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Energetics and Cost Economics of Laying Plastic Mulch in Vegetable Cultivation

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Authors' contributions

This work was carried out in collaboration among all authors. Author Omprabha designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors VMV and NPB managed the analyses of the study. Authors AKC managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The use of plastic mulch in agriculture is increasing day by day due for increasing crop yield. Mulch film are available in different types but plastic mulching requires less efforts. This paper highlights a new developed mulch laying machine for spreading of polyethylene black plastic mulch on soil. Animal drawn plastic mulch laying machine was developed at the SV College of Agricultural Engineering and Technology, IGKV, Raipur and was evaluated for its performance by conducting field trials. The average field capacity and average field efficiency was found to be 0.115 ha/h and 71% respectively. The average speed of operation was found 1.35 km/h for developed machine and 0.226 km/h for traditional method of mulch laying. The cost of operation was found to be Rs.1343/ha. Energy requirement of developed machine in mulch laying operation was found 187.34 MJ/ha it was found very less than the energy requirement 754.60 MJ/ha of traditional method of mulch laying. This machine will avoid the wages of labours used for laying plastic mulch and covers the plastic mulch with the soil on its either side edges. Using the mechanical system, the accuracy and ease during plastic laying was achieved.

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1. INTRODUCTION

The production of agricultural crops is still poor and some suitable practices require time to develop, resulting in an increase in yield. Mulching with organic or inorganic materials aims to cover soils and forms a physical barrier to limit soil water evaporation, control weeds, maintain a good soil structure and protect crops from soil contamination. Natural mulches are those derived from animal and plant materials. If properly used, they can offer all the benefits of other types of mulches. Natural mulches help in maintaining soil organic matter and tilth [1] and provide food and shelter for earthworms and other desirable soil biota [2].

India has emerged as the second largest producer of fruits and vegetables in the world. Formerly agriculture was more dependent on the nature and all the operations were carried out manually and draught animal, however new technologies have been developed to increase the production and productivity of crops. Raipur region is the part of Eastern Plateau of Chhattisgarh having dry moist, sub humid and the region receives 1489 mm rainfall annually. [3] The climatic conditions are suitable for growing various fruit and vegetable crops. The total area of vegetable crops in the state was recorded 4,63,251 ha in the year 2016-17 with the production of 6,55,652 Mt. [4]. In Chhattisgarh, area under vegetable crops is increasing day by day, especially under plastic-culture cultivation. In Chhattisgarh, Durg District is ranked first in cultivation of vegetables under plasticulture followed by Rajnandgaon and Mahasamund District.

Livestock have been used in agriculture for thousands of years supplying energy for crop production in terms of draught power and organic manure. But due to mechanization in agriculture, the role of animals in crop production became less relevant. But in a country like India where 78% of farmers have less than 2 ha of area for cultivation, the question whether the use of tractors and tillers are economical put forward the importance of draught animals in agriculture. Draught animal power are still the main source of farm power for small and marginal farmers to carry out farm operations such as field preparation, intercultural operation and for transportation especially in a state like Chhattisgarh.

Traditional manual mulch laying process characterized as labour intensive, poor quality of work, disturbances due to wind during laying of mulch sheet, tearing of sheet during handling and difficulty in the covering of mulch sheet. Laying plastic mulch manually required 4 labours [5]. Power operated plastic mulch laying machine are economical but needed specific characteristics for effective working such as high land holding, uniformity in the topography, needed road facility to reach the machinery in the field as well as high hp power sources (high hp tractor) to operate the machine. Animal drawn machineries are suitable alternatives for small and marginal farmers. Now a day's animal drawn plastic mulch laying machines are also available. Recently an animal drawn plastic mulch laying machine was developed at IGKV, Raipur. This paper presents performance evaluation of plastic mulch laying methods on the basis of energy required and cost evolved in the operation.

2. MATERIALS AND METHODS

Current experiment was conducted at compartment of experimental research farm, IGKV Raipur in plot size (40×25 m^2). In the present study during this experiment, animal drawn plastic mulch-laying machine was used for laying plastic mulch and compared with the traditional method of plastic mulch laying by human labour. Two vegetable crops cauliflower and knol-khol crops were selected for the present study. The soil of the experimental area was inceptisol, with a structure in the form of sandy loam. The texture of the soil was sand 30%, silt 46 % and clay 24% and pH was 7.50 recorded. The effect of mulching for the physical properties of the soil was well reported. Through the reviews the soil properties, i.e. moisture content, bulk density and mean mass diameter of clods have been studied. The following exercises were done in the experimental area before laying plastic mulch on the bed. Mould board plough was used for primary tillage operation followed by two passes of rotavator to achieve finer seedbed preparation.

Afterward beds are prepared manually. The width, height and length of the bed were 60 cm, 15 cm and 60 m respectively. On pre-prepared soil bed animal drawn plastic mulch laying machine was used for laying plastic sheets and for comparison traditional method of laying plastic mulch sheet with human labour was

performed. To know the cost involving in plastic mulch laying machine the following processor was followed, such as fabrication cost, material cost, black smith charges, machine charges, workshop expenditure, supervision charges etc. Operational cost of the machine is the sum of fixed cost and variable cost of the machine. Fixed cost includes depreciation, interest per hour, housing, tax, insurance and operating cost includes repair and maintenance per hour and, wage of bullock with operator per day [6].

To estimate the operational energy of plastic mulch laying machine total time required to carry out the operation, total weight of machine, labour required, animal required was taken. The energy was calculated by using the following formula reported by Binning et al. [7].

$$\text{Implement usage for mulch laying } \frac{\text{MJ}}{\text{ha}} = \frac{\text{TIW}}{\text{LH}} \times \text{HOU} \times \text{EE}$$

Where,

TIW = Total weight of implement, kg;
LH = Total useful working life of implement;
HOU= Hours of useful life of implement h/ha, and
EE = Equivalent Energy.

3. RESULTS

3.1 Performance Evaluation of Animal Drawn Plastic Mulch Laying Machine

Animal drawn plastic mulch laying machine (Fig. 1) was evaluated in the experimental plots for laying of plastic film on the prepared bed and compared with plastic mulch laying by human labour. The animal drawn plastic mulch laying machine was effective for laying mulch film and covered laid plastic mulch film from both side with soil. The effective field capacity was found to 0.162 ha/h at an average speed of 1.35 km/h with a field efficiency of 71%. The average draught required to pull the machine was found to be 447.86 N., which was within the capacity of local bullocks found in this region. These animals are small to medium size (250 to 450 kg) with a draught ability of 10 to12 percent of their body weight [8]. It was observed that the actual field capacity of animal drawn plastic mulch laying machine and manually mulch laying were 0.115 ha/h and 0.013 ha/h respectively. Finally, it was determined that cost of operation of traditional method is higher as i.e 9615 Rs/ha as compared to mulch laying machine which was 1343 Rs/ha, as depicted in Table 1.The time required to cover a hectare of the field by manual mulch laying was about 8.55 times more than, that of time taken by the animal drawn plastic mulch laying machine. For the animal drawn plastic mulch laying machine the man-days required per hectare was 4 which were found to be relatively less than manual mulch laying, which required 48 man-days per hectare.

Fig. 1. Animal drawn plastic mulch laying machine

3.2 Energy Consumption

The energy consumed during mulch laying operation of laying of plastic sheet under different method of mulch laying is depicted in Table 2 and Fig. 2. It reveals that the maximum energy consumed 754.6 MJ/ha was recorded under laying of plastic by manually method of mulching. Developed mulch laying machine was consumed less energy 187.34 MJ/ha.

3.3 Cost Economic

The cost of operation included the hire charges of a pair of bullocks with the operator which came out to be 112.5 Rs/h. The cost of operation of the machine per hour as well as per ha is presented in Table 3. The annual use of the mulch laying machine was taken only 180 h/year, in present assumption the fixed cost of mulch laying machine 16.77 Rs/h and Repair and maintenance cost was 6.38 Rs/h. The total variable cost was found 137.63 Rs/h, finally it was observed that cost of operation of traditional method is highest i.e. 9615 Rs/ha then followed by of mulch laying machine which is 1196.78 Rs/ha Depicted in Table 3.

The data related to cost of cultivation, gross return, net return and benefit cost ratio are presented in table 4. Mulching method of vegetable cultivation was also compared with traditional method i.e. without mulching. The

lowest cost of cultivation was observed under traditional method of vegetable cultivation this may be due to that it does not required cost of plastic mulch and its laying cost. But the higher yield was observed in vegetable cultivation under mulching practices thus higher net return is noted under the same in both the crops. Higher benefit cost ratio for cauliflower and knol-khol was estimated as 2.38 and 2.44 respectively under mulching practice by using animal drawn plastic mulch laying machine. For the mulch laying machine the B:C ratio was relatively higher than the traditional method of mulch laying.

Table 1. Performance evaluation of animal drawn plastic mulch laying machine

Sr. No.	Particulars	Animal drawn plastic mulch laying machine	Traditional method
1.	Source of power	A pair of Bullock	Man
2.	Speed of operation, km/h	1.35	0.22
3.	Draft, N	448	-
4.	Theoretical field capacity, (ha/h)	0.162	0.027
5.	Actual field capacity, (ha/h)	0.115	0.013
6.	Field efficiency, %	71	48
7.	Power, hp	0.22	-
8.	Time req. h/ha	9	77
9.	Man-h /ha	27	385
10.	Man-days/ha	4	48

Table 2. Energy consumption of animal drawn plastic mulch laying machine

Sr. No.	Energy requirement for field preparation	Animal drawn plastic mulch laying machine	Traditional Method
1	Implement Weight, kg	75	-
2	Implement operational time, h/ha	9	-
3	Manual operational time, h/ha	-	77
4	Energy equivalent for human, MJ/h	1.96	1.96
5	Labour required	3	4
6	Energy equivalent for implement, MJ/h	62.70	-
7	Energy equivalent for animal, MJ/h	10.10	-
8	Useful life of implement, h	2500	-
9	Human, h	8	8
10	Machine energy equivalent, MJ/ha	16.35	-
11	Animal energy equivalent, MJ/ha	108.07	-
12	Human energy equivalent, MJ/ha	62.92	754.6
Total energy in mulch laying operation		187.34	754.60

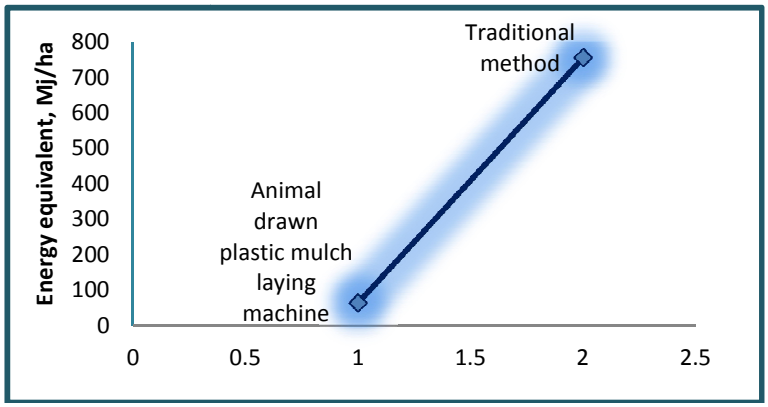

Fig 2. Energy consumption in mulch laying operation

Table 3. Calculation of cost of mulch laying operation per hour and per ha

S. No.	Particulars	Animal drawn plastic mulch laying machine	Traditional method of mulch laying
1.	Cost of machine, Rs	11500	-
2.	Life machine year, y	6	-
3.	Annual use, h/year	180	-
4.	Annual deprecation, Rs /h	9.58	-
5.	Annual interest @ 10% per annum, Rs/h	5.27	-
6.	Insurance 1%of the initial cost of machine	0.63	-
7.	Taxes 1% of the initial cost of machine	0.63	-
8.	Housing 1% of the initial cost of machine	0.63	-
Total	Fixed cost (Rs/year) annual use 180* h	3018.75	-
A.	Fixed cost, (Rs/h)	16.77	-
B.	Operational cost		-
1.	Repair and maintenance cost of @ 10% of capital cost per annum, Rs/h	6.38	-
2.	Wages of 1 operator (Rs 250/day***)	131.25	125
C.	Sum of operational cost, Rs/h	137.63	-
Total of (A+C)	Cost of operation, (Rs/h)	154.4	125
a.	Cost of operation, Rs/ha	1343	9615

** Annual use hours of developed animal drawn plastic mulch laying machine ***Wages of operator including bullock with mulch laying machine*

Table 4. Economic analysis of different vegetable growing methods

Particulars	Cauliflower			Knol-khol		
	Traditional	Manual mulching	Animal drawn machine	Traditional	Manual mulching	Animal drawn machine
Yield, q/ha	110.67	222.35	223.86	115.67	227.34	229.99
Cost of cultivation, Rs/ha	80323	103314	93674	82464	103728	94088
Gross return, Rs/ha	110670	222356	223861	115670	227340	229990
Net return, Rs/ha	30347	119042	130187	33206	123612	135902
B:C ratio	1.37	2.15	2.38	1.40	2.19	2.44

4. CONCLUSIONS

With a developed machine, we complete 1 ha in 9 hours and laying manual mulch takes 77 hours to complete 1 ha, so the developed machine works 8.55 times more than manual mulch laying. Field efficiency of developed machine was found 71%, which is 23% more than the manual mulch laying operation. Cost of operation of developed machine was found 1343 Rs/ha which is very less as compared to manual mulch laying 9615 Rs/ha. Mulch laying machine was cost effective technology for lying of plastic mulch at vegetable farms. The draft requirement (447.86 N) of developed machine was within the pulling capacity of local draught animal. The energy consumption of a developed machine was found to be 187.34 MJ/ha, which was lower than the conventional method of mulch laying operation. It saves time, labour and increases timeliness of operation. Low cost of machine which can be affordable for the farmers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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