*Plant Archives* **Vol. 25, Special Issue (ICTPAIRS-JAU, Junagadh) Jan. 2025 pp. 711-716**
e-ISSN:2581-6063 (online), ISSN:0972-5210

**Plant Archives**
**Journal homepage: http://www.plantarchives.org**
**DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.SP.ICTPAIRS-103**

# DEVELOPMENT AND PERFORMANCE EVALUATION OF MINI TRACTOR OPERATED PLASTIC MULCH LAYING MACHINE

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**ABSTRACT**

In modern era plasticulture is increasing in agriculture. The combination of raised bed, drip irrigation, plastic mulching and fumigation leads more yield as compare to traditional cropping practices. The plastic mulch laying with traditional manual practices is very time consuming, more laborious and costly. Hence, mini tractor operated plastic mulch laying machine was developed at Department of Renewable Energy Engineering, CAET, JAU, Junagadh. During the field performance test moisture content of soil bed, speed of operation, effective field capacity, theoretical field capacity, field efficiency, draft requirement and power requirement were recorded as 9.52 % db, 2.77 km/h, 0.301 ha/h, 0.415 ha/h, 72.60 %, 180 kgf and 1.84 hp respectively. The fuel consumption was found 1.20 l/h as well 4.02 l/ha. The total cost of mulch laying machine was 24760.79 rupees. The hourly operational cost of mini tractor operated mulch laying machine was found 1153.67 Rs./ha and time require to cover one hectare area was found as 3.34 h. The cost of mulch laying manually was found as 5878.09 Rs./ha. The time required for plastic mulch laying in one hectare area by manually was recorded as 47.02 h. There was 92.91 % benefit in time saving and 80.37 % benefit in the cost of operation per hectare. Thus, it is clear from the study that plastic mulch laying by mini tractor operated much laying machine is economically viable and time saving as compare to laying of mulch manually.

***Key words*:** plastic mulching, mulch laying machine, mini tractor, field capacity, filed efficiency, cost economics

## Introduction

Mulching is the process or practice of covering the soil to make more favorable conditions for plant growth, development and efficient crop production. Mulch technical term means ‘covering of soil’. Plastic mulches are completely impermeable to water. Therefore, it prevents direct evaporation of moisture from the soil and thus limits the water losses and soil erosion over the surface. In this manner it plays a positive role in water conservation. The suppression of evaporation also has a supplementary effect; it prevents the rise of water containing salt, which is important in countries with high salt content water resources. (Anon., 2020).

The application of plastic mulching in agriculture is called plasticulture, It has increasing dramatically throughout the world since 2000 (Kyrikou and Briassoulis, 2007). Plastic mulch film is used in horticulture as well vegetable crops. Plastic mulching helps to improve the soil temperature (Abdul-Baki *et al.*, 1992). Soil temperature varies according to colour of plastic mulch film (Schonbeck and Evanylo 1998). Mulching helps to conserve soil moisture content, also it modifies physical environment of soil, which helps in appropriate growth of crops (Chakraborty 2008, 2010). Plastic mulching resist the growth of unwanted weeds ultimately the insect population will decrease which grow on leaves of weed. Also mulching create obstacle between soil insect and crop, this position helps to proper and insect free growth of plant (Jenni *et al.*, 2004). Plastic mulching leads to higher yield in early duration crops and it has ability to

grow some crops, which cannot be possible without plastic mulch (Clarkson, 1957). The combination of raised bed, drip irrigation, plastic mulching and fumigation leads more yield as compare to traditional cropping practices (Omprabha, 2019). Covering of the soil bed is done by the plastic mulch film before planting or transplanting of crop seedlings. This includes preparation of seed bed, spread mulch film and anchoring of edges of film. Raised seed bed has to be prepared for plastic mulching. In this operation, two persons are required for laying the plastic over the soil bed, while one more person behind them to shovel the soil onto the edges of the mulch. These operations when done by manually become very time consuming, labour intensive, tedious and costly. Manual method is economical for the small fields but not economical for the large fields (Siddesh and Veerangouda, 2017).

Tractor is used in most of farm operation *viz*. land development, tillage, sowing, harvesting, threshing and transportation. Tractors help in reducing the time required for these operations. Hence, it has become the integral part of mechanized agriculture. Plastic mulching by conventional method requires more human labour, more time and more cost of operation. Now a days tractor operated plastic mulch laying machine is made by some local manufactures. Due to higher initial cost and high cost of operation, farmers dispute to adopt this technology. In Saurashtra region of Gujarat, small and medium farmers are adopting mini-tractor as compare to high horse powered tractor. Some researchers have made automatic mulch laying machine, but it is not suitable to add more extra power when sufficient power is available at farm. Considering these facts, it is need to develop mini-tractor operated plastic mulch laying machine to minimizing the cost of operation, timeliness of operation, efficient use of fuel and the tractor power.

## Material and Methods

Development and performance evaluation of a mini-tractor operated plastic mulch laying machine was done under AICRP on Plasticulture Engineering and Technology at Department of Renewable Energy Engineering, College of Agricultural Engineering & Technology, Junagadh Agricultural University, Junagadh.

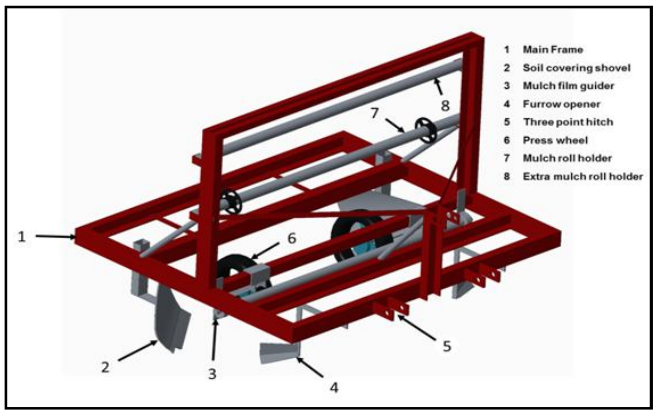


**Fig. 1:** Isometric view of plastic mulch laying machine.

### Construction Details

The main components of the machine consists of main frame with standard three point hitch, furrow openers at the edge of the bed, press wheels, soil covering shovels and mulch roll assembly. Different views and detailed drawing of the machine are shown in Fig. 1 and 2.

### Main frame with standard three point hitch for mini tractor

The rectangular main frame is developed with the dimension so as to lay a plastic mulch film roll width up to 1000 mm. The size of main frame is 1440 mm × 1220 mm and it is fabricated from mild steel C-channel of 75 mm 5 40 mm × 4 mm. The standard three point hitch for mini tractor is attached to the main frame as per the dimensions specified in IS 4468 (Part I) : 1997. The specifications of the hitch pyramid would be as per the IS : 4468-2001 (Part-I) category-II.

### Furrow openers at the edge of the bed

Furrow openers at both edges of the bed are provided for creating a depression in which edges of the film are pressed by the press wheel. Size of the furrow opener is 180 mm × 60 mm made from 2 mm MS sheet. At the bottom edge of furrow opener, carbon steel blade is provided for ease cutting of the soil and to enhance life of that part. Furrow opener is attached with L-shape tyne made of MS flat of 40 mm x 10 mm with length of 270 mm vertically attached between frame to furrow opener and another 280 mm length horizontally attached between frame to support member made of C-channel.

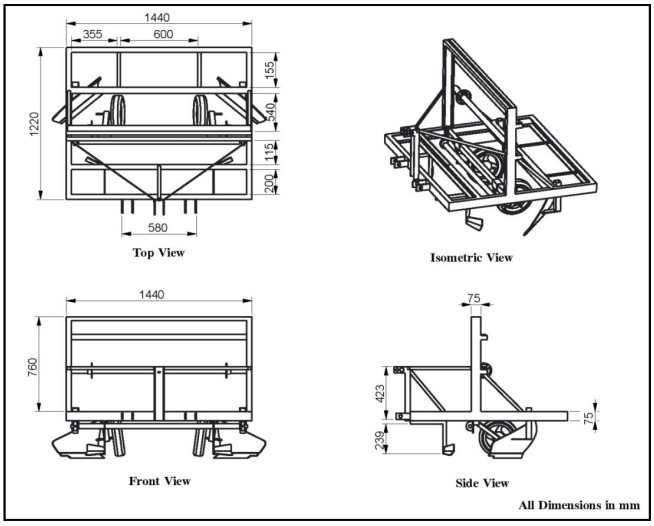


**Fig. 2:** Detailed drawing of plastic mulch laying machine.

**Press wheels assembly**

Behind the mulch guide roller two press wheels are provided. Press wheels receive the plastic film from mulch guide roller and press it into the depression created by the furrow openers at the edge of the bed. Press wheels protect the film against the high wind velocity before the covering of the soil. Rubber wheels (size : 3-10 4PR ) were used in the machine for pressing the plastic film edges to the ground. For the attachment of the press wheels with the main frame, a press wheel support made of rectangle GI pipe of 50 mm × 35 mm is welded at a distance of 40 cm from hitch point. On the support two slider saddle of size 125 mm × 65 mm is inserted and it can be fixed at any point on the support with nut-bolt. At the lower side of the slider two MS flat of size 5 mm x 5 mm are welded and hole of 10 mm diameter is made to insert bolt for freely fixing of link pipe of length 30 cm. On the other end of the link pipe, wheel shaft is welded and shaft is attached with wheel through hub & bearing.

**Soil covering shovels**

Soil covering shovels cover the edges of the plastic film with soil. Soil covering shovel includes clamp for fixing the shovel at any distance on main frame, 30 cm long rectangle GI pipe of 50 mm × 40 mm; its upper end is fixed with clamp through nut-bolt and at the lower end; MS flat is welded at the inclination of 150o, at the other end of MS flat; carbon steel blade is welded and at upper edge of the blade; curve shovel is attached. Soil covering shovels are attached at the end of the main frame through clamp. Four holes of 10 mm diameter spaced at 25 mm are made on the GI pipe so that it can be adjusted at 25 mm up and down and it can be clamped on the shovel supporting channel through nut-bolt. Materia of curve shovel is 1 mm GI sheet and its dimensions are 90 mm & 320 mm width at front and tail end respectively with length of 550 mm.

**Mulch roll assembly**

Mulch rolls assembly hold and unroll the mulch roll as well it also guide the mulch film before edges of the film is pressed by the press wheels. Mulch rolls assembly consist of two columns made from mild steel C-channel of 75 mm × 40 mm × 4 mm welded at a distance of cm from front edge of the main frame with the height of 76 cm, top horizontal support of MS angle 30 mm × 3 mm welded and joining the top edges of the columns, mulch roll holder of GI pipe of 40 mm dimeter attached at height of 40 cm, Mulch film guider made of 20 mm round bar at center of 50 mm GI pipe it's both the end are fitted in to the pedestal. There is also an arrangement is made for holding an extra roll.

**Field Performance Testes**

The mulch laying machine was tested in medium black soil at College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh. The mulch laying operation was carried out with the help of 15 HP mini-tractor.

**Soil beds**

Soil beds were formed by using mini tractor operated bund former. The centre to centre distance between two bed was 1.5 m. Height, top width and bottom width of soil bed was 10-15 cm, 60 cm and 80 cm respectively.

**Moisture content**

Moisture content for soil was computed on dry basis. The moisture content was determined in the laboratory by oven dry method and the samples were collected randomly from the test plot. The samples were kept in oven for 24 hour at temperature of 105 degree Celsius. The samples were weighted before and after drying. Moisture content (%,db) of soil was by using following formula. (Smith *et al.*, 1994).

$$\text{Moisture content (\%, db)} = \frac{W_w - W_d}{W_d} \times 100 \qquad (1)$$

Where, $W_w$ = Weight of wet soil sample and

$W_d$ = Weight of dry soil sample

**Plastic mulch roll**

The developed machine can be used for laying of plastic mulch film up to 1000 mm due to flexibility of fully adjustable components like furrow openers, press wheels, soil covering shovels, respectively. During the field trial plastic mulch roll used which having width of 900 mm.

**Draft requirement**

Draft requirement of machine was measured by

**Fig. 3:** Field performance test of mulch laying machine.

**Table 1:** Cost of the different componet and total cost of mulch laying machine.

| Sr. No. | Component | Cost, Rs |
|---|---|---|
| 1 | Main frame with standard three-point hitch for mini tractor | 3182.69 |
| 2 | Furrow openers at the edge of the bed | 274.49 |
| 3 | Press wheels assembly | 2918.41 |
| 4 | Soil covering shovels | 903.76 |
| 5 | Mulch roll assembly | 2842.82 |
| 6 | Bund former | 1551.97 |
| 7 | Sub-main pipe protector | 1357.85 |
| **a. Total cost of material used** | | **13032.00** |
| **b. Fabrication cost and cost of wastage of material (90% of total cost of material used)** | | **11728.80** |
| **Total cost of mulch laying machine (a+b)** | | **24760.79** |

digital dynamometer. Data were recorded for with load and without load condition of mini tractor in the 30 m distance (Fig. 3). Draft was calculated by substituting the average values of with load and without load (RNAM, 1983).

### Speed of operation

Time was recorded for 30 m run of the mulch laying operation. The speed of operation was calculated by using following formula (Sahay J., 2006).

$$\text{Speed of operation (km/h)} = \frac{3.6 \times \text{distances traveled (m)}}{\text{time (s)}} \times 100 \quad (2)$$

### Power requirement

Power requirement of the mulch laying machine was calculated from draft requirement and speed of operation, formulated as given below (Sahay J., 2006).

$$\text{Power requirement (hp)} = \frac{\text{draft (kgf)} \times \text{speed (m/s)}}{75} \times 100 \quad (3)$$

### Theoretical field capacity

The theoretical field capacity is the rate of field coverage that would be obtain if implement were performing its function 100% of the time at the rated speed and always covering 100% of its rated width (Kepner *et al.*, 1972).

$$\text{Theoretical field capacity (ha/h)} = \frac{\text{width of implement (m)} \times \text{speed (km/h)}}{10} \times 100 \quad (4)$$

### Effective field capacity

The actual field capacity is the actual average rate of coverage by the implement. The total time required to complete the operation was recorded and the effective field capacity was calculated as follow (Kepner *et al.*, 1972).

$$\text{Effective field capacity (ha/h)} = \frac{\text{actual area covered by imlement (ha)}}{\text{effective time (h)}} \quad (5)$$

### Field efficiency

It is the ratio of effective field capacity and theoretical field capacity expressed in percent. It was calculated by following formula (Mehta *et al.*, 2005).

$$\text{Field efficiency (\%)} = \frac{\text{Effective field capacity (ha/h)}}{\text{theoretical field capacity (ha/h)}} \times 100 \quad (6)$$

### Fuel consumption

Fuel consumption is the amount of fuel used per unit time. The fuel tank was filled to its capacity before the operation. Amount of refilling after the operation was measured, which is the actual fuel consumption. (Siddesh *et al.*, 2018)

### Labour Requirement

One labour is required for initial adjustments like anchoring the mulch film initially at the starting of each bed and cutting the mulch film at the end of each bed.

**Table 2:** Performance of the mini tractor operated plastic mulch laying machine.

| Sr. No. | Parameters | Test trials | | | | | |
|---|---|---|---|---|---|---|---|
| | | I | II | III | IV | V | Avg. |
| 1 | Soil moisture (%, d.b.) | 9.60 | 9.20 | 9.50 | 9.40 | 9.90 | 9.52 |
| 2 | Time for 30 m run (sec) | 40.00 | 35.00 | 38.00 | 42.00 | 41.00 | 39.20 |
| 3 | Speed of operation (km/h) | 2.70 | 3.09 | 2.84 | 2.57 | 2.63 | 2.77 |
| 4 | Avg. width of coverage (m) | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 |
| 6 | Effective field capacity (ha/h) | 0.300 | 0.318 | 0.306 | 0.270 | 0.310 | 0.301 |
| 7 | Time required for 1 ha (h) | 3.33 | 3.14 | 3.27 | 3.70 | 3.23 | 3.34 |
| 8 | Theoretical field capacity (ha/h) | 0.405 | 0.463 | 0.426 | 0.386 | 0.395 | 0.415 |
| 9 | Field efficiency (%) | 74.07 | 68.70 | 71.78 | 70.00 | 78.46 | 72.60 |
| 10 | Fuel consumption (l/h) | 1.20 | 1.32 | 1.00 | 1.30 | 1.20 | 1.20 |
| 11 | Fuel consumption (l/ha) | 4.00 | 4.15 | 3.27 | 4.81 | 3.87 | 4.02 |
| 12 | Avg. implement pull (kg) | 182.00 | 175.00 | 179.00 | 180.00 | 184.00 | 180.00 |
| 13 | Avg. implement draft (kgf) | 182.00 | 175.00 | 179.00 | 180.00 | 184.00 | 180.00 |
| 14 | Power requirement (hp) | 1.82 | 2.00 | 1.88 | 1.71 | 1.80 | 1.84 |

**Table 3:** Hourly operational cost calculation of the developed mulch laying machine.

| S. | Particular | Value |
|---|---|---|
| **1** | **Fixed cost** | |
| | a) Depreciation, Rs/h | 22.28 |
| | b) Interest, Rs/h | 13.62 |
| | c) Insurance, housing and taxes, Rs/h | 7.43 |
| | **Total fixed cost, Rs/h** | **43.33** |
| **2** | **Variable cost** | |
| | a) Repair and maintenance, Rs/h | 12.38 |
| | b) Labour and tractor hire charges, Rs/h | 291.31 |
| | **Total Variable cost, Rs/h** | **303.69** |
| **3** | **Total (fixed+variable) cost of operation, Rs/h** | **347.02** |
| **4** | **Total cost of operation, Rs/ha** | **1153.67** |

### Economical and time saving comparison of mulch laying operation

The economics in terms of time and cost have been determined and compared for both by machine and manual laying of plastic mulch film.

### Plastic mulch film laying manually

Information on existing mulch laying operation was collected during field visits and it was found that fours men are required for manual laying of mulch film on the bed. Labour wages is Rs. 250 per day of 8 hours.

### Plastic mulch film laying by developed machine

The component wise cost of mulch laying machine was calculated and presented in Table 1 and thereby, the total cost of mulch laying machine was worked out to be Rs. 24760.79/-. For the cost of operation of plastic mulch laying by the developed machine, tractor driver and tractor hire charges were considered. (Table 5) The cost of operation plastic mulch laying with the developed mulch laying machine was worked out by the straight line method. Provide sufficient information to allow the experiment to be reproduced. This section should include sub-sections.

## Results and Discussion

As results shown in Table 2, during the field trial of mini tractor operated plastic mulch laying machine the moisture content of the soil was found as 9.52% and it was ranging between 9.20-90.90%. Speed of operation for 30 m run was recorded as 2.77 km/h which was ranging between 2.57-3.09 km/h. As center to center distance between two beds was 1.5 m, the width of coverage considered as 1.5 m. The effective field capacity, theoretical field capacity and field efficiency was calculated as 0.301 ha/h, 0.415 ha/h and 72.60% which was ranging between 0.270-0.318 ha/h, 0.306-0.463 ha/h and 68.70-78.46 % respectively. The average area covered in one hour was recorded as 3.34 h. The average fuel consumption was found as 1.20 l/h and 4.02 l/ha. The average draft of the mini tractor operated mulch laying machine was found as 180 kgf (175-184 kgf). The average power requirement was found 1.84 hp (1.71-2.00 hp) which was quite low compare to available power of the mini tractor. Thus, the field operation was observed very smooth and free from destructions. The quality of work done was also found better.The developed mulch laying machine laid plastic mulch film efficiently over the bed. The plastic mulch film was stretched effectively without tearing on the beds. The plastic mulch film was effectively pressed on slopes of beds and anchored on both edges by the action of the press wheel and soil covering shovels. Both the edges of film were covered properly by the soil gathered by the soil covering shovels. Hence, the overall working of the machine was found satisfactory.

**Table 4:** Economical and time saving comparisonof mulch laying operation.

| Sr. No. | Particular | Plastic film mulch laying by machine | Plastic film mulch laying manually | Benefit, % |
|---|---|---|---|---|
| 1 | Total Time required, h/ha | 3.34 | 47.02 | 92.91 |
| 2 | Total mulch film laying cost, Rs/ha | 1153.67 | 5878.09 | 80.37 |

The cost analysis, comparison between manual mulch laying operation and mulch laying by mini tractor operated mulch laying machine is shown in Table 3 and 4. The hourly operational cost of mini tractor operated mulch laying machine was found 1153.67 Rs./ha and time require

**Table 5:** Consideration for hourly operational cost calculation of the developed machine.

| Sr. No. | Particular | Value |
|---|---|---|
| 1 | Cost of equipment, Rs. | 24760.79 |
| 2 | Useful life, yr | 10 |
| 3 | Annual use, h | 100 |
| 4 | salvage value (% of equipment cost), % | 10 |
| 5 | Rate of interest per year, % | 10 |
| 6 | Insurance, housing and taxes (% of equipment cost), % | 3 |
| 7 | Repair and maintenance (% of equipment cost), % | 5 |
| 8 | Labour and tractor hire charges per hour, Rs. | 291.3125 |
| 9 | Effective field capacity, ha/h | 0.301 |

to cover one hectare area was found as 3.34 h. The mulch laying operation by mini tractor was complete by mulch laying machine, tractor with operator and one labour. While in case of manual mulch laying, four labour were required to complete the mulch laying. The cost of mulch laying manually was found as 5878.09 Rs./ha. The time required for plastic mulch laying in one hectare area by manually was recorded as 47.02 h. Thus, it is clear from the study that plastic mulch laying by mini tractor operated much laying machine is economically viable and time saving as compare to manual method. There was 92.91% benefit in time saving and 80.37% benefit in the cost of operation per hectare.

## Conclusion

The mini tractor operated plastic mulch laying machine can be used for laying of plastic mulch film up to 1000 mm due to flexibility of fully adjustable components like furrow openers, press wheels, soil covering shovels, respectively. It saves about 92.91% time and 80.37% in cost of laying plastic mulch as compare to conventional manual laying method.

## Acknowledgement

Authors are highly thankful to All India Coordinated Research Project (AICRP) on Plasticulture Engineering and Technology (PET), ICAR-Central Institute of Post Harvest Engineering and Technology (CIPHET), Ludhiana and Junagadh Agricultural University, Junagadh for financial support for the research work.

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