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Research Paper: RD—Rural Development

Optimisation of machine parameters of a pedal-operated paddy thresher using RSM

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A pedal-operated paddy thresher (the VL paddy thresher) was designed and developed at VPKAS, Almora, Uttrakhand, India. The machine performance was evaluated for optimal design parameters, viz., wire loop spacing 39.1 mm, wire loop tip height 60.6 mm and threshing drum speed 339.46 m min^{-1}. The corresponding threshing capacity and efficiency were 64.6 kg h^{-1} against predicted 66.8 kg h^{-1} and 96.4% against predicted 98.3%, respectively, for variety Thapa Chini. Comparative performance tests between the newly developed thresher and the old pedal thresher were conducted to test the effects optimisation. Test results indicated that the VL paddy thresher performed better compared to the existing pedal thresher with rice varieties VL-62, Thapa Chini, China-4, VL-85 and VL-61. It was inferred that the wire loop geometry and drum speed have major effect on the threshing performances of paddy threshers. The weight and cost (32 kg and INR 3500 or 88 US$) of the VL paddy thresher were lower than the existing pedal thresher (50 kg and INR 5500 or 138 US$). The power source for operating the thresher is either one person or a 0.373 kW electric motor.

1. Introduction

In North-Western Himalayan region (NWHR) of India, paddy (*Oryza sativa* L.) is grown over in 0.6 million ha, producing 1.0 million tons of rice. In the hilly and mountainous agro-ecosystem of the NWHR, the average farm size is less than 0.4 ha, and this limits rice production to around 400 kg per household. Due to the low production and income, farmers cannot afford costly and high-capacity paddy threshers. In view of the prevailing socio-economic conditions of farmers in NWHR, large-capacity threshers are inappropriate and even sophisticated but small-sized Japanese harvesting equipment is not easily adopted (Quick, 1998). Considering efficiency and cost, rice grown in less than 1 ha is not suitable for mechanical harvesting and threshing, particularly in small fragmented land holdings (Hussain, 1982). In northern India, although 1.5 million powered threshers are presently used for wheat threshing, pedal-operated threshers are used for threshing most of the paddy crop. However, in the areas where wheat threshers are common, paddy is often threshed by bullock treading and manual beating with sticks. Manual beating is common in all paddy-growing areas across the country (Datt, 2003), but particularly in cases of marginal land holdings. In the hills, threshing of paddy is normally carried out manually, either by beating out the grains with sticks or by rubbing out under feet, both of which are time- and labour-intensive. The process of paddy threshing by foot is mostly carried out by farm women and the sharp edges of paddy kernels often wound their feet. The beating method of paddy threshing often leads to grain loss due to shattering. Pinar

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Nomenclature

a_d	accuracy of variable
a_m	extreme coded value (maximum = $+a_m$; minimum = $-a_m$)
b_0	constant
b_i	linear regression coefficient
b_{ii}	quadratic regression coefficient
b_{ij}	interaction regression coefficient
CCRD	central composite rotatable design
F_{loc}	F-value for lack of fit
k	number of independent variables considered for optimisation
N	total number of experiments
n_c	number of central experiments
RSM	response surface methodology
X_1	wire loop tip height, mm
X_2	wire loop spacing, mm
X_3	peripheral speed of drum, $m\,min^{-1}$
X_i	actual value of the ith variable
X_{max}	maximum value of independent variables
X_{min}	minimum value of independent variables
x_1	coded value of X_1
x_2	coded value of X_2
x_3	coded value of X_3
x_i	coded value of the ith variable
Y_{ai}	experimental value of the ith response
Y_{ci}	calculated value of the ith response
$\overline{Y}$	average of actual values of responses
l	threshing capacity, $kg\,h^{-1}$
h	threshing efficiency, %

(1987) reported that the selection of improper threshing methods causes grain losses in the range 2.88–4.5%.

Transportation of heavy machines in hilly areas is also very difficult. Most of the farmers in these areas prefer to own machines that can be transported by a single man on his back. As a result, machines need to weigh less than 35 kg. Several engine- or power-operated paddy threshers have been designed and developed in the past, but they have not been successful in the hilly areas because of cost, weight, and electric power requirement problems. Das and Das (1989) developed and studied a paddy thresher and observed that higher capacity and optimum threshing efficiency can be achieved by threshing the paddy crop at a peripheral velocity of 622 $m\,min^{-1}$. However, because of electric power requirements it was found to be unsuitable for the farms of NWHR. Another axial paddy thresher was developed at IRRI, Philippines, with a capacity of 100 $kg\,h^{-1}$ (Khan, 1971). Although it was used extensively in some pockets of the Northeast region of India, Bengal and Orissa, hill farmers in the NWHR were reluctant to purchase it because they had difficult terrain, small land holdings and low production, and it cost more than INR 4000 (100 US$) and weighed more than 35 kg. Prakash (1979) designed and developed a pedal-operated multi-crop thresher that had a capacity of 140 $kg\,h^{-1}$ with a wire loop tip height of 62 mm at a peripheral velocity (linear velocity of the peg tip) of 750 $m\,min^{-1}$; the peg height (height of the peg tip from the drum surface) was 60 mm and tip clearance (distance between the inner surface of housing and the peg tip) was 32 mm. The threshing capacity and efficiency of the pedal thresher was significantly higher (at 1% level of significance) as compared to bullock treading, drum beating and manual treading (Miah et al., 1994). This pedal-operated paddy thresher (Fig. 1) was tested at the Vivekananda Institute of Hill Agriculture, Almora, Uttrakhand, India, where it was observed that the threshing mechanism was satisfactory. However, during operation the operator had sit in a bent position (15–20° from vertical), which was ergonomically not desirable for long-time operation, since wrong posture may cause serious injury (Kumar et al., 2001). Apart from the wrong operating posture, it has been observed that existing pedal threshers produce uneven threshing, which causes wrapping of paddy stems around the drum and leaves grain unthreshed. This may be due to the improper wire loop geometry since the spacing and tip heights of wire loops are not equal and uniform. Thus, the objective of the present study was to determine optimum machine parameters, for achieving maximum threshing capacity and efficiency, using response surface methodology (RSM) and central composite rotatable design (CCRD) techniques.

2. Materials and methods

2.1. Raw material

Five paddy varieties, VL-61, Thapa Chini, China-4, VL-62 and VL-85, were obtained from the experimental farm of VPKAS, Almora. The experiments were carried out at fixed moisture content (17 ± 1%) d.b. The moisture content of the crops was determined with the help of the digital moisture analyzer (A&D Company Limited, model-MX-50).

2.2. Existing pedal threshers used in the region

The paddy produced in the NWHR is usually threshed by bullock treading or by manual beating. In the hilly areas, threshing of paddy is conventionally carried out using muscle power, either by beating out the grains with sticks or by rubbing out under feet, both of which involve much time and labour. The traditional pedal paddy thresher, shown in Fig. 2, is used very rarely in hills. A mild steel sheet has been used as the covering material in this thresher, but this increases the total weight of the machine to around 50 kg.

2.3. Development of the VL paddy thresher

The seat and hand rest of the VL paddy thresher was designed in such a way that the spinal column (15 ± 5° from the vertical plane) and arms (angle between the upper and lower arm 135°) of the operator remain in a comfortable position (Fig. 3) during operation. The height of the hand rest and seat can be adjusted according to the need of the operator. The power was

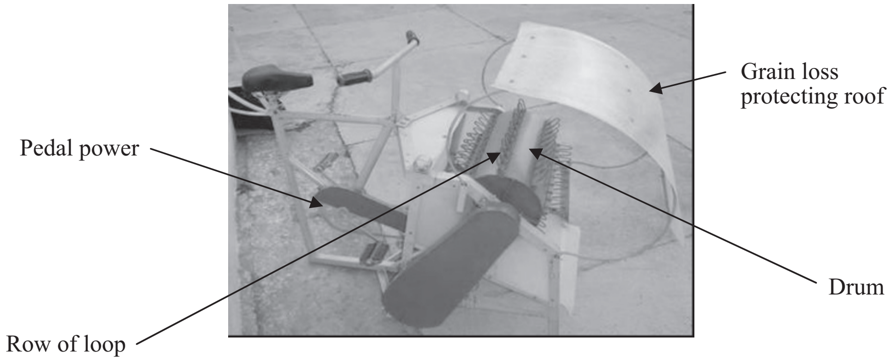

Fig. 1 – VL paddy thresher.

Fig. 2 – Traditional pedal thresher.

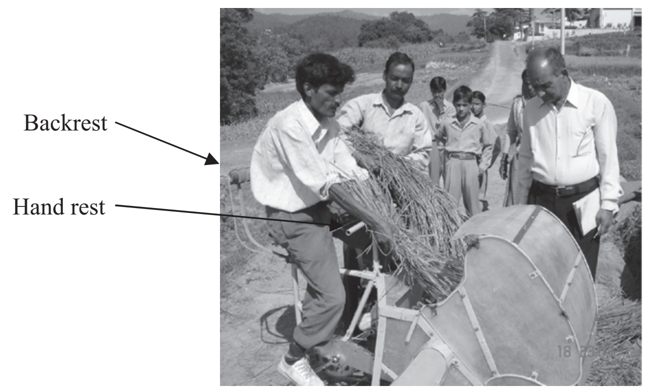

Fig. 3 – VL paddy thresher in operation.

transmitted from the pedal to the threshing cylinder through a chain and sprocket system having a speed ratio of 1:7. The threshing drum diameter was 350 mm at the tip of wire loops. A safety cover was also provided in the thresher to protect the operator as per norms (IS: 9020, 1979) and to save the grain losses during operation. The MS sheet in the body of the pedal thresher was replaced by a polycarbonate sheet of 1 mm thickness to reduce the total weight. The machine was designed adhering to the National Standards and guidelines on working posture (Hunang and Suggs, 1967). The material used for the threshing drum was as per the Indian Standard Institute (IS: 3327, 1962). The frame of the machine was made using the combination of a standard MS angle ($40 \times 40 \times 5$ mm) and an MS pipe (40/38 mm diameter). The machine is manually operated by a single person. A chain and sprocket system was used for transmitting power from the pedals to the threshing drum. The drum of the thresher was made of MS flat (40×5 mm), MS sheet (1 mm) and MS angle ($30 \times 30 \times 5$ mm). For beating action, V-shaped wire loops made of 5 mm MS round bars were welded in a staggered manner on the MS angle. These angles with wire loops were fitted on the periphery of the threshing drum with the help of a nut and a bolt.

2.4. *Central composite rotatable experiment design (CCRD)*

Three independent variables, viz., loop tip height (X_1), loop spacing (X_2) and drum speed (X_3) were considered for optimisation. The experimental plan for optimisation consisted of four dependent variables, viz., threshing capacity and threshing efficiency. For this purpose, RSM, using a CCRD (Hunter, 1959; Rastogi et al., 1998; Das, 2005; Myres, 1971) to fit a second-order polynomial equation, was employed. Values of loop X_1 vary from 35 to 45 mm, X_2 from 55 to 65 mm and X_3 from 385 to 440 m min^{-1}. The limiting values of the wire loop spacing and the tip height were based on an old paddy thresher. The maximum and minimum values of drum speed were based on ready-made sprockets available in the market. The transmission system of the VL paddy thresher was equipped with a set of four sprockets and two chains. Two gear combinations providing gear ratios 1:7.1 and 1:6.75 were used to achieve the maximum and minimum peripheral speeds, respectively. The pedal rotation speed of a normal man, operating a VL paddy thresher, was found to be 57 min^{-1}. For experimental purposes, a 0.373 kW electric motor (VL paddy thresher is normally pedal-operated) with different combinations of V-groove pulleys was used to achieve the drum speeds within the range of man-powered maximum and minimum drum speeds.

With the help of the limiting values of independent variables, 5 different levels of coded values, viz., +1.682, +1, 0, −1 and −1.682 were selected (Myres, 1971). In the design

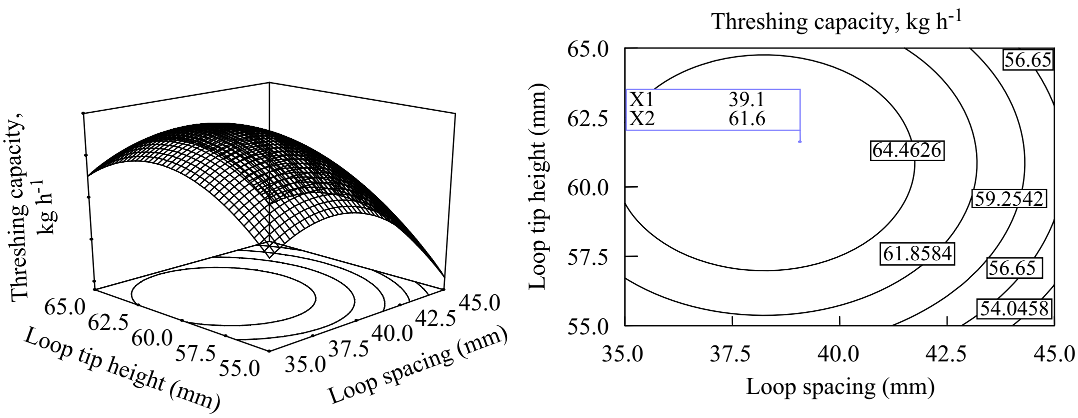

Fig. 4 – Effect of loop spacing (mm) and loop tip height (mm) on the threshing capacity (kg h^{-1}) at optimum drum speed of 439.46 m min^{-1}.

Table 1 – Experimental design for conducting the study (design: CCRD, total no. of experiments: 20)

Sl. no.	Variable	Level 1 (−1.68)	Level 2 (−1)	Level 3 (0)	Level 4 (+1)	Level 5 (+1.68)
1	Loop spacing (X_1), mm	35	37	40	43	45
2	Tip height (X_2), mm	55	57	60	63	65
3	Drum speed (X_3), m min^{-1}	385	396	412.5	429	440

Table 2 – Design of experiments using CCRD

Expt. no.	Loop spacing, mm	Loop tip height, mm	Drum speed, m min^{-1}	λ, kg h^{-1}	η, %
1	37 (−1)	57 (−1)	396.0 (−1)	58.0	95.5
2	43 (+1)	57 (−1)	396.0 (−1)	53.0	94.1
3	37 (−1)	63 (+1)	396.0 (−1)	60.0	96.1
4	43 (+1)	63 (+1)	396.0 (−1)	55.0	94.8
5	37 (−1)	57 (−1)	429.0 (+1)	60.3	96.3
6	43 (+1)	57 (−1)	429.0 (+1)	55.6	94.9
7	37 (−1)	63 (+1)	429.0 (+1)	61.5	97.0
8	43 (+1)	63 (+1)	429.0 (+1)	57.5	95.6
9	35 (−1.68)	60 (0)	412.5 (0)	58.0	95.5
10	45 (+1.68)	60 (0)	412.5 (0)	51.0	93.3
11	40 (0)	55 (−1.68)	412.5 (0)	54.0	94.4
12	40 (0)	65 (+1.68)	412.5 (0)	57.0	95.5
13	40 (0)	60 (0)	385.0 (−1.68)	63.1	96.5
14	40 (0)	60 (0)	440.0 (+1.68)	66.7	98.0
15	40 (0)	60 (0)	412.5 (0)	59.5	95.3
16	40 (0)	60 (0)	412.5 (0)	60.0	95.7
17	40 (0)	60 (0)	412.5 (0)	59.3	95.1
18	40 (0)	60 (0)	412.5 (0)	59.2	95.0
19	40 (0)	60 (0)	412.5 (0)	60.1	95.3
20	40 (0)	60 (0)	412.5 (0)	58.7	95.6

(Tables 1 and 2), the coded values of independent variables, viz., x_1, x_2 and x_3 were converted into their real form as X_1, X_2 and X_3, respectively, using the following equations:

$$x_i = \frac{X_i - X_m}{X_D} \tag{1}$$

Here i = 1, 2 and 3

$$X_D = \frac{X_{max} - X_m}{a_m} \tag{2}$$

$$X_m = \frac{X_{max} + X_{min}}{2} \tag{3}$$

$$a_m = 2^{0.25k} \tag{4}$$

The drums with five levels of wire loop spacing and tip heights were fabricated in the workshop of the Vivekananda Institute of Hill Agriculture, Almora. Nonlinear second-order regression equations, Eqs. (5) and (6), were developed to optimise the threshing capacity (λ) and the threshing efficiency (η) for response as functions of the coded value of the independent parameters

$$\lambda = b_0 + \sum_{i=0}^{3} b_i x_i + \sum_{i=1}^{3} b_{ii} x_i^2 + \sum_{i=1}^{2}\sum_{j=i+1}^{3} b_{ij} x_i x_j \quad (5)$$

$$\eta = b_0 + \sum_{i=0}^{3} b_i x_i + \sum_{i=1}^{3} b_{ii} x_i^2 + \sum_{i=1}^{2}\sum_{j=i+1}^{3} b_{ij} x_i x_j \quad (6)$$

The goodness of fit of the developed nonlinear equations was tested by F-value for lack of fit (F_{lof}).

The value of F_{lof} was calculated by

$$F_{lof} = \frac{\sum_{i=1}^{N}(Y_{ai} - Y_{ci})^2 - \sum_{i=1}^{n_c}(Y_{ai} - \overline{Y}_a)^2}{N - no.\ of\ coefficients\ in\ regression\ equation - n_c + 1} \quad (7)$$

The independent variables were fixed at five levels as per the CCRD-type experimental design and a total number of 20 experiments were carried out as evident from Table 2. The experiments were conducted in a random order. To calculate the error sum of squares and the lack of fit of the developed regression equation between the responses and independent variables, six replicated experiments were conducted at the central points of the coded variables (Myres, 1971).

2.5. *Comparative performance evaluation of a VL paddy thresher and the existing pedal thresher*

A comparative study of a VL paddy thresher and an old pedal thresher was conducted with the five hill rice varieties. Threshing capacities and efficiencies were recorded and analysed in order to determine the suitability of the machine for threshing different varieties of paddy.

3. Results and discussion

The optimised machine parameters were used to develop a machine that was easily powered and operated by one person. The chain and sprocket system was found to effectively transmit power from the pedal to the threshing drum. The V-shaped wire loops, which were welded on the periphery of the drum, provided the required beating action for detaching the paddy from the straw. The performance was further evaluated based on the threshing capacity and the threshing efficiency.

3.1. *Threshing capacity*

It can be observed from Fig. 4 that, at fixed drum speed (439.46 m min^{-1}), the threshing capacity increased with loop spacing up to 40 mm and reduced thereafter, achieving the maxima at about 64 kg h^{-1}. Similarly, the threshing capacity increased with loop tip height up to 61 mm, reducing thereafter. At a fixed value of loop tip height of 61.6 mm, the threshing capacity decreased with drum speed up to 410 m min^{-1} and increased thereafter up to 439.46 m min^{-1} at all loop spacings (Fig. 5). At a fixed value of optimum loop spacing of 39.1 mm, the threshing capacity decreased with a drum speed up to 410 m min^{-1} at all loop tip heights (mm) and increased thereafter, attaining maxima at a threshing capacity of 64.7 kg h^{-1} at 440 m min^{-1} of drum speed (Fig. 6). As per F-values indicated in Table 3, the linear term of loop spacing has more influence on the threshing capacity than drum speed and loop tip height. The threshing capacity is highly effected by all three parameters ($p<0.0001$) at the linear and quadratic levels but no significant effect was observed at the interactions level.

The numerical presentation in variation of the threshing capacity (λ, kg h^{-1}) with different variables X_1, X_2 and X_3 was fitted well in polynomial equation (Eq. (8)) with a coefficient of determination (R_2) of 0.99 (neglecting the high error-generating terms, $p<0.0001$) as given below:

$$\lambda = 224.883 + 16.251X_1 + 20.993X_2 - 5.469X_3 - 0.212X_1^2 - 0.172X_2^2 + 0.007X_3^2 \quad (8)$$

3.2. *Threshing efficiency*

At a fixed value of drum speed (440 m min^{-1}), the threshing efficiency (TE, %) increased with loop spacing up to 40 mm and reduced thereafter, achieving maxima at 97.8%. Similarly

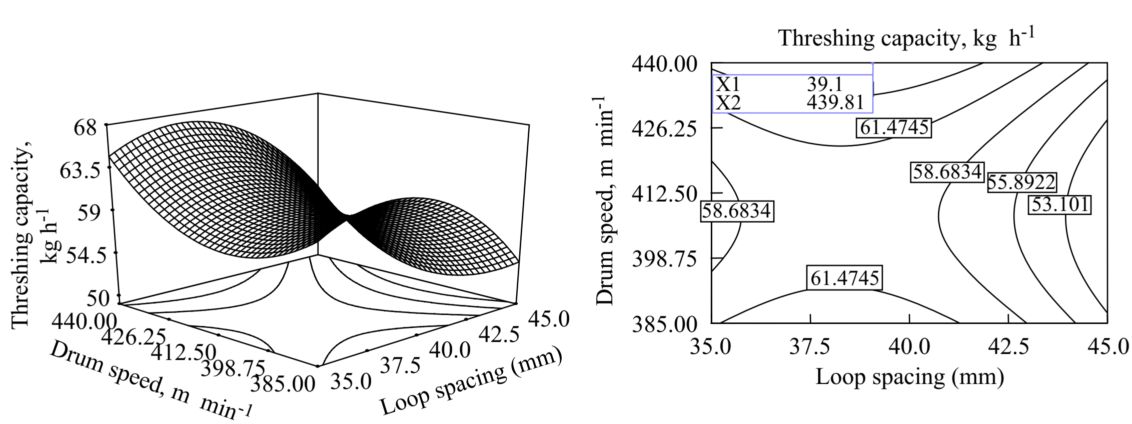

Fig. 5 – Effect of drum speed (m min^{-1}) and loop spacing (mm) on the threshing capacity (kg h^{-1}) at optimum loop tip height of 61.6 mm.

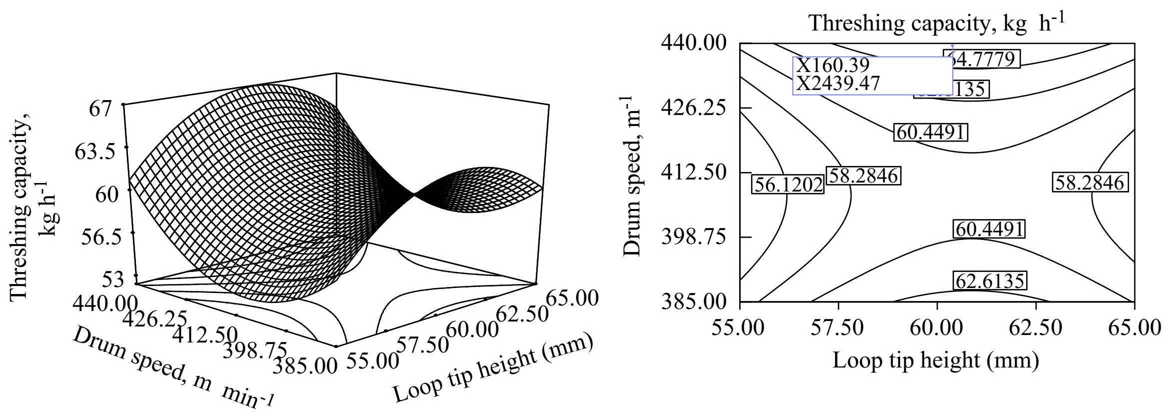

Fig. 6 – Effect of drum speed ($m\,min^{-1}$) and loop tip height (mm) on the threshing capacity ($kg\,h^{-1}$) at optimum loop spacing of 39.1 mm.

Table 3 – Analysis of variance (ANOVA) for threshing capacity applying Response Surface Quadratic Model

Source	Sum of squares	df	Mean square	F-value	p-Value Prob > F	
Model	237.12	9	26.35	95.61	< 0.0001	Significant
X_1	67.80	1	67.80	246.05	< 0.0001	
X_2	10.89	1	10.89	39.52	< 0.0001	
X_3	16.16	1	16.16	58.64	< 0.0001	
X_1X_2	0.053	1	0.053	0.19	**0.6709**	
X_1X_3	0.23	1	0.23	0.83	**0.3846**	
X_2X_3	0.090	1	0.090	0.33	**0.5796**	
X_1^2	51.29	1	51.29	186.12	< 0.0001	
X_2^2	33.79	1	33.79	122.63	< 0.0001	
X_3^2	46.80	1	46.80	169.83	< 0.0001	
Residual	2.76	10	0.28			
Lack of fit	1.34	5	0.27	0.95	0.5223	Not significant
Pure error	1.41	5	0.28			
Correlation total	239.87	19				

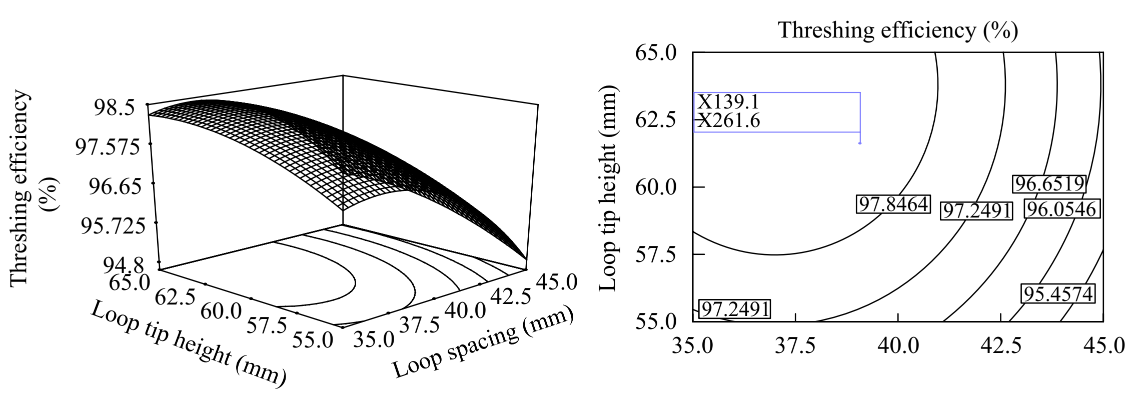

Fig. 7 – Effect of loop spacing (mm) and loop tip height (mm) on the threshing efficiency (%) at optimum drum speed of 439.46 $m\,min^{-1}$.

it increased with loop tip height up to 61 mm and reduced thereafter (Fig. 7). At a fixed value of loop tip height (61.6 mm) (Fig. 8), the threshing efficiency decreased with a drum speed up to 410 $m\,min^{-1}$ and increased thereafter up to 440 $m\,min^{-1}$ at all loop spacings. At a fixed value of optimum loop spacing of 39.1 mm, the threshing efficiency decreased with a drum speed of 410 $m\,min^{-1}$ at all loop tip heights (mm) and increased thereafter (Fig. 9). The threshing efficiency was highest (97.8%) at 440 $m\,min^{-1}$ of drum speed. Thus, the maximum threshing efficiency was found at a loop spacing of 39.1 mm, loop tip height of 61.6 mm and drum speed of 440 $m\,min^{-1}$. As per F-values indicated in Table 4, the linear term of loop spacing and quadratic term of drum speed influenced more threshing efficiency as compared to other terms. The threshing efficiency was highly influenced by the terms loop spacing and drum speed ($p<0.0001$) at both linear and quadratic levels. A significant effect of loop tip height ($p<0.001$) was observed at the linear level but this was not more significant at the quadratic level ($p>0.01$). Interaction terms of all three variables did not have a significant effect on the threshing efficiency even at the 10% level of significance ($p>0.1$). The mathematical representation in variation of the threshing efficiency with different variables X_1, X_2 and X_3 were well fitted in the second-order polynomial equation (Eq. (9)) with R_2 of 0.98, (neglecting the high error-generating terms, p-value >10%) as given below:

$$\eta = 400.34 + 2.810X_1 + 1.909X_2 - 2.049X_3 - 0.038X_1^2 - 0.015X_2^2 + 0.003X_3^2 \quad (9)$$

3.3. Optimisation of the design parameters for development of an appropriate thresher

The numerical values (Table 5) and the graphical optimisation (Figs. 10–12) investigated the independent design parameters of the machine to obtain the optimum threshing capacity and threshing efficiency. The Design-Expert program (V 7.0.0) of the STAT-EASE software was utilised (Design Expert, 2002) and

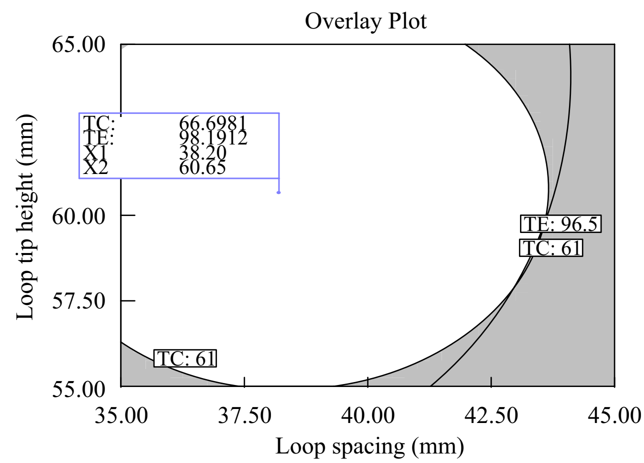

Fig. 10 – Superimposed contours for threshing capacity (TC, kg h^{-1}) and threshing efficiency (TE, %) at varying loop spacing (mm) and loop tip height (mm) at fixed drum speed of 439.46 m min^{-1}.

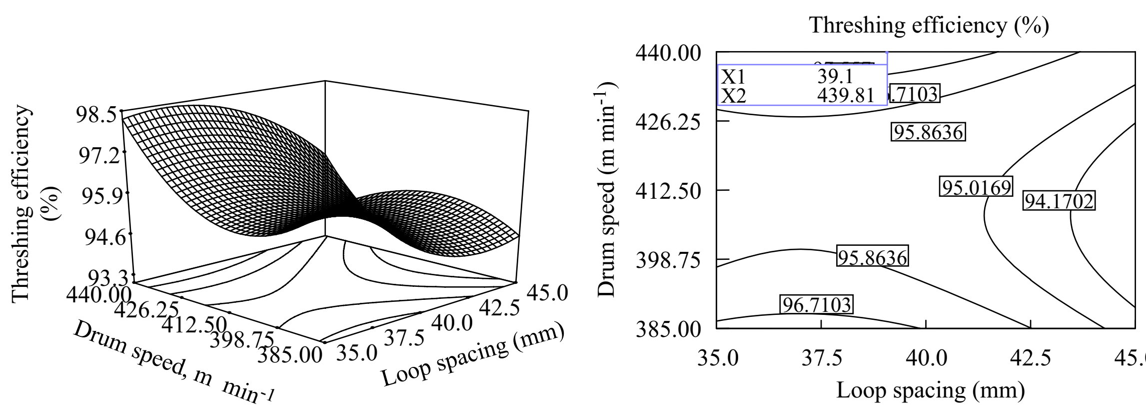

Fig. 8 – Effect of drum speed (m min^{-1}) and loop spacing (mm) on the threshing efficiency (%) at optimum loop tip height of 61.6 mm.

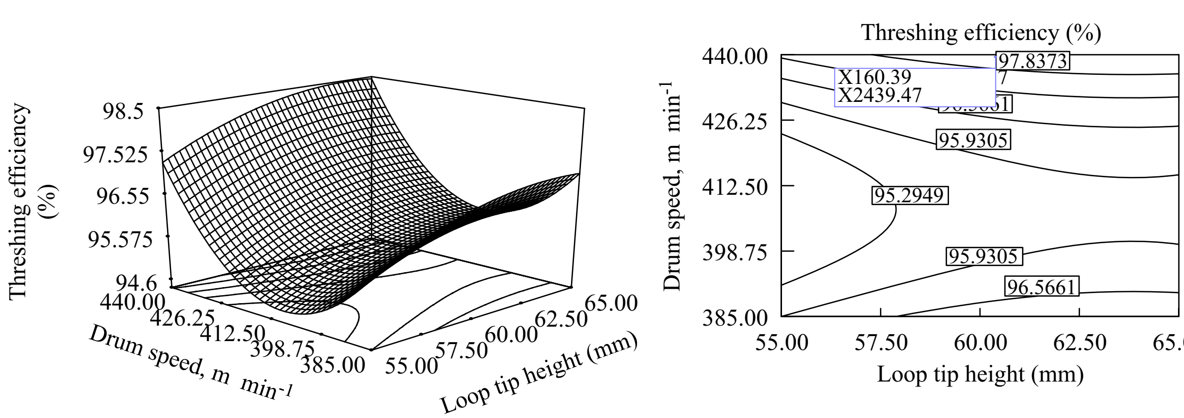

Fig. 9 – Effect of drum speed (m min^{-1}) and loop tip height (mm) on the threshing efficiency (%) at optimum loop spacing of 39.1 mm.

Table 4 – Analysis of variance (ANOVA) for threshing efficiency applying Response Surface Quadratic Model

Source	Sum of squares	df	Mean square	F-value	p-Value Prob > F	
Model	19.47	9	2.16	52.23	< 0.0001	Significant
X_1	6.30	1	6.30	152.06	< 0.0001	
X_2	1.58	1	1.58	38.07	0.0001	
X_3	2.34	1	2.34	56.39	< 0.0001	
X_1X_2	1.250E−005	1	1.250E−005	3.018E−004	**0.9865**	
X_1X_3	1.250E−005	1	1.250E−005	3.018E−004	**0.9865**	
X_2X_3	1.512E−003	1	1.512E−003	0.037	**0.8523**	
X_1^2	1.64	1	1.64	39.53	< 0.0001	
X_2^2	0.25	1	0.25	6.14	0.0327	
X_3^2	6.57	1	6.57	158.62	< 0.0001	
Residual	0.41	10	0.041			
Lack of fit	6.875E−003	5	1.375E−003	0.017	0.9998	Not significant
Pure error	0.41	5	0.081			
Correlation total	19.88	19				

Table 5 – Solutions for optimum conditions

Sl. no.	X_1, mm	X_2, mm	X_3, m min^{-1}	λ, kg h^{-1}	η, %
1	39.1	60.55	439.46	66.69	98.29
2	38.57	61.55	439.81	66.72	98.29
3	38.58	59.46	439.96	66.68	98.09
4	38.51	60	439.78	66.77	98.14
5	37.73	60.61	439.99	66.82	98.31

used for simultaneous optimisation of the multiple responses. The desired goals (maximise or minimise) for each variable and response were chosen and different weights (i.e. a number between 0.1 and 1.0, which shows the importance of the desired goal) were assigned to each goal to adjust the shape of its particular desirability function. Table 5 shows software generated five optimum conditions of independent variables with the predicted values of responses. The values given in the flagged area in Figs. 10–12 were grouped together and the optimised values of variables such as drum speed 439.46, wire loop spacing 38.2 mm, wire loop tip height 60.65 mm, threshing capacity 66.69 kg h^{-1} and threshing efficiency 98.19% were determined. The values obtained in solution number one (Table 5), of the numerical optimisation method, were found to be closer to the values obtained in the graphical optimisation method. On this basis, a new paddy-threshing unit, having a loop spacing of 39.1 mm, a loop tip height of 60.5 mm and a drum speed of 439.46 (Table 5 solution 1), was fabricated.

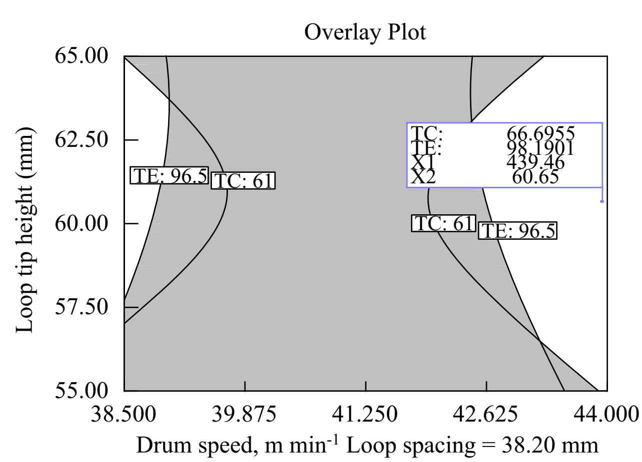

Fig. 11 – Superimposed contours for threshing capacity (TC, kg h^{-1}) and threshing efficiency (TE, %) at varying drum speed (m min^{-1}) and loop tip height (mm) at fixed loop spacing of 38.20 mm.

3.4. *Comparative performances of the VL paddy thresher and the existing pedal thresher*

A comparative study of the newly developed VL paddy thresher (Fig. 1) and an old pedal thresher (Fig. 2) was conducted using the selected five hill rice varieties. It is evident from Table 7 that the weight and cost of the VL paddy thresher (32 kg and INR 3500 or 88 US$) was lower than the existing pedal thresher (50 kg and INR 5500 or 138 US$). Threshing capacities and efficiencies of the VL paddy thresher and the old pedal thresher were recorded and analysed in order to assess the suitability of the two machines for different paddy varieties. Threshing capacities and efficiencies of both machines were analysed in SPSS (v-10) in which values were arranged according to the Duncan multiple ranges test (DMRT) in Table 6. The threshing capacities of the VL paddy thresher for all paddy varieties like VL-61 (100.9 kg h^{-1} against pedal thresher 62.6 kg h^{-1}), VL-85 (97.4 kg h^{-1} against 61.7 kg h^{-1}), China-4 (70.9 kg h^{-1} against 61.7 kg h^{-1}), Thapa chini (64.6 kg h^{-1} against 50 kg h^{-1}) and VL-62 (62 kg h^{-1} against 55 kg h^{-1}) were significantly higher, at the 5% level of significance, than the traditional pedal thresher. This is probably due to the uniform beating action given by the VL paddy thresher on paddy grain due to appropriate tip height and loop spacing. However, in case of the old pedal thresher, the non-uniform beating and the repeated wrapping of paddy stems around the drum during threshing caused a significant reduction in the threshing capacity. Significant differences were not observed in case of threshing efficiencies. (Table 6).

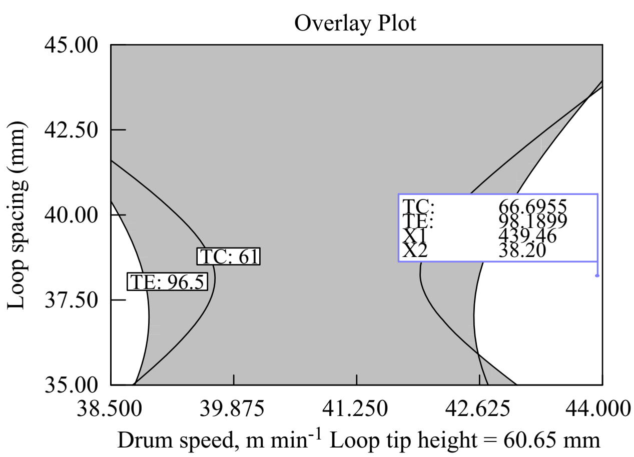

Fig. 12 – Superimposed contours for threshing capacity (TC, kg h^{-1}) and threshing efficiency (TE, %) at varying drum speed (m min^{-1}) and loop spacing (mm) at fixed loop tip height of 60.65 mm.

4. Conclusions

The machine performance was found optimum on wire loop spacing 39.1 mm, wire loop tip height 60.6 mm and threshing drum speed 339.46 m min^{-1}. The corresponding threshing capacity and efficiency was 64.6 kg h^{-1} against predicted 66.8 kg h^{-1} and 96.4% against predicted 98.3%, respectively, for variety Thapa Chini. Test results indicated that the VL paddy thresher performed better compared to the existing pedal thresher with rice varieties VL-62, Thapa Chini, China-4, VL-85 and VL-61. The weight and cost (32 kg and INR 3500 or 88 US$) of the VL paddy thresher were lower than the existing pedal thresher (50 kg and INR 5500 or 138 US$). Therefore, on the basis of the above results, it can be inferred that the wire loop geometry

Table 7 – Comparative specification of the VL paddy thresher and the existing pedal thresher

Items	Specifications	
	VL paddy thresher	Pedal thresher
Wire loop spacing, mm	39.1	Varies from 35 to 45
Wire loop tip height, mm	60.55	Varies from 50 to 60
Weight, kg	32	50
Cost, INR	3500	5500
Power source	One person or .373 kW electric motor	One person
Operating mode	Seating posture	Standing posture
Threshing capacity, kg h^{-1}	62–100	55–63
Threshing efficiency, %	97–99	97–99

Table 6 – Comparative performance evaluation of the VL paddy thresher and the existing pedal thresher

Rice variety	λ, kg h^{-1}	η, %	1000 grain weight, kg	Straw–grain ratio
Threshing with the VL paddy thresher				
VL-62	62^{cd}	97.2^{b}	0.0251^{a}	3.75^{d}
Thapa Chini	64.6^{d}	96.4^{b}	0.0263^{ab}	2.36^{b}
China-4	70.9^{e}	96.2^{b}	0.0265^{ab}	2.89^{c}
VL-85	97.4^{f}	98.5^{cd}	0.0268^{ab}	1.65^{a}
VL-61	100.9^{g}	98.7^{d}	0.0283^{b}	1.66^{a}
Threshing with the old pedal thresher				
VL-62	55^{b}	97.0^{b}	0.0251^{a}	3.75^{d}
Thapa Chini	50^{a}	94.4^{a}	0.0263^{ab}	2.36^{b}
China-4	55.8^{b}	96.7^{b}	0.0265^{ab}	2.89^{c}
VL-85	61.7^{c}	98.9^{d}	0.0268^{ab}	1.65^{a}
VL-61	62.6^{cd}	97.4^{bc}	0.0283^{b}	1.66^{a}

Level of significance = 5%.

and drum speed have a major effect on the threshing performances of paddy threshers. The VL paddy thresher was receiving a good response in North Western Himalayan Region (NWHR) of India, with more than 500 threshers being sold in 2005 and 2006.

REFERENCES

Das H (2005). Food Processing Operation Analysis, 1st edn. Asian Book Private Limited, New Delhi, India

Das S K; Das D K (1989). Development of power-operated paddy thresher. Agricultural Mechanization in Asia, Africa and Latin America, **20**(3), 37–40

Datt P (2003). Design of paddy thresher. Proceedings of the National Workshop on Design Methodology of Agricultural Machinery, pp 192–198. CIAE, Bhopal

Hunang B K; Suggs C W (1967). Vibration studies of tractor drivers. Transactions of the American Society of Agricultural Engineers, **10**(4), 476–482

Hunter J S (1959). Determination of optimum condition by experimental methods. Indian Quality Control, **15,** 6–16

Hussain M H (1982). Mechanization of paddy production in Malaysia. Agricultural Mechanization in Asia, Africa and Latin America, **13**(3), 56–58

IS: 3327 (1962). Indian Standard. Test Code for Threshing Drum of Pedal Thresher. Bureau of Indian Standard (Indian Standard Institution), New Delhi

IS: 9020 (1979). Indian Standard. Test Code for General and Safety Requirements for Power Threshers. Bureau of Indian Standard (Indian Standard Institution), New Delhi

Khan A U (1971). Semi-annual Report. Department of Agricultural Engineering, IRRI, Los Banos, Philippines

Kumar A; Mohan D; Patel R; Varghese M (2001). Development of grain threshers based on ergonomics design criteria. Applied Ergonomics, **33**(2002), 503–508

Myres R H (1971). Response Surface Methodology. Allyan and Bacon, Boston

Miah M A K; Roy B C; Hafiz A; Haroon M; Siddique S B (1994). A comparative study on the effect of rice threshing method on grain quality. Agricultural Mechanization in Asia, Africa and Latin America, **25**(3), 63–66

Pinar Y (1987). Grain losses at harvesting and threshing of paddy in Turkey. Agricultural Mechanization in Asia, Africa and Latin America, **18**(4), 61–64

Prakash B (1979). Design and testing of manually operated multi crop thresher. Unpublished MTech Thesis, Agricultural Engineering Department, I.I.T., Kharagpur, India

Quick G R (1998). Global assessment of power threshers for rice. Agricultural Mechanization in Asia, Africa and Latin America, **29**(3), 47–54

Rastogi N K; Rajesh G; Shamala T R (1998). Optimization of enzymatic degradation of coconut residue. Journal of Science and Food Agriculture, **76,** 129–134