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Performance Evaluation of Manually Operated Mulch Laying Machine on Different Soil Conditions

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ABSTRACT

A machine with manual operation for mulch-laying machine with a punching arrangement was developed, and its performance was assessed at three different mulch paper thicknesses (15 m, 20 m and 25 m), three different disc angles (35 degrees, 40 degrees, and 45 degrees), three different punch spacings (250 mm, 500 mm, and 1000 mm), and three different forward speeds (1.3 km/h, 1.5 km/h, 1.7 km/h) to investigate their effects on field capacity, effective field efficiency, and punching efficiency. Utilizing randomised block design and response surface methods, the experimental plan for optimization was created. All of the independent variables' combined effects on the dependent variables were found to be statistically significant. The influence of operating speed and mulch paper thickness was found to be the most significant on the dependent variable. The effective field capacity and field efficiency increased from 0.11 ha/h to 0.19 ha/h and 72.04 percent to 89.51 percent, respectively, by increasing mulch paper thickness from 15 µm to 25 µm and operating speed from 1.3 km/h to 1.7 km/h, whereas punching efficiency fell from 85.18 percent to 84.40 percent. Mulch paper of 15 µm and a disc angle value of 40 degrees were optimised from the independent factors that were chosen for optimal soil covering over the laid plastic mulch sheet. Punching efficiency was maximised with performance optimised at 500 mm punch spacing. Additionally, the machine operated more efficiently at 1.5 km/h.

1. Introduction

In India, agriculture and allied sectors contributed 18% of the India's gross domestic product (GDP) in the year 2014-2015 [1,2]. A large proportion of this contribution comes from the horticultural sub-sector.

Konkan region of Maharashtra is specially known as horticultural zone. Vegetable cultivation and floriculture are commercial ventures in Palghar, Thane and Raigad districts. Mulching operation and shade-net houses are

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used for capsicum, cucurbits, water melon, betel vine and other vegetables cultivation. In order to protect the plant and its roots from the impact of high temperature variations, the mulching process entails covering the soil surrounding the plant's root area. The advantages of mulching are to reduce deterioration of soil by controlling the rate of movement of water and its runoff, restrict the rain water flow rate, soil water runoff and avoiding the direct entry of solar radiation.

Manual mulch laying operations are time consuming, labour intensive, costly, tedious and result in improper laying of mulch paper, poor quality of work, tearing of paper during handling and difficulty in covering of mulch paper. The popularity of using mulch paper for growing vegetables and fruit crops is increasing day by day in Konkan region but application of mulch paper in the field with manual method limits its effective use [2]. Also, different tractor operated mulch paper laying equipment were developed and are commercially available. But, in spite of having higher efficiency, they are unsuitable to use in Konkan region due to, marginal lands, undulated slope of land and poor economical condition, Considering all these points it became necessary to develop manual operated mulch laying machine suitable for small scale farmers of Konkan region [5].

2. Material and Methods

2.1 Experimental Setup

The field was prepared with the help of tractor drawn rotavator and land leveler was used to level the field before mulching operation. The constructional components of the developed machine included main frame, bund former, mulch holder, press wheels, covering discs, punching wheels and handle. The overall weight of the machine was about 60 kg. The components were fabricated using galvanized iron and mild steel. The overall dimensions of the machine were 2000 × 1500 × 1000 mm. The developed mulch laying machine and its components are shown in Figure 1. The bund former mounted on main frame was developed for preparation of soil beds. The height of the bund former was adjusted as the field condition and the width of bed could be adjusted as per crop requirement. The mulch holder was mounted behind the bund former to lay the plastic mulch paper which was raised at a height of about 4 inches. The use of pneumatic press wheels was done to compress the laid mulch paper on the prepared bed. Two discs inclined at a variable angle of 35 degree, 40 degree and 45 degrees were attached at the end of main frame to cover the edges of mulch paper. The width of mulch paper used was 1200 mm. Four punching cups of variable spacing (i.e. 250 mm, 500 mm and 1000 mm) were mounted on the periphery of the wheels. The machine was manually pulled by two persons.

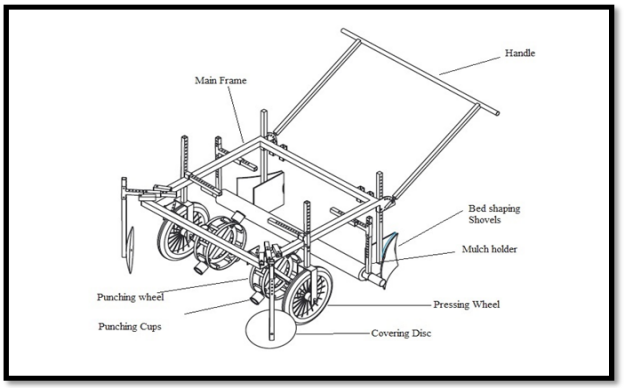

Figure 1. Different components of developed manually operated mulch laying machine response surface method

Four independent variable of disc angle (35 degree, 40 degree and 45 degree), thickness of mulch paper (15 µm, 20 µm and 25 µm), speed of operation (1.3 km/h, 1.5 km/h and 1.7 km/h) and punch spacing (250 mm, 500 mm and 1000 mm) were considered for optimization. The experimental plan for optimization included three dependent variables, viz. field efficiency field capacity and punching efficiency. Thus, response surface methodology (RSM) with randomized block experimental design (RBD) was employed to fit a second order quadratic equation on the experimental data.

The independent variables were implemented at three levels in RBD-type experimental design and finally, 81 experiments were conducted as shown in Table 1. The experiments were carried out in a continuous order. The three replications were performed. The design expert software (Version 11) was used for simultaneous optimization of the multiple responses.

2.2 Evaluation Procedure

For calculating the effective field capacity the data sheet were prepared for recording the time loss during turning, adjusting punching wheels and adjustment in field and actual performance of machine was also recorded [3].

$$EFC(ha/h) = \frac{A}{T_p + T_t} \quad (1)$$

where,
EFC = Effective field capacity, ha/h
A = Area covered, ha
Tp = Productive time, h
Tt = Non-productive time, h

Table 1. Design Experiment Using Randomized Block Design (RBD)

Experiment	Thickness of mulch paper	Disc angle	Punch spacing	Speed of operation
1	15	35	250	1.3
2	15	35	250	1.5
3	15	35	250	1.7
4	15	35	500	1.3
5	15	35	500	1.5
6	15	35	500	1.7
7	15	35	1000	1.3
8	15	35	1000	1.5
9	15	35	1000	1.7
10	15	40	250	1.3
11	15	40	250	1.5
12	15	40	250	1.7
13	15	40	500	1.3
14	15	40	500	1.5
15	15	40	500	1.7
16	15	40	1000	1.3
17	15	40	1000	1.5
18	15	40	1000	1.7
19	15	45	250	1.3
20	15	45	250	1.5
21	15	45	250	1.7
22	15	45	500	1.3
23	15	45	500	1.5
24	15	45	500	1.7
25	15	45	1000	1.3
26	15	45	1000	1.5
27	15	45	1000	1.7
28	20	35	250	1.3
29	20	35	250	1.5
30	20	35	250	1.7
31	20	35	500	1.3
32	20	35	500	1.5
33	20	35	500	1.7
34	20	35	1000	1.3
35	20	35	1000	1.5
36	20	35	1000	1.7
37	20	40	250	1.3
38	20	40	250	1.5
39	20	40	250	1.7
40	20	40	500	1.3
41	20	40	500	1.5
42	20	40	500	1.7
43	20	40	1000	1.3
44	20	40	1000	1.5
45	20	40	1000	1.7

Table 1 continued

Experiment	Thickness of mulch paper	Disc angle	Punch spacing	Speed of operation
46	20	45	250	1.3
47	20	45	250	1.5
48	20	45	250	1.7
49	20	45	500	1.3
50	20	45	500	1.5
51	20	45	500	1.7
52	20	45	1000	1.3
53	20	45	1000	1.5
54	20	45	1000	1.7
55	25	35	250	1.3
56	25	35	250	1.5
57	25	35	250	1.7
58	25	35	500	1.3
59	25	35	500	1.5
60	25	35	500	1.7
61	25	35	1000	1.3
62	25	35	1000	1.5
63	25	35	1000	1.7
64	25	40	250	1.3
65	25	40	250	1.5
66	25	40	250	1.7
67	25	40	500	1.3
68	25	40	500	1.5
69	25	40	500	1.7
70	25	40	1000	1.3
71	25	40	1000	1.5
72	25	40	1000	1.7
73	25	45	250	1.3
74	25	45	250	1.5
75	25	45	250	1.7
76	25	45	500	1.3
77	25	45	500	1.5
78	25	45	500	1.7
79	25	45	1000	1.3
80	25	45	1000	1.5
81	25	45	1000	1.7

Field efficiency was calculated by the ratio of effective field capacity to theoretical field capacity and expressed in percentage.

$$\text{Field Efficiency, per cent} = \frac{\text{Effective Field Capacity}}{\text{Theoretical Field Capacity}} \times 100 \quad (2)$$

Punching efficiency was calculated by the ratio of actual punches to the calculated punches on mulch paper and expressed in percentage.

$$\text{Punching Efficiency, per cent} = \frac{\text{Actual punches}}{\text{Calculated punches}} \times 100 \quad (3)$$

3. Results and Discussion

The effect of selected independent variables, individually and in combination are discussed in sections 1 to 8.

3.1 Effect of Mulch Paper Thickness on Field Capacity, Field Efficiency and Punching Efficiency

It was observed from Table 2 that, effective field capacity and field efficiency increased with increase in mulch paper thickness. It might be because reduction in mulch paper thickness resulted in increased paper weight

ultimately adding extra load on the machine frame. Conversely, the punching efficiency decreased with increase in thickness of mulch paper which would have been due to easy penetration of punching cups on the minimum thickness mulch paper.

Table 2. Mean value table for effect of thickness of mulch paper on field capacity, field efficiency and punching efficiency

Thickness of paper (µm)	Field capacity (ha/h)	Field efficiency (%)	Punching efficiency (%)
15	0.142	77.43	88.20
20	0.146	79.72	86.85
25	0.149	80.73	78.55

3.2 Effect of Disc Angles on Field Capacity, Field Efficiency and Punching Efficiency

The effect of disc angles at 35, 40 and 45 degree on effective field capacity, field efficiency and punching efficiency calculated separately concluded that field capacity and field efficiency decreased with an increase in disc angle. It might be because 45 degree angle of soil covering disc carried greater volume of soil than 35 degree disc angle. Also, there was no considerable effect on the punching efficiency with increase in disc angle which might be due to the consideration that changing of the disc angle did not directly or indirectly affected the performance of punching cups which can be seen in Table 3.

Table 3. Mean value table for effect of disc angles on field capacity, field efficiency and punching efficiency

Disc angles (degree)	Field capacity (ha/h)	Field efficiency (%)	Punching efficiency (%)
35	0.151	82.29	84.19
40	0.148	80.98	84.78
45	0.141	77.19	84.62

3.3 Effect of Punch Spacing on Field Capacity, Field Efficiency and Punching Efficiency

The results as shown in Table 4 concluded that effective field capacity, field efficiency and punching efficiency increased with increased punch spacing. It might be due to the observation that, single cup mounted on punching wheel rotated freely on the laid mulch bed producing punch spacing of 1000 mm without any disturbance in making punch holes.

Table 4. Mean value table for effect of punch spacing on field capacity, field efficiency and punching efficiency

Punch spacing (mm)	Field capacity (ha/h)	Field efficiency (%)	Punching efficiency (%)
250	0.138	75.84	80.09
500	0.145	79.56	84.48
1000	0.150	81.96	85.8

3.4 Effect of Operational Speed on Field Capacity, Field Efficiency and Punching Efficiency

It was observed that effective field capacity and field efficiency were increased with increase in speed of operation. It might be because when machine operated at maximum speed, the area covered per unit time was maximum. But, punching efficiency varied with increased speed of operation as shown in Table 5.

Table 5. Mean value table for effect speed of operation on field capacity, field efficiency and punching efficiency

Speed of Operation (km/h)	Field capacity (ha/h)	Field efficiency (%)	Punching efficiency (%)
1.3	0.11	72.04	85.18
1.5	0.15	80.00	84.01
1.7	0.19	89.51	84.40

3.5 The Analysis of Variance Showing Effect of Selected Independent Parameters on Dependent Parameters

The statistical analysis of the data was carried out to study the significance of selected independent parameters on dependent parameters and obtained ANOVA table presented in Table 6.

Analysis of variance (ANOVA) for the suggested model was presented in Table 6. As it was observed that the replications "Mean Square Value" of field capacity, field efficiency and punching efficiency was 0.00029, 84.97 and 12.88, respectively which implies that the model were significant. The value of "p-value probability" less than 0.01 indicated that the model terms were significant at 1 per cent level of significance. It may be because of uncontrollable variations such as weather conditions, soil conditions etc. Also, the effect may be due to the handling conditions of the machine by the labour at the time of operations.

It was observed from the Table 6, the selected individual parameters for the experiment, viz. thickness of mulch paper, disc angle, punch spacing and speed of operation were observed to be significant at 1 per cent level of

significance. Which shows that the selected parameters were effectively affect on the field capacity and field efficiency but the disc angle does not have the significant effect on punching efficiency.

The combination of thickness of mulch paper and disc angle shows the significant effect on field capacity and field efficiency as because as the thickness of mulch paper were reduced the length and weight of the paper were increased which implies the extra additional load on machine frame also as the disc were not provided with any anti functional accessories such as bearing, it pulls the soil like scraper and covers the soil over the edges of the laid mulch paper which directly affect on the performance of the machine. It also shows the combine effect of thickness of mulch paper and disc angle has the non significant effect on punching efficiency, it may be because as an arrangement of the punching cups provided on the punching wheel which do not have any direct link with soil covering disc. Hence, the effect of changing of soil covering disc angle do not directly or indirectly affect on the performance of punching cups.

The combined effect of thickness of mulch paper and the punch spacing shows the significant effect at the 5 per cent level of significance, it may be due to the increased thickness of mulch paper requires the more pressure by the punching cups for making the holes, which directly affect on the pulling force of machine, ultimately the field capacity and field efficiency of machine get affected. It also shows the combined effect of thickness of mulch paper and the punch spacing has been observed as significant at 1 per cent level of significance on punching efficiency. This may be because as the lesser thickness, punching where effectively carried out on the laid mulch paper, as the thickness increases it directly affects the punching operations [4]. Hence, the effect of the combination of both were observed to be significant.

Table 6. Analysis of variance showing effect of selected independent parameters on dependent parameters

Source	Df	Type I SS			Mean Square		
		EFC (ha/h)	FE (per cent)	PE (per cent)	EFC (ha/h)	FE (per cent)	PE (per cent)
Rep	2	0.00058	169.94	25.78	0.0003**	84.97**	12.88**
Thickness of mulch	2	0.00308	986.50	4422.33	0.0016**	493.2**	2211.1*
Disc Angle	2	0.00093	242.31	14.98	0.0004**	121.15**	7.48 ^{NS}
Punch Spacing	2	0.00034	124.52	357.66	0.0001**	62.26**	178.8**
Speed of operation	2	0.20018	11355.47	57.01	0.1000**	5677.7**	28.50**
Thick×D.Angle	4	0.00022	75.28	59.72	0.0006**	18.82**	14.92**
Thick×Spacing	4	0.00016	56.49	117.26	0.00004*	14.12*	29.31**
Thick×Speed	4	0.00031	134.25	63.44	0.00008**	33.56**	15.85**
D.Angle×Spacing	4	0.00028	105.18	80.65	0.00007**	26.29**	20.16**
D.Angle×Speed	4	0.00065	158.09	15.13	0.00016**	39.52**	3.78*
Spacing×Speed	4	0.00026	94.33	95.74	0.00007**	23.58**	23.93**
Thick×D.Angl×Spacing	8	0.00031	105.22	36.93	0.00004**	13.15**	4.61 ^{NS}
Thick×D.Angle×Speed	8	0.00020	66.90	80.86	0.00002*	8.36*	10.10**
Thick×Spacing×Speed	8	0.00042	143.48	168.68	0.00005**	17.93**	21.08**
D.Angl×Spacing×Speed	8	0.00080	288.12	94.42	0.0001**	36.01**	11.80**
Thick×D.An×Spacing×Speed	16	0.00038	139.54	181.64	0.00003*	8.72**	11.35**

"**" Highly significant at 1% level; "*" Significant at 5% level; "*NS"* Non-significant.

The combined effect of the thickness of mulch paper with speed shows the significant effect at 5 per cent level of significance on field capacity and field efficiency and also shows the significant effect at 1 per cent level of significance on punching efficiency, it may be due to the operating speed of machine which may be fluctuated due to weight of mulch paper and the soil conditions which implies the resistive force on the bed forming shovels. Therefore, the combined effect of these two parameters directly affects on the field capacity, field efficiency and punching efficiency of machine [6,7].

The Table 6 shows the highly significant effect of disc angle and punch spacing at 1 per cent level of significance on field capacity and field efficiency and also at 1 per cent level of significance on punching efficiency, it may be because of as the disc angle increases the required pulling force were increased due to which the rotating speed of the punching wheel reduces which requires the more efforts to press the hole on the mulch paper and also it increases the holding time of punches pressing holes on laid mulch. The resultant combined effect of these two parameters directly affects the field capacity, field efficiency and punching efficiency of machine, respectively.

The combine effect of disc angle and speed of operations were seen to be significant at 1 per cent level of significance it may be because as increased angle of disc carries the more volume of soil for covering the edges of laid mulch which implies more pulling force due to which the speed of operation decreases and as a combined effect of both the field capacity and field efficiency of the machine get decreases. It also shows the combine effect of disc angle and speed of operations were seen to be significant at 1 per cent level of significance it may be because as a combined effect of both the punching efficiency of the machine get increases as punch resting time increases due to reduction in speed of operation [8].

It was perceived from the Table 6 that the combine effect of the punch spacing and speed of operation has the significant effect at 5 per cent level of significance. It may be because as the punch spacing increased the contact time of punching cups were reduced and the machine moves speedily on the bed due to which more area were covered with less duration of time. With the combined effect of both, the field capacity and field efficiency of the machine was increased. It was also perceived that the combine effect of the punch spacing and speed of operation has the significant effect at 1 per cent level of significance. It may be because as the speed of machine reduced the contact time of punching cups were increased on the bed due to which the punch formation where more accurate and increases the punching efficiency of machine. Hence, as a result combined effect of both the punching efficiency of machine shows the significant effect on machine performance.

Table 6 shows that the combined effect of three and four parameters were highly significant, which directly affects the performance parameters of the machine viz. field capacity, field efficiency and punching efficiency. This was observed because of the individual parameters significantly affects in the selected combined parameters as such effect of the selected individual variables do not override by the effect of other variables.

3.6 The Effect of Selected Independent Parameters on Field Capacity and Field Efficiency

The effect of three sets of mulch paper thickness, disc angle, punch spacing viz., 250, and speed of operation on field capacity and field efficiency were studied. The graphical representations of the results were shown in Figure 2.

Figure 2a represents the effect of thickness of mulch paper and disc angle on the field efficiency. It was perceived from the figure, that the field capacity and field efficiency was increases with increased thickness of mulch paper from 15 µm to 25 µm. The highest field capacity and field efficiency was observed as 0.15 ha/h and 82 per cent at the 25 µm thickness of mulch paper and at 35 degree disc angle. Similarly, the field capacity and field efficiency decreasing with increased disc angle from 35 degree to 45 degree. The highest field capacity and field efficiency was observed at 35 degree disc angle.

The effect of thickness of mulch and punch spacing on field capacity and field efficiency was shown in Figure 2b. It was observed that the field capacity and field efficiency were increased with increased punch spacing from 250 mm to 1000 mm. The highest field capacity and field efficiency was found 0.15 ha/h and 84 per cent at 1000 mm punch spacing.

Figure 2c presents the effect of thickness of mulch and speed of operation on field capacity and field efficiency. It was observed that the field capacity and field efficiency was increasing with increasing speed of operation from 1.3 km/h to 1.7 km/h. The maximum field capacity and field efficiency was found as 0.185 ha/h and 90 per cent at 1.7 km/h operating speed of machine.

The effect of disc angle and punch spacing on field capacity and field efficiency was presented in Figure 2d. It can be seen that, the field capacity and field efficiency were decreasing with increased disc angle. The maximum field capacity and field efficiency was observed as 0.15 ha/h and 79 percent at the 35 degree disc angle. Similarly, the field capacity and field efficiency was increased with increase in punch spacing from 250 mm to

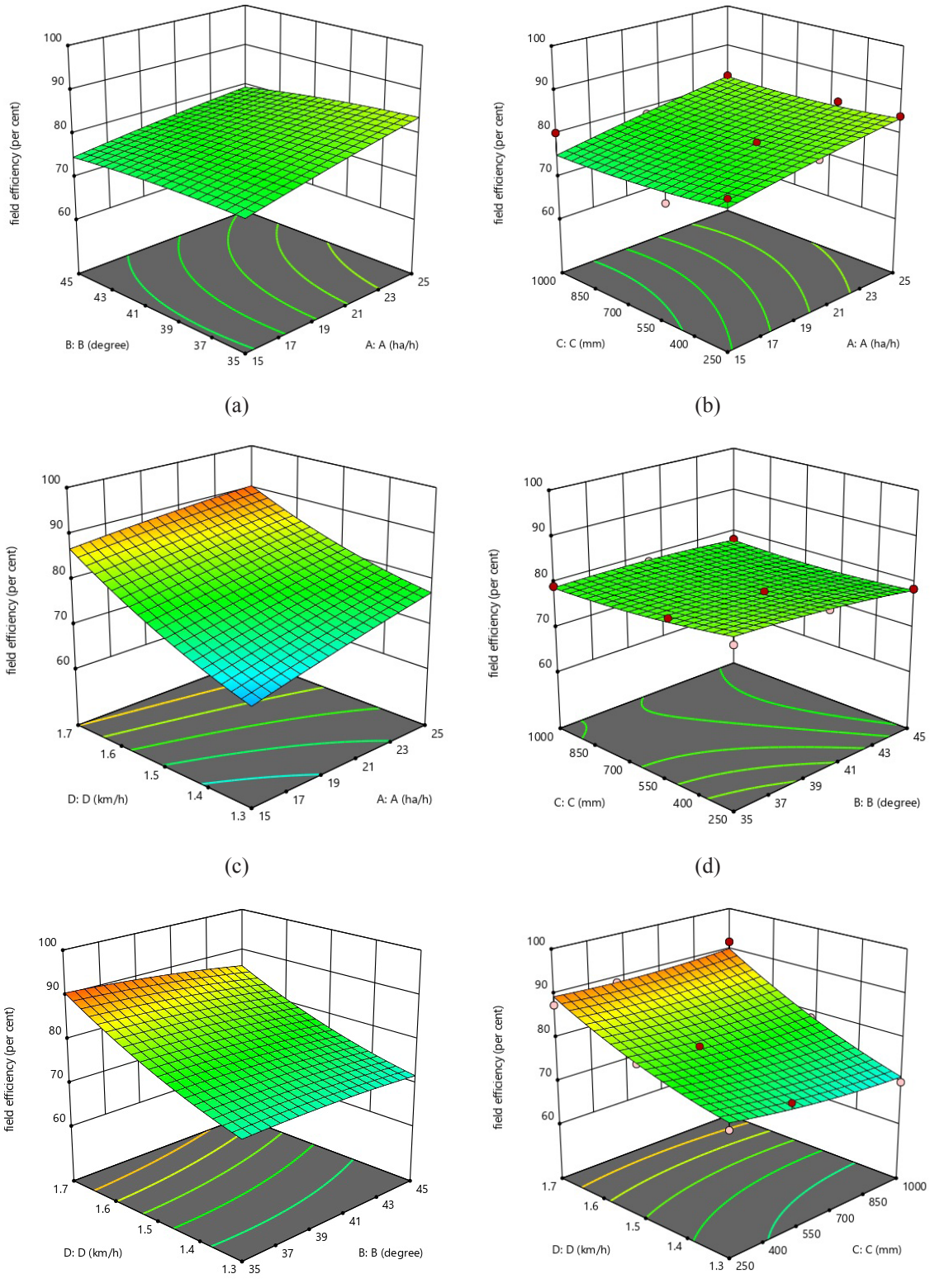

Figure 2. Effect of (a) thickness of mulch and disc angle, (b) thickness of mulch and punch spacing, (c) thickness of mulch and speed of operation, (d) disc angle and punch spacing, (e) disc angle and speed of operation and (f) punch spacing and speed of operation, on field capacity and field efficiency

1000 mm. The highest field capacity and field efficiency was observed as 0.145 ha/h and 79 per cent at the 1000 mm punch spacing.

In Figure 2e, it can be seen that, the field capacity and field efficiency was increasing with increase the speed of operation from 1.3 km/h to 1.7 km/h. the highest field capacity and field efficiency was found that is 0.19 ha/h and 90 per cent at the speed of 1.7 km/h. Similarly, for the disc angle it was observed that the field capacity and field efficiency decreasing with the increased disc angle from 35 degree to 45 degree. The highest field capacity and field efficiency was found at 35 degree disc angle.

Figure 2f presents the effect of punch spacing and speed of operation on field capacity and field efficiency. It was noted that the field capacity and field efficiency were increasing with increase punch spacing from 250 mm to 1000 mm. The maximum field capacity and field efficiency was observed as 0.18 ha/h and 91 per cent at 1000 mm punch spacing at 1.7 km/h speed of operation. Equivalently the field capacity and field efficiency were increase with increasing speed of operation from 1.3 km/h to 1.7 km/h.

3.7 The Effect of Selected Independent Parameters on Effective Punching Efficiency

The effect of three different settings of mulch paper thickness, disc angle, punch spacing and speed of operation on punching efficiency was studied. The results were presented graphically in Figure 3.

Figure 3a shows the effect of thickness of mulch and disc angle on the punching efficiency. It was observed that punching efficiency decreases with increased thickness of mulch sheet from 15 µm to 25 µm. The highest punching efficiency was observed as 87.5 per cent at 15 µm thickness of mulch paper. Similarly, the punching efficiency was observed to be increased with disc angle from 35 degree to 45 degree.

The effect of thickness of mulch and punch spacing on punching efficiency was shown in Figure 3b. It was found that the punching efficiency was increasing with increased punch spacing from 250 mm to 1000 mm. The highest punching efficiency was observed as 89 per cent at 1000 mm punch spacing and at 15 µm thickness of mulch paper.

Figure 3c represents the effect of thickness of mulch paper and speed of operation on punching efficiency. It was perceived that the punching efficiency were decreasing with increased speed of operation from 1.3 km/h to 1.7 km/h. The maximum punching efficiency was observed above 89 per cent at 1.3 km/h speed of operation. Similarly, it was decreasing with increased thickness of mulch paper from 15 µm to 25 µm.

The effect of disc angle and punch spacing on punching efficiency were presented Figure 3d. It was observed that, the punching efficiency was increasing with increased the punch spacing from 250 mm to 1000 mm. The maximum punching efficiency was found as 87 per cent at 1000 mm punch spacing. Similarly, the punching efficiency was found decreased with increased disc angle from 35 degree to 45 degree.

Figure 3e shows the effect of disc angle and speed of operation on punching efficiency. It was observed that, the punching efficiency was decreasing with increased speed of operation from 1.3 km/h to 1.7 km/h. The highest field efficiency was found as 85 per cent at the speed of 1.7 km/h. Similarly, it was seen that the punching efficiency was decreasing with the increased disc angle from 35 degree to 45 degree.

The effect of punch spacing and speed of operation on punching efficiency was presented in Figure 3f. It had been seen that the punching efficiency was increasing with increased punch spacing from 250 mm to 1000 mm. The maximum punching efficiency was recorded as 90 per cent at 1000 mm punch spacing. Equivalently, the punching efficiency was decreased with increased speed of operation from 1.3 km/h to 1.7 km/h.

3.8 Optimization of Selected Independent Parameters of Developed Mulch Laying Machine

For optimizing the values of selected independent parameters, numerical multi-response optimizing technique was used through the Design expert 11.0 of the Stat-EASE Software (Stat ease in Mineapolis, USA, Trial Version).

The outcome shows that the machine performs better at 17.55 µm size of mulch paper as the mulch paper thickness were selected as 15 µm, 20 µm and 25 µm size [9]. As per the availability of 15 µm sheet was selected as the optimize value of paper mulch thickness.

The range of disc angle for the experiment has been selected as 35 degree, 40 degree and 45 degree where the performance were optimized at 40 degree disc angle for effective coverage of soil over the laid plastic mulch sheet.

The punch spacing was selected for the experiment value as 250 mm, 500 mm and 1000 mm respectively; it was observed that at 500 mm punch spacing the field capacity, field efficiency and punching efficiency were increased.

The speed of operation was selected for the experiment value as 1.3 km/h, 1.5 km/h and 1.7 km/h respectively, it was observed that at 1.7 km/h the effective field capacity and field efficiency were increased but the punching efficiency was reduced. So as per the optimized outcome of the data the speed of operation has been selected as 1.5 km/h where the machine performs better on all the selected dependent parameters.

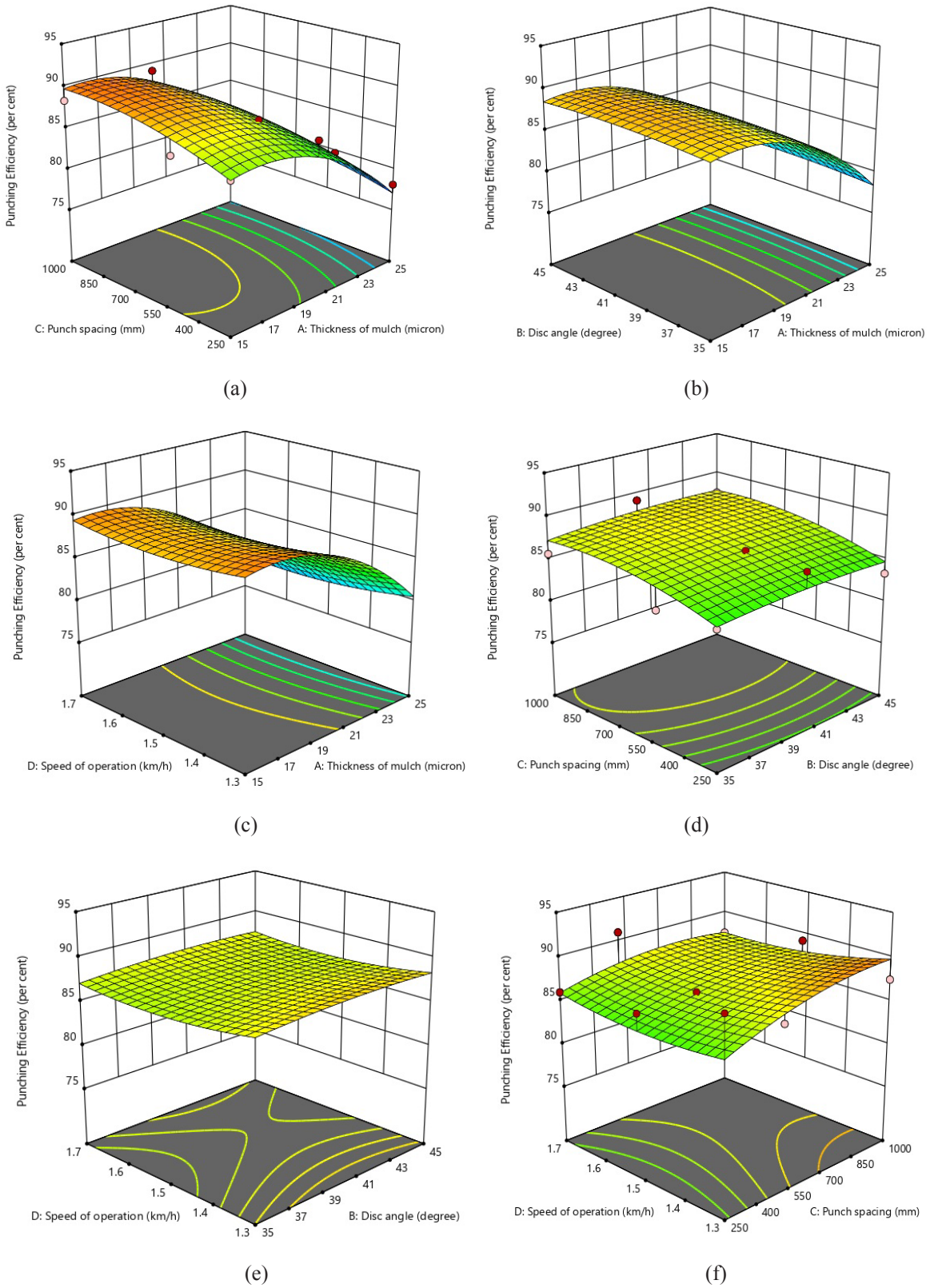

Figure 3. Effect of (a) thickness of mulch and disc angle, (b) thickness of mulch and punch spacing, (c) thickness of mulch and speed of operation, (d) disc angle and punch spacing, (e) disc angle and speed of operation and (f) punch spacing and speed of operation, on punching efficiency

The desired goal for each independent parameters and responses were shown in Table 7. The software generated optimum conditions of independent variables with the predicted values of response was shown in Table 7.

Table 7. Solution generated by the software for manually operated mulch laying machine

Thickness 0f mulch paper µm	Disc angle Degree	Punch spacing mm	Speed of operation km/h	Field capacity ha/h	Field efficiency Per cent	Punching efficiency Per cent
17.16	40.36	444.01	1.55	0.153	80.96	88.55

4. Conclusions

Thickness of mulch paper, disc angles, punch spacing and speed of operation played an important role in mulch laying and punching operation and had significant effect on effective field capacity, field efficiency and punching efficiency. Effective field capacity and field efficiency increases with increase in the thickness of mulch paper, speed of operation and punch spacing but decrease with increase disc angle. Punching efficiency increases with increase in the forward speed and punch spacing, and the effect of thickness of mulch paper was observed the punching efficiency was decrease with increase thickness of mulch paper. Disc angle had no significant effect on punching efficiency. The obtained optimized parameters were set on machine for better performance of selected independent parameters such as 15 µm mulch thickness of mulch, 40 degree angle of soil covering disc for effective coverage of mulch paper, 500 mm punch spacing and 1.5 km/h speed.

Conflict of Interest

There is no conflict of interest.

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