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Performance Evaluation and Economic Analysis of Developed Manual Mulch Laying Machine

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A B S T R A C T

Globally every year over 80,000 square km of agricultural lands are covered with plastic mulch films. These benefits lead to higher yields (by up to 100% for certain crops) in early duration crops (by upto one month) and in some case the ability to grow certain crop, which would not be possible without the mulch film. The performance of the newly developed manual mulching machine was evaluated. The average draft recorded 45.7 kgf was at an angle of inclination of 35.50° with speed of operation varies from 1.3 to 1.36 km/hr. The average power required for developed mulch laying machine was found to be 447.86 N. The actual field capacity of mulch laying machine was found to be 0.113 ha/h, whereas the theoretical field capacity was found to be 0.162 ha/h. It was found that the actual field capacity of developed mulch laying machine varies by 0.1 in comparison to manually mulch laying.

Introduction

To make more effective mulching in agriculture can be done with plastic and since last 10 years, visible increase in plastic mulching is found in India. This plastic mulching helps in maintaining soil temperatures, proper weed management, moisture conservation, reduction of certain insect pests, high crop yields, improved germination rates and more efficient use of soil nutrients. According to Reynolds (2009), Globallyevery year over 80,000 square km of agricultural lands are covered with plastic mulch films. These benefits lead to higher yields (by up to 100% for certain crops) in early duration crops (by upto one month) and in some case the ability to grow certain crop, which would not be possible without the mulch film (Clarkson, 1957)**.**

Plasticulture began in the 1950s and early 1960s with the introduction and use of plastic films, mulches, and drip irrigation systems (Maughan and Drost, 2016). They are used commercially for both vegetables and small fruit crops. Vegetable crops that are well suited to production with plastic mulch are typically high value row crops such as crops from the Solanaceae (tomato, eggplant, and pepper) and Cucurbitaceae (melons, watermelons, squash, cucumber) families, strawberries, green beans, asparagus, and salads, among others, have shown significant

gains when cultivated with mulch (Witter and Castilla, 1995).The demand for mulching machine in India is increasing day by day. Most of the farming operation such as transplanting, harvesting, threshing is done by labour which is time consuming and costlier also and lastly they will not gain that much benefit as they wished or they deserved. So mulching machine is the best way to recover and redeveloped farming in different style. Traditional; manual mulching process characterized as labour intensive, poor quality of work, disturbances due to wind during laying of mulch sheet additionally causes problem of tearing of sheet during handling and most importantly difficulty in the covering of mulch sheet. Presently, for laying plastic mulch sheet manually around 4-5 labours are required. Power operated machine is effective but not economical for small farmers and it requires larger field, uniformity in the topography, needed road facility to reach the machinery in the field as well as high powered tractor is required to operate the machine. Keeping this consideration newly developed manual mulching machine is tested for calculation of the efficiency and cost analysis. The performance of the mulching machine was evaluated.

Materials and Methods

The Development of manual plastic mulch laying machine was designed as a functional and experimental unit. The design of machine components was based on the principles of operations and field tests. It was compared with the traditionalmethod, to give a correct shape in form of prototype. The mechanical design details were also given with due attention so that it gave adequate functional rigidity for the design of machine.

Economical consideration

The cost of the mulch laying machine should be as low as possible so, that small farmers can afford to purchase the machine.

The material of construction of different components should be easily and locally available.

Cost calculation

Cost of operation = Fixed cost + Variable cost

Fixed cost: Depreciation: $D = \frac{C - S}{L \times H}$

Where: C = initial cost
S = 10% of C, L = 6 years, H = 300 (hr/yr)

Interest

$$I = \frac{C + S \times i}{2 \times H}$$

Housing tax+insurance@1% of each C
Repair and maintenance @10% of C
variable cost

Wages of operator@250 rupees per day

Total operational cost =fixed +variable

Cost of plastic mulch laying=time taken ×operational cost per hour

Total cost of plastic sheet laying=time ×cost per hour

Power requirement

Calculation of power is needed to determine the efficient use of manual power. A man can produce power equal to 0.1 hp. It was the power required to operate the machine by a person with an average pulling force and speed. It was calculated by using the formula.

$$\text{Power(hp)} = \frac{\text{Pulling force (kg)} \times \text{Speed(m/s)}}{75}$$

Field capacity

Theoretical field capacity was measured as per following formula (Bainer *et al*., 1960):

$$\text{Theoretical Field capacity (ha/h)} = \frac{W \times S}{10}$$

Where,
W = Effective width of implement, m; and
S = Speed of operation, km/h.

Actual field capacity was measured by taking an area of 10x10 square meter i.e. and measuring the time in actual field condition. It includes turning loss, filling time and break down time also.

Field efficiency

From the actual and theoretical field capacity, the field efficiency was calculated (Bainer *et al*., 1960),

$$\text{Field efficiency (\%)} = \frac{AFC}{TFC} \times 100$$

Where,
FE= Field efficiency (%);
AFC=Actual field capacity (ha/h); and
TFC=Theoretical field capacity (ha/h).

The data were recorded for all three mulching methods under actual field conditions and also compared (Michael and Ojha, 2003).

Energy input

$H = t \times e$
H = human energy input = time taken by human
e= energy coefficient for male is 1.96 for female is 1.56

Results and Discussion

The performance of the manual plastic mulch laying machine was evaluated along with its comparative performance evaluation with manually mulch laying method was done. The cost economics and energy requirement of the developed machine was also calculated.

Speed of operation

The average speed of operation was found 1.65 km/h.

The average speed of operation for mulching operation was found to be 1.65 km/h, respectively, for a distance of 10m (Table 1).

Measurement of draft

The spring balance was hitched between the handle and the machines frames beam during the operation. The pulling force varied from minimum 4.0 to maximum 4.2 kg at 45° angle of inclination. The draft accordingly computed varied from 28.0 kgf to 29.4 kgf. The average draft recorded was 28.7 kgf (Table 2).

Power requirement

The average power required for mulching was found to be 0.0249 hp for which may be operated by men with average output of 0.1 hp (Table 3).

Physiological response

During the field perform evaluation, the human physiological response was measured by the equipment and recorded the data in data sheet (Table 4).

Cost calculation of manually operated mulching machine

The economic evaluation of the developed machine is also necessary for adopt it. After developed the machine we did a field work with it and evaluate it on the basis of required cost for work (Table 5).

Cost comparison of tractor operated mulching machine

Cost of operation is the very important factor to judge the performing the same operation.

Thus in order to compare the economics of the tractor, MB Plough and sugarcane of operation was calculated (Table 6).

Field efficiency

The field efficiency was calculated for mulch using standard method as in Table 7. The average actual field capacity was found 0.166 ha/h, whereas the average theoretical field capacity was found to be 0.15 ha/h. From the actual and theoretical field capacity the average field efficiency of the machine was found to be 80 %.

Table.1 Speed of operation

Sr.no.	distance(m)	time(s)	speed(km/h)
1	10	22	1.63
2	10	21	1.71
3	10	22	1.63
Average	10	21.66	1.65

Table.2 Draft required for manually operated mulching machine

Sr.no.	pull(kg)	angle of inclination (degrees)	draft(kgf)
1	41	45	28.7
2	40	45	28.0
3	42	45	29.0
Average	41	45	28.7

Table.3 Power requirement for the mulching machine

Sr.no.	speed of operation (km/h)	draft (kgf)	Hp
1	1.63	28.7	0.0246
2	1.71	28.0	0.0250
3	1.63	29.4	0.0252
Average	1.65	28.7	0.0249

Table.4 Physiological response

Subject	Standard		Initial		Final		
	Pulse rate b/m	Blood pressure	pulse rate	blood pressure	pulse rate	blood pressure	Time(sec)
S1	72	120/80-140/90	76	109/64	148	121/77	22
S2	72	120/80-140/90	102	124/84	149	125/88	21
S3	72	120/80-140/90	80	119/79	94	129/72	22

Table.5 Calculation of manually operated mulching machine

Depreciation cost (Rs/hr)	1.75
Interest (Rs/hr)	0.64
Housing + tax + insurance @ 1% of C (Rs/hr)	0.35
Repair and maintenance @ 10% of C (Rs/hr)	1.16
Wager of operator (Rs/hr)	31.25
Total operation cost (Rs/hr)	35.15
Time taken to cover 1 ha. Field (hr)	6.06
Field capacity (ha/hr)	0.165
Cost of plastic laying for single men (Rs/hr)	213.00
Total cost of plastic laying for 2 men (Rs/hr)	625.00

Table.6 Cost of operation

Assumptions	Tractor	Mb plough	Sugarcane
a) Initial cost (C)	500000	18000	100000
b) Salvage Cost(10% of C)	50000	1800	10000
c) Life (YEARS)	10	10	
d) No. of useful working hours(H)	-		
e) Interest rate per year(I_r)	-		
Fixed Cost (per hour)	**Tractor**	**Mb Plough**	**Sugarcane**
a) Depreciation (D)	45	54	45
b) Interest(I_r)	33	3.96	33
c) Insurance and taxes, housing@3% of C	15	18.72	15

Table.7 Field efficiency

Subject	speed(km/h)	Theoretical field capacity (ha/hr)	Actual field capacity (ha/hr)	Field efficiency %
S1	1	0.1	0.163	85
S2	1.5	0.15	0.171	80
S3	2	0.2	0.163	75
Average	1.5	0.15	0.166	80

Field efficiency

From the above test the performance of manual mulch machine was evaluated and the final conclusion is as follows.

The speed of operation was found to vary from 1.33 to 1.36 km/h. The average speed of operation of developed mulch laying machine for laying of plastic sheet was found to be 1.35 km/h for a distance of 30m.

The average power required for developed mulch laying machine was found to be 0.162kW (0.22hp), which may be operated by a pair of bullocks with average output of 0.50 hp.

The major conclusions drawn from the present study are specified below.

The average draft recorded 45.7 kgf was at an angle of inclination of 35.50° with speed of operation varies from 1.3 to 1.36 km/hr.
The average power required for developed mulch laying machine was found to be 447.86 N.
The actual field capacity of mulch laying machine was found to be 0.113 ha/h, whereas the theoretical field capacity was found to be 0.162 ha/h.
It was found that the actual field capacity of developed mulch laying machine varies by 0.1 in comparison to manually mulch lying.

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