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Performance evaluation of different weeders in cotton

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■ **ABSTRACT :** The present study was carried out to predict the performance different type's weeder in cotton crop so that efficient machine can be selected by farmer. The crop and machine performance parameter were recorded at three stages of cotton crop *i.e.* pre-square, square and flowering. The soil resistance was recorded before, just after weeding (3rd stage) and at the time of harvest. Yield data (g/plant) was recorded under all the treatments taken in both varieties. The weeding efficiency of different weeder was found between 74 to 89 per cent. The field capacity of tractor operated inter row rotary weeder was in the range of 0.54 to 0.59 ha/h whereas it was 0.8 ha/h in tractor operated high clearance cultivator, 0.16 ha/h with engine operated power weeder and 0.05 ha/h with manual hand hoe. The per cent saving in cost of operation with mechanical weeder over manual hand hoe was in the range of 80 to 93. The B:C ratio of mechanical weeder selected for study was in the range of 1.57 to 4.4 and payback period was in the range of 0.44 to 1.7 years. Time saving over manual hand hoe in weeding operation with the use of tractor operated weeder was 90 to 93 per cent whereas in engine operated weeder it was 68.7 per cent over manual hand hoe. The per cent saving in labour requirement with the use of mechanical weeder was in the range of 96 to 99 per cent over manual hand hoe. From result obtained from the study tractor operated weeder (operating width= 1500mm) was found suitable for cotton crop.

■ **KEY WORDS :** Cotton, Weeder, Hand hoe, Cultivator, Field capacity

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Cotton is a soft, fluffy staple fibre that grows in a boll, around the seed. It belongs to plants of the genus Gossypium. World cotton production during 2012-13 was 118.95 million bales (of 480 kg each), which was 4 per cent less than the year 2011-2012. World cotton area and productivity during 2012-13 was 34.129 million ha and 759 kg/ha, respectively (Anonymous, 2013). In India during year 2012-13, 11.70 million ha area with production of 25 million bales and productivity of 552 kg/ha was recorded. It is very gratifying to note that India has registered the highest growth with regards to cotton production with a share of 21 per cent in global cotton production, which is a giant leap by all imagination (Dogra *et al.,* 2010). India continued to maintain the largest area under cotton and second largest producer of cotton next to China with 34 per cent of world area. Area under across the world has been sluggish for the past few years. In general, the condition required for the cultivation of cotton are met within the seasonally dry tropic and subtropics in the Northern and Southern hemispheres, but a large proportion of cotton grown today is cultivated in areas with less rainfall (Cherkiattipol *et al.,* 2008). One of the main reasons for low productivity of cotton in India is the weed infestation as they compete for vital inputs (water, nutrients and sunlight) with main crop. However, production has increased due to sharp rise in yield.

Manual weeding is labour and time consuming, labourous, costly, and more fatigue in bending posture to do weeding with manual hand hoe (Bishwas *et al.,* 2000). The weeding operation in cotton represents a significant portion of operation cost (Veerangouda *et al.,* 2010). Most of the cost in cotton cultivation in India is attributed due to labour engaged in weeding and cotton boll picking operation. In developed countries like USA, Australia, China weeding and picking operations are done with machine. In India, some attempts have been made in recent years to develop tractor operated as well as engine operated power weeders for adoption under local Indian condition (Narang and Tiwari, 2005). There was large variation among these performance under different crop and conditions. A need was felt to test different types of weeders in cotton for their better suitability and adoptability among farmers. To meet the requirement of a suitable power weeder, different make of tractor operated rotary weeders and walk behind engine operated power weeder were tested and their performance were evaluated in this study to assess their feasibility for adaptability.

■ METHODOLOGY

Experimental site and treatments:

The experimental study on Performance evaluation of weeders in cotton was planned and conducted during *Kharif* (summer season). Performance evaluation of five different weeding methods was conducted on two varieties (American and Desi) of cotton crop. The following data had taken field evaluation, specification of weeders used, soil parameter, performance parameter of weeders used and economic feasibility.

T_1 = Tractor operated inter row rotary weeder having operating witdh 1440mm

T_2 = Tractor operated inter row rotary weeder having operating witdh 1540mm

T_3 = Tractor operated high clearance cultivator

T_4 = Walk behind engine operated power weeder

T_5 = Hand Hoe *i.e.* Kasola

Soil parameters:

Type, moisture content, bulk density and resistance force of soil are important parameters, which affect the

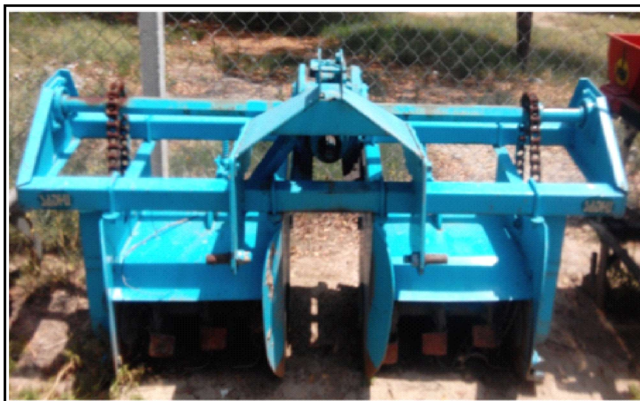

Fig. A : Inter row weeder (Width=1440mm)

Fig. B : Inter row weeder (Width= 1540)

Fig. C : High clearance cultivator

Fig. D : Walk behind power weeder

Fig. E : Hand hoe (Kasola)

performance of different weeders during weeding operation. Therefore, these parameters were recorded. The relative proportions of sand, silt and clay in a soil mass determine the texture of soil. Samples were taken from upper layer of 15 cm soil depth from the experiment site.

Moisture content of soil, per cent (db):

Soil moisture content of the experimental field was determined by thermo-gravimetric method. At first, the soil samples were dried in a hot air oven at 105ºC for about 24 hours until all the moisture present in the samples were lost and then the moisture content of a samples were calculated on dry weight basis with the help of following formula.

$$\text{Moisture content \% (db)} = \frac{\text{Wet weight of a soil sample} - \text{Dry weight of a soil sample}}{\text{Dry weight of a soil sample}} \times 100$$

Bulk density of soil (gcc^{-1}):

Bulk density of soil is defined as the mass of soil of a unit volume. Bulk density of soil was determined by core cutter sampling method. A core cutter of 1000cc was taken after soil samples were taken from different locations. The soil inside the core cutter was weighed dried in oven and bulk density was found out by dividing the dried weight of soil by volume of core cutter.

Soil resistance (kgf/cm^2):

Soil resistance is a parameter which affects soil compaction and plant root development. Soil resistance was measured by using electronic cone penetrometer at five randomly selected different locations in each treatment of both plots. Soil resistance was measured before, after weeding and at the time of harvest. The penetrometer was pushed vertically into the soil profile at a slow steady speed. The penetrometer automatically records the soil resistance data in the form of graph. GPS data was also recorded with each graph. The data recorded in cone penetrometer was uploaded in computer. The soil resistance is recorded corresponding to depth in form of a graph automatically by using software.

Performance parameters of selected weeders:

Speed of operation:

The speed of operation of tractor operated weeder and walk behind engine operated power weeder was determined in test plots by covering a distance of 20 m apart. The time was recorded to travel the distance of 20 m with the help of stop watch. The speed of operation was calculated in km h^{-1} as given below (Tajuddin, 2006):

$$S = \frac{D}{T} \times 3.6$$

where,

S = Speed of operation, km h^{-1}

T = Time in second to cover 20 m distance

D = Distance in meter

Weeding efficiency, per cent:

$$\frac{W_1 - W_2}{W_1} \times 100$$

where, W_1 = numbers of weeds in one square meter area before operation

W_2 = numbers of weeds in one square meter area after operation

Fuel consumption, l/h:

For measuring the fuel consumption, the fuel tank was top up to neck of fuel tank (full capacity) with diesel before weeding operation. The amount of refilling of fuel was measured with the help of measuring cylinder after each operation. The fuel consumption (litre) for that particular operation was recorded and it was expressed as liter per hour. At the time of refueling, careful attention was paid to keep the tank horizontal and not to leave empty space in tank and for checking proper level of tank, sprit level was used.

Field efficiency, per cent:

It is the ratio of actual field capacity to theoretical field capacity, usually expressed in percentage. It was calculated as follows,

$$E_e = \frac{A_{FC}}{T_{FC}} \times 100$$

where,

E_e = Field efficiency, %

T_{FC} = Theoretical field capacity, ha $h^{-1} = \frac{W \times S}{10}$

A_{FC} = Actual field capacity, ha h^{-1}

W = Theoretical width of operation, m

S = Average speed of travel, km h^{-1}

$$A_{FC} = \frac{A}{T_P + T_I}$$

where,

A_{FC} = Actual field capacity, ha h^{-1}

A = Area covered, ha

T_P = Productive time, h

T_I = Non-productive time, h (Time lost for turning, excluding refueling and machine trouble)

Economics:

The economic feasibility of tractor operated weeders was determined for making a decision to educate farmers for purchasing a new weeder by individual farmer (own) or use on custom hiring. There are two components of the cost of a machine namely; fixed cost and variable cost. Fixed cost includes such as depreciation, interest, insurances taxes and housing. Variable cost includes fuel, lubricates, operator's wages and repair and maintenance cost. Cost of operation was compared with conventional practice.

Labour requirement, man-h ha^{-1}:

It was calculated on basis of man hours required to carry out various tasks.

Cost of operation, Rs. h^{-1} and Rs. ha^{-1}:

The total cost of operation was determined as the sum of the fixed and variable cost. The total cost of operation per hour of the machine was computed. The cost of operation of the tractor was also calculated by the same procedure as given below. The cost of fuel, lubrication and operator were added to the variable cost. The total cost of operation of the weeder was determined by adding the hourly cost of operation of the weeder and tractor and expressed in rupees per hour. It was converted into area basis by multiplying it with the effective field capacity of the machine and expressed in rupees per hectare.

The cost of manual weeding was calculated by taking into account the cost of man-hour required for weeding the crop. The man-hour requirement for weeding was recorded on the test plot. The manual weeding was done by farm labourers. The costs thus observed under mechanical weeding/tractor drawn weeding and manual weeding was compared.

Estimation of cost of operation of weeding:

Fixed cost:

– Depreciation: This cost reflected the reduction in value of machine with use (wear) and time. While actual depreciation would depend on the sale price of the machines after its use, on basis of different computational method depreciation can be estimated. The following formula based on straight line method was used.

$$D = \frac{(P - S)}{L}$$

where,

D = Depreciation cost average per year

P = Purchase price of the machine (Rs.)

S = Salvage value of the machine taken as 10% of purchase price

L = Useful life of the machine in hrs per year

– Interest: Annual charges of interest were calculated on the basis of the actual rate of interest payable. It was taken at the rate of 7% of average purchase price of the machine.

$$A = \frac{(P+S)}{2} \times \frac{i}{100}$$

where,

A = Annual charges of interest, Rs. per year

P = Purchase price of the machine, Rs.

S = Salvage value of the machine, Rs.

i = Interest rate, per cent

– Insurances and taxes: It was calculated as 1 per cent of the average purchase price of the machine.

– Housing cost: It was calculated on the basis of 1 per cent of the average purchase price of the machine.

Variable cost:

Fuel cost: The fuel consumption depends on the size of the power unit and operating condition. The fuel cost was calculated by the following formula :

Fuel cost (Rs. h^{-1})=Rate of fuel (Rs. l^{-1}) x Fuel consumption (l h^{-1})

Lubrication cost:

It was considered as 30 per cent of fuel cost.

Repair and maintenance:

Repair and maintenance cost was considered 10 per cent for tractor and 5 per cent for different weeder used.

Skilled labour charges:

Charges which were taken by the laborers on the basis of the working 8 hours per day in the field. At present, a labour generally charges Rs. 300/- for one day (8 h) during weeding season.

B:C ratio:

It is the ratio of gross income to gross expenditure. The B:C ratio must be unity or more for a project investment to be considered worthwhile. This technique also ranks the project investments for selection. The ratio of unity indicates the coverage of costs without any surplus benefits. But usually the ratio has to be more than unity in order to provide some additional return over the costs for clear decision

$$B:C\ ratio = \frac{\text{Gross income, with use of machine}}{\text{Total expenditure, with the use of machine}}$$

Pay back period:

It is the number of year that would take for an investment to return its original cost through annual cash revenues generated, if the net cash revenues are constant each year, the payback period may be calculated from the equation;

$$P = \frac{I}{E}$$

where,

P = Payback period, yrs

I = Annual investment, Rs.

E = Expected annual net revenue, Rs.

RESULTS AND DISCUSSION

The soil samples were taken from different locations in the field at the time of weeding. The soil moisture content on dry weight basis was obtained. The average moisture content recorded at pre square, square formation and flowering stage was 12.07 per cent, 12.22 per cent and 12.29 per cent, respectively in American cotton (H1098-i). In Desi cotton (HD123) the average moisture content was 11.50 per cent 11.70 per cent and 11.28 per cent at pre square, square formation and flowering stage respectively as shown in Table 1. It was because of the reason that at all the three stages of weeding; there was a rainfall before weeding operation performed.

Bulk density, (gcc^{-1}):

Bulk density of soil was recorded at five different locations in the field. It ranged between 1.40-1.45 and 1.38-1.42 gcc^{-1} before and after operation respectively in cotton field as represented in Table 2. The average bulk density of soil at different stages was almost same.

Soil resistance, (kgf/cm^2):

The soil resistance was measured at different location in the field before and after weeding, at different stages (pre-square, square and flowering). Digital cone penetrometer was used to measure soil resistance force at various depths. The results clearly revealed that the soil resistance force after the use of rotary weeders when measured at the time of harvest was almost same *i.e.* in the range of 2500 kPa at soil depth of 0-750 mm. The soil resistance force just after weeding operation at flowering stage was upto 1500 kPa at all depth. It has been found that the soil resistance in the soil profile of 0-750 mm depth before and immediately after the tillage operation were within the prescribed limits *i.e.* 2000 kPa.

Table 1 : Soil moisture content in per cent of cotton field under study

	American cotton field			Desi cotton field		
	Pre Square	Square	Flowering	Pre Square	Square	Flowering
	12.15	12.90	12.70	11.20	11.10	11.30
	11.85	12.10	12.50	11.80	11.50	11.50
	12.45	12.00	12.30	11.70	11.80	11.00
	11.80	11.90	11.95	10.90	12.10	10.90
	12.10	12.20	12.00	11.90	12.00	11.70
Mean	12.07	12.22	12.29	11.50	11.70	11.28

Table 2 : Bulk density (gcc^{-1}) of soil

Treatments	Pre square		Square		Flowering	
	Before	After	Before	After	Before	After
T_1	1.45	1.41	1.44	1.41	1.42	1.39
T_2	1.42	1.39	1.41	1.39	1.41	1.38
T_3	1.41	1.40	1.40	1.39	1.40	1.39
T_4	1.44	1.41	1.43	1.42	1.42	1.40
T_5	1.43	1.42	1.42	1.41	1.41	1.40
Mean	1.43	1.40	1.42	1.40	1.41	1.39

There was no adverse effect on development of plant roots when the soil resistance force was 2000 to 2500 kPa in case of cotton crop. It means compaction was within the prescribed limit with the use of rotary weeder. Anonymous also reported that the soil resistance in the soil profile of 0-750 mm depth before and immediately after the tillage operation with rotavator and power harrow were within the prescribed limits *i.e.* 2000 kPa in wheat crop. However, it was more than 2000 kPa before using the tillage implements. The soil resistance

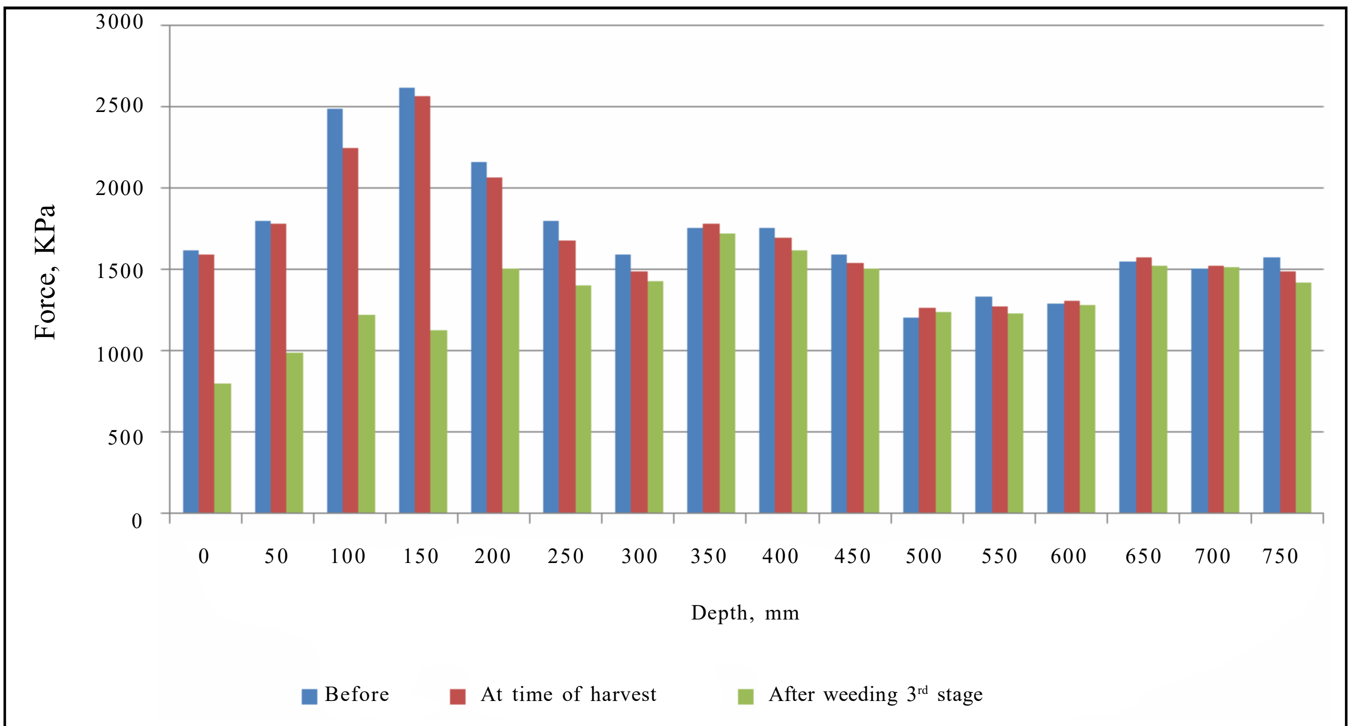

Fig. 1 : The soil resistance force at various depth of soil on three stages (T_1, Field-1)

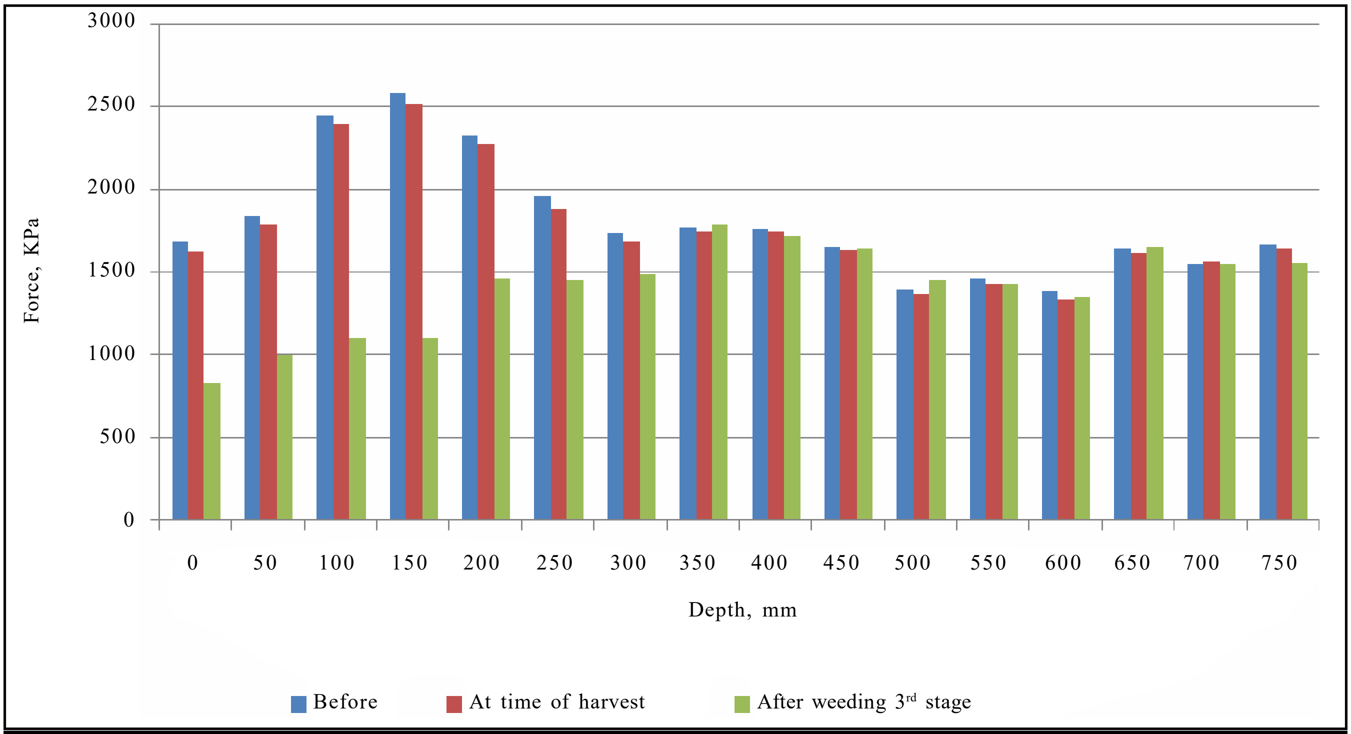

Fig. 2 : The soil resistance force at various depth of soil on three stages (T_1, Field-2)

Fig. 3 : A view of digital cone penetrometer to record soil resistance force

force up to 2000 kPa does not affect the development of plant root in wheat and paddy crop. Therefore, in case of cotton crop where the roots are penetrates for nutrients into soil for up to higher soil depth. So the results clearly indicates that the soil resistance force with the use of tractor operated rotary weeder upto 2500 kPa not affects the development of roots of plant. It was because of with the use of tractor operated rotary weeder (T_2). The higher depth of cut (95 mm), better soil pulverization and uniform leveling of soil in rows of cotton plants. The tractor operated rotary weeder use in treatment T_2 have a shaper of trapezoidal section behind the rotary weeder unit for leveling. This resulted in uniform depth of irrigation water applied and better aeration.

Weeding efficiency, per cent:

The average weeding efficiency was found more (85.5 to 89.61%) with the use of manual hand hoe (kasola) whereas with the use of mechanical weeders, the maximum average weeding efficiency (74.24 to 76.32 %) was observed in treatment T_2. The result clearly revealed that the weeding efficiency under selected varieties was non-significant whereas weeding efficiency was significantly affected with the use of different type of weeders at all the stages of crop in both the selected varieties. The weeding efficiency was non-significant at all the three stages with the use of treatment T_1, T_2 and T_4. The weeding efficiency was maximum (88.45 % at pre square, 88.61 % at square and 85.50 % at flowering) and was highly significant at all the three stages with the use of treatment T_5 in comparison to other treatment. The weeding efficiency was more in manual hand hoe because of the reason that the weeds between the plants were also uprooted whereas in mechanical weeders it was not possible to uproot the weeds grown in between the plants. There was no effect of weeding efficiency by growing different cotton cultivars (variety). Pannu *et al.* (2002); Anonymous (2010); Kathirve *et al.* (2007) and Kumar *et al.* (2014) reported that the weeding efficiency was found maximum (80 %) with the use manual hand hoe as with the use of tractor operated weeders it was 65-85 per cent.

Machine performance parameter:

The maximum field capacity of 0.8 ha/h was recorded in treatment T_3 at forward speed of 5.0 km/h. Minimum field capacity among mechanical weeders used (0.16 ha/h) was observed in treatment T_4 with forward speed of 2.5 km/h. However, the minimum field capacity of 0.05 ha/h was recorded in treatment T_5 (manual weeding with hand hoe). The results reported in Table 3 revealed that minimum fuel consumption was recorded in treatment T_3 (3.00 l/h) and maximum (3.50 l/h) was in treatment T_1, when compared among all the selected tractor operated weeders. However, the minimum fuel consumption was observed (1.25 l/h) in treatment T_4 (walk behind engine operated power weeder). The fuel consumption was directly correlated with the field capacity of the machine. The fuel consumption decreases with increases of field capacity. The per cent time saving over manual hand hoe was 90 to 93 per cent with the use of tractor operated weeder whereas it was 68.70 per cent with the use of walk behind engine operated power weeder over control. The machine performance parameter revealed that the average field capacity (0.54-0.59 ha/h) of tractor operated inter row rotary weeders *i.e.* under treatment T_1 and T_2 was almost same with field efficiency 68-70 per cent it was because of the forward speed and width of row covered per pass was almost similar. The minimum field capacity was observed in treatment T_5 (manual hand hoe). The average field capacity with the use of walk behind engine operated power weeders was 0.16 ha/h with field efficiency of 65 per cent. The average time taken was found maximum in manual hand hoe (20 h/ha) by engaging 20 persons working with 8 hours per day. It means 160 man-h/ha were required where as in tractor operated rotary weeder 1.69 to 1.85 man-h/ha was obtained. The average depth of cut was obtained with the use of tractor operated weeders *i.e.* T_1, T_2 and T_3, 90-95 mm whereas in manual hand hoe (T_5) the average depth of cut was 45 mm. Anonymous (2010) and Krishan *et al.* (2004) reported that the average field capacity of 0.3-0.5 ha/h with tractor rotary weeders. Pannu *et al.* (2002) also reported the average field capacity of 0.075-0.12 ha/h walk behind engine operated power weeder. It is evident from the results that the saving in time with the use of tractor operated weeder (T_1, T_2 and T_3) was about 90-93 per cent over manual hand hoe whereas with the use of walk behind engine operated power weeder it was 68.7 per cent.

Economics:

Labour requirement:

The results reported in Table 4 revealed that the T_5 have maximum labour requirement (160 man-h ha^{-1}) for weeding operation followed by treatment T_4 (6.25 man-h ha^{-1}), whereas in treatment T_1, T_2 and T_3 the labour requirement was about same. The labour requirement was maximum 160 man-h/ha in manual hand hoe whereas the minimum labour requirement was found in tractor operated weeders followed by walk behind engine operated power weeder. Kathirve *et al.* (2007) confirmed the various reporting that there was 96.5, 96.6 and 98.9 per cent of time saving with the use animal drawn weeder, walk behind engine operated power weeder and tractor

Table 3 : Performance parameters of the different weeders

Sr. No.	Parameters	Treatments				
		T_1	T_2	T_3	T_4	T_5
1.	Avg. field capacity, ha/h	0.54	0.59	0.80	0.16	0.05
2.	Avg. field efficiency, %	68.00	70.00	83.00	65.00	–
3.	Avg. time taken, h/ha	1.85	1.69	1.25	6.25	20.00
4.	Time saving over manual hand hoe, %	90.75	91.50	93.75	68.70	–
5.	Avg. speed of operation, km/h	4.00	4.20	5.00	2.50	–
6.	Avg. Fuel consumption, l/h	3.50	3.40	3.00	1.25	–
7.	Average depth of cut, mm	95	95	90	80	45

operated weeder-cum earthing implement, respectively.

Cost of operation:

To determine the economic prospectus of different weeders used, the cost of operation was determined. The cost of operation was calculated for each treatment. The cost of operation was maximum in treatment T_5 (8000Rs./ha) and minimum was observed in treatment T_3 (496.31 Rs./ha). The saving in cost of operation (Rs./ha) with the use of tractor operator weeders T_1, T_2 and T_3 was in the range of 7060.47, 7203.41 and 7503.69, respectively. The saving in the cost of operation with the use of walk behind engine operated power weeder was Rs. 6870.32/ha.

B:C ratio:

This criteria indicates the rate of return per rupee invested on machine. The benefit cost ratio was found to be highest *i.e.* 4.4 in treatment T_4 followed by T_3 (2.01), T_2 (1.70) and T_1 (1.57). The data are represented in Table 4. The results clearly indicate that investment in machine is economically viable. The B:C ratio was found maximum (4.4) with the use of engine operated power weeder whereas with the use of tractor operated weeder, the B:C ratio was in the range of 1.57 to 1.70 while for tractor operated high clearance cultivator the B:C ratio was 2.01. The reason for higher B:C ratio in walk behind engine operated power weeder was because of low cost of operation in comparison to other methods used.

Payback period:

It is the period required to recover the initial investment made on machine. The Pay Back period for tractor operated weeder make T_1, T_2 and T_3 was calculated by considering 250 hours of use per year and the payback period of mechanical weeders was found to be 1.7, 1.1 and 0.44 years, respectively. Payback period in case of walk behind engine operated weeder was found to be 0.8 years when working hours assumed 250 per year. The results were shown in Table 4. The payback period was minimum (0.44 years) in treatment T_3 because the initial investment of high clearance cultivator was less among mechanical weeders. The payback period with the use of other mechanical weeders used was 1.1 to 1.7 years. All the selected mechanical weeders were found economical viable.

Conclusion:

There was no significant effect of rotary weeder on soil compaction. The soil resistance force was within the prescribed limit *i.e.* 2000-2500 kPa. The field capacity of tractor operated inter row rotary weeders were in the range of 0.54-0.59 ha/h whereas the field capacity of tractor operated high clearance cultivator was 0.80 ha/h, in walk behind engine operated power weeder was 0.16 ha/h while in manual hand hoe it was 0.05 ha/h. The saving in cost of operation (Rs./ha) with the use of tractor operated weeder T_1, T_2 and T_3 was in the range of 7060.47, 7203.41 and 7503.69, respectively. The saving in cost of operation (Rs./ha) with the use of walk behind engine operated power weeder was 6870.32 over manual hand hoe. The weeding operation in cotton represents a significant portion of operation cost. Most of the cost in cotton cultivation in India is attributed due to labour engaged in weeding. The performance, field capacity, weeding efficiency, economics and ergonomics of tractor operated inter row rotary weeder (T_2) was found better in comparison to other weeders selected for study. Therefore, the tractor operated inter row rotary weeder used in treatment (T_2) is recommended. Provision for adjustment of row to row spacing should be provided depending upon crop row spacing. Check

Table 4: Economic parameters of different weeding method

Sr. No.	Parameters	Treatments				
		T_1	T_2	T_3	T_4	T_5
1.	Cost of operation, Rs./h	507.35	469.99	397.05	180.75	50.00
2.	Cost of operation, Rs./ha	939.53	796.59	496.31	1129.68	8000.00
3.	Saving in cost of operation over control, Rs./ha	7060.47	7203.41	7503.69	6870.32	-
4.	Saving in cost of operation over control, %	88.00	90.00	93.00	80.00	-
5.	B:C ratio, machine	1.57	1.70	2.01	4.4	-
6.	Payback period, years	1.7	1.1	0.44	0.80	-
7.	Labour requirement man-h/ha	1.85	1.69	1.25	6.25	160
8.	Saving in labour requirement, %	98.80	98.94	99.20	96.00	-

row planting in cotton may be studied so that the weeders can be operated in both the direction to increase weeding efficiency.

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