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Performance evaluation of power operated wetland paddy weeder in Odisha

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Abstract
Weeding is one of the most laborious, costly, time consuming and drudgeries operation in the paddy cultivation. The mechanical power weeder has been promoted to reduce the drudgery, time and cost of operation. The study was conducted to evaluate the performance of mechanical Paddy Power Weeder. The weeding was done 35 days after transplanting in the variety of Swarna at 25 cm row to row spacing during Kharif season in the Central Farm of Orissa University of Agriculture and Technology in sandy loam soil. The various mean performance parameters such as Speed of Operation, Effective field capacity, Field efficiency, Weeding efficiency, Plant damage and Fuel consumption was observed to be 1.65km/h, 0.065 ha/h, 78.9 percent, 84.8 percent, 4.12 percent and 16.9 l respectively. The mean physiological parameters such as working Heart rate, Oxygen Consumption Rate, Relative Cost of Work Load and Energy Expenditure Rate observed to be 139 beats/min, 1.13 l/min, 55.9 percent and 23.78 kJ/min respectively. The Body Parts Feeling Discomfort Score of the subjects using a 10 point scale was observed to be maximum in right and left foot, right and left leg, right and left palm, right and left elbow.

Keywords: field efficiency, weeding efficiency, oxygen consumption rate, relative cost work load, energy expenditure rate and body part discomfort scale

1. Introduction
Paddy is one of the major food crops in East Coastal India. In Odisha paddy cultivation accounts about 38.8 lakh hectares area covered in Kharif and 3.01 lakh hectares in Rabi season. The production of rice was 65.8 lakh metric tons in Kharif and 10.3 lakh metric tons in Rabi season [1]. In paddy cultivation weeds are one of the major problems for the reduction of yield. Weeds decrease the crop yields from 15 to 50 percent depends upon the species, density and weeding time [2]. So timeliness weeding operation necessary for the paddy crop to increase the production. The different types of weed control methods are manual, chemical and mechanical weeding. Manual weeding requires huge labor force and time consuming process. It accounts for about 25 percent of the total labor requirement (900-1200 man-hours requirement) during a cultivating season [3]. Manual weeding can give a clean weeding but it is a slow process [4]. Chemical weeding is extensively used method of weed removal [5]. Chemicals used in this weeding are harmful to the living organisms and toxic in nature. Its adverse effects on the environment are making the farmers to consider and accept the mechanical methods [6]. Mechanical weeding not only uproot the weeds between the crop rows but also keeps the soil surface loose, ensuring the better soil aeration and water intake capacity [7]. Mechanical weeding either by hand tools or weeders are most effective in both dryland and wetland [1, 8, 9]. Mechanical wetland weeding was mostly done by Cono weeders, Mandwa weeders and power weeders. Cono weeder and Mandwa weeder have long handles to be used in 'standing-bending' postures by push and pull action. During the weeding operation nearly 30 percent energy required to walk in the puddled field and with the remaining energy he has to operate the above type of weeder which is very tedious. To reduce the drudgery involved in weeding operation and non-availability of labor assert the necessary for the introduction of power weeder. Evaluation of the power weeders are of peak importance to reduce the considerable strain to the operator involved in the weeding operation. The wetland paddy power weeder available in Odisha market is Garuda Paddy Weeder taken for the evaluation.

2. Review on literature
Manuwa [10] developed and evaluated performance of row crop mechanical weeder. This test was conducted in a field planted with plantain in sandy loam soil at federal university of technology, Akure in Nigeria. The components of the weeder are main frame, handle, cutting blades, blades shield, transmission system and wheels. A commercial 5 hp petrol Honda engine was used as power source. L type blades were used with cutting edge of blades beveled at an angle of 30˚ to minimize the effort required in cutting the soil. The forward speed ranged from 0.25 to 0.5 m/s. the width of the cut was 0.24 m and speed of cutting blade was 800 rpm. The effective field capacity was 0.053 a/h and the weeding efficiency was 93 percent respectively. Sabaji [11] designed and developed a Ridge Profile Power Weeder for ridge planted crops. L type, C type and Flat type blades were selected and observed the performance parameters like weeding efficiency, plant damage, average forward speed, field capacity, performance index and average field machine index in sandy loam soil. The optimal field parameters for C type of blade weeding efficiency 89.93 percent, plant damage 1.77 percent and field

capacity 0.08 ha h^{-1} were recorded. Power requirement, design of rotor shaft and design of cutting blade were calculated. Bending stress, shear stress and equivalent stress were determined as 85.40 MPa, 167.65 MPa and 346 MPa respectively. Sripriyan [12] analyzed experimentally the Fork Type Semi- Automated weeding machine in paddy field. The components of the machine are cultivator, battery, V-belt and pulley, high torque DC motor, cage wheel, lead screw and remote control unit. The tool used is cultivator which looks like five fork in plough. New cage wheels were developed for traction and lead screw for depth control. The design parameters like power requirement, belt selection, pulley diameter, belt length and power rating were calculated. The fork was developed as Pro-E model and analyzed in ANSYS. The plasticity hyper elasticity, stress stiffening, creep, large deflection and strain of the element were analyzed. 500N of force applied on the face of the fork to find the solution. Based on results modifications are made in design on stress concentrations. Bini Sam [13] developed and ergonomically evaluated the Three Row Power Paddy Weeder for wetland paddy cultivation. Modification was done to attach a Cono weeder in line with the float of power paddy weeder to cover the weeding in three rows at time. The weeding efficiency was 88 percent and area covered was 40 cent/hour on 30cm row spacing. Modified power weeder was ergonomically evaluated. Aerobic capacity, overall discomfort rating, body part discomfort score, limit of continuous performance and work rest cycle were observed. The mean working heart rate of operator was 110 beats/min graded as moderately heavy. Mean overall discomfort rating was 4.0 scaled as more than light discomfort. Weerasooria [14] tested newly designed burial type lowland power cultivator for effective weed control in North-Central province of Srilanka. The components of machine are crank shaft, handle, engine, weed burring unit and front wheel. The bulk density was measured by cone penetrometer and moisture content measured by gravimetric method. The parameters like field efficiency, weeding efficiency, plant damage, performance index, fuel consumption, speed of operation, labor and power requirement. The performance index was 580, weeding efficiency 80 percent and plant damage 6.34 percent.

3. Materials and Methods

The Power Paddy Weeder was evaluated in the Central Farm of Orissa University of Agriculture and Technology, Bhubaneswar in the month of September. The variety of the paddy was Swarna (120 days) at row to row spacing of 25 cm in sandy loam soil. The weeding was done 35 days after transplanting. The technical specifications of Garuda power paddy weeder was shown in the Table 1.

Fig 1: Power Paddy Weeder

Table 1: The technical specifications of Power Paddy Weeder.

S. No	Item	Specifications
1	Weight, kg	17.00
2	Vertical height, mm	850
3	Width, mm	720
4	**Prime mover**	
	Type of engine	Two stroke single cylinder forced air cooled petrol engine.
	Displacement	43 cc (Bore 40 mm, Stroke 34 mm)
	Power	1.5 hp
	Rated speed	6500 rpm
	Torque	2.35 Nm @ 4000 rpm
	Carburetor	Diaphragm type
	Starting	Recoil start
	Dry weight	3.8 kg
5	**Drive**	

	Clutch	Centrifugal expanding shoe type
	Gear reduction	Worm type reduction of 40:1
6	**Skid**	
	Skid dimensions (L×B×H)	1000×150×50 mm
	Runners below skid	2 Nos. wooden/ nylon runners
7	**Weeding rotor**	
	Type of weeder	Rotary
	Blade shape	L blade
	No of blades/rotor	4
	Row spacing	Adjustable 220,240,260 and 300 mm
	Width of weeding rotor	150, 140 and 130 mm variable by changing the blade

Five healthy male operators were made as subject for the study. The strength or power is expected to be maximum in the age group of 18 to 35 years [15]. Hence subjects were chosen from the group of 18 to 35 years. Before going to the field the weight, height, HR rest, HR max, VO_2 rest, VO_2 max, blood pressure, BMI and BSA were measured in the laboratory. The Body Surface Area of a worker was calculated by using the formula [16].

$$BSA = W^{0.425} \times H^{0.725} \times 74.66$$

Where,
BSA = Body Surface Area, m^2
W = weight of the worker kg
H = Height of the worker.

Table 2: The physiological parameters of selected subjects (N=5).

SI. No	Physiological parameters		Men (N=5)					Range	Mean	Standard deviation
			M_1	M_2	M_3	M_4	M_5			
1.	Age, years		18	22	28	30	35	18-35	26.6	6.69
2.	Weight, kg		58	59	54	59	65	54-65	59.0	3.93
3.	Height, cm		162	161	156	158	160	156-162	159.4	2.40
4.	HRrest, beats/min		70	72	76	81	80	70-80	75.8	4.81
5.	HRmax,beats/min		202	198	192	190	185	185-202	193.4	6.69
6.	VO_2rest, l/min		0.26	0.25	0.22	0.19	0.23	0.19-0.26	0.23	0.027
7.	VO_2max, l/min		2.1	2.2	1.9	2.2	2.0	1.9-2.2	2.08	0.13
8.	Blood pressure mm of Hg.	Sys	120	118	130	132	128	118-132	125.6	6.22
		Dia	82	78	82	84	81	78-84	81.4	2.19
9.	BMI, kg/m^2		22.1	22.7	22.1	23.6	25.3	22.1-25.3	23.2	1.36
10.	BSA, m^2		1.67	1.68	1.58	1.65	1.74	1.58-1.74	1.66	0.05

Fig 2: Field Observation with Wetland Paddy Power Weeder.

3.1. Field Performance Parameter

Speed of the operation, km h^{-1}

To determine the speed of the operation, mark the length of the 20m and the machine was operated in the marked run length. A stop watch was used to record the time for the machine to traverse the marked run so that the speed of the travel was computed in ms^{-1}.

Effective field capacity, ha h^{-1}

Effective field capacity was measured by the actual area covered by the machine, based on its total time consumed its width. The effective field capacity was determined b the following relationship.

$$\text{Effective field capacity, ha}^{\text{h-1}} = \frac{\text{Total area covered, ha}}{\text{Total time taken, h}}$$

Theoretical field capacity, ha h^{-1}

Theoretical field capacity is the rate of field coverage of the machine, based on 100 percent time at the rated speed and convening 100 percent of its rated width. The theoretical field capacity was determined by the following relationship.

$$\text{Theoretical field capacity ha h-}^{1} = \frac{\text{Width (m)} \times \text{Speed (km/h)}}{10}$$

Field efficiency, %

Field efficiency is the ratio of effective field capacity to the theoretical field capacity. It was determined by using the formula.

$$\text{Field efficiency, \%} = \frac{\text{Effective field capacity, ha/h}}{\text{Theoretical field capacity, ha/h}} \times 100$$

Fuel consumption, lha^{-1}

The fuel consumption was measured by the top fill method. The fuel tank of the machine was filled at its full capacity. The machine was run in the field at constant speed. After the completion of the operation the fuel was refilled in the tank up to the top level. The quantity of refilled fuel was measured by measuring cylinder. This observation was used for the computation of fuel consumption in lh^{-1} and lha^{-1}.

Weeding efficiency, %

It is the ratio of number of weeds removed after weeding to the number of weeds present before weeding. The square metallic frame of 1 m^2 was randomly placed on the field and the number of weeds was counted before and after weeding. The weeding efficiency were determined using the formula.

$$\text{Weeding efficiency, \%} = \frac{w1 - w2}{w1} \times 100$$

Where W_1 = weeds before weeding in 1 m^2 area
W_2 = weeds after weeding in 1 m^2 area

Plant damage, %

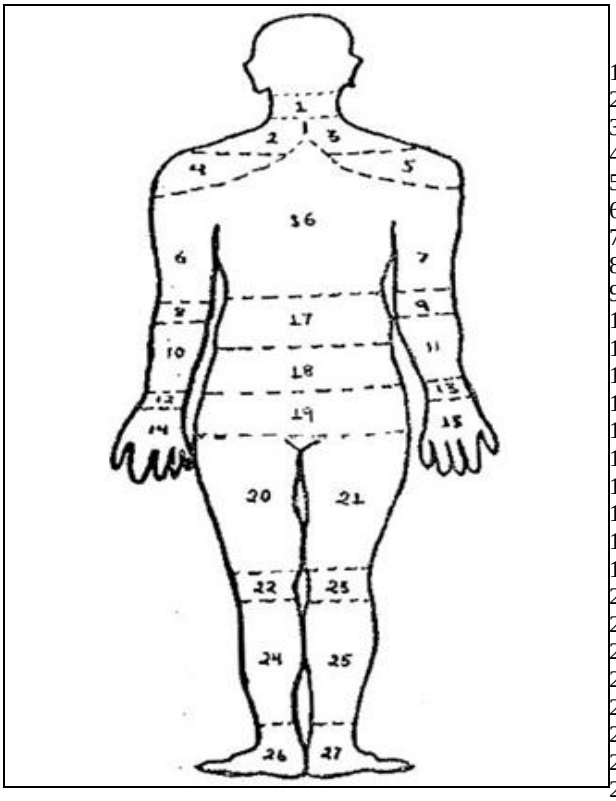
It is the ratio of number of plants damaged in a row before and after weeding. It was calculated by using the formula

$$\text{Plant damage, \%} = 1 - \frac{q}{p} \times 100$$

Where q = number of plants damaged in 10 m row after weeding
P = number of plants damaged in 10 m row before weeding

3.2. Body part feeling discomfort

The localized discomfort in the body was measured by the technique that body was divided into 27 regions [17]. The subjects were asked to mention the discomfort regions in body and score were given out of 10 according to subjects discomfort feeling. The total body part discomfort score was the sum of all individual scores of the body parts assigned by the subject. The body discomfort score all the subjects was added and averaged to get a mean score. The regions for evaluating the body part discomfort score was given in the Figure 3.



1. Neck
2. Clavicle left
3. Clavicle right
4. Left shoulder
5. Right shoulder
6. Left arm
7. Right arm
8. Left elbow
9. Right elbow
10. Left forearm
11. Right forearm
12. Left wrist
13. Right wrist
14. Left palm
15. Right palm
16. Upper back
17. Mid back
18. Lower back
19. Buttocks
20. Lift thigh
21. Right thigh
22. Left knee
23. Right knee
24. Left leg
25. Right leg
26. Left foot
27. Right foot

Fig 3: Regions for Evaluating Body Discomfort Score.

4. Results and Discussion

The field performance parameters of speed of operation, theoretical field capacity, effective field capacity field efficiency, average time of operation, fuel consumption, Heart Rate work, Oxygen consumption work, Relative Cost Work Load and Energy Expenditure Rate was calculated and shown in the Table 3.

Table 3: The Field Performance parameters of Power weeder.

SI. No	Parameters	M_1	M_2	M_3	M_4	M_5	Range	Mean	Standard deviation
1.	Working speed, km/h,	1.82	1.62	1.41	1.75	1.69	1.41-1.82	1.65	0.15
2.	Theoretical field capacity, ha/h	0.091	0.081	0.070	0.087	0.084	0.070-0.091	0.082	0.007
3.	Effective field capacity, ha/h	0.068	0.065	0.059	0.067	0.066	0.059-0.068	0.065	0.003
4.	Field efficiency, %	74.7	80.2	84.2	77.0	78.5	74.7-84.2	78.92	3.57
5.	Average time required to cover one hectare, h/ha	14.7	15.38	16.94	14.92	15.15	14.7-16.94	15.41	0.88
6.	Fuel consumption, l/ha	16.2	16.9	18.6	16.4	16.6	16.2-18.6	16.9	4.06
7.	Weeding efficiency, %	82.3	85.5	87.5	83.7	85.1	82.3-87.5	84.8	1.94
8.	Plant damage, %	5.78	3.67	2.58	4.25	4.33	2.58-5.78	4.12	1.16
9. HR work, beats/min	After 5 min	138	133	131	132	131	131-138	133	2.91
	After 10 min	142	138	132	135	133	132-142	136	4.06
	After 15 min	156	152	141	151	147	141-156	149	5.68
Mean HR work, beats/min		145	141	135	139	137	135-145	139	4.22
10. VO_2 work, l/min	After 5 min	1.02	1.12	1.11	0.99	1.05	0.99-1.12	1.05	0.05
	After 10 min	1.04	1.15	1..13	1.01	1.08	1.04-1.15	1.07	0.48
	After 15 min	1.31	1.28	1.23	1.33	1.27	1.28-1.33	1.28	0.03
Mean VO_2, l/min		1.12	1.18	1.17	1.11	1.13	1.11-1.18	1.13	0.19
11.	RCWL, % of VO_2 max	53.4	53.7	60.8	50.4	56.6	50.4-60.8	55.9	3.92
12.	Energy expenditure rate, kJ/min	23.5	24.7	24.2	22.8	23.7	22.8-24.7	23.78	0.71

From the results the highest speed of operation 1.82 km/h was recorded with the M_1. The range of speed of operation was 1.41-1.75 km/h and the mean of 1.65 km/h with the standard deviation of ± 0.15. The effective field capacity was highest recorded 0.068 ha/h with the M_1. The range of effective field capacity was 0.059-0.068 ha/h and the mean of 0.065 ha/h with the standard deviation of ±0.003. The theoretical field capacity was highest recorded 0.068 ha/h with the S_1. The range of theoretical field capacity was 0.070-0.091 ha/h and the mean of 0.082 ha/h with the standard deviation of ± 0.007. The field efficiency was highest recorded 0.068 ha/h with the M_1. The range of field efficiency was 74.7-84.2ha/h and the mean of 78.92 ha/h with the standard deviation of ± 3.57. The highest weeding efficiency was 87.51% observed with M_1. The range of weeding efficiency was 84.8 % and with the standard deviation of ± 1.94. The highest plant damage was 5.78 observed with the M_1. The range of plant damage was 4.12 % and with the standard deviation of ±1.16. The highest time of operation was recorded 16.94 h/ha with the M_3. The range of time of operation was 14.7-16.94 h/ha and the mean of 15.41 h/ha with the standard deviation of ±0.88. The fuel consumption was recorded 18.63 l/ha with the M_3. The range of fuel consumption was 16.1-18.6 l/ha and the mean of 16.9 l/ha with the standard deviation of ±4.06. The noise level measured from the operator's ear was 92 dB.

From the observation the highest field efficiency observed with M_1 due the speed of the operation was more compared to others. Due to the highest field efficiency the average time required to cover the operation and fuel consumption was less comparatively. The plant damage was observed less with M_3 due to the speed of operation was less. The operators handling while walking in the puddled field was difficult with more speed of operation. So the speed of operation influences the operator and the plant damage in the puddled field. The suggestions were asked form the operators feeling during the weeding operation, they felt drudgery due to vibration of the machine, noise level and the exhaust gas emission from the engine directly hits the operator while in operation.

The HR work was measured 5, 10 and 15 minutes after the operation of weeder. The mean HR work after 5 minutes was recorded 1.33±2.91 beats/min, after 10 minutes recorded 136 ±4.06beats/min and after 15 minutes recorded 149.4±5.68 beats/min. The overall mean value of HR work was 139±4.05 beats/min. The VO_2 work was measured 5, 10 and 15 minutes after the operation of weeder. The mean VO_2 work after 5 minutes recorded 1.05±0.05 l/min, after 10 minutes recorded 1.07 ±0.48 l/min and after 15 minutes recorded 1.28±0.03 l/min. The overall mean value of VO_2 was 1.13±0.19 l/min. The RCWL 75.2% was observed highest in M_3. The range of RCWL was 69.5-75.6 % and the mean was 73.32 with the standard deviation of ± 2.79. The EER 23.41 kJ/min observed highest in M_1. The range of EER was 21.03-23.41 kJ/min and the mean was 22.36 kJ/min with the standard deviation of ±0.90 kJ/min. The results of the body part discomfort score of all subjects was shown in the Table 4.

Table 4: The body part feeling discomfort score of subjects using 10-point Visual Analog Discomfort score.

SI. No.	Body part	M_1	M_2	M_3	M_4	M_5	Range	Mean	Standard Deviation
1.	Neck	4.0	3.5	3.5	4.5	3.0	3-4.5	3.7	0.57
2.	Clavicle left	6.5	6.0	7.0	6.5	8.0	6-8	6.8	0.75
3.	Clavicle right	6.5	6.0	7.5	7.0	8.0	6-8	7.0	0.79
4.	Left shoulder	7.0	6.5	7.0	8.0	7.5	6.5-8	7.2	0.57
5.	Right shoulder	7.0	7.0	7.5	8.0	7.5	6.5-8	7.4	0.41
6.	Left arm	7.0	7.0	6.5	7.0	7.5	6-8	7.0	0.35
7.	Right arm	7.5	7.0	6.5	7.5	8.0	6-8	7.3	0.57
8.	Left elbow	7.5	7.0	7.0	8.0	7.5	7-8	7.4	0.41
9.	Right elbow	8.0	7.5	7.0	7.5	7.0	7-8	7.4	0.41
10.	Left forearm	6.5	6.5	7.0	8.0	7.5	6.5-8	7.1	0.65
11.	Right forearm	6.5	6.5	7.5	7.5	8.0	6.5-8	7.2	0.67
12.	Left wrist	7.5	8.0	7.5	6.0	6.5	6-8	7.1	0.65
13.	Right wrist	8.0	7.5	7.0	6.5	7.0	6-8	7.2	0.57
14.	Left palm	7.0	7.5	7.5	7.0	8.0	7-8	7.4	0.41
15.	Right palm	7.5	7.5	8.0	7.0	7.0	7-8	7.4	0.41
16.	Upper back	4.5	5.5	6.0	5.0	5.5	4.5-6	5.3	0.57
17.	Mid back	5.0	4.5	6.0	5.5	6.0	4.5-6	5.4	0.65
18.	Lower back	4.5	5.0	5.5	5.0	6.0	4.5-6	5.2	0.57
19.	Buttocks	3.0	3.5	5.0	4.0	4.5	3-4.5	4.0	0.79
20.	Lift thigh	5.0	5.5	6.5	5.0	6.0	5-6.5	5.6	0.65
21.	Right thigh	5.5	6.0	6.5	5.5	6.0	5-6.5	5.9	0.41
22.	Left knee	5.0	5.0	6.0	5.5	4.5	4.5-6	5.2	0.57
23.	Right knee	5.5	4.5	5.5	6.0	5.0	4.5-6	5.3	0.57
24.	Left leg	8.0	6.5	7.0	8.5	7.5	6.5-8.5	7.5	0.59
25.	Right leg	8.5	7.0	6.5	8.0	8.0	6.5-8.5	7.6	0.82
26.	Left foot	8.0	7.5	8.5	8.0	7.5	6.5-8.5	7.9	0.41
27.	Right foot	8.5	8.0	8.0	7.5	8.5	6.5-8.5	8.1	0.41

The discomfort during the weeding operation was mapped by using a 27 parts Corlett and Bishop Scale. For each part, the discomfort rating was scored by using a 10 point Visual Analogue Discomfort Scale through participatory method. Each male subject was asked about the severity of pain or discomfort during the weeding operation. The high score was recorded in the case of right and left foot followed by the right and left leg. This may be due to the fact that the workers had to walk behind the weeder walking at a speed of 1.4-1.8 km/h. It is also reported by simple walking in the puddled field the heart increases by 20 beats. Based on the data of the selected subjects the majority of the discomfort was felt in the left shoulder, right shoulder, left wrist, right wrist, left leg, right leg, left elbow, right elbow, left thigh and right thigh region.

5. Conclusion

The performance evaluation of Power Operated Lowland Paddy Weeder was evaluated in the Central Farm of Orissa University of Agriculture during Kharif 2017. It was evaluated with five male workers with the age group of 18-35. The mean value of age, height and weight observed to be 26.6 years, 159.4 cm and 59 kg respectively. The weight of the Power Weeder was 17 kg without fuel. The mean value of physiological parameters was working Heart rate, Oxygen Consumption Rate, Relative Cost of Work Load and Energy Expenditure Rate observed to be 139 beats/min, 1.13 l/min, 55.9% and 23.78 kJ/min respectively. The operators operated the weeder at the average speed of 1.65 km/h with the field efficiency of 78.9%. The average fuel consumption rate was recorded 16.9 litre's to cover one hectare of area. The Body Parts Feeling Discomfort Score of the subjects using a 10-point scale was observed to be maximum in right and left foot, right and left leg, right and left palm, right and left elbow.

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