

DEVELOPMENT AND EVALUATION OF A MANUAL OPERATED PLASTIC MULCH LAYING MACHINE

Abstract

Mulching involves the application of plastic sheeting around plants, yielding various benefits such as enhanced moisture retention, weed control, elevated soil temperature, reduced crop contamination, diminished soil compaction, improved germination rates, and water impermeability. Mulching is regarded as a superior water conservation method, particularly valuable in regions facing water scarcity. Diverse mulch materials, including organic and inorganic options, are utilized. Plastic mulches come in various thicknesses, sizes, and colours to suit specific requirements. Among these, black plastic sheeting stands out as an excellent choice for mulching. A manually operated mulch laying machine with a punching mechanism has been developed to streamline multiple tasks in a single pass. This machine not only lays plastic mulch but also firmly presses it onto the prepared bed, covers the edges of the mulch sheet, and creates punched holes at desired intervals simultaneously. It comprises two concave discs, two press wheels, and punching wheels for perforating the sheet where crops are planted. Mulch roll holders are affixed to the main frame for ease of use. The evaluation of the newly developed mechanized apparatus involved the utilization of 16-micron thick mulch paper, disc inclinations set at 30°, 35°, and 45° punch intervals of 400 mm and three distinct forward velocities (0.74, 0.936, and 1.125 km h⁻¹). This evaluation aimed to investigate their impact on parameters such as effective field capacity, field efficiency and punching efficiency. The effective field capacity was determined to be 0.0618 ha hr⁻¹. The manually operated mulch laying machine exhibited varying levels of field efficiency, registering percentages within the range of 82.6%, 83.4%, and 83.5% at different forward

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speeds. The punching efficiency of the manually operated mulch laying machine was found to be 81.5%. The optimal configuration involved the use of 16-micron thick mulch paper, a 45° disc angle, and an operational speed of 0.74 km h⁻¹, demonstrating superior performance across all selected performance metrics when coupled with a 400 mm punch spacing.

Keywords: Mulch Laying Machine, Soil protection, punching efficiency

I. INTRODUCTION

Mulching, also known as soil covering or soil protection, entails the practice of shielding the soil around a plant's root zone from the detrimental effects of extreme temperature fluctuations. This technique involves creating a controlled microenvironment for the plant, which optimizes its performance by regulating key factors such as soil moisture levels, temperature, humidity, CO₂ concentration, and fostering enhanced microbial activity within the soil. Throughout history, mulching has been recognized as a valuable water conservation method, particularly in regions facing water scarcity challenges. To cater to the evolving needs of farmers and enhance profitability by leveraging more cost-effective machinery, the manual mulching apparatus emerges as a viable solution. In contemporary horticulture, the use of plastic materials to enhance crop yields is a burgeoning field referred to as "plasticulture." Plasticulture research predominantly centres on the influence of plastics on horticultural crop plants and their resulting yields, rather than delving into the engineering aspects of machinery designed specifically for planting and harvesting processes. In the early 1920s, paper mulches gained significant attention and were regularly employed.

Traditional mulch application procedures involve the preparation of the seedbed and the application of mulch paper. Following the placement of the mulch paper, circular perforations are created at its centre, typically achieved using a punch or a larger-diameter pipe and mallet. Alternatively, a heated pipe end may be employed. These manual operations are characterized by their time-consuming, labour-intensive, costly, and tedious nature. Furthermore, manual methods often result in uneven mulch paper placement, compromised work quality, paper tearing during handling, and difficulties in securing the mulch paper adequately. Recognizing these limitations of manual techniques, various power-operated or tractor-driven mulch paper laying apparatus have been developed and are commercially available. These machines boast high work capacity, the ability to apply mulch paper uniformly, reduced labour demands, and increased overall work efficiency. However, it is important to note that tractor-operated mulch laying machines may not be suitable for small-scale farmers. According to the 2015-16 agricultural census in India, the majority of landholdings, accounting for 86%, are categorized as small and marginal, with sizes of less than two hectares. These farmers often face constraints in affording high-cost machinery and may not possess tractors. So taken these considerations "Development and evaluation of manual operated mulch laying machine" is undertaken. Manual operated mulch laying machine consists of three operations such as mulch laying, soil covering, punching holes on the sheet.

II. OBJECTIVES

1. To develop low-cost manual operated mulch laying machine.
2. To evaluate mulch laying machine in laboratory and field conditions.
3. To estimate cost of the mulch laying machine

III. REVIEW OF LITERATURE

1. Lawrence, M.J. (2004) developed a pneumatic dibbling apparatus equipped with a three-point hitch mounting system. This innovative machine was showcased in field trials involving two distinct horticultural crops, each with unique intra-row and inter-row

spacing needs. The piercing mechanisms were driven by pneumatic cylinders, and the integrated control system afforded operators the flexibility to modify the quantity and distribution of boreholes.

2. M. Veerangouda (2017) developed and evaluated a tractor operated plastic mulch laying equipment. A tractor operated plastic mulch laying equipment was developed to mechanize the conventional plastic mulching. A 35 hp tractor was used as a power unit for both plastic mulching and drip laying operation.
3. S.D. Ratnakar (2017) focused on design and manufacture of a small size portable mulching paper laying machine working either manually or powered externally.
4. U.Y.Siddha (2017) developed Advanced Mulching paper and drip laying machine. Here Authors have worked on automatic mulching paper laying machine which also have attachment for the drip laying. They have prepared one working model in which drip line is guided below the paper by drip line director and at the same time mulch paper is placed over the bed by paper pressing rollers.

IV. DEVELOPED MANUAL OPERATED MULCH LAYNG MACHINE

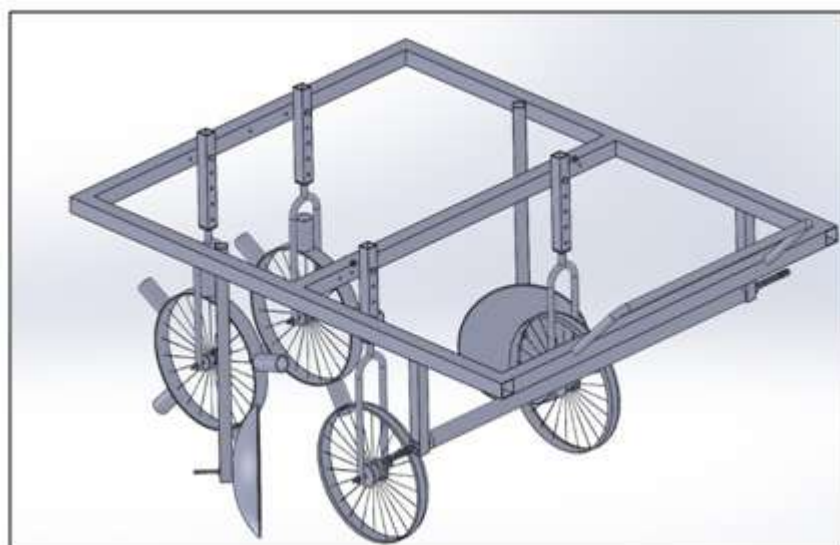
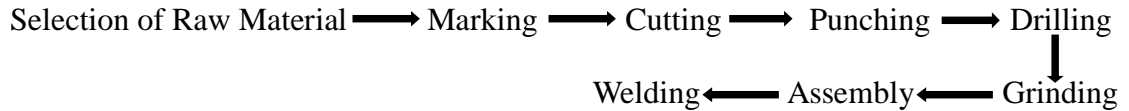


Figure 1: Creo model of the manual operated mulch laying machine

- Components of the machine
 - Main frame
 - Handle
 - Mulch laying unit
 - Press wheels
 - Soil covering unit
 - Punching unit

- **Process of fabrication:** Fabrication is the process of constructing products by combining typically standardized parts using one or more individual processes.

Flowchart of fabrication:



1. Constructional Details of The Manual Operated Mulch Laying Machine: The main frame, a paper holder for mulch, press wheels, covering discs, punching wheels, and a handle were all part of the machine's construction.

- The overall weight of the machine was 60 kg and it was fabricated using material like galvanized steel and mild steel.
- The overall dimensions of the frame are 1800 × 1400 × 950 mm.
- A handle, using hollow round pipe of mild steel is welded to the frame to pull the implement.
- The mulch holder was mounted to lay the plastic mulch paper.
- Two pneumatic press wheels was attached to the frame by using square pipes with adjusting holes. Pneumatic tires are used to press the mulch paper.



Figure 2: Assembly of the machine

- The punching wheels were attached at the end of the frame by using square pipes with adjusting nuts. Punching wheel punches the holes at uniform distance.
- Covering discs were attached to the implement at an angle by square pipes with adjusting nuts. These discs are used to cover the soil on mulch paper.

2. Working of the Developed Mulch Laying Machine: The primary function of the apparatus was to apply plastic mulch film onto prepared soil and create perforations in the film following its application. This machinery required the coordinated effort of two operators, who manually advanced it across the prepared terrain. As the machine

progressed, it unfurled the plastic mulch film from its holder and carefully positioned it onto the prepared bed. Once the film was in place, a covering disc aided in securing the film onto the soil surface while concealing its edges beneath a layer of soil, resulting in a smooth, even surface.

To prevent wind from passing beneath the laid plastic mulch, the press wheels held the film in place until the side discs completely covered the film's edges with soil. Upon completing this process, a simultaneous action occurred, involving the creation of perforations in the laid film. The machine was equipped with a punching wheel that rotated as it was pulled forward, featuring sharp-edged cups designed for the purpose of creating these perforations. The arrangement was made in such a way that the holes were punched on the mulch laid surface because of the sharp edge cups provided on wheels. The punching arrangement was attached as per the row to row spacing.

3. Performance Evaluation of Manual Operated Mulch Laying Machine

Laboratory test:

- The laboratory test of manual operated mulch laying machine was conducted in CAE workshop.
- The test was conducted to check the functioning of parts(roller, guiding wheels and punch wheels) of the mulch machine.

Field test:

- The field test of manual operated mulch laying machine was conducted for evaluation of the machine.
- The evaluation is done for calculating travel speed, theoretical field capacity, actual field capacity, field efficiency, punching efficiency, punch to punch time and speed ratio of the punching wheel.



Figure 3: Laboratory Test



Figure 4: Field Test

V. MEASUREMENT OF REQUIRED PARAMETERS

1. **Forward Speed of the Machine:** Two poles were fixed at 11m distance. By using stopwatch, time required to cover 11m distance was measured, respectively. The speed was

calculated. Then the experiment was carried out at three different speed si.e., 0.74km/hr, 0.936km/hr and 1.125km/hr. The operators were trained to maintain the required steps distance to achieve the selected speed of operation.

- Forward speed of the machine = length covered (km)/ time taken (hr)
2. **Theoretical Field Capacity:** The theoretical field capacity is calculated by considering forward speed and width of the machine and calculated by using following equation.
 - Theoretical field capacity (ha/hr) = width (m) × speed (km/hr) / 10
 3. **Actual Field Capacity:** For calculating the actual field capacity, the data is prepared for recording the time loss during turning, adjusting punching wheels and adjustment in field and actual performance of machine was also recorded. The field capacity was calculated by using the equation:
 - Actual field capacity (ha/hr) = $A / (T_P + T_{NP})$
 4. **Field Efficiency:** Field efficiency was by the ratio of actual field capacity to theoretical field capacity and expressed in percentage. The field efficiency was calculated using the equation.
 - Field efficiency (%) = (Actual field capacity / Theoretical field capacity) × 100
 5. **Punching Efficiency:** Punching efficiency was calculated by the ratio of actual punches to the calculated punches on mulch paper and expressed in percentage. The punching efficiency was calculated by using the equation
 - Punching efficiency = (Actual punches/Theoretical punches) × 100
 $= (22 / 27) \times 100$
 $= 81.5 \%$

VI. RESULTS AND DISCUSSION

A manually operated mulch laying device equipped with a punching mechanism was engineered in accordance with certain criteria. The machine's performance underwent assessment under specific independent variables to investigate their impact on effective field capacity, field productivity, and punching effectiveness. The findings from the performance evaluation, along with other recorded parameters during the assessment, are presented and discussed in the subsequent subsections.

1. **Effect of disc angles on field capacity, field efficiency:** The effect of disc angles on theoretical field throughput, operational field capacity, and field productivity was investigated, and the findings are presented in the table. It was noted that as the disk angle rose, operational field capacity exhibited a decline, paralleled by a corresponding decrease in field productivity.

From table it was observed that for the 30° disc angle the theoretical field capacity was 0.1125 effective field capacity was 0.0931 ha/hr and it was observed to 35° disc angle the TFC was 0.0936 ha/hr, EFC was 0.078 ha/hr. The field efficiency was observed as 83.5 per cent for 30° disc angle and 83.4 percent for 35° disc angle as compared with the values of 30, 35 degrees angle the values of TFC, EFC and field efficiency at 45° was

decreased to 0.074ha/hr,0.0618ha/hrand82.6percent. It may be because of 45° disc angle of soil covering disc was taken greatervolumethan35° disc angle.

Table 1: Effect of disc angle on field capacity

Disc angle	Field capacity(ha/hr)
30°	0.0931
35°	0.078
45°	0.0618

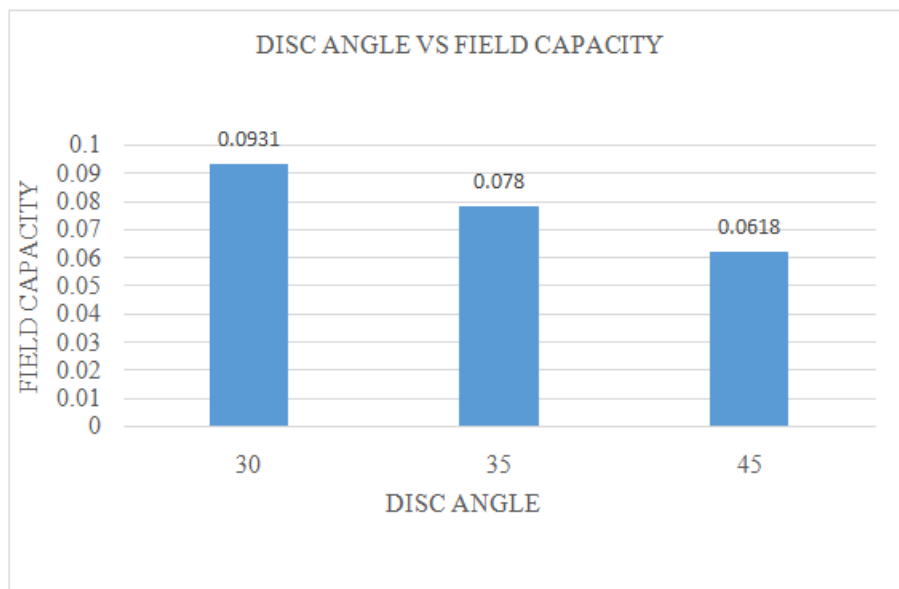


Figure 5: Disc Angle Vs Field Capacity

2. **Effect of speed of operation on field efficiency and field capacity:** The effect of speed of operation *viz.*, 0.74, 0.936 and 1.125 km/hr on field efficiency and field capacity was studied and obtained results were shown in table. It was observed that field efficiency and field capacity was increased with increased speed of operation.

Table 2: Effect of speed of operation on field capacity and field efficiency

Forwardspeed (km/hr)	Field capacity (ha/hr)	Field efficiency (%)
1.125	0.0931	83.5
0.936	0.078	83.4
0.74	0.0618	82.6

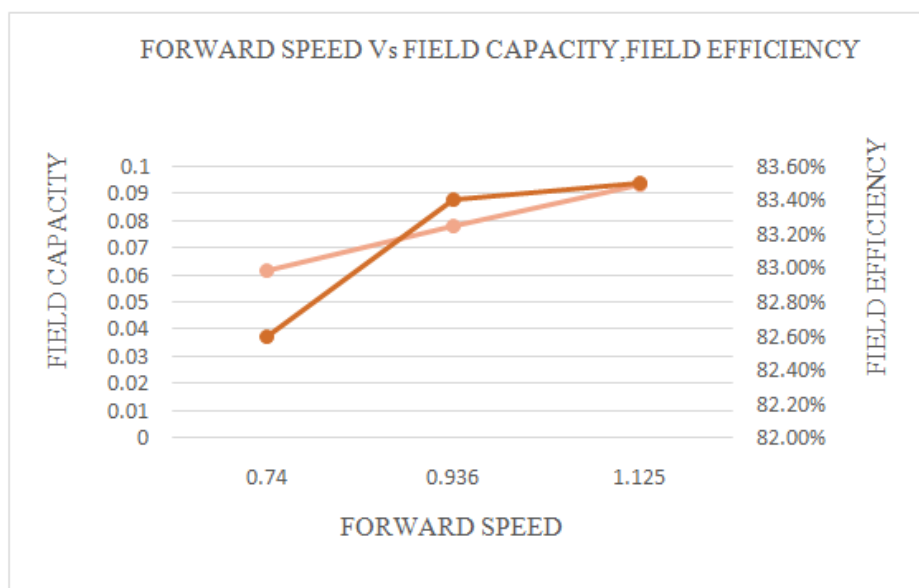


Figure 6: Forward Speed Vs Field Capacity, Field Efficiency

3. Cost estimation of manual operated mulch laying machine

S.NO.	Component	Specification	Quantity	Weight	Rate	Amount
1.	Mainframe	MS square pipe (8m)	1	20Kg	75/m	1500
2.	Mulch roller	GS round pipe (1.2m)	1	3kg	75/m	250
3.	Handle	MS round pipe (1.4m)	1	Round off to 25kg	75/m	1500
4.	Press wheel	Tube less tyre (420mm)	2		450/tire	900
5.	Covering disc	Cast iron (300mm)	2		500/disc	1000
6.	Punching wheel	Dia 420mm	2		100/wheel	200
7.	Shaft	MS rod (460mm)	1	3kg	55/kg	165
8.	Punching cup	Cup height = 100mm Cup Dia = 50mm	10	2kg	30/cup	300
9.	Nuts and bolts	4 inch	12	720g	20/unit	240
		2 inch	20	400g	15/unit	300
Total						6355 \cong 6360

VII. CONCLUSIONS

1. Intended operations have been achieved by the machine such as bed forming, laying of mulch, covering of mulch from both sides and punching holes on mulchpaper.
2. Disc angle shows the significant effect on effective field capacity. As the angle increases effective field capacity decreases. The EFC are recorded as 0.0931, 0.078 and 0.0618 ha/hr and TFC are recorded as 0.1145, 0.0936 and 0.074 ha/hr at 30, 35 and 45-degree disc angles.
3. The operation's speed exhibits a significant effect as operation speed rises, field efficiency rises. When used at varying forward speeds of 0.74, 0.936 and 1.125 km/hr, the field efficiency of the manually operated mulch laying machine was measured in the range of 82.6, 83.4 and 83.5 %.
4. The optimum parameter of the developed machine at optimized performance were observed as 45 degrees disc angle and 0.74 km/hr speed of operation.

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