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Evaluation of intercultural implements for their operational performance, energetics and economics utilized under rainfed maize cultivation

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Abstract
Infestation of weeds is a serious challenge under rainfed situations and intermittent rains aggravate the situation towards more complexity and their management remains crucial and requires matching strategies. Besides, for facilitating aeration, that is highly required for maize, and conservation of soil moisture through mechanical manipulation of soil through different devices is also very important for rainfed maize cultivation. In order to facilitate these objectives, often in rainfed maize growing regions, field operations are planned with various implements. The various implements meant for these purposes have their own relevance in terms of their operational performance, energetics and economics. Improved intercultural implements namely *kudali*, CIAE Dryland Weeder, Arjia Improved Dry land Weeder, Bullock Drawn *kulpha* and Power Weeder were evaluated at Dryland Farming Research Station, Arjia Bhilwara, India for their performance at field level in comparison to traditional implements (*kudali*) during the *Kharif* season of 2009 in maize crop. Results revealed that Power Weeder with blade was better than manual weeding by *kudali* followed by bullock drawn *kulpha* with respect to energy conservation (48.9 and 42.2%, respectively) and reduction in operating cost (74 and 52.3%, respectively) for weeding in maize. The power weeder required the least labour in terms of man days (8.7 man days / ha) in comparison to other implements. Arjia Improved Dryland Weeder required less supplementary manual labour (16.3 man days / ha) as compared to CIAE Dry land Weeder and reduced weed control cost by 34% in comparison to control.

Keywords: Power weeder, weeding efficiency, *kulpha*, soil moisture, energetics

Introduction
Globally maize is the third most important cereal crop after wheat and rice and in India, cultivated on 9.22 million hectares area, producing 28.78 million tonnes with productivity of 3.12 tonnes per hectare (Nayak *et al.,* 2023) [14]. Generally maize is grown during *Kharif* (June to October) characterized by intermittent rains inducing spans of high humidity and dry spells with consequent flushes of weed infestation. Weeds are the most severe limiting factor for crop production causing 33% of losses. Weeds compete with crops for nutrients, moisture, light, and space particularly under rainfed regions where the crop is sparsely grown, severe weed infestation is experienced (Naidu and Murthy 2014) [11]. In maize, initial 17-29 days are critical period for weed competition (Rani *et al.* 2020) [20] with infestation of both types of weeds namely grassy and broad leaved causing considerable detrimental effect on growth and yield, reducing maize yields considerably and this may go up to 90% (Dalley *et al.* 2006 Reddy and Tyagi 2005 and Gharde *et al.* 2018) [2, 21, 5].
Thus, timely weed management is essential (Rao and Nagamani) that counts for 10% of the total cost of cultivation (Tajuddin *et al*., 1991 and padole, 2007) [17].
Herbicidal weed management under such situations is not preferred because of uncertainties of moisture and increase of cost under low input production systems of *rainfed* regions, besides, their impact of polluting the soil health. Mechanical weeding is preferred because it keeps the soil surface loose by producing soil mulch with better aeration and moisture conservation (Duraisamy and Tajuddin, 1999) [4].

Manual weeding is time-consuming and labour-intensive, under small-scale farming systems (Anwar *et al.* 2021) [1] coupled with lower labour productivity. Bullock drawn implements also have limitation *viz.* low field capacity, high maintenance cost, less field efficiency, and feasibility of application under adverse weather conditions. Some of new agricultural machinery has reduced drudgeries of operations with the passage of time and are popular among the farmers (Kunnathadi *et al.* 2016) [7]. Mechanical weeding, through use of machines, powered by different sources, (Kramer *et al.* 2015) [6], is faster and more efficient than manual weeding particularly with recently introduced some of such devices (Mynavathi *et al.* 2009) [8] and use of such mechanical weeders are improving the maize yield up to the extent of herbicidal weed management (Mynavathi *et al.*, 2015) [9].
Diesel operated mechanical weeders are also used in maize proving highly efficient and economical (Pandian and Nalliah Durairaj 2004 and Shekhar *et al.* 2010) [18, 22]. Tractor operated weeder save 75% time and 20% cost compared to bullock drawn weeder, but cause higher plant damage (Pachghare and Narkhede, 1999). Power tiller cost is about 44.4 and 11.4% less than bullock and tractor farming, respectively (Varma *et al.*, 1991). Whereas, cost of weeding by engine operated weeder comes to only one third of the manual labour (Tajuddin, 2006). Row crop weeders are simple, economically feasible and useful for small to medium size farm holding and are important in reduction of drudgery (Olawale and Oguntunde, 2006) [15] and have better acceptability among farmers due to lower lower cost (Behera and Swain, 2005).
Therefore, present study was undertaken to find out the performance of different weed management implements for their efficiency, cost, time, drudgery and energy used upon

Materials and Methods

The study was conducted at Dryland Farming Research Station Arjia, Bhilwara, India during the *khaki* season (June to September) of year of 2009. The soil of experimental site was sandy clay loam in texture having pH 8.8, electrical conductivity 0.25 ds/m and organic carbon content of 0.26%. The field capacity and wilting point were 23.9 and 9.2%, respectively. Maize crop (PHEM-2) was grown following recommended package of practices in the NARP zone. Three trail plots of 25m x 5m size were selected in maize field for each implement. Tests were conducted thrice and observation noted carefully. Average values obtained for three observations were considered for calculation of performance parameters as suggested by (Padole, 2007) [17]. The implements used for mechanical weeding is have been given with their specifications Table 1.
For measurement of Soil moisture, three soil sample were collected from each test plots while field test of weeders with the help of soil sampling auger. Initial weight (w_1) of each sample was taken on digital balance and dried in oven at 105°c for 8 hours. Dried sample and final weight (w_2) was noted. Moisture content on dry weight basis was calculated with following formula.

Soil moisture content,%(db)}=$\frac{W_1-W_2}{W_2}$ x100 …. (1)

A metallic tape was used to measure and to mark the layout the test plot. A steel tape was used to measure the working depth and width of weeder during the test.
Number of weeds in one square meter area was counted before operation (w_b) and number of weeds lefts after operation (w_a) and average of such three readings were counted and taken for calculation of weeding efficiency by using following formula:

Weeding efficiency (%) = $\frac{Wa}{Wb} \times 100$ ……. (2)

Two poles, 25 m apart were placed in the test plot. The time required to travel this 25 m distance was recorded to calculate the forward travel speed of machine.
Plant damage was calculated by counting the number of plants in 10 m row before inter-culture (n_1) and number of plants damaged after operation (n_2). And it was calculated by the following formula and recorded as plant damage in%.

Plant damage, (%) = $\frac{n_2}{n_1} \times 100$ ……. (3)

Field capacity and field efficiency were calculated by recording time consumed in operation (T_p) and time that lost for other activities such as turning at head lands, blade cleaning (when clogged with weeds and soil) (T_c) and field efficiency with the actual field capacity was calculated by the following formula:

Actual field capacity (ha / hr) = $A/T_p + T_c$ ….(4)

And

Field efficiency (%) = $10A/WS(T_p+T_c)$ ……………(5)

Where,
A=Area covered,(ha),
W=Width of operation,(m),
S= Speed of operation,(km/hr),
T_p= Productive time, (hr), and
T_c =Unproductive time,(hr).

The machine was kept on level platform and fuel tank was filled to full capacity mark. The amount of fuel required to refill the fuel tank again after one hour continuous operation up to the full capacity mark was measured with the help of measuring jar and fuel consumption per hour was calculated.
Cost of weeding was calculated considering, depreciation, interest, housing, repair and maintenance, cost and operator wages etc. The energy use pattern was calculated on using the Energy Coefficients as suggested by Mittal and Dhawan (1988) [10] and the energy coefficient used are presented in Table 2

Results and Discussion

Performance parameters

The performance parameters for different intercultural implements in maize cultivation have been summarized in Table 3. Results revealed that power weeder with blade harrow recorded maximum field capacity (0.275 ha/ hr) with the least supplementary labour (8.7 man-days) for complete weeding with the highest forward speed (2:2km/hr). This might be due to increased working width and operating speed of implement. The highest working depth 4.5 cm) was also recorded with power weeder with blade harrow followed by bullock drawn *kulpha* due to weight of implements and ease of operation at same soil moisture on dry weight basis (16.97%) The highest plant damage of 2.3% was recorded in bullock drawn *kulpha* due to movement of bullocks in standing crop during weeding and short length of yoke. In power weeding, the plant damage could be reduced up to 2.0% by provision of safe guard and adequate space available in between rows for the running of the machine. The least number of total man-days (8.7%) was required to complete weeding with power weeder with blade harrow which saved the total man-days by 41.4% in comparison to manual weeding (*kudali*) (Table 4). The least weeding efficiency (67.5%) was recorded with CIAE dry land weeder and manual weeding gave the highest weeding efficiency as compared to other implements. This might be due to the fact the least weeds were left in plant rows and in spaces available in between the plants. Power weeder may be operated easily by farmer or unskilled labour after some practice in the field. Its maintenance cost is very low. It can be a best source of income generation for poor and small scale farmers in dry land ecosystem.

Energetics

The highest quantum of energy (502.4 MJ/ha) was consumed with manual weeding with *kudali* at 30 DAS at 65 cm height of crop and soil moisture content was 16.97% on dry weight basis (Table 4). Among the different implements, power weeder required the least energy input (256.76 MJ / ha) followed by bullock drawn *kulpha* which utilized 53.7% human energy and 46.3% animal energy for weeding of one ha of maize field. Power weeder with blade harrow and bullock drawn *kulpha* utilized the amount of least quantum of renewable energy (135.78 MJ / ha) with corresponding high value of (143.59 MJ / ha) nonrenewable energy. The power weeder and bullock drawn *kulpha* saved the energy to the extent of 48.89 and 42.2%, respectively over manual weeding. Among different manual weeding implements, CIAE Dryland Weeder and Arjia Improved Dry land Weeder saved the energy use by 10.0 and 34.1%, respectively, over manual weeding (*kudali*).

Economics

Among the different interculture implements, the least operating cost (Rs 726.65 / ha) for weeding was recorded with power weeder with blade harrow, followed by bullock drawn *kulpha* (Table 4). These saved the operating cost by 74 *and* 54.2% respectively, over manual weeding (*kudali*) (Table 5). However, bullocks required more maintenance cost as compared to power weeder and power weeder require more utilization of non renewable fossil fuel. Among the different manual operating implements, CIAE Dry land Weeder and Arjia improved Dry land Weeder saved the operating cost by 10.05 and 34.1%, respectively over manual weeding practiced with *kudali*. This might be due to the least requirement of supplementary labour for doing complete weeding in inter and intra row spaces.

Soil Moisture

Soil moisture was recorded at different depths and time intervals. It revealed that the highest soil moisture content was recorded with power weeder with blade harrow followed by bullock drawn *kulpha*. This might be due to increased depth of operation. However among different manual operating implements, the least soil moisture content was recorded with CIAE Dry land Weeder at all depths and at all times. This might be due to lesser depth of operation. The regression equation is developed between working depth of interculture implements and soil moisture stored in the soil profile after operating intercultural implements at different depth. The correlation was found to be significant at all the depth (Table 6). The developed regression equation may be used for prediction soil moisture storage in the soil profile at different depth of soil. The differential conservation of soil moisture under operation of various implements is critically valuable under moisture deficit situations giving support to the growth and production of crop. More frequently, it has been observed that during terminal stages of maize crop depreciating soil moisture has strong diminishing effect on grain yield and reduction in soil moisture due to operations of such implements will have direct effect on enhancing the grain yield of maize.

Table 1: Details of Interculture implements used.

S. No.	Name of implements	Specifications				
		Make	Length of blade (cm)	Type	Length of handle (M)	Power source
1	Kudali (kassi) for manual weeding	Local	4.0	Used	0.80	One women/man
2	CIAE dryland weeder	CIAE,Bhopal	25.0	L’ shape blade	1.68	One women/man
3	Arjia Improved dry land weeder	DFRS,Arjia Bhilwara	25.0	L’ shape blade	1.7	One women/man
4	Bullock drawn Kulpha	DFRS,Arjia Bhilwara	40.0	L’ shape blade	(3.5) Length of beam	Pair of bullock
5	Power weeder	CIAE Bhopal	2x40	L’ shape blade	-	5 hp diesel operated engine

Table 2: Energy equivalent use for estimation of energy requirement for different intercultural implement

Particular	Unit	Equivalent Energy, (MJ)	Remark
Human labour			
Adult man	Man-hour	1.96	1 Adult woman=0.8 adult man
Woman	Woman- hour	1.57	
Child	Child-hour	0.98	
Animal			
(a)Bullocks			
1 large	Pair-hour	14.05	Body weight above 450 kg
2 medium	Pair-hour	10.10	Body weight 352-450 kg
3 small	Pair-hour	8.07	Body weight <350 kg
(b) He-buffalo	Pair-hour	15.15	He-buffalo =1.5 medium bullock
(c) Camel or horse	Animal -hour	10.10	Camel or horse = medium bullock pair
(d) Mules and other small animals	Animal -hour	4.04	Small animals=0.4 medium bullock pair
Diesel	Liter	56.31	It includes the cost of lubricants
Petrol	Liter	48.23	
Farm machinery	Kg	62.70	
Fertilizer			
N	kg	60.60	

P_2O_5 K_2O	kg	10.10	
Weedicide	Kg	120.00	
Out put			
Seed (maize)	Kg	14.70	
Stover (maize)	Kg	12.50	

Table 3: Performance parameters for mechanical weeding by different devices in maize.

S. No.	Parameter	Implements				
		Manual (Kudali)	CIAE dryland weeder	Arjia improved dryland weeder	Bullock drawn kulpha	Power weeder With blade harrow
1.	Working width(cm)	4.0	20	24	40	80
2.	Depth of cut (cm)	3.5	3.0	3.2	4.5	4.5
3.	Forward speed(km/hr)	-	0.35	0.52	1.9	2.2
4.	Field capacity(ha/hr)	-	0.007	0.012	0.076	0.275
5.	Supplementary labour (man days/ha)	-	18.18	16.34	8.25	8.20
6.	Labour required for operating machine (man days/ha)	40	17.8	10.01	1.68	0.46
7.	Total man-days/ha	40	35.98	26.35	9.93	8.66
8.	Plant damage (%)	-	--	-	2.3	2.0
9.	Plant height(cm)	65	65.00	65.0	65.0	65.0
10.	Weeding efficiency	95.64	67.50	75.3	80.00	80.13
11.	Weeding days after sowing	30	30.00	30.0	30.0	30

Weeding density (q/ha) on dry weight basis =4.5 q/ha

Table 4: Energy use pattern and operating cost for mechanical weeding in maize

S. No.		Renewable						Non Renewable			Total Energy (MJ / ha)	Operating cost (Rs / ha)
		Human				Animal		Diesel		Machinery		
		Man-days	Supl. Man-days/ha	Total man-days	Energy MJ/ha	Days/ha	Energy M J/ha	Consumption Lit/ha	Energy (MJ/ha)	(M J/ha)		
1.	Manual (Kudali)	40.0	-	40.0	502.4	-	-	-	-	-	502.4	2800.08
2.	CIAE dryland Weeder	17.8	18.18	35.98	451.9	-	-	-	-	---	451.9	2518.6
3.	Arjia Improved Dryland Weeder	10.01	16.34	26.35	330.96	-	-	-	-	-	330.96	1844.5
4.	Bullock drawn kulpha	1.68	8.25	9.93	155.17 (53.7)	1.68	134.5 (46.3)	-	-	-	290.20	1283.1
5.	Power Weeder	0.46	8.20	8.66 (41.4)	135.78 (41.4)	-	-	2.55	143.59 (55.9)	6.9	256.76	726.65

Table 5: Reduction in energy and operating cost per ha by mechanical weeding with different devices in maize

S. No.	Treatment	Total energy use per ha(MJ/ha)	Operating cost per ha(Rs/ha)	Reduction over control (%)	
				Energy	Operating cost
1.	Manual (kudali) Control	502.4	2800.00	-	-
2.	CIAE dryland weeder	451.9	2518.60	10.05	10.05
3.	Arjia improved dryland weeder	330.96	1844.00	34.12	34.14
4.	Bullock drawn kulpha	290.20	1283.1	42.20	54.18
5.	Power weeder	256.76	726.65	48.89	74.05

Table 6: Regression coefficient and correlation coefficient (r) between working depth of cut with intercultural implements and soil moisture storage at different depth of soil

S. No.	Soil depth (cm)	Regression coefficient		r^2
		a	B	
1.	0-15	0.263	1.409	0.51
2.	15-30	2.24	1.667	0.69
3.	30-45	5.562	1.365	0.76

Conclusion

It may be concluded that power weeder with blade harrow saved the energy use by 48.9% and operating cost by 74% followed by bullock drawn *kulpha* with blade harrow over manual weeding (*kudali*) in maize field. They also retained more soil moisture at all depth and time. Among the different manual operating implements, Arjia Improved Dryland Weeder was found more for economical viable and energy saving implement for mechanical weeding in maize cultivation.

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