8.09	73.67
18	10	0	0	0	11.65	15	3.25	94.55**	6.54	78.05
17	11	0	0	0	11.65	15	3.25	93.09	6.51	78.31
7	12	− 1	1	1	9.5	20	4	87.21	8.99	74.73
16	13	0	0	0	11.65	15	3.25	93.05	6.21*	78.91
8	14	1	1	1	13.8	20	4	86.61	9.35**	71.48*
1	15	− 1	− 1	− 1	9.5	10	2.5	88.28	7.93	75.15
13	16	0	0	− α	11.65	15	1.986	90.11	7.49	73.57
5	17	− 1	− 1	1	9.5	10	4	87.55	7.88	74.53
12	18	0	+ α	0	11.65	23.40	3.25	90.55	8.47	77.19
20	19	0	0	0	11.65	15	3.25	93.95	6.81	78.95**
3	20	− 1	1	− 1	9.5	20	2.5	90.79	7.97	75.25

*, ** indicate highest and lowest values of the responses, respectively

Experimental Procedure

The developed machine (Figs. 1 and 2) was evaluated for its performance under field conditions at university Vegetable research center (VRC), (GBPUA&T) Pantnagar, Uttarakhand, India, during 2019–2020. Before operating machine in actual field condition, soil and crop parameters were recorded.

The crop was irrigated to get a required moisture for digging. While testing, the width of blade and depth of operation were kept as 650 mm and 70 mm, respectively. The rake angle 10° was positioned by adjusting the slots provided on side flanges of the digging unit. The gear position and throttle lever in the tractor were set to have 2.5 km/h forward speed. The affected response variables, i.e., digging efficiency, topping efficiency and damage percentage values, were recorded, and the average value was calculated as per the standard test code of potato digger shakers [8]. The time taken to span the distance was also noted.

The above experiment was repeated for rake angles set at 15° and 20° and the forward speeds at 3.0 and 4.5 km/h. Similarly for the remaining selected soil moisture levels the above procedure was repeated and the observations were recorded and tabulated.

Optimization of Levels of Variables for Developed Machine using CCD of RSM

The main experiment was performed according to the CCD of RSM using Design Expert software as mentioned in Table 2.

Results and Discussion

Optimization of Independent Parameters on Digging Efficiency, Damage Percentage and Topping Efficiency

Generally, the number of onions dug to the total number of onions, i.e., (dug + undug), is referred as digging efficiency. Damage percentage was referred as the ratio of number of onions damaged to total number onions to be harvested. Any harvesting system could be considered to function properly, when the damage caused to harvested material is minimum. Topping efficiency is defined as the

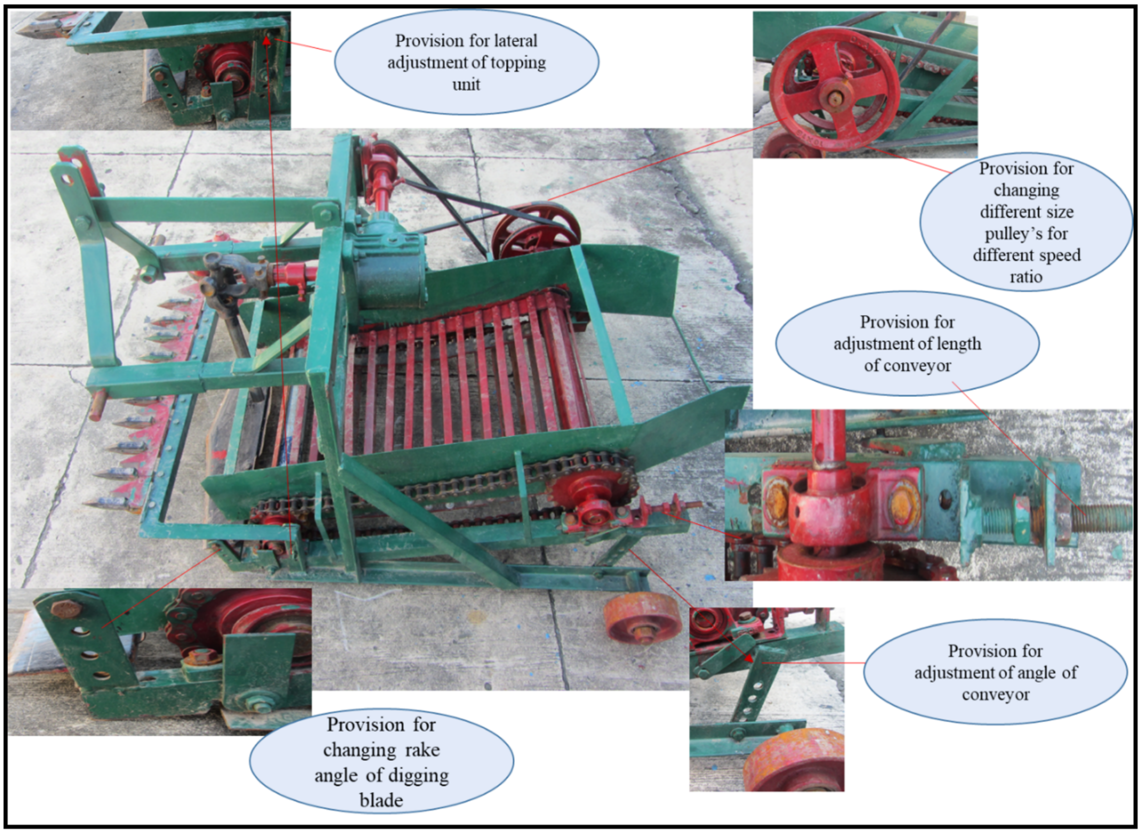

Fig. 1 Different adjustment provisions in developed machine

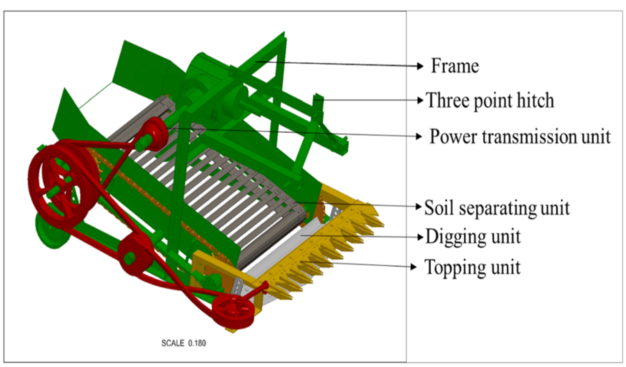

Fig. 2 3D diagram of developed machine (onion digger with cutter bar topping unit)

ratio of no of onions topped to a length up to less than or equal to 38 mm irrespective of no visible sign of mechanical damage to the total no of onions to be performed for topping. It is clear from Table 2 that minimum and maximum digging efficiencies are 85.01 and 94.05%, respectively, and minimum and maximum damage percentages are 6.21 and 9.35%, respectively; similarly, the minimum and maximum topping efficiencies are 71.48 and 78.95%, respectively. The acceptability and significance of the model were explained through (ANOVA) analysis of variance. Table 3 shows the ANOVA for digging efficiency, damage percentage and topping efficiency. Lan et al. [9] reported that the smaller "*P*" value (Prob. $> F$) and higher *F*-value indicate model was more significant for corresponding coefficient. Table 3 shows that the model F value for digging efficiency, damage percentage and topping efficiencies is 42.95, 41.95 and 32.84, respectively, and "Prob $\geq F$" value of 0.0001 denotes the models was significant. Additionally, the digging efficiency was mostly affected by (*A*, *B*, *C*) main factors, and (*AC*, *BC*) interactions and remaining factors got insignificant. In case of damage percentage, moisture content (*A*), rake angle (*B*), speed of operation (*C*) as well as quadratics (A^2, B^2, C^2) factors and the interactions (*BC*) were found significant to model, whereas the other interaction terms *AB* and *AC* were nonsignificant to their responses. In case of the topping efficiency from Table 3, the individual factors *A*, *C*, A^2, C^2 and interactions *AC*, terms are significant and remaining are not significant.

From Table 3, it was observed that the "lack of fit of *F*-value" of digging efficiency, damage percentage and topping efficiencies are 1.44, 1.22 and 2.45 which is insignificant. The lack of fit is non-significant means model F statistics value was significant which is an indication that independent variables are highly affected by experimental

Table 3 ANOVA analysis for the regression model of digging efficiency, damage percentage and topping efficiency

Source	Digging efficiency					Damage percentage					Topping efficiency					Comments
	SS	df	MS	*F*-value	*p*-value Prob > *F*	SS	df	MS	*F*-value	*p*-value Prob > *F*	SS	df	MS	*F*-value	*p*-value Prob > *F*	
Model	155.95	9	17.33	42.95	< 0.0001	16.34	9	1.82	41.95	< 0.0001	96.96	9	10.77	32.84	< 0.0001	Significant
Moisture content (*A*)	3.73	1	3.73	9.24	0.0125*	0.43	1	0.43	9.86	0.0105*	2.98	1	2.98	9.09	0.0130*	
Rake	4.78	1	4.78	11.85	0.0063**	0.73	1	0.73	16.84	0.0021**	0.12	1	0.12	0.38	0.5531	
Angle (*B*)																
Speed of operation (*C*)	3.41	1	3.41	8.44	0.0157*	1.08	1	1.08	24.86	0.0005**	3.84	1	3.84	11.70	0.0065**	
AB	0.37	1	0.37	0.91	0.3636	0.019	1	0.019	0.44	0.5225	0.70	1	0.70	2.14	0.1742	
AC	3.71	1	3.71	9.20	0.0126*	0.070	1	0.070	1.62	0.2313	1.85	1	1.85	5.65	0.0389*	
BC	5.43	1	5.43	13.46	0.0043**	0.33	1	0.33	7.67	0.0198*	0.25	1	0.25	0.76	0.4045	
A^2	74.18	1	74.18	183.86	< 0.0001**	7.01	1	7.01	161.98	< 0.0001**	47.09	1	47.09	143.52	< 0.0001**	
B^2	43.91	1	43.91	108.83	< 0.0001**	5.44	1	5.44	125.69	< 0.0001**	3.39	1	3.39	10.35	0.0092*	
C^2	42.23	1	42.23	104.68	< 0.0001**	3.88	1	3.88	89.66	< 0.0001**	48.39	1	48.39	147.48	< 0.0001**	
Residual	4.03	10	0.40			0.43	10	0.043			3.28	10	0.33			Not significant
Lack of fit of model	2.38	5	0.48	1.44	0.3493	0.24	5	0.048	1.22	0.4170	2.33	5	0.47	2.45	0.1740	

*, ** indicate 1% and 5% level of significance, respectively

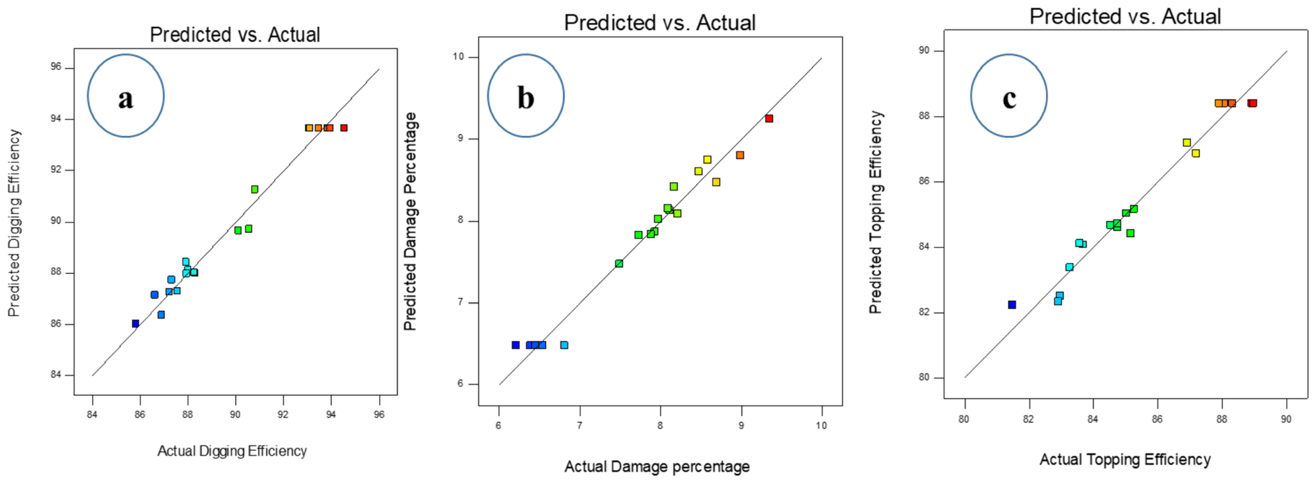

Fig. 3 **a** Digging efficiency, **b** damage percentage, **c** topping efficiency plot of actual and predicted values

design runs and there is only 1.44%, 1.22% and 2.45% chances for digging efficiency, damage percentage and topping efficiency will occurs due to noise. The R^2 value will indicate the perfectly up to which extent the model is varied by experimental data. The value of R^2 for the three responses is 0.9748, 0.9742, and 0.9763 which indicates that 97.48%, 97.42%, and 97.63% variation in digging efficiency, damage percentage, and topping efficiencies are due to the experimental variables and the remaining is due to noise.

The actual and the predicted values of digging efficiency, damage percentage and topping efficiencies by the model are shown in Fig. 3. It clearly shows that actual values of data points for digging efficiency, damage percentage and topping efficiencies obtained through the test runs during experiment and the predicted values accessed by quadratic model were nearly adjacent to straight line. This type of model curve shows excellent fit to the model, and the model sufficiently covers the independent parameters within experimental range. Regression analysis was performed to develop a model for predicting digging efficiency of the digger with topping unit from variables under the study. The coded values were used for the prediction model which is expressed by the fallowing equation.

$$\begin{aligned}\text{Digging efficiency}\,(\%) = {} & +93.67 - 0.52A + 0.59B \\ & - 0.50C - 0.21AB \\ & + 0.68AC - 0.82BC \\ & - 2.27A^2 - 1.75B^2 - 1.71C^2\end{aligned} \tag{3}$$

$$\begin{aligned}\text{Damage percentage}\,(\%) = {} & +6.48 \\ & + 0.18A + 0.23B + 0.28C \\ & + 0.094AC + 0.20BC \\ & + 0.70A^2 + 0.61B^2 + 0.52C^2\end{aligned} \tag{4}$$

$$\begin{aligned}\text{Topping efficiency}(\%) = {} & +78.41 - 0.47A - 0.095B \\ & - 0.53C - 0.30AB - 0.48AC \\ & - 0.18BC - 1.81A^2 \\ & - 0.49B^2 - 1.83C^2\end{aligned} \tag{5}$$

where in Eqs. 3, 4, and 5 A, B and C are the coded values of moisture content, rake angle, speed of operation, respectively. The magnitude and sign of the coefficients in Eqs. 3, 4 and 5 show that the significant effect on the responses with the independent parameters taken under the study. From the above equations, it was clearly shown that the positive sign coefficient of moisture content (A), rake angle (B) and travel speed (C) signified the increase in the digging efficiency, damage percentage and topping efficiency, respectively, with increment in level of these variables.

Influence of Design Variables on Digging Efficiency, Damage Percentage and Topping Efficiency

The variation of digging efficiency, damage percentage and topping efficiency with different design variables such as soil moisture content, rake angle and travel speed is observed from the response surface plots, as illustrated in Fig. 4. The response surface plots of digging efficiency, damage percentage and topping efficiency was shown in Fig. 4.

In digging efficiency (Fig. 4a–c), all the response surface curves shapes are convex down at edges with the red color at center indicating that area has maximum digging efficiency. It can be noticed from the figures that the digging efficiency initially increased with increment of rake angle, soil moisture content; after that, it attains certain value and then again decreases with the further increase in rake angle and soil moisture content. The digging efficiency variation as a function of rake angle was higher than that of function of moisture content and speed of operation.

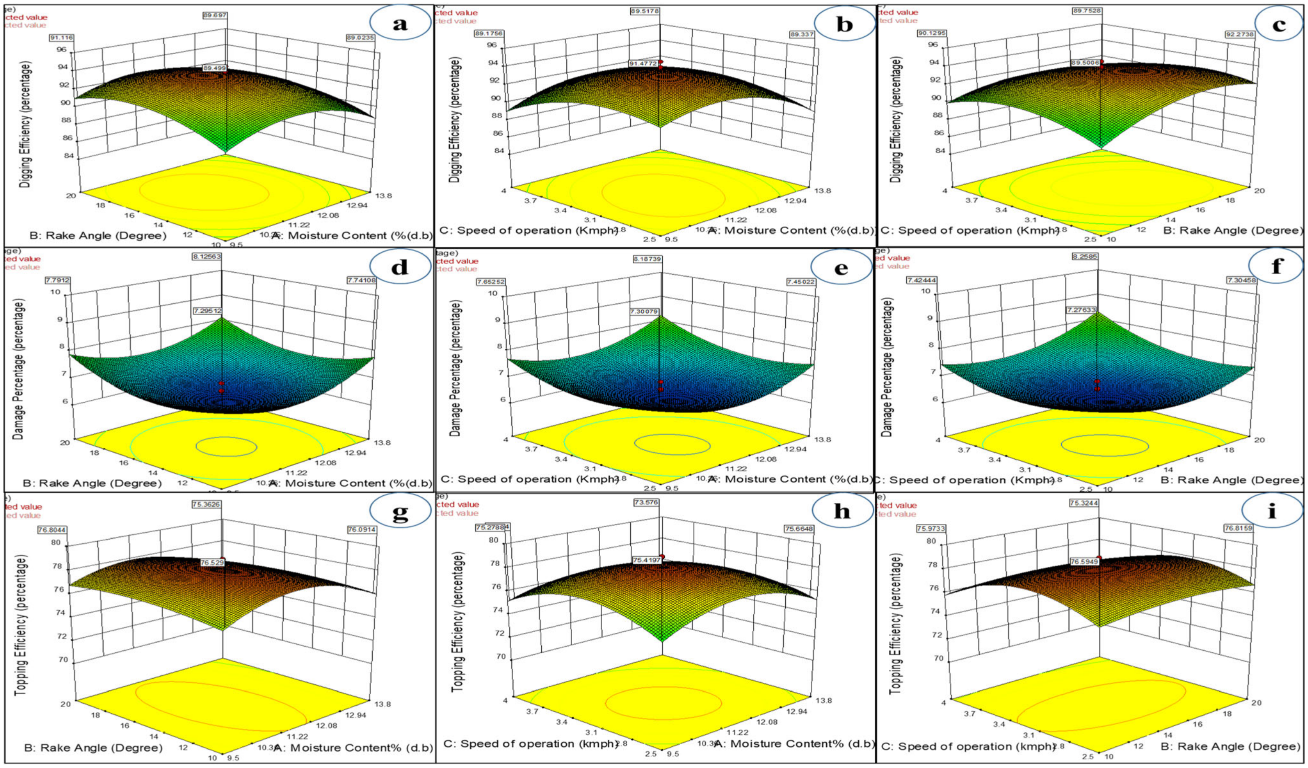

Fig. 4 Interaction effect of design variables: **a** soil moisture content (*A*) and rake angle (*B*); **b** soil moisture (*A*) and speed of operation (*C*); **c** rake angle (*B*) and speed of operation (*C*) on digging efficiency, damage percentage and topping efficiency

The interaction between the rake angle and speed of operation was the most important factor for higher digging efficiency. Similar type of observations was observed by Totaram [10]. From Fig. 4a, it is observed that the digging efficiency increases initially with increase in rake angle being up to 94.55% when the rake angle is in the range of 14°–16° and then again digging efficiency decreases significantly with further increase in rake angle with in the experimental range. This may be because the at lower rake angle less depth of operation occurred than the required depth for bulb digging. At a higher rake angle, the digging efficiency is low because the amount of soil and plant dug by the blade is high, and that leads to the high amount of dug material on soil separation unit and there may not be a satisfactory soil–onion separation. Similarly, for moisture content digging efficiency increases with increase in moisture content within the moisture 11.2 -12.8% (d.b.); digging efficiency was found maximum (93.85%); with further increase in moisture content, digging efficiency decreases. Similar findings were observed by Shailaja et al. [11]. This study reveals that the lower rake angle and lower moisture content always give better digging efficiency because of easy soil separation and minimum volume of soil dug.

In case of damage percentage from Table 3, the *F*-value indicates that individually speed of operation (*C*) imposed most significant effect, followed by rake angle (*B*) and moisture content (*A*); interaction *BC* was found significant and other interactions are insignificant. Le Pori and Hobgood [12] also reported similar findings. From Fig. 4c–e, it clearly shows that all the graphs are concave at the center with blue color indicating that at the middle values the damage percentage is minimum and slightly raising at edges. From Fig. 4c–e, it is observed that as the speed of operation, rake angle and the moisture content increase initially, the damage percentage was found minimum and then significantly the damage percentage increases when the design variables increase within the range of variables. Similar findings were observed by Totaram [10]. The damage percentage from Fig. 4e decreases with increment of rake angle initially within the range of 14°–16° rake angle and 3.1 to 3.4 km/h speed of operation at 11.65% (d.b.) moisture content; the damage percentage was found minimum (6.39%) further increasing of design variables within the range the damage percentage increases. This is because at lower rake the depth of operation causes less damage and at higher rake angle, if machine is operated at high soil moisture content, the amount of soil dug will be more which sequentially causes the damage due to high impact of clods on bulb; similarly, for higher speed of operation the damage is more similar findings was observed by [13]. This study reveals that at very low and

Table 4 Constraints of design parameters for optimization of responses

Name of variable	Goal	Minimum limit	Maximum limit
A: moisture content	Is in range	9.5 (− 1)	13.8 (1)
B: rake angle	Is in range	10 (− 1)	20 (1)
C: speed of operation	Is in range	2.5 (− 1)	4 (1)
R1: digging efficiency	Maximize	85.81	94.55
R2: damage percentage	Minimize	6.21	9.35
R3: topping efficiency	Maximize	71.48	78.95

Table 5 Optimum conditions for maximizing responses

Number	Moisture content% (d.b.)	Rake angle, (°)	Speed of operation, km/h	Digging efficiency	Damage percentage	Topping efficiency	Desirability
1	11.38	15.12	3.11	93.76	6.44	78.46	0.92

very high moisture content the damage percentage is high; this is because of at higher soil moisture content the bulb also has relative moisture within it causes the small element of machine element strikes the bulb during operation leads to damage the bulb and rot formation in storage.

In case of topping efficiency from Table 3, it is showing that speed of operation (*C*) has major effect on the topping efficiency in comparison with other variables. The moisture content was also found significant. Additionally, the interaction *AC* was found significant and then other interactions were found insignificant. The values in the axis of response surface plots are real values. Figure 4g–i shows that the increase in speed of operation and moisture content initially increases the topping efficiency and then decreases significantly after further increase in the design variables within the experimental range. The data obtained from the experimental variables of this study reveal that rake angle has no effect on the topping efficiency. Figure 4h shows interaction between moisture content (*A*) and speed of operation (*C*); at constant rake angle 15°, the response surface shows the convex shape at middle red color showing higher topping efficiency and slightly down at the corners downward. The topping efficiency increases initially with the increase in forward speed to an interval of 3.1–3.4 km/h and soil moisture content of 11.2–12.08% (d.b.); the topping efficiency was found maximum (78.31%) and then it decreased slightly by further increase in design variables within the range of variables. Wintage-Hill [14] reported in his study that the vehicle travel speed was one main factor which will vary depending on onion tops. This is because at the lower forward speed there is a low cutter bar blade velocity will lead to miss the topping of onion leaves and at the higher speed of operation the high amount onions tops will lodge the cutter bar blades leading to low topping efficiency. Le ori and Hobgood [15] suggested that with the high vehicle travel speed there is more risk of losing onions. But with higher vehicle speeds the loss in income may have outweighted with depletion in costs per tonne. During high soil moisture content, the moisture content will also present within the onion tops which causes onion tops to slip from the cutter bar blade leads to a decrease in the topping efficiency. The rake angle had no effect on the topping efficiency.

Optimization of Design Variables on Responses

To find the most favorable conditions for the machine operation for the best values of responses i.e., maximum digging efficiency (*R1*), minimum damage percentage (*R2*) and maximum topping efficiency (*R3*) was conducted using Design Expert software. Firstly based on model and surface contour plots the goal of maximum and minimum limits of each variable is given as: is in range and their responses are given based on requirements. Then, by using Design Expert software the constraints of each variable are presented in Table 4.

The best possible solutions for optimum values of design variables for good responses proposed by the Design Expert software are shown in Table 5. The best values of responses such as digging efficiency (93.76%), damage percentage (6.44%) and topping efficiency (78.46%) are obtained at an optimum values of 11.36% (d.b.), 15.12° and 3.114 km/h of soil moisture content, rake angle and forward speed, respectively. The model desirability 0.92, which is approaching unity, indicates minimum error value and portrays the model applicability toward the responses.

The optimum values of design variables analyzed using the Design Expert software are soil moisture content, rake angle and forward speed of 11.36% (d.b.), 15.12° and

3.114 km/h, respectively. For these optimized values of design variables, the machine parameters, i.e., theoretical field capacity, effective field capacity, and field efficiencies, are 0.20 ha/h, 0.17 ha/h, and 85%, respectively.

Conclusion

The use of the modern developed machine was very much needed to the farmers during peak harvesting season in order to meet the market needs in a single operation which will reduce the cost and timeliness of the operation. From the study, the optimum conditions for maximum digging efficiency (93.76%), minimum damage percentage (6.44%) and topping efficiency (78.46%) were found at 11.39% (d.b.) moisture content, 15.12° rake angle and 3.11 km/h travel speed, respectively. For optimum values of independent parameters, the field efficiency, actual field capacity and theoretical field capacities were found to be 85%, 0.17 ha/h and 0.20 ha/h, respectively.

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Declarations

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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