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A Upadhyay
Department of Farm Machinery and Power Engineering, CAET, Junagadh Agricultural University, Junagadh, Gujarat, India

K B Jhala
Professor and Head, Department of Farm Machinery and Power Engineering, CAET, Junagadh Agricultural University, Junagadh, Gujarat, India

H Chavda
Department of Farm Machinery and Power Engineering, CAET, Junagadh Agricultural University, Junagadh, Gujarat, India

S Pandey
Ph.D. Scholar, Department of Farm Machinery and Power Engineering, SVCAET, IGKV, Raipur, Chhattisgarh, India

Corresponding Author:
A Upadhyay
Department of Farm Machinery and Power Engineering, CAET, Junagadh Agricultural University, Junagadh, Gujarat, India

Feasibility analysis of flame weeding in comparison to mechanical weeding and hand weeding

A Upadhyay, KB Jhala, H Chavda and S Pandey

Abstract
An experiment was conducted at the experimental field of Junagadh Agricultural University, Gujarat, India during summer season of 2021. Three weeding methods *viz*. flame weeding (T_1), mechanical weeding (T_2) and hand or manual weeding (T_3) were performed in experimental plot. The performance of different weeding methods was compared in terms of weed control efficiency, operational time, energy consumption and cost of operation by using Randomized Block Design. The performance parameters were evaluated and analyzed to draw conclusion in accordance to statistical analysis, in which it was concluded that treatments had significantly (p<0.05) influenced the performance parameters. The weed control efficiency for T_1, T_2 and T_3 were observed as 91.10%, 78.26% and 98.06%, respectively. The operational time for T_1, T_2 and T_3 were observed as 13.24 man-h/ha, 80.56 man-h/ha and 255.75 man-h/ha, respectively. The energy expended manually for T_1, T_2 and T_3 were observed as 2500.24 MJ/ha, 157.89 MJ/ha and 501.27 MJ/ha, respectively. The operational cost T_1, T_2 and T_3 were observed as 4754.62 ₹/ha, 3180.01 ₹/ha and 9590.79 ₹/ha, respectively. Keeping in view the number of labours required and the cost of operation, the overall performance of flame weeding was found better than that of mechanical and hand weeding.

Keywords: Energy consumption, flame weeding, mechanical weeding, thermal weed control, weed research

Introduction
In agriculture, among several constraints like climate change, insect, pests and weeds, weeds are major reasons for reduction in per unit area yield in India. It is considered that reduction due to weed only, in yield is estimated to be 16-42% which depends upon location and crop, it includes 1/3rd of the cultivation cost (Rangasamy *et al*., 1993) [11]. Weed control is the most essential operations done in farm under cropping system, but in agricultural unit operation, it is also equally labour-intensive. During a cultivation season, weeding accounts for 25% of the total labours required (900-1200 man-h/ha) (Yadav and Pund, 2007) [13]. To overcome this worldwide problem, weed scientists are finding an alternate weeding practice based on the principles of integrated weed management in order to help in reducing dependence on herbicide and also give organic farmers with an effective method of weeding or weed management.

In flame weeding recently, scientists' interest has been renewed, especially due to the current advancement in flame technology. Weed control methods are categorized into chemical. cultural, physical and biological. Each method of weed control has its own pros and cons. Under all weed types and situations, none of the single method is successful. Various methods used for weed control like hand weeding or manual weeding, mechanical weeding, chemical weeding, flame weeding, khurpi, animal drawn blade hoe weeders, power weeders, tractor drawn weeders, push type weeders etc. are in existence. By applying direct heat to plants, flame weeding systems control weeds, which causes a rapid change in the temperature of plant cells internally. This phenomenon blows out the cell's content 95% of which is water that causes rupture in the walls of cell. Flame weeding also helps in preventing other crucial weeds from being spread by inhibiting development of weeds, when the field is not being ploughed and also by restricting them in the early growth stage. (Mojzis *et al*., 2015) [7].

Physical or mechanical methods of weeding are being employed ever since man started cultivation of crops. The mechanical method includes cheeling, hand weeding, sickling, mowing, tillage, flooding, hoeing, digging, mulching etc. Tillage eradicates weeds from the soil which results in their death. It damages plants through stem pruning and injury of root, reducing their regenerative capacity or competitiveness.

Hoeing is more effective particularly on annuals and biennials as growth of weed can be reduced. Hand weeding is precise but requires about 900-1200 man-h/ha land (Nag and Dutta, 1979) [8]. Weeding cannot be carried out within short duration of time, due to less availability of labour in peak cultivating seasons. Moreover, due to awkward posture during working of an operator, the operation is cumbersome which causes drudgery to operator. Drudgery causes pain in back which may leads to musculoskeletal problem or disorder (Rainbird and Neil, 1995) [10]. It also depends upon the infestation of weeds. The availability of labour is also a primary concern. So, In order to find the feasible method of weeding, statistical analysis of comparison of performance parameters between flame weeding, mechanical weeding and hand weeding was observed.

Materials and Methods

An experiment was conducted at the field of Junagadh Agricultural University, Junagadh (Gujarat) (20°30'N latitude and 69°41'E longitude) in summer season in 2021. In the experimental plot, soil was clay loam (silt: 39.64%, sand: 23.36% and clay: 37%). Field observations like number of weeds, operational time, width of operation and required labours for weeding were recorded. The performance of flame weeder was evaluated and compared with mechanical weeding and hand weeding in terms of weed control efficiency, operational time, energy consumption and cost of operation.

Flame weeding

A Flame weeder was used for weeding in the experimental field and its effect on weeds were recorded for determination of weed control efficiency, operational time, energy consumption and cost of operation. Flame weeding operation and its effect on weeds are shown in figure 1.

Fig 1: (a) Flame weeding operation

Fig 1: (b) View of field 7 days after treatment

Mechanical weeding

A double wheel blade hoe was used for mechanical weeding in the experimental field and its effect on weeds were recorded for evaluation of performance parameters. Mechanical weeding operation and its effect on weeds are shown in figure 2.

Fig 2: (a) Mechanical weeding operation

Fig 2: (b) View of field after operation

Hand weeding

Hand weeding operation was carried out in the experimental field and its effect on weeds were recorded for evaluation of performance parameters. Hand weeding operation and its effect on weeds are shown in figure 3.

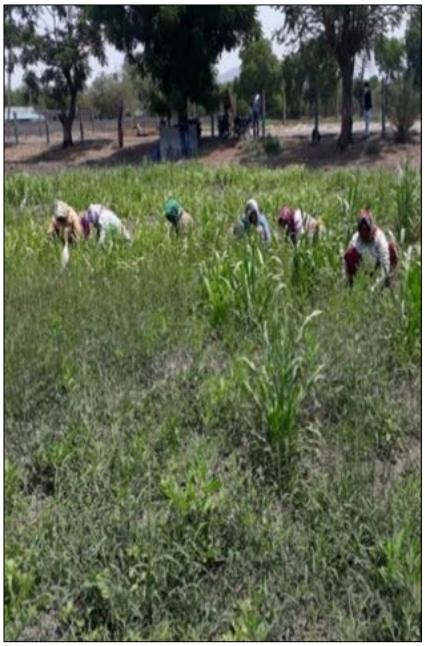

Fig 3: (a) Hand weeding operation

Fig 3: (b) View of field after operation

Performance parameters studied for all the three methods under this study, are as follows

The experiment was conducted using Randomized Block Design with a plot size of 10 x 3 m. with three replications. Treatment includes Flame weeding as T_1, Mechanical weeding as T_2 and Hand weeding as T_3.

1. Weed control efficiency

Weed control efficiency was determined using following suggested formula by Rangasamy *et al*. (1993) [11].

Weed control efficiency (%) = $\frac{N_1-N_2}{N_1}\times 100$ .... (1)

Where,

N_1 = Number of weeds present before operation
N_2 = Number of weeds present after operation

2. Operational time

The value of operational time per hectare for all the three weeding methods, were calculated using area of experimental plot and the time taken for the operation in particular method.

3. Energy consumption

All the three methods under study were employed in the field and the energy consumption in each method were determined on the basis of time spent and number of labours involved in the operation using the formula given by (Chaudhary *et. al*, 2006) [3]:

$$E_m = 1.96\, N_m T_m \quad \ldots(2)$$

Where,
E_m = Manual energy expended (MJ/ha);
N_m = Number of labours indulge on farm activity;
T_m= Time usefully spent by a labour during farm work (h/ha)
Fuel energy was also taken into consideration along with manual energy in case of flame weeding method.

4. Cost of operation

The operational cost of weeding on hectare basis was calculated by taking fixed costs and variable costs into consideration which was involved in the operation by using straight line method.

Results and Discussion

The results of performance parameters in terms of weed control efficiency, operational time, energy consumption and cost of operation for different treatments were statistically analyzed and conclusions were drawn accordingly.

Weed control efficiency

The maximum value of weeding efficiency or weed control efficiency was 98.06% for hand weeding (T_3) whereas the minimum value of weed control efficiency was 78.26% for mechanical weeding (T_2). Weed control efficiency of flame weeding (T_1) was 12.84% more as compared to mechanical weeding but, 6.96% less than hand weeding. Since, hand weeding was highly selective and precise but the posture in which it is carried out, is not ergonomically comfortable/safe.

Operational time

The maximum value of operational time was 255.75 man-hr./ha for hand weeding (T_3) whereas the minimum value of operational time was 13.24 man-hr./ha for flame weeding(T_1). Operational time for flame weeding was found to be 83.58% and 94.82% less than that of mechanical weeding (T_2) and hand weeding, respectively. Flame weeding seems to be best with the least operating time.

Energy consumption

The maximum value of energy consumption was 2500.24 MJ/ha for flame weeding (T_1) whereas the minimum value of energy consumption was 157.89 MJ/ha for mechanical weeding (T_2). Energy consumption for mechanical weeding was 93.68% less than that of flame weeding and hand weeding (T_3) was 79.95% less than that of flame weeding, respectively.

Cost of operation

The maximum value of operational cost was 9590.79 ₹/ha for hand weeding (T_3) whereas the minimum value of cost of operation was 3,208.67 ₹/ha for mechanical weeding (T_2). Cost of operation for flame weeding (T_1) was 50.42% less

than that of hand weeding but 32.51% more than that of mechanical weeding because cost of operation for flame weeding mainly depends on the fuel cost. Since, mechanical weeding had given gives less weed control than flame weeding. Therefore, flame weeding was better than mechanical weeding.

Comparison of different parameters

The performance parameters such as weed control efficiency, operational time, energy consumption and cost of operation were influenced significantly (p<0.05) by different method of treatments as given in table 1.

Table 1: Effect of different treatments on performance parameters

Treatment	Weed control efficiency (%)	Operational time (man-h/ha)	Energy consumption (MJ/ha)	Cost of operation (₹/ha)
Flame weeding (T_1)	91.10	13.24	2500.24	4754.62
Mechanical weeding (T_2)	78.26	19.84	157.89	3208.67
Hand weeding (T_3)	98.06	255.75	501.27	9590.79
SEm±	0.818	1.456	17.443	77.869
CD	2.708	4.823	57.769	257.884
CV	2.051	3.382	3.704	2.981

It is revealed from the figures that the weed control efficiency is found to be highest for hand weeding followed by flame weeding and mechanical weeding respectively, whereas the operational time is found to be highest for hand weeding followed by mechanical weeding and flame weeding respectively. The energy consumption is found to be highest for flame weeding followed by hand weeding and mechanical weeding respectively, whereas cost of operation is found to be highest for hand weeding followed by flame weeding and mechanical weeding respectively.

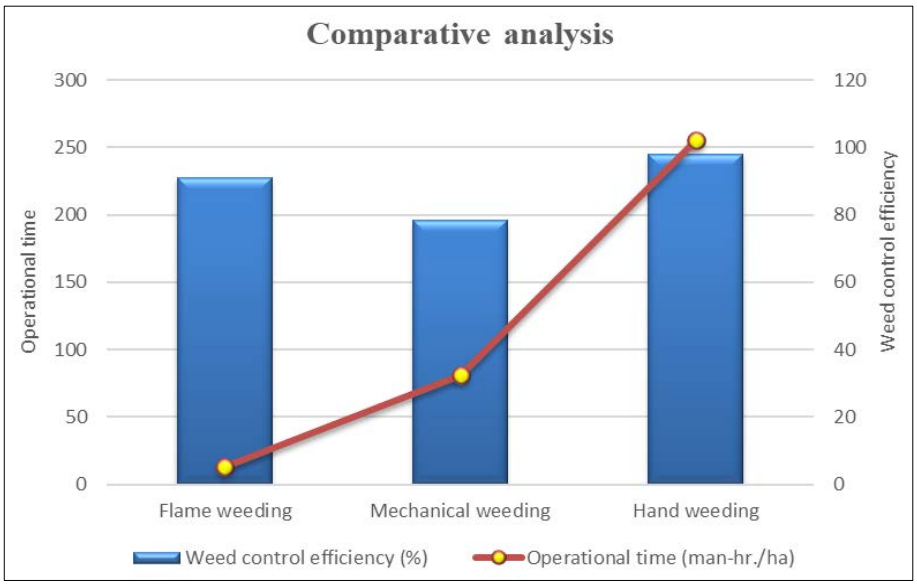

Fig 1: Comparison of weed control efficiency and operational time for different weeding methods

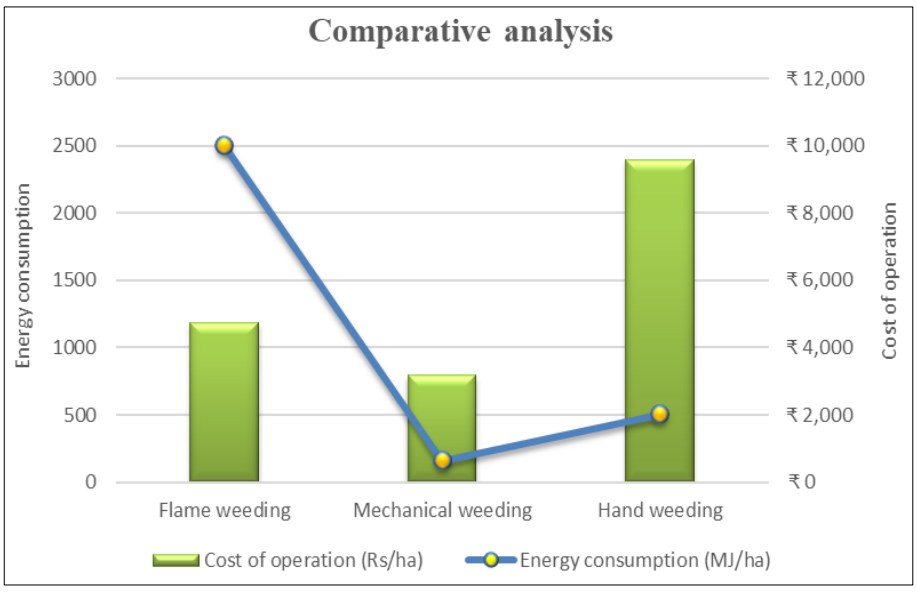

Fig 2: Comparison of cost of operation and energy consumption for different weeding methods

Conclusions

Flame weeding controls, less weeds than hand weeding but more than mechanical weeding. Since, hand weeding is highly selective and precise, but the operation is cumbersome causing drudgery due to awkward posture of working of an operator, it is ergonomically not comfortable. Flame weeding takes very less time for completing operation as compared to other methods. Looking to the results obtained, it can be concluded that the overall performance of flame weeding was found more feasible than other methods, irrespective of energy consumption.

Conflict of Interests

There is no conflict of interest among Authors and Co-authors and have no conflict of interest to declare.

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