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Development and evaluation of tractor operated plastic mulch laying equipment

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■ **ABSTRACT :** A tractor operated plastic mulch laying equipment was developed to mechanize the conventional plastic mulching. A plastic mulch roller was mounted on the main frame of equipment and drip roll carrier assembly also mounted on main frame. The soil covering unit and press wheel assembly have been attached to it with the help of clamps. A 35 hp tractor was used as a power unit for both plastic mulching and drip laying operation. Various parameters such as soil moisture content, draft, fuel consumption and soil temperature were measured. The average soil moisture of the plastic mulched beds was 19.20, 19.30 and 19.20 % at forward speed of 2.0, 3.0 and 4.0 km h^{-1}, respectively. The average values of draft were 3139, 3193 and 3222 N at forward speed of 2.0, 3.0 and 4.0 km h^{-1}, respectively.

■ **KEY WORDS :** Plastic mulch roller units, Drip roll carrier assembly, Soil covering unit, Press wheel assembly

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Mulching is the process or practice of covering the soil or ground to make more favorable conditions for plant growth, development and efficient crop production. Natural mulches such as leaf, straw, dead leaves and compost have been used for centuries, during the last 60 years the advent of synthetic materials has altered the methods and benefits of mulching. These new materials have combined features exhibiting strength, flexibility, light-weight, easy and low-cost production. The technology and practice of using plastics to improve horticultural crop yield is a relatively new science commonly referred to as plasticulture. Plastics are man-made long chain polymeric molecules (Scott and Gilead, 1995). The word plastic comes from the Greek word "plastikos", which means 'able to be molded into different shapes' (Joel, 1995).

Plasticulture research and documentation largely focus on the impact of plastics on horticultural crop plants and their associated yields rather than the science behind machinery-designed specifically for the planting and harvesting processes. Mulch helps to prevent the establishment of weeds in many vegetable crops. Black sheet mulches prevent most weeds by excluding light. Intact plastic and other materials control essentially all annual weeds except at planting holes and mulch edges, where additional control measures are needed. Along with enhanced moisture regulation, mulch allows for greater control of nutrients and fertilizer loss since leaching is reduced.

Plastic films are laid before crop planting or transplanting. 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. 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.

In modern agriculture, tractor has become one of the major sources of power which is generally used for majority of the agricultural operations like irrigation, 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. Keeping the above facts in view, present study has been undertaken to develop tractor operated plastic mulch laying equipment.

METHODOLOGY

Tractor operated plastic mulch laying equipment consist of plastic mulch roller assembly, drip roll carrier assembly, soil covering device and press wheel assembly. A plastic mulch roll carrier (1.40 meter in length) was selected based on the width of plastic mulching on raised soil beds. The width of the plastic roller can be adjusted as per the mulching requirement. Plastic mulch used for the study is of two type *viz.*, silver colour and black colour. Thickness of the both the materials used are of 30 micron and or are 80 gauge. Both the plastic mulch used is selected with three different widths *i.e.*, 1200 mm, 1000 mm and 900 mm. The light absorption (%) of silver colour plastic mulch is 51 % and light reflection (%) is 49 % whereas, light absorption (%) of black colour plastic mulch is 100 % and light reflection (%) is 0 %. The drip roller is to be slide onto the drip roll carrier so that drip emitter will be turned up toward plastic mulch. The plastic mulch and drip lateral was placed under the press wheel assembly before going to start the plastic mulch laying operation. The soil covering assembly was adjusted properly to lift and through the soil over the edges of the plastic mulch to make air tight plastic mulched soil beds. Press wheels have been made to run at the bottom of the trench and not on the side to stretch the plastic properly. The prototype of tractor operated plastic mulch laying equipment was fabricated based on the design. The prototype consists of main frame, plastic mulch roller assembly, drip roll carrier assembly, soil covering device and press wheel assembly. A schematic view of tractor operated plastic mulch laying equipment is shown in Fig. A.

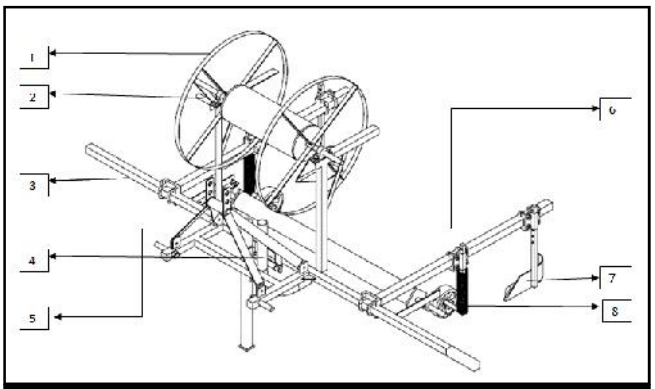

Fig. A : Components of developed tractor operated plastic laying equipment:
1. Drip lateral assembly; 2. Handle; 3. Main frame; 4. Down pipe; 5. Three point hitch; 6. Plastic roller assembly; 7. Soil covering device; 8. Press wheel assembly

Development procedure for tractor operated plastic mulch laying equipment :

The tractor operated plastic mulch laying equipment was developed by considering the agronomic and machine parameters. The parameters considered in development of tractor operated plastic mulch laying equipment are discussed under the following sub headings. The tractor operated plastic mulch laying equipment was developed by considering the following parameters.

Selection of power source :

Selection of proper power source is very important while developing the machine. According to the power requirement, commercial 35 hp, (Mahindra sarpanch 595 DI) tractor was selected as the source of power. The draft was measured by using two tractors and a digital hydraulic dynamometer.

The power requirement was measured by using following formula.

$$P = \frac{\text{Draft (kg)} \times \text{Speed (m/s)}}{75}$$

$$P = \frac{330 \times 4000}{75 \times 3600}$$

$$P = 4.889 \approx 5.0 \text{ hp}$$

So for this equipment the small hp tractor can be used for operation. The available tractor of 35hp (Mahindra sarpanch 595 DI) was selected.

Fabrication of tractor operated plastic mulch laying equipment :

The tractor operated plastic mulch laying equipment has been designed for vegetables crop like tomato, okra, cucumber and row crops like maize, cotton and having row spacing of 900 mm**.** The tractor operated plastic mulch laying equipment consists of one plastic mulch laying unit having a working width of 900-1200 mm and one drip pipe laying unit have been developed to cover single row mulch laying operation. The overall dimensions of the prototype tractor operated plastic mulch laying equipment are 2520 mm in length, 2440 mm in width and 1900 mm in height. The tractor operated plastic mulch laying equipment gets power for motion from drawbar of the tractor.

Main frame :

The frame of farm machines must be as light as possible to reduce cost, soil compaction and propelling power but strong enough to resist the shocks due to rough fields or obstacles. The main frame of mild steel was made of square cross section. The overall dimensions of the main frame are 2440 mm in length, 2440 mm in width and 1900 mm in height. Main frame made of mild steel structure of suitable sections to mount various components.

Plastic roller unit :

The plastic roll has to be slide onto the plastic roll carrier provided below the main frame of the equipment. The plastic paper has to be placed under the press wheel assembly before going to start the plastic mulch laying operation.

Drip irrigation roll carrier :

The drip roller is to be slide onto the drip roll carrier so that drip emitter will be turned up toward plastic (for less clogging). Feed drip line through the down pipe and adjust down pipe about 1 inch to 2 inch below the plastic mulch. As the tractor moves forward drip lateral laid simultaneously with plastic mulch. Lateral will be laid beneath the plastic mulch and above the soil bed.

Soil covering unit :

Soil covering unit is used for cutting, lifting, turning and throwing the soil over the plastic mulch. The M.B. plough bottom is attached to the soil covering to cut, lift and throw the soil on the plastic mulch.

Press wheel assembly :

Press wheels need to run at the bottom of the trench and not on the side to stretch the plastic properly. Tilt the front of the press wheel on an inward angle to stretch the plastic. The press wheel height and distance can be adjusted as needed.

Performance evaluation of tractor operated plastic mulch laying equipment :

The performance of tractor operated plastic mulch laying equipment was analyzed in terms of moisture content of soil, draft, fuel consumption and soil temperature. Tractor operated plastic mulch laying equipment was operated under optimized conditions.

Soil moisture :

The plastic mulch laying operation was carried out at optimum soil moisture content in order to minimize field time losses and energy input. Soil samples at 10 cm depth during plastic mulch laying in ten different locations were randomly collected in the field, weighed and then oven dried at 105 ºC for 8 hours. The weight of the dried samples was recorded using electronic balance. The moisture content on dry basis was calculated using following formula.

$$\text{Soil moisture content (\% by weight basis)} = \frac{w_1 - w_2}{w_1} \times 100$$

where,

w_1 - Weight of wet soil sample, kg

w_2 - Weight of the oven dried soil, kg

Draft of equipment :

Total draft exerted on the equipment was computed using the formula.

$$D = D_1 - D_2$$

where,

D = Draft of equipment, kg or N

D_1 = Draft of equipment when equipment in operating condition, kg or N

D_2 = Draft of equipment when equipment in not

Table 1 : Effect of forward speed, width of material with black colour plastic mulch on field parameters

Forward speed (km h^{-1})	Width of mulch (mm)	Soil moisture (%)	Draft (N)	Fuel consumption (l h^{-1})	Soil temperature (^{o}C)
2	1200	20.00	3141	4.00	36.40
	1000	19.20	3139	3.80	36.40
	900	18.50	3138	3.50	36.40
3	1200	20.10	3195	4.30	36.40
	1000	19.30	3193	4.10	36.40
	900	18.70	3192	3.80	36.40
4	1200	20.00	3224	4.60	36.40
	1000	19.20	3222	4.40	36.40
	900	18.60	3221	4.10	36.40

operating condition, kg or N

Fuel consumption :

Fuel consumption is the amount of fuel used per unit distance. The fuel tank is filled to its capacity before and after the operation. Amount of refilling after the operation is measured which is the actual fuel consumption.

Soil temperature :

Soil temperature is an important parameter in crop production. The plants require optimum soil temperature for their growth in soil. The plastic mulch laying operation was carried out at optimum soil moisture content. Thermometer was used to determine the soil temperature.

RESULTS AND DISCUSSION

Field trials of tractor operated plastic mulch laying equipment were conducted at research farm of UAS, Raichur. From the results (Table 1) it is observed that as forward speed increases, soil moisture slightly increased and then decreased. It was found that when forward . . . . . $^{-1}$ the soil moisture content increases from 18.50 to 20.10 %. It was found to be higher soil moisture content when operating at a forward speed of 3 km h^{-1}. This is because of soil thrown over the plastic mulch was optimum and at higher forward speed the soil moisture reduced as because of the soil thrown over plastic mulch was higher and formed some openings at the bottom edges of plastic mulch (Heipner *et al.*, 2005).

When forward speed increases from 2 to 4 km h^{-1} the average draft increases from 3138 to 3224 N. As the forward speed increases draft increases this is because of increase in acceleration forces between the soil and machine (Kepner *et al.*, 2005).

The fuel consumption for operating plastic mulch laying equipment increases with increase in forward speed of the equipment. When forward speed increases from 2 to 4 km h^{-1} the average fuel consumption increases from 3.50 to 4.60 l h^{-1}. This is due to increase in draft, which leads to increase in acceleration. The acceleration forces increases it increases the normal loads on soil engaging surfaces (Kepner *et al.*, 2005).

The soil temperature was found constant at all the forward speeds with three different width of material. This is because of forward speed does not significantly affect the soil temperature (Jimenez *et al.*, 2004 and Tarara, 2000).

Conclusion:

A tractor operated plastic mulch laying equipment was developed to mechanize the conventional plastic mulching. It saves time, labour and increases timeliness of operation. By using plastic mulch of black colour, it maintains the soil moisture and soil temperature. From the study, it was found that as forward speed increased draft also increased. For satisfactory operation of plastic mulch laying equipment, 3 km h^{-1} speed is found to be better.

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