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Performance Evaluation of Mulching Machine as an Attachment to a Rotavator

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Abstract: Mulching is done to conserve moisture, improve the fertility & health of the soil, reduce weed growth, and enhance the Beauty of the area. Before the laying of mulch sheets, suitable seedbed preparation is major tasks before the farmers. Traditionally, seedbeds are prepared with help of draught animals or machines and then mulching is done by manually which is very time and energy consuming. However, each of these operations are done individually, resulted more time and energy requirement to complete the whole operation. Thus, a machine was developed which performs all required operations for mulching in a single pass to save operational time and energy. The performance of the machine was evaluated by determining effective field capacity, field efficiency, fuel consumption, energy requirement and mulch sheet covering percentage. Machine was tested at three levels of forward speed as 1.0-1.5 km/h, 1.5-2.0 km/h and 2.0-2.5 km/h. The highest effective field capacity of the machine was found as 0.1595 ha/h at the forward speed of 2.0-2.5 km/h. The highest field efficiency of the developed machine was obtained as 83.07 % at 1.0-1.5 km/h speed level. The lowest fuel consumption of developed machine was obtained as 3.0 l/h at 1.0- 1.5 m/h and the mulch sheet covering efficiency was 94%.

Keywords: Plastic mulching machine, rotavator, bund former, combination tillage implement

1. INTRODUCTION

India has emerged as the second largest producer of fruits and vegetables in the world. Fruits and vegetables accounts 90% of total horticulture production in the country. Formerly agriculture was more dependent on the nature and all the operations were carried out manually, however new technologies have been developed to increase the productivity and production of crops. To increase in production and to be more competitive in today's markets farmers are looking for new technologies, plastic mulching is one of among them. Mulches affect the plant microclimate, modifying the energy balance of the environment and decreasing the soil water loss (Tarara, 2000). It was found that the plastic mulches are superior to natural organic mulches. Earlier the films used have thickness of 60-75 micron but today it is possible to have 15-micron thick mulch film. The film width depends on width of seedbed. Normally 1-1.5 wide film can be easily adapted. Also, they are available in different colours as Black, white, green, brown, red, silver, and blue etc. Variety of vegetables can be grown successfully using plastic mulches i.e., muskmelons, watermelons, cucumbers, tomatoes, peppers, eggplant, okra, sweet corn, cotton and Cole crops have shown significant increases in earliness, total yield, and improved quality.

Plastic mulch films are laid before crop planting or transplanting. This includes preparation of seed bed, spreading of mulch film on prepared bed and covering of edges of mulch film by soil. Traditionally mulching is done by manually or with the help of animals. Raised beds are often preferred for plastic mulches because they warm quicker than flat beds and offers superior drainage (Lamont, 1996, Tarara,2000). Traditionally for formation of beds bullock drawn implements such as the wooden (desi) plough and ridger are used and plastic mulches are laid manually. This traditional methods of using animal or human power in bed preparation are time consuming and labour intensive. Along with manual laying of plastic mulch sheet farmers also use bullock drawn mulch laying machines. But its use is still limited due to difficulty of laying mulch. This is because lack of availability of skilled labour, high labour cost and it has very less field efficiency about 50.77 to 52.98% (Kothiya et al., 2021). The tractor operated bund former cum- packer can reduce about 96% dependency of farmers on manual labour requirement for packing the bund. (Singh et al., 2016). There are some tractor operated mulching machines are also available but to lay the mulch sheet by this machines farmer needs to prior prepare the field and form the beds. Which requires more time and energy and there is also risk of operation getting delayed by various environmental and technical parameters.

Approximately 20% of energy in agriculture is used for field operations, with most of this energy applied toward tillage operations (Stout, 1984). The combination tillage tool concept has the salient features of combining sliding actions and rotary motions encountered in primary and secondary tillage operations. If all the required operation for mulching performed simultaneously it will save time, energy and reduces cost of operation. Looking to the above views a mulching machine as an attachment to a tractor operated rotavator was developed which was easily attachable and detachable from rotavator and its performance evaluation was carried out.

2. MATERIALS AND METHODS

2.1 Location of experiment

The mulching machine as an attachment to a tractor operated rotavator was designed and developed at the Department of Farm Machinery and Power Engineering, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh.

2.2 Working principle

The machine prepares a field by tilling, pulverizing and levelling with the help of rotavator and forms a soil bed using the bund former. Simultaneously, the machine lays the drip laterals and the plastic mulch sheet over the prepared soil bed. Both the edges of the plastic sheet are covered by the soil using soil covering discs. Thus, all the three operations Viz. field preparation, bed formation and mulch laying are completed in a single pass. These operations were also observed by Marihonnappanavara and Veerangouda (2017), Tipayale *et. al.*, (2017) and Gowd and Prasad (2017). Fig. 1 shows the working of the developed machine in field.

Fig. 1: Working of the developed mulching machine

Performance evaluation of developed machine

2.3 Performance parameters

Following observations were taken during field performance evaluation of the developed machine.

a. Speed of operation

Speed of operation was calculated as time required to cover the distance of 20 m. Time was recorded using stopwatch.

$$\text{Speed (km/h)} = \frac{3.6 \text{ x Disctance (m)}}{\text{Time (s)}} \quad ..(1)$$

b. Width and height of bund

The width and height of bund formed by the bund making unit attached at the rear side of rotavator was measured by measuring tape and depth gauge by measuring the horizontal distance between two edges of bund formed and the distance between surface of soil and upper edge of bund respectively. Fig. 2 shows the measurement of width and height of formed bunds.

Fig. 2: Measuring width and depth of formed bund

c. Wheel slip

Wheel slip of drive wheels of tractors was measured all field operations. Percentage of wheel slip is also called travel reduction ratio. However, the travelled distance of tractor in each number of revolutions increases in a few cases when the mounted implement pushes the tractor as in case of rotavator. Thus, the wheel slip is negative. The distance covered in ten-wheel revolutions was recorded with and without load and the values were used to calculate slip using following expression.

$$S = \frac{D1 - D2}{D1} \quad ………… (2)$$

Where, S = Slip (%),

D1 = Distance covered in 10 revolutions of drive wheel at no load in field (m),

D2 = Distance covered in 10 revolutions of drive wheel at load in field (m).

d. Theoretical field capacity

Theoretical field capacity (TFC) is the rate of area covered without loss of time. It was calculated by using following formula.

$$\text{TFC}\left(\frac{\text{ha}}{\text{h}}\right)=\frac{\text{Width of coverage (m)}\times\text{Speed}\left(\frac{\text{km}}{\text{h}}\right)}{10} \quad \text{....(3)}$$

e. Effective field capacity

Effective field capacity (EFC) is the actual rate of work which includes the time lost in turning at the end of rows and time lost during changing of mulch roll. It was calculated by using following formula.

$$\text{EFC}\left(\frac{\text{ha}}{\text{h}}\right)=\frac{\text{Width of coverage (m)}\times\text{Length of strip (m)}}{\text{Time taken (h)}\times 10{,}000} \quad \text{....(4)}$$

f. Field efficiency

Field efficiency (FE) is defined as the percentage of time the machine operates at its full rated speed and width while in the field. It was calculated by using following formula.

$$\text{FE (\%)}=\frac{\text{Effective field capacity}}{\text{Theoretical field capacity}}\times 100 \quad \text{.....(5)}$$

g. Fuel consumption

The auxiliary tank/jar (Fuel meter) was attached on tractor in between fuel tank and engine. Fig. 3 shows the auxiliary tank attached on tractor. The time of operation by tractor and fuel consumed in auxiliary tank were recorded. Fuel consumption of tractor was determined by dividing the fuel consumed to the time of operation.

Fig. 3: Fuel consumption measuring jar attached on tractor

h. Energy requirement of the developed machine

Energy consumption (FC) for soil pulverization, bund making and plastic mulch film laying was calculated by standard energy consumption formula in MJ/ha. The energy is obtained by multiplying fuel consumption of tractor (l/ha) by 47.78 MJ/l. Whereby, 47.78 MJ/l is the energy equivalence for diesel per liter (Umar, 2003).

$$E_f = 47.78\times\text{FC of tractor (l/ha)} \quad \text{...... (6)}$$

Where,

E_f = Total energy requirement (MJ/ha),

47.78 = Unit energy value of diesel, MJ/l.

i. Mulch sheet covering percentage

During the field testing of the developed machine the length of mulch sheet which was properly covered and not properly covered by soil was measured with the help of measuring tape. And mulch sheet covering percentage was calculated.

2.4 RESULTS AND DISCUSSION

Traditionally mulching operation includes field preparation, preparation of seed bed, laying of the drip laterals, spreading of mulch film on prepared bed and covering of edges of mulch film by soil. When these operations done individually, they require more time and energy. to save the operational time, labour problems and operational energy a machine was developed.

The developed machine was evaluated in the experimental plots for laying of plastic mulch films.

a. Speed of operation

As per the experimental design, machine was evaluated at three different forward speeds of tractor as 1.0-1.5, 1.5-2.0 and 2.0-2.5 km/h respectively. The average speed of operation during operation was found 1.23, 1.52 and 2.1 km/h.

b. Width and height of bund formed

The width and height of bund formed were measured at different locations with the help of measuring tape and depth gauge. The average width and height of the bund formed by the developed tractor operated bund former was 84 cm and 20.6 cm respectively.

c. Wheel slip

The observations for the wheel slip were measured at speed of 1.0-1.5 km/h, 1.5-2.0 km/h and 2.0-2.5 km/h resp. The obtained wheel slip was -1.75, -2.22 and -2.43% resp. The mounted rotavator on a tractor pushes the tractor thus it produces negative slip.

d. **Theoretical field capacity**

The theoretical field capacities of the developed mulching machine were found 0.13, 0.195 and 0.26 ha/h at 1.0-1.5, 1.5-2.0 and 2.0-2.5 km/h speeds respectively.

e. Effective field capacity

During the operation the effective field capacities were measured for individual treatment plot. Table 1 shows the effect of forward speed on effective field capacity. The average effective field capacity calculated at 1.0-1.5, 1.5-2.0 and 2.0-2.5 km/h speeds were 0.1080, 0.1314 and 0.1595 ha/h respectively. The graphical representation of mean values of the effective field capacities under different operating conditions is shown in Fig. 5. Results were analysed statistically, and it shows that operating speed had highly significant effect on the EFC at 1% level of significant. The results showed that effective field capacity of the developed machine increased with increasing speed of operation.

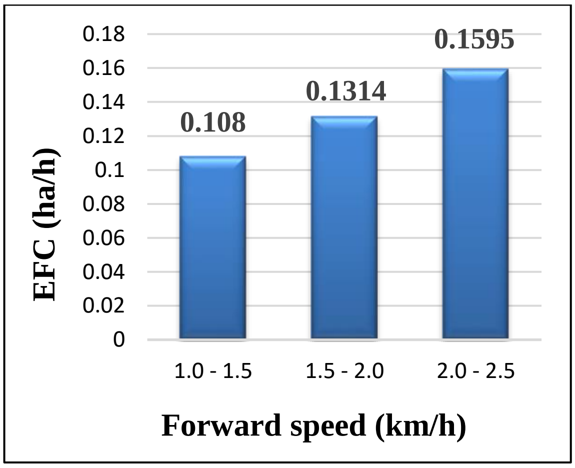

Fig. 5: Effect of forward speed on effective field capacity

f. Field efficiency

During the operation the field efficiency was calculated for individual plot from theoretical field capacity and effective field capacity. Table 1 shows effect of forward speed on field efficiency. The average field efficiency was found 83.07, 67.5 and 61.21 % at 1.0-1.5, 1.5-2.0 and 2.0-2.5 km/h speeds respectively. During the operation it was found that the field efficiency decreased with increasing the forward speed (Tripathy et. al. 2020 obtained the similar results). The graphical representation of Effect of forward speed on field efficiency is shown in Fig. 6. Results were analysed statistically, and it showed that speed had highly significant effect on the field efficiency at 1% level of significant. The results show that field efficiency of the developed machine decreased with increasing speed of operation.

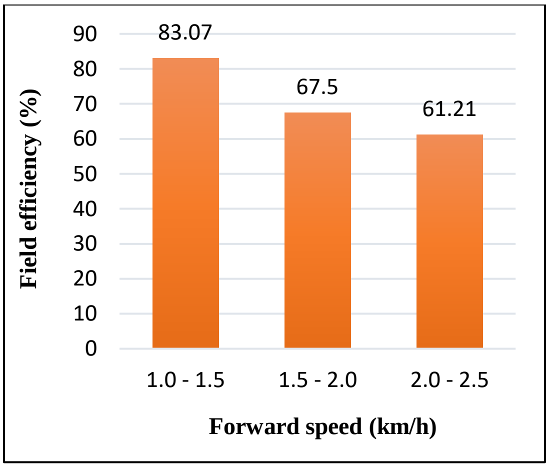

Fig. 6: Effect of forward speed on field efficiency

g. Fuel consumption

The fuel consumption for individual treatment was measured by fuel measuring jar mounted on tractor. Table 1 shows the effect of forward speed on fuel consumption. The average fuel consumption observed at 1.0-1.5, 1.5-2.0 and 2.0-2.5 km/h speeds were 3.0, 4.05 and 5.34 l/h respectively. The graphical representation of values of the fuel consumption is shown in Fig. 7. Results were analysed statistically, and it shows that speed had highly significant effect on the fuel consumption at 1% level of significant. The results show that fuel consumption of the developed machine increased with increasing speed of operation.

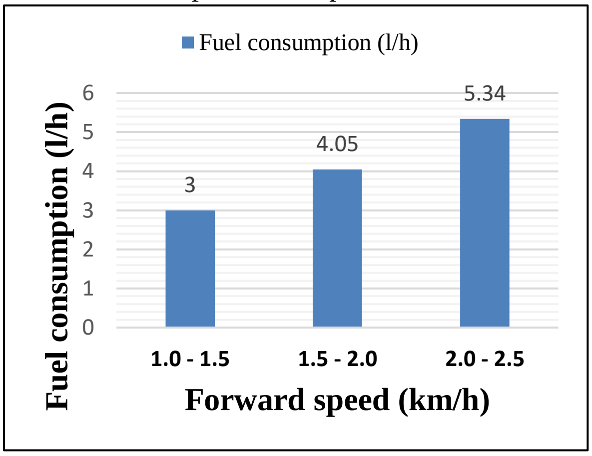

Fig. 7: Effect of forward speed on fuel consumption

h. Energy requirement of the developed machine

At the time of operation, the energy requirement was found 1137.6, 1208.72 and 1265.6 MJ/ha at the operational speed of 1.0-1.5, 1.5-2.0 and 2.0-2.5 km/h respectively.

During the field testing of the developed machine, the percentage of coverage of plastic mulch sheet from both sides by soil was measured. The average percentage of mulch sheet properly covered was 94%.

Table 1: Effect of forward speed on different parameters

Parameters	Speed (km/h)			Average	CD	CV (%)
	1.0-1.5	1.5-2.0	2.0-2.5			
EFC (ha/h)	0.1080	0.1314	0.1595	0.1230	0.012	5.65
FE (%)	83.07	67.5	61.21	70.60	2.98	3.77
FC (l/h)	3.0	4.05	5.34	4.13	5.834	8.49

3. CONCLUSION

The major components of the developed machine include bund making unit, mulch laying and soil covering unit and drip lateral laying unit. Experiments were conducted in the field by varying forward speed of operation at 1.0-1.5 km/h, 1.5-2.0 km/h and 2.0-2.5 km/h speeds. Completely randomized design was adopted for the experiment by taking seven replications. The performance of the machine was evaluated by determining the width and height of formed bund, effective field capacity, field efficiency, and fuel consumption. During the performance evaluation the machine worked satisfactorily and formed bund of required width. Also, the machine laid the plastic mulch sheet without tearing. The highest effective field capacity of the developed machine was found as 0.1595 ha/h at the forward speed of 2.0-2.5 km/h. The overall field efficiency of developed machine was 70.59%, however the highest field efficiency was found as 83.07 % at forward speed of 1.0-1.5 km/h. The average mulch sheet covering percentage of developed machine was 94%. The overall fuel consumption of machine was 4.13 l/h, however the lowest fuel consumption was found as 3.0 l/h at speed of 1.0-1.5 km/h. The overall energy requirement of developed machine was 1203.97 MJ/ha.

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