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Comparative performance evaluation of different mechanical equipment for weed control in sugarcane crop in Northern-Western Tarai Region of Uttarakhand

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Manual weeding/ interculture in sugarcane is a common method adopted by the farmers, in *Tarai* region of Uttarakhand, for weed control. However, due to non- availability of labour especially during peak season, the weeding/interculture operation is jeopardized. Also the labour demand in sugarcane weeding is very high compared to other cereal crops making this operation expensive. This study includes comparative performance evaluation of three different types of equipment, namely rotary tiller (T_{1S} -single pass and T_{1D} - two pass of rotary tiller), cultivator (T_2) and rotavator (T_3) for weeding operation in sugarcane. It was also compared with manual method of weed control (T_4) including the cost economics. The result revealed that among the mechanical methods, the highest weeding efficiency (93.20%) was obtained in T_{1D} followed by T_{1S} (88.01%), T_3 (87.97%) and T_2 (83.22%). The plant damage was observed highest (3.67%) in T_2 compared to T_3 (2.63%), T_{1D} (1.83) and T_{1S} (1.11%). Cost of weeding operation was found minimum (INR 374.37 per ha) for treatment T_2 followed by T_3 (INR 507.27 per ha), T_1 (INR 1186.18 per ha) and T_4 (INR 13194.55 per ha). The reduction in cost of weeding over the conventional method was found highest (97.16%) in T_2 followed by T_3 (96.16%) and T_1 (91.01%). The use of rotary tiller can be recommended to the farmer for weed management in sugarcane even at later stage of the crop when plant is tall enough making use of other equipment unfeasible.

Key words: Rotary tiller, intra-row weeder, cultivator, rotavator, manual weeding, mechanical weeding, sugarcane, economics.

INTRODUCTION

Sugarcane, *Saccharum officinarum* L., is grown under diverse agro-climatic conditions around the world. It is a renewable and natural agricultural resource that provides sugar, besides biofuel, fibre and fertilizer. Out of the total white crystal sugar production, approximately 70% comes from sugarcane and 30% from sugar beet. According to FAO, 2011 report, worldwide sugarcane occupies an area of 25.44 million ha with a total production of 1794 million metric tons. Out of 121 sugarcane producing countries, Brazil, India, China, Thailand, Pakistan,

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Table 1. Man-days requirement per hectare in different operations.

Operations	Crops		
	Sugarcane	Rice	Wheat
Planting/sowing	35-40	35-40	10-12
Interculture/weeding	65-70	25-30	22-25
Irrigation	10-12	10-12	8-10
Fertilizer	5-6	5-7	4-5
Harvesting including detrashing	150-200	60-70	35-40
Plant protection	12-15	4-5	4-5
Transport and loading	20-25	6-7	15-20
Total	332	158	106

Mexico, Cuba, Columbia, Australia, USA, Philippines, South Africa, Argentina, Myanmar and Bangladesh collectively represent 86% of the area and 87% of production. Brazil has the highest area (9.601 million ha), while Australia has the highest productivity (81.7 tons/ha).

India, the second largest sugarcane producing country after Brazil, cultivated sugarcane in 5.09 million ha area, which is much less compared to area under cereals, pulses and oilseeds, with a production of 357.67 Million Tones in the year 2011 to 2012. Sugarcane is grown mainly in the states of Maharashtra, Karnataka, Gujarat, Tamil Nadu, Uttar Pradesh, Punjab, Haryana and Bihar. Among these, Uttar Pradesh alone occupies about 43% of the total area under sugarcane cultivation dominating in production but in terms of productivity, Tamil Nadu leads with 104 tons/ha followed by Karnataka (90 tons/ha) and Maharashtra (83 tons/ha) which is higher than the national average productivity of 68.6 tons/ha. In the state of Uttarakhand it is grown mainly in its *Tarai* region (foot hills) where its production has gone down to 5.05 million tonnes in year 2010 compared to 7.34 million tonnes in year 2001. Highest sugarcane production of 7.68 million tonnes was registered during the year 2008.

It has been observed that the productivity of sugarcane, national average, is stagnating around 65-70 tons/ha for the last about 2 decades. Non implementation of package of practices and shortage of agricultural labour to undertake various cultural practices in time including poor weed management are some of the reasons responsible for low sugarcane yield. Therefore, there is a need to focus on other means including proper weed management for improving the production and productivity. It is reported that the yield loss caused by weeds may range from 15 to 75% depending upon its nature and intensity (Olaoye and Adekanye, 2006; Hasanuzzaman et al., 2009). The initial 90 to 120 days period of crop growth is considered as most critical period of weed competition and therefore weed-free field condition during these days must be ensured for higher yield.

Manual weeding, which is a common practice including in *Tarai* region of Uttarakhand, provides almost a clean weed free field but is highly labour demanding operation. The labour requirement for weeding/ interculture operation alone ranges between 400 to 600 man-h/ha (Tajuddin, 1996; Singh and Panghal, 2012) which is the highest when compared to wheat and rice (Table 1). Also it is a slow, arduous and time consuming process leading to higher cost of production. Scarcity of agricultural labourers during the peak season makes this task more difficult. Because of this reason as well as concern over environmental degradation and a growing demand for organically produced food, mechanical method of weed control is gaining popularity over manual and chemical methods. It is very effective, eliminates drudgery involved in manual weeding, kills the weeds and also keeps the soil surface loose ensuring better soil aeration and water intake capacity. Most of the tractors owning farmers, in Tarai region of Uttarakhand state, are using cultivator and rotavator, by manipulating the tynes/blades spacing, to cope up with the shortage of labour for weeding operation in sugarcane. Also there has been an increasing interest in the use of rotary tillers (mechanical intra-row weeders) due to their availability in the area during the recent years for weeding operation in sugarcane crop. However, systematic data is not available in respect of these equipment for weeding operation in sugarcane. The present study was, therefore, undertaken to compare the field performance of a rotary tiller, cultivator and rotavator for weeding operation in sugarcane crop along with traditional method including their economics.

MATERIALS AND METHODS

Description of equipment used

Three types of equipment namely self propelled rotary tiller (3.5 kW petrol engine operated), tractor drawn cultivator and rotavator were used for this study. The rotary tiller has a working width of 50 cm and only one row was covered during its operation. The second equipment was a tractor mounted type spring loaded 11 tine cultivator with overall width of 230 cm. Out of 11 tines, 5 tines were removed to adjust the cultivator within the row spacing of sugarcane. Three rows of sugarcane were covered at a time during

Table 2. Technical details of equipments used for the experiment.

S/ No	Parameter	Rotary tiller	Cultivator	Rotavator
1	Overall dimensions (length × width × height), mm	1280×620×1140	2600 x700 x103	2100x950x1150
2	Working width, mm	500	2300	2000
3	Weight, kg	42	210	446
4	Number of blades/ shovels in use	16	6	12
5	Number of rows covered in single pass	01	03	03
6	Type of soil working tool	C-type blade	Reversible shovel	L-type blade
7	Power source	Single cylinder, 4-stroke, air cooled, petrol engine with rated engine speed of 3600 rpm	Tractor operated	Tractor operated

single pass of this implement. The third equipment was a tractor mounted type rotavator having a work width of 200 cm. It had 8 flanges arranged on a rotor shaft with four L-shaped blades on each flange. Out of 8 flanges, 5 flanges were removed to adjust the rotavator to operate in between the rows of sugarcane. Three rows of sugarcane were covered at a time during single pass of this rotavator. Table 2 shows the technical details of the equipment used for the experiment. Manual method of weeding, a very common practice, was used as control for this experiment. The common tool used for manual weeding is *Kassi* which is a long handled spade with 20 cm wide blade. It is commonly used in upright posture by the labourers. Figure 1 shows the different equipment in weeding operation.

Experimental field

The performance evaluation of all the three mechanical equipment as well as manual weeding was carried out on University Farm (T-block, Eastern Zone Beni) of G. B. Pant University of Agriculture and Technology, Pantnagar, India during the month of April. The sugarcane crop was planted at a row space of 75 cm. The soil of experimental field is of alluvial origin and classified as silty-clay-loam having 15.1, 55.2 and 29.7% of sand, silt and clay respectively. The weeding operation was performed after 80 days of planting of sugarcane crop. The main field was divided into 20 sub plots each of size 20 × 6 m. Figure 2 shows the layout of the experimental field.

Experimental parameters

The experiment was laid out in Completely Randomized Design (CRD) with five treatments (T_{1S} -single pass of rotary tiller; T_{1D} - two passes of rotary tiller; T_2 -weeding by cultivator; T_3 -weeding by rotavator and T_4 - manual weeding) and four replications of each treatment.

Performance indicators

Weeding efficiency, plant damage and field capacity was taken as performance indicators. Besides these field efficiency, fuel consumption, size of soil aggregate, bulk density and cost of operation were also determined. Weeding efficiency and plant damage were determined as per the standard procedure (RNAM, 1983) using the following equations:

$$\text{Weeding efficiency, \%} = \frac{W_1 - W_2}{W_2} \times 100 \quad (1)$$

$$\text{Plant damage, \%} = \frac{Q_2}{Q_1} \times 100 \quad (2)$$

Where, W_1 and W_2 are the weight of weeds, in grams, before and after weeding operation respectively. Q_1 and Q_2 are the number of plants in 10 m row length before and after tilling operation respectively.

Effective field capacity (F_c), field efficiency (Fe) and work capacity (Wc) were calculated by the following equations (Hunt, 1995).

$$F_c = SWE/10 \quad (3)$$

$$E = (T_e/T_t) \times 100 \quad (4)$$

$$W_c = 1/F_c \quad (5)$$

Where, F_c is the effective field capacity (ha/h), *S* is the speed of operation (km/h), W is the effective width of coverage per run (m), E is the field efficiency (%) of equipment, T_e and T_t are the effective and total working time (h) and W_c is the working capacity (h/ha), respectively.

Cost analysis was performed by determining the fixed and variable cost for all the equipment. Straight line method was used for determining the depreciation cost. Salvage value has been assumed as 10% of the purchase price. Insurance, taxes and shelter has been assumed negligible for the equipment and the same has been taken as 3% for tractor. Rate of interest has been assumed as 10% per annum. Fuel charge has been determined based on actual fuel consumed and its prevailing rate in the market. Lubrication charge has been assumed as 30% of the fuel charge. Repair and maintenance has been assumed as 6% of purchase price per annum. Labour charge has been considered as per the prevailing rate per day (8 h work). Annual operation of the equipment has been considered as 720 h based on maximum 90 days (daily 8 h) of actual use in sugarcane weeding. The following equation was used to determine the cost of operation as suggested by Hunt (1995).

$$C = Fc + Rm + F + O + L \quad (6)$$

Where, C = Cost of operation, INR/h, Fc = Fixed cost, INR/h which includes depreciation, interest on capital, insurance-taxes and shelter cost, RM = Repair and maintenance costs, INR/h, F = Fuel cost, INR/h, O = Lubrication cost, INR/h, L = Labour cost, INR/h (assumed as INR 190/day).

Statistical method

The data collected during the experiment was analyzed for its

Treatment T_1- Rotary tiller

Treatment T_2 - Cultivator 11 tine (6 tines in use and others removed)

Treatment T_3 - Rotavator (200 cm wide with 8 flanges, 3 flanges in use while others removed)

Treatment T_4- *Kassi* (Spade with long handle, 20 cm wide blade)

Figure 1. Equipments in weeding operation in sugarcane field.

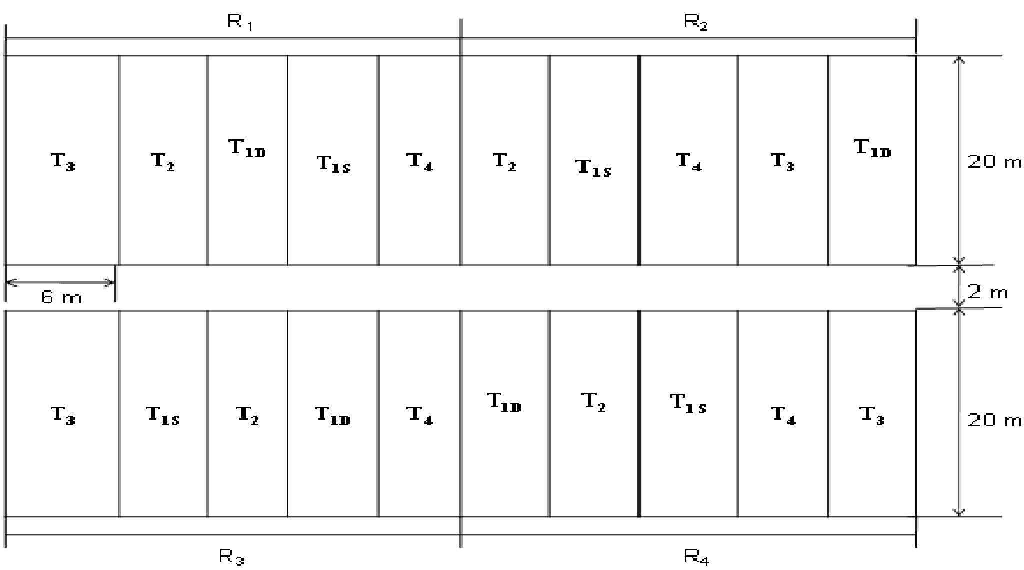

Figure 2: Layout of the experimental field. T1S – Weeding by single pass of rotary tiller, T1D - Weeding by double pass of rotary tiller, T2 – Weeding by cultivator, T3 – Weeding by rotavator T4 – Manual weeding, R1….4 – replications.

significance using Completely Randomized Design (CRD).

RESULTS AND DISCUSSION

Weeding efficiency

The weeding efficiency was determined by considering the weight of weeds before and after weeding operation. The weeding efficiency for single pass and double pass of rotary tiller was found highest followed by treatment T_3 and T_2 (Table 3). Weeding efficiency for double pass of rotary tiller was found higher by 5% than its single pass. The higher soil cutting ability of rotary tiller and rotavator contributed to higher weeding efficiency where as the

Table 3. Machine Parameters as observed in various treatments.

Treatments	Weeding efficiency, %	Plant damage, %	Actual field capacity, ha/h	Field efficiency, %
T_{1S}	88.01	1.11	0.063	96.93
T_{1D}	93.20	1.83	0.085	94.10
T_2	83.22	3.67	0.940	80.92
T_3	87.97	2.63	0.690	87.08
T_4	98.02	0.56	0.0018	-

Table 4. Analysis of variance for performance indicators and other parameters.

Source	Weeding efficiency	Plant damage	Bulk density	Clod mean weight diameter	Actual field capacity, ha/h	Fuel consumption
	F-values					
Replication	0.7044182	2.468080	14.54738	0.7598153	1.560357	0.3691275
Treatments	262.6447**	32.28242**	3.768921*	48.69866**	650.8756**	14463.56**

*Significant and ** Highly significant, respectively at $P \leq 0.05$.

reversible shovel does not provide better soil cutting leading to lower weeding efficiency. Weeding efficiency of manual weeding method (T_4) was observed highest among all the treatments which may be due to the fact that more precisely intra row area could be covered in manual method of weeding. Statistical analysis (Table 4) indicated that the weeding efficiency for different weeding methods varied significantly at 5% level of significance except treatments T_{1S} and T_3.

Plant damage

The plant damage for single pass and double pass of rotary tiller was found 1.11 and 1.83% (Table 3). The plant damage for treatment T_{1D} (double pass of rotary tiller) was found to increase by about 0.72% compared to treatment T_{1S} (single pass of rotary tiller). This may be due to the increase in depth of operation causing more uprooting of the plants. The plant damage, on an average, for other weeding methods viz manual weeding, rotavator and cultivator was found 0.56, 2.63 and 3.67% respectively. The lowest plant damage was observed in case of manual weeding that may be because of shallow depth of operation and care taken during the weeding operation. Among the mechanical methods of weeding, single pass of rotary tiller showed minimum plant damage. The plant damage was found statistically significant for all the weeding methods (Table 4).

Field capacity and field efficiency

Actual field capacity for different weeding methods was determined which showed higher field capacity for treatment T_2 followed by treatments T_3 and T_1 (Table 3). The higher field capacity for treatment T2 was due to more width of operation of cultivator. The field capacity of rotary tiller in double pass ($\mathbf{T_{1D}}$) was found 35% higher when compared with its single pass which may be due to higher speed of operation. The field capacity for different weeding methods was found statistically significant (Table 4). The field efficiency (Table 3) for single pass of rotary tiller was found to vary in between 96.69 to 97.18% with an average of 96.93% which was found slightly less (94.1%) for double pass of the tiller. The average field efficiency of weeding by rotavator and cultivator was 87.08 and 80.92% respectively.

Fuel consumption

The fuel consumption for single pass of rotary tiller (T_{1S}) was found 0.58 l/h and little less, 0.53 l/h, for its double pass operation (T_{1D}). The fuel consumption for other treatment T_2 and T_3 (weeding by cultivator and rotavator) was found as 3.19 and 2.87 l/h respectively (Table 5). The statistical result indicated that the fuel consumption for different weeding methods varied significantly at 5% level of significance (Table 4).

Clod size and bulk density

The clod mean weight diameter for single and double pass of rotary tiller was found as 7.67 mm and 4.01 mm respectively (Table 5). The reduction in clod size, in case of double pass, was about 47.7% which may be due to

Table 5. Fuel consumption and changes in soil parameter values in different treatments.

Treatments	Fuel consumption, l/h	Fuel consumption, l/ha	Clod size, mm	Bulk density, g/cc	Moisture content, %
Initial			-	1.34	16.68
T_{1S}	0.58	9.21	7.67	1.27	15.16
T_{1D}	0.53	6.24	4.01	1.26	13.63
T_2	3.19	3.39	8.08	1.29	13.92
T_3	2.87	4.16	4.98	1.23	14.99
T_4	-	-	8.09	1.24	13.78

Table 6. Basic parameters for cost estimation of different equipment.

Power source/ Equipment	Initial cost, INR	Salvage value, INR	Useful life, year	Annual use, h	Effective field capacity, ha/h	Work capacity, h/ha
Tractor	575000	57500	10	1000	-	
Rotavator	73000	7300	8	720	0.69	1.45
Cultivator	27000	2700	10	720	0.94	1.06
Rotary tiller	46000	4600	10	720	0.074	13.51
Manual method	ND	ND	ND	ND	0.0018	555.56

ND- Not defined.

Similarly clod size in treatment T_2 and T_4 was also comparable. However, statistical analysis showed that clod size varied significantly, at 5%, for all the weeding methods (Table 4).

The average bulk density (Table 5) for treatment T_{1S} and T_{1D} was found as 1.27 and 1.26 g/cc. The reduction in bulk density values, in rotary tiller, was observed nearly same. The average bulk density for treatments T_2, T_3 and T_4 was found as 1.29, 1.23 and 1.24 g/cc respectively. The decrease in bulk density was observed higher (8.05%) in case of treatment T_3 and the same was observed less (3.88%) in case of weeding by cultivator (T_2) when compared with other treatments. The bulk density value for treatment T_2 was found significantly higher than other treatments. The change in bulk density values for all other treatments except T_2 was found insignificant (Table 4).

Moisture content

Soil moisture content was determined for each test plot and the results have been presented in Table 5. The average initial soil moisture content of the experimental plots was observed as 16.68%. The final soil moisture content was observed to reduce for all the treatments as compared to initial value, however, the moisture loss was observed more in treatments T_{1D} and T_4 followed by T_2, T_3 and T_{1S}. In treatments T_2 and T_4 the moisture loss was observed to be almost similar that may be due to bigger size of clods providing more surface area for moisture evaporation.

Cost analysis

Cost of weeding operation for different treatments was determined using the data presented in Table 6. The detailed analysis is presented in Table 7 which showed least expenditure (INR 374.37 per ha) for treatment T_2 followed by T_3 (INR 507.27 per ha), T_1 (INR 1186.18 per ha). Highest expenditure of INR 13194.55 per ha was found incase of T_4 that is, manual method of weeding. The minimum cost of weeding in T_2 is due to the higher field capacity of cultivator as compared to weeding by other methods. Manual weeding was found to be expensive which is due to very less field coverage per unit of time. Similarly the cost reduction over the conventional method was found highest (97.16%) in T_2 followed by T_3 (96.16%) and T_1 (91.01%).

Conclusion

Among the mechanical methods, treatment T_{1D} and T_{1S} (weeding by rotary tiller - one and two pass) was found more effective compared to treatments T_2 (weeding by cultivator) and T_3 (weeding by rotavator) based on higher weeding efficiency and minimum plant damage. Treatment T_{1S} and T_3 was found equally effective as far as weeding efficiency is concern. The cost of weeding, when compared with conventional method, reduced in

Table 7: Different components of cost estimation for various treatments

Power source/ Equipment	Depreciation, INR/h	Interest on capital @ 10% per anum, INR/h	Insurance, taxes & shelter @ 3% per anum, INR/h	Total fixed cost with tractor, INR/h	Fuel cost, INR/h	Lubrication cost @30% of fuel cost, INR/h	Total repair and maintenance cost with tractor @ 6%,, INR/h	Labour charge, INR/h	Total variable cost, INR/h	Total cost of operation		Cost reduction over manual method, %
										INR/h	INR/ha	
Tractor	51.75	31.63	17.25	-	-	-	-	-	-		-	-
Rotary tiller (T_1)	5.75	3.51	-	9.26	39.20	11.76	3.83	23.75	78.54	87.8	1186.18	91.01
Cultivator (T_2)	3.38	2.06	-	106.06	143.55	43.07	36.75	23.75	247.12	353.18	374.37	97.16
Rotavator (T_3)	11.41	5.58	-	117.61	129.15	38.75	40.58	23.75	232.23	349.84	507.27	96. 16
Manual weeding/ interculture (T_4)	-	-	-	-	-	-	-	23.75	-	-	13194.55	Base

Assumptions: The insurance, taxes and shelter cost have been considered negligible for equipment, Fuel rate: Diesel @INR 45/lit and Petrol @INR 70 /lit, labour wage - INR 190 per day of 8 h.

T2, T3 and T1 by 97.16, 96.16 and 91.01% respectively. The conventional method of weeding was found expensive compared to mechanical methods. The use of rotary tiller, among the mechanical methods, can be recommended to the farmers for efficient weed management even though the cost of operation is high. The advantage is that as it covers single row of the crop it can be used even at a later stage when plant grows tall enough. The use of cultivator and rotavator is not feasible at later stage (beyond 120 days of crop) as it covers more than one row and the plant will get damage when the height of the plant is more than the toolbar height.

Conflict of Interest

The authors have not declared any conflict of interest.

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