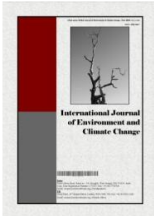

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Development of Solar Operated Walking Type Power Weeder

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Authors' contributions

This work was carried out in collaboration among all authors. Authors ARK and MSD designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors JMM and UDD managed the analyses of the study. Author ALV managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Power weeders are most commonly used machines for removing weeds, to prevent them from competing with main crops. However, these power weeders are power by either petrol or diesel engine. With the shortage of fossil fuel, its unavailability in rural areas and for reducing emission due to burning of fossil fuel, an alternative energy powered weeder is very much required. As solar energy was very available and weeding usually carried out during daytime, hence an attempt made to develop a solar energy operated weeder for dryland. It comprised of a powering system and a blade assembly. The power source included solar photovoltaic panel, solar charge controller, battery, motor charge controller and BLDC motor. The sweep type blade was used, which is mounted behind the main frame and power was given to the rear wheels by 750 watt 48 volt BLDC motor using a chain and sprocket drive. The performance of weeder was evaluated at three different forward speed of S1, S2 and S3 is 1.0 - 1.5, 1.5 - 2.0 and 2.0 – 2.5 km/h respectively. Total weight of weeder is 88 kg and total force required to push the weeder at 2.5 km/h was 107 kg (730 watt). Four batteries, each of size 12 V, 12 amp, powered the motor. Two solar panels were

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use to charge the battery, each with a power of 150 watts, and it takes 2 h to completely charge the battery while weeder is in steady state. The battery was discharge in 1.3 h in field when solar panel disconnected. With simultaneous charging and discharging of battery, this solar power system could run the weeder for 7.3 h. The developed weeder was teste in groundnut crop having 600 mm row-to-row spacing up to 30 to 40 mm depth with a field capacity of S1, S2 and S3 was 0.042, 0.059 and 0.075 ha/h. The weeding and field efficiency for S1, S2 and S3 were found to be 90.94, 84.69, 83.50% and 79.21, 83.97, 85.68% respectively. The effect of forward speed S1, S2 and S3 on Energy expenditure rate and heart rate was found to be 8.23, 9.27 and 10.34 kJ/min or 94, 98 and 50 bpm respectively. The plant damage increased with increasing forward speed of operation, Hence the developed solar operated walking type power weeder could be used successfully by the a small scale farmer for carrying out weeding operations.

Keywords: Solar weeder; weeding efficiency; field capacity; different speed.

1. INTRODUCTION

Agriculture is the largest provider of livelihood in rural India. Agriculture sector is the mainstay of the Indian economy, contributing about 17 per cent of national Gross Domestic Product (GDP) [1] vand more importantly, about half of India's population is wholly or partially dependent on agriculture and allied activities for their livelihood. There are several constraints in agriculture like climate change, insect and pests but weeds are one of the major reasons for declined yield per unit agricultural area in India. Reduction in yield due to weed alone is estimated to be 16-42 per cent depending on crop and location and involves 1/3 rd of the cost of cultivation [2]. Weed growth is a major problem for dry land crops particularly in oilseed crops like groundnut and mustard causing a considerable lower yield. As oilseeds constitute the second major agricultural crops in India next to food grains in terms of quantity and cost, it is necessary to mechanize different farm operations of this crop. India is the third largest producers of groundnut in the world and accounts for about one-fifth of world's production [3]. Manual weeding requires huge labour force and accounts for about 25 per cent of the total labour requirement (900-1200 man-hours/hectare) [4]. Weeds are generally plants that have absolutely no redeeming value as far as food, nutrition or medicine are concerned. Weeds compete with flowers, grasses, vegetables and fruit plants for water, sunlight and nutrients leaving non-weed plants starving. This loss of nitrogen, phosphorus and potassium leaves them weak and prone to insect and disease infestation.

Various methods was use to control weeds like manual weeding, cultural, mechanical, biological and chemical. Mechanical weeding using improved hand tools or power operated machines appear to be most practical and efficient method [5]. Weeding is an important but equally labour intensive agricultural unit operation and one third of the cost of cultivation is spent on weeding alone when carried out manually [6]. Renewable energy has been an important part of India's energy planning process. To ensure energy security and to reduce the dependency on oil import, India started to develop and deploy alternative fuels such as hydrogen, bio-fuels and synthetic fuels. The technology that opted by India are bio, wind, hydro, solar, geothermal and tidal energy technologies [7].

India was second biggest growth driver of primary energy consumption in the world, behind China, in 2019 even though it witnessed fall in demand in oil and coal [8]. India's energy needs are high and being a developing country the requirements are growing further. According to world energy report, India gets around 80 per cent of our energy from conventional fossil fuels like oil (36 per cent), natural gas (21 per cent) and coal (23 per cent) [9]. It is well known that the time is not so far when all these sources will be completely exhausted. So, alternative sources should be used to avoid energy crisis in the nearby future. A large amount of solar radiation falls on the earth. In most part of our country very few days are without sunshine. India lies within the latitude of 8^o N to 37^o N with annual average intensity of solar radiation of 1361 W/m^2 [10].

2. MATERIALS AND METHODS

Development of solar operated walking type power weeder designed and developed at the Department of Farm Machinery and Power Engineering, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh. Field experiments was conducted at Main Research Farm of Oil Seeds

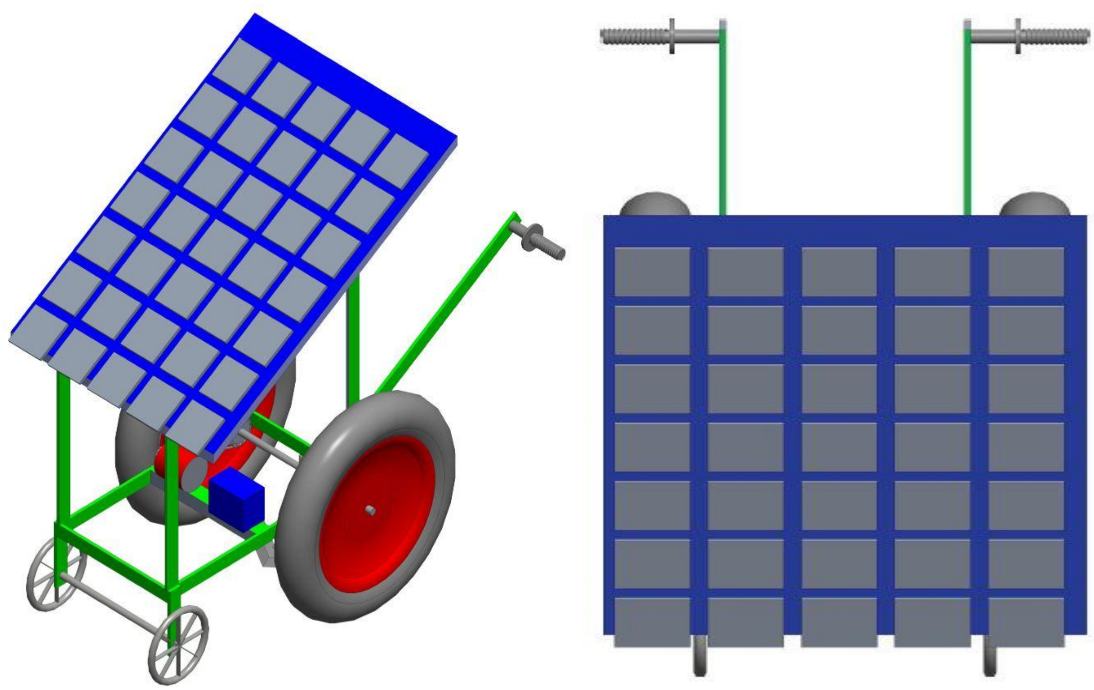
Research Station Junagadh Agricultural University, Junagadh.

2.1 Design Consideration

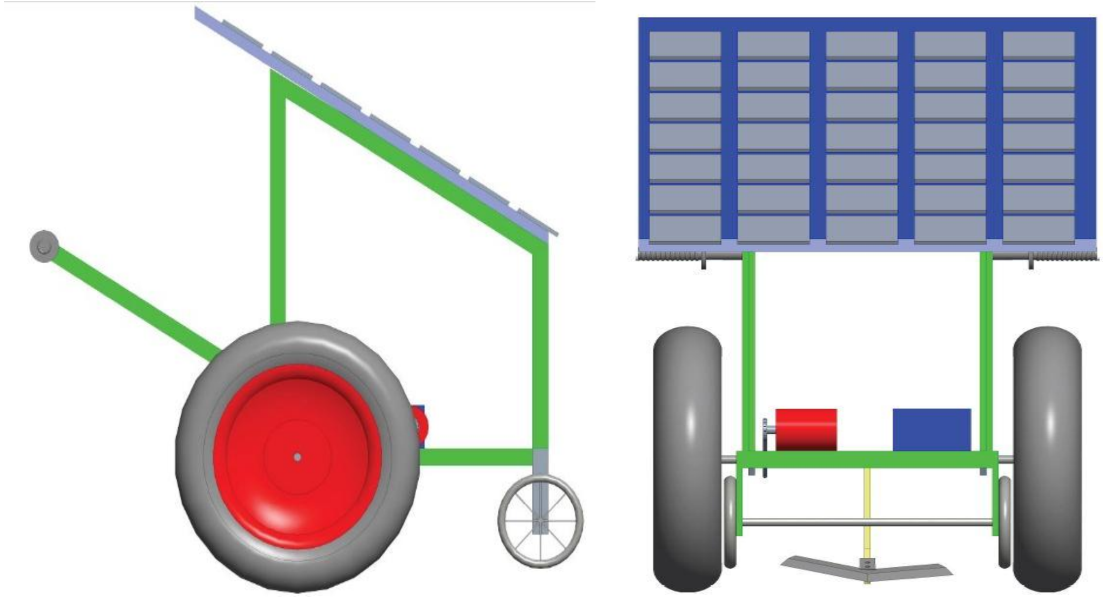
Inter-row weeder is useful device for removing the weeds, stirring and pulverizing the soil and for loosening, the soil after the crop has begun to grow. Development of solar operated walking type power weeder is useful inter row weeding operation. The row space can be adjusted by sliding the units on the main frames. The working depth adjusted by the nut and bolt. Solar operated walking type power weeder was efficiently work in dry and hard soil for removing of weed without clod formation. Specification of the solar operated walking type power weeder is shown the below Table 1 and conceptual view of Solar operated walking type power weeder shown in the Fig. 1.

Table 1. Specifications of development of solar operated walking type power weeder

Sl. No.	Specification	Value
1	Type of solar panel	Polycrystalline
2	Rated maximum power (P_{max})	150 W ± 3% 8.13 A
3	Size of solar panel	1485 × 670 mm
4	Number of solar panel	2
5	Size of battery	12V 12A
6	Number of battery	4
7	Type of motor	BLDC motor
8	Number of BLDC motor	1
9	Maximum BLDC motor rpm	400
10	Maximum BLDC motor power at 400 rpm	750 W
11	Cutting width	35 cm
12	Operational width	60 cm
13	No. of Blades	1
14	Weeding depth	30 mm
15	Power transmission	Chain and sprocket
16	Gear ratio	1:0.36
17	Material of blade	Mild Steel



(a) Isometric View **(b) Top View**



(c) Side View (d) Front View

Fig. 1. Solar operated walking type power weeder

2.2 Design of Solar Operated Walking Type Power Weeder

Designing solar operated walking type power weeder, following parameters was considered for its efficient utilization. Load on various parts of the weeder were uniformly distributed. Unbalancing of theparts during operation may cause sudden or impact load which may cause failure of the machine parts. Motion of the moving parts of the weeder was smooth without any undesired constraints. The power transmission unit used was properly lubricate to avoid frictional resistance. There is always a loss of power due to frictional resistance. Safety of operator considered while designing of weeder. Parts of weeder were free from sharp edges to avoid any accidental damage. The operational cost and maintenance cost of the weeder was negligible. It was also aimed to design at lowest possible cost so that it could be affordable for small and marginal farmers. The weeder was aimed to be light in weight so that there will be minimum energy consumption of the operator while operation. The developed weeder was aimed to require least maintenance time so that operator can utilize those time for other productive work. Weeder was provided with good material surface and finish. Environmental factor such as harmful emissions were considered while designing of weeder. These harmful emissions caused by engine operated power weeder are the major cause of environmental pollution and greenhouse effect.

2.3 Power Requirement for Power Source

The power requirement of the solar operated walking type power weeder would be estimated using factors related to implement and the type of soil. Row to row distance was 60 cm. The specific soil resistance of medium black soil of the area was considered as 0.75 kg /cm^2 [11].

$$D = W \times d_w \times R_{sOR} \quad \text{Power (hp)} = (D \times S) / 75$$

Tractive Force (F) is calculate by this equation

$$F = AC + W\tan\phi \; [12]$$

Co-efficient of sinkage of soil (n) = 0.2

Find out how much rolling resistance (R_r) developed when weeder was working

$$R_r = \frac{2}{[(n+1)(Kc+bK\phi)^{(\frac{1}{n})}]} \times [\frac{W}{2l}]^{(\frac{n+1}{n})}$$

Pull developed by the rear wheel, $P = F - R_r$

2.4 Selection of Solar Photovoltaic Panel

Total PV panels energy needed = Total power consumption / (efficiency of all the auxiliary unit)

$$\text{Size of the panel} = \frac{Total\ power\ required\ for\ motor}{(Esc\ x\ x\ Eb\ x\ Emc)}$$

$$\text{Battery capacity} = \frac{Total\ Watthours\ per\ day\ used\ by\ appliance \times Days\ of\ autonomy}{Discharge\ rate\ of\ battery \times nominal\ battery\ voltage}$$

2.5 Components of the Solar Operated Walking Type Power Weeder

The detailed design of the functional components and different mechanisms was carried out. The machine consisted of BLDC motor, solar panel, battery, Motor charge controller, speed controller system, blade assembly, and transmission system. The BLDC motor and Battery specification shown in the Table 2. Fig. 2 are different components of solar operated walking type power weeder.

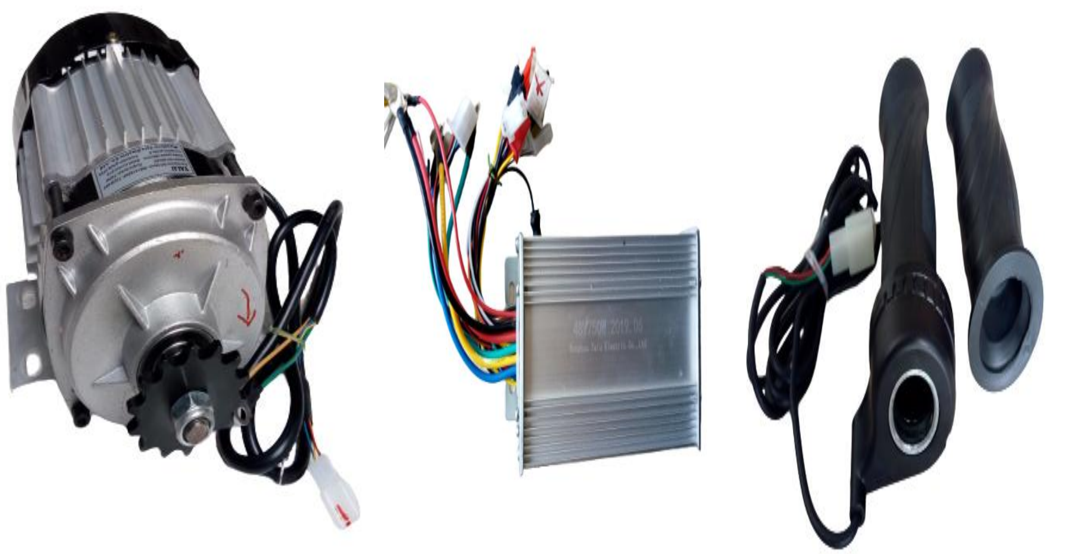
A motor charge controller the actual device that energizes and de-energizes the circuit to the BLDC motor so that it can start and stop. Motor controllers may include some or all of the following BLDC motor control functions: starting. Stopping, over current protection, overload protection, reversing, speed changing, jogging, plugging, sequence control and pilot light indication. Controllers range from simple to complex and can provide control for one BLDC motor, group of BLDC motors, or auxiliary equipment such as breaks, clutches, solenoids, heaters, or other signals. Higher power requirement, panel size can be minimized by increasing charging time of battery because cost of panel is also one of major factor to select suitable solar power system. Specifications of solar panel shown in the Table 3.

2.6 Layout of Experimental Plot

Detail of experimental plot shown in the Table 4. Each plot was having headland for turning and pre-setting of test implement. For three different forward speed (S1 = 1.0-1.5 km/h, S2 = 1.5-2.0 km/h, S3 = 2.0-2.5 km/h) having three experiment plot.

Table 2. Specification of BLDC motor & Battery

BLDC motor		Battery	
Parameters	**Value**	**Parameters**	**Value**
Model	BM1418ZXF-750W48V	No. of battery	**4**
Power	750 W	Voltage	12 V
Actual Speed	400 rpm	Current	12 A
Voltage	48 V	Size (l*b*h) mm	150 x 90 x90
Current	21 A	Discharge rate	Upto 80%



(a)BLDC motor **(b)Charge Controller** **(c)Throttle controller system**

Fig. 2. Different components of solar operated walking type power weeder

Table 3. Specifications of solar panel

Sr. No.	Specification	Value
1	Module	LE12P150
2	Type	Polycrystalline
3	Rated maximum power (P_{max})	150 W ± 3% 8.13 A
4	Rated operating voltage (V_{max})	18.55 V
5	Rated operating current (I_{max})	8.13 As
6	Open circuit voltage (V_{oc})	22.54 V
7	short circuit current (Isc)	8.59 A
8	Maximum system voltage	1000 V
9	Module dimensions (L×W×T)	1480 mm × 675 mm × 35 mm
10	Module weight	10.52 kg

Table 4. Details of experimental field

Sr. No.	Variables	Parameters	Levels
1	Independent Parameters	Forward speed	S1 = 1.0-1.5 km/h, S2 = 1.5-2.0 km/h, S3 = 2.0-2.5 km/h
		Type of Blade	Sweep Type Blade
2	Dependent Parameters	Weeding efficiency (%), Field efficiency (%), Plant damage (%), Heart rate (bt/min.), Energy expenditure rate (kJ/min)	

A total number of 24 experiments were performed on the Solar operated walking type power weeder at three levels of speed 1.0-1.5 km/h, 1.5-2.0 km/h, and 2.0-2.5 km/h and one sweep type blade respectively with 8 replications

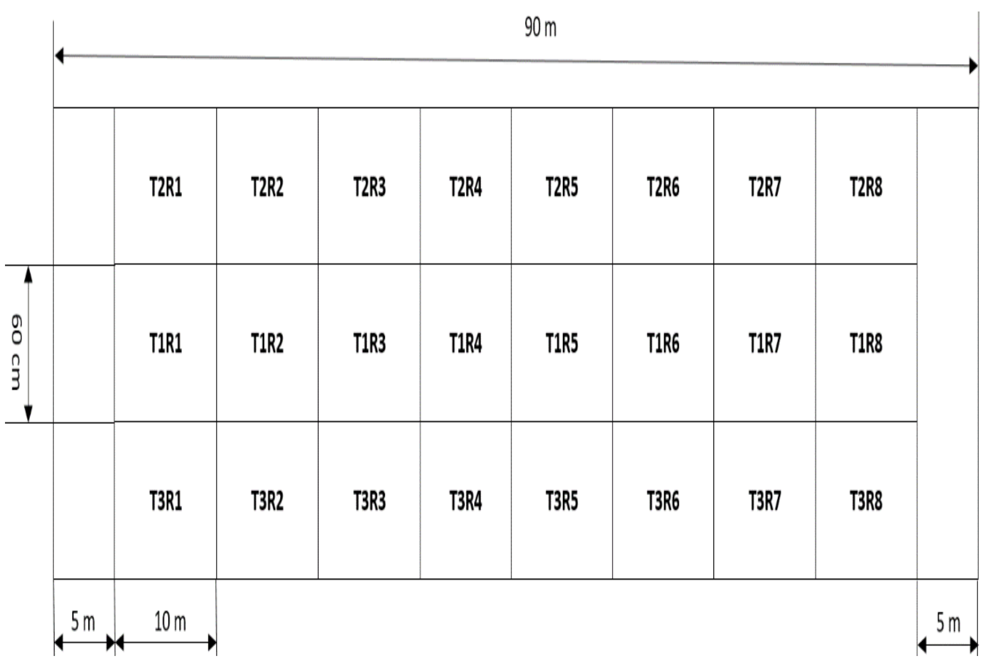


Fig. 3. Detailed layout of experimental plot

2.7 Operating Speed

Outside the long boundary of the test plot, two poles 20 mapart (A,B) are placed approximately in the middle of the test run. On the opposite side also two poles are placed in a similar position, 20 m apart (C,D) so that all four poles form corners of rectangle, parallel to at least one long side of the test plot. The speed calculated from the time required the machine to travel the distance (20 m) between the assumed line connecting two poles on opposite sides AC and BD. The easily visible point of the machine selected for measuring the time.

3. RESULTS AND DISCUSSION

Performance evaluation of the newly designed solar operated walking type power weeder after the testing it in field. The design and detailed dimensions of the main components of developed rotary weeder presented schematically in this chapter.

3.1 Detail Specifications of Developed Rotary Weeder

Details specifications of all parts of developed solar operated walking type power weeder given in Table 5.

3.2 Field-Testing and Evaluation

Field-testing conducted at main Research farm of Oil Seed Research Station, Junagadh Agricultural University. The developed solar operated walking type power weeder was tested in the field of groundnut sown at 60 cm row to row spacing. During its performance evaluation, its field capacity, weeding efficiency, plant damage, speed of operation, cost of operation etc. were determined. Developed solar operated walking type power weeder shown in Fig. 5. This solar weeder is portable type and develop a low-cost we can use the uneven size of row to row distance for the weeding and flexible in nature. In future work more ecofriendly, this type of weeder can be used at small farmer's field.

3.3 India and the Rest of the World

India and other developing countries saw emission increases in 2018, due to economic growth that is "not yet decoupled" from greenhouse gas emissions, the GCP says. India's emissions are expected to increase by 6.3% in 2018 – with a range of 4.3% to 8.3% – and the rest of the world's emissions are expected to increase by 1.8% – with a range of 0.5% to 3.0%. (https://www.carbonbrief.org/analysis-fossil-fuel-emissions-in-2018-increasing-at-fastest-rate-for-seven-years). After a rapid increase in global emissions of around 3% per year between 2000 and 2013, emissions only grew by 0.4% per year between 2013 and 2016. This was reversed over the last two years, with emissions growing by 1.6% in 2017 and expected to grow in 2018 by 2.7% (with an uncertainty range of between 1.8% and 3.7%).But developed Solar operated walking type power weeder is not produce pollution of environment. Solar weeder is the environment friendly and clean nature.

3.4 Field Parameters

The preliminary observations of the field prior to the field-testinggiven in Table 6. Makavana et al. [13] find out bulk density of various crop residues.

The working depth of cut was found as 2 to 3 cm during the operation by the developed solar operated walking type power weeder. Measurement depth of cut and width of cut shown the Fig. 6 and Fig. 7.

3.5 Effect of Forward Speed on Plant Damage

Developed solar operated walking type power weeder, plant damage increased with increase in speed of operation. ANOVA Table 7 shows non-significant effect of the speed of operation on plant damage percentage at 5 per cent and 1 per cent level. For developed solar operated walking type power weeder, plant damage increased with increase in speed of operation. If the speed of operation was high, then plant damage was high. The maximum plant damage observed at 2.0 – 2.5 km/h speed of solar weeder. Plant damage at 1-1.5, 1.5-2.0 and 2.0-2.5 km/h observed as 7.40, 7.86 and 8.45 respectively shown in Fig. 8.

Effect of forward speed on weeding efficiency shown in Table 8. Weeds uprooted and mixed in soil by the operation of the implement, before and after the weeding operation was observe to calculate weeding efficiency. Weeding efficiency for at 1-1.5, 1.5-2.0 and 2.0-2.5 km/h was found to be 90.24, 84.69 and 83.50% respectively shown Fig. 9. Theoretical field capacity depends on the width of weeding and speed of operation. The average theoretical field capacity of the developed solar weeder was found as 0.12 ha/h.

3.6 Effect of forward Speed on Effective Field Capacity

Comparisons of mean of effective field capacity among all three levels of forward speed obtained from statistical analysis presented in Table 9. The results revealed that effective field capacity for all three levels was highly significant.

It is the actual rate of work, which includes the time lost in turning at the end of rows, making adjustments etc. Effective field capacity of developed solar weeder was found 0.129 ha/h at 2.0–2.5 km/h.

3.7 Effect of Forward Speed on Field Efficiency

Comparisons of mean of field efficiency among all three levels of forward speed obtained from statistical analysis presented in Table 10. The results revealed that field efficiency for all three levels was highly significant. Graphical representation of Field efficiency Vs speed of operation shown in Fig. 11.

Table 5. Details Specifications of developed solar operated walking type power weeder

Sr. No.	Particulars	Specifications
1	**Main frame**	
	Length, mm	1260 (GI square pipe)
	Width, mm	960 (GI rectangle pipe)
2	**Solar panel frame**	
	Length, mm	1040
	Width, mm	1300
	Number of supporting pipe	4 (2 at front and 2 at back)
	Height of supporting pipe from main frame, mm	Front 2 pipes, mm 500 Back 2 pipes, mm 680
	Material used	GI rectangle pipe
3	**Material used for frame**	
	GI square pipe, mm	40 X 40
	GI rectangle pipe, mm	40 X 20
4	**Wheel unit**	
	Front wheel	
	Type	Pneumatic
	Width of tyre, mm	80
	Rim diameter, mm	480
	Overall diameter, mm	610
	Rear wheel	
	Type	Pneumatic
	Width of tyre, mm	80
	Rim diameter, mm	240
	Overall diameter, mm	390
5	**Power transmission unit**	
	Sprockets	
	No. of teeth on driven	14
	No. of teeth on driver	38
	Sprocket thickness, mm	5
	Chain	
	Pitch, mm	14
	Width, mm	13
	Length, mm	1010
	Material	Steel
6	**Pedestal bearing**	
	Length, mm	140
	Diameter, mm	25.4
	Height, mm	68
	Material	Cast iron
7	**Weeding blade**	
	Length, mm	480
	Width, mm	350
	Thickness, mm	5
	Material of fabrication	Mild Steel
8	**Total weight of weeder, kg**	**88**

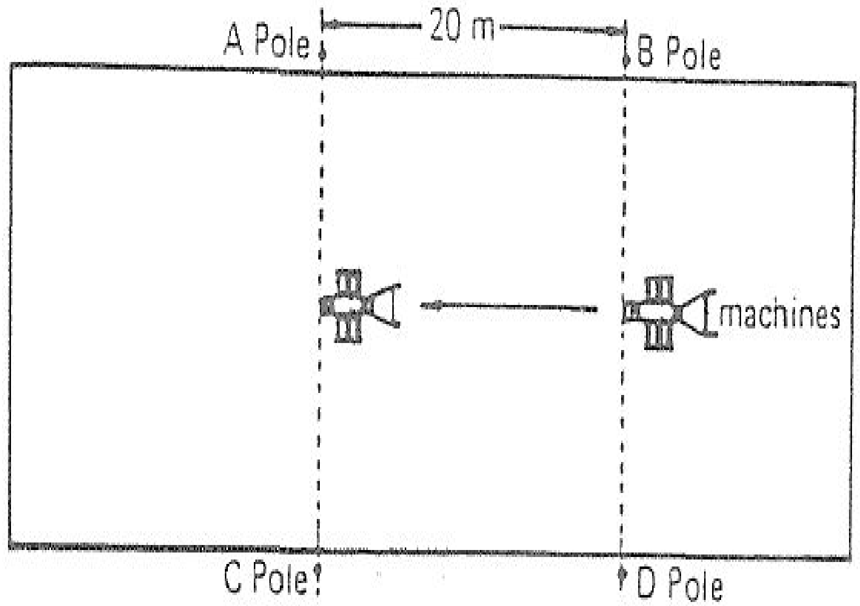


Fig. 4. Field measurement of operating speed
(Source: RNAM, 1983)

Fig. 5. Field testingand evaluation

Table 6. Preliminary observations during weeding operation

Sr. No	Particular	Observation
1	Name of the crop	Groundnut
2	Variety of crop	GG-20
3	Type of soil	Medium black soil
4	Plant geometry	R – R: 60 cm
5	Day of weeding after sowing	40 day
6	Soil bulk density	1.18 g/cc
7	Height of crop at time of weeing operation	14 to 18 cm
8	Depth of weeding	2 to 3 cm
9	Width of weeding	35 cm
10	Rpm of motor	400

Table 7. ANOVA showing effect of forward speed on plant damage

Source	DF	SS	MSS	CAL F	TAB F	TEST	SEM	CD
Treatment	2	4.430	2.21	0.325	3.46	NS	0.924	NS
Error	21	143.366	6.82	-	2.75	CV %		
Total	23	147.796	-	-	-	=4.132		

Table 8. ANOVA showing effect of forward speed onweeding efficiency

Source	DF	SS	MSS	CAL F	TAB F	TEST	SEM	CD
Treatment	2	206.888	103.44	4.330	3.467	**	1.73	5.08
Error	21	501.743	23.893	-	2.758	CV % = 0.709		
Total	23	708.631	-	-	-			

Table 9. ANOVA showing effect of forward speed on effective field capacity

Source	DF	SS	MSS	CAL F	TAB F	TEST	SEM	CD
Treatment	2	0.012	0.006558348	140.01	3.466	**	0.002419	0.00711702
Error	21	0.001	0.000046848	-	2.758	CV % =		
Total	23	0.014	-	-	-	0.851102077		

Fig. 6. Measurement of depth of cut

Fig. 7. Measurement of width of cut

3.8 Effect of Forward Speed on Energy Expenditure Rate

The mean values energy expenditure rate of all three forward speeds are statistically analysed shown in Table 11. The results revealed that energy expenditure for all three levels was highly significant.

The increasing trend with increase with forward speed. It seems to be due to higher energy requirement in moving the machine at higher forward speed. Graphical representation of Energy expenditure rate Vs speed of operation shown in Fig. 12.

3.9 Effect of Forward Speed on Heart Rate

The mean values of heart rate for all three forward speeds are statistically analysed, compared and given in Table 12. From the table, it is clear that the forward speed had highly significant effect on heart rate. Graphical representation of Heart rate Vs speed of operation shown in Fig. 13.

Heart rate of operator was found 103.00 bt/min at 2.0 – 2.5 km/h. The reason seems to be that a human body expends higher amount of energy and there for heart rate is elevated.

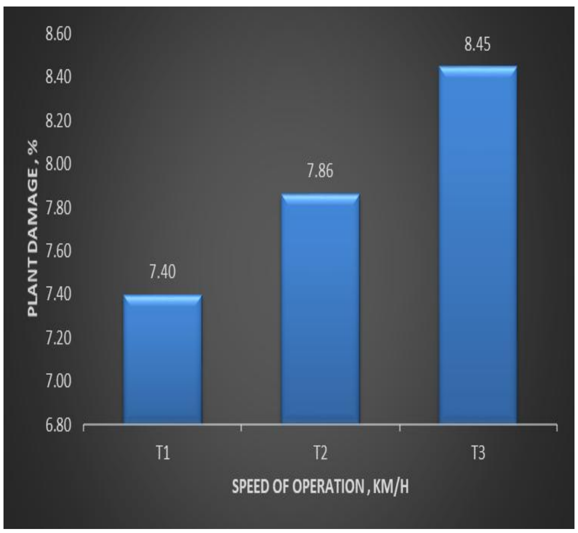


Fig. 8. Graphical representation of plant damage Vs speed of operation

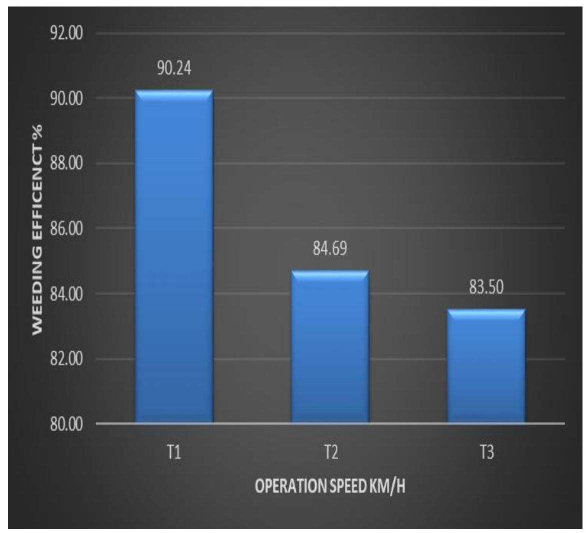


Fig. 9. Graphical representation of weeding efficiency Vs speed of operation

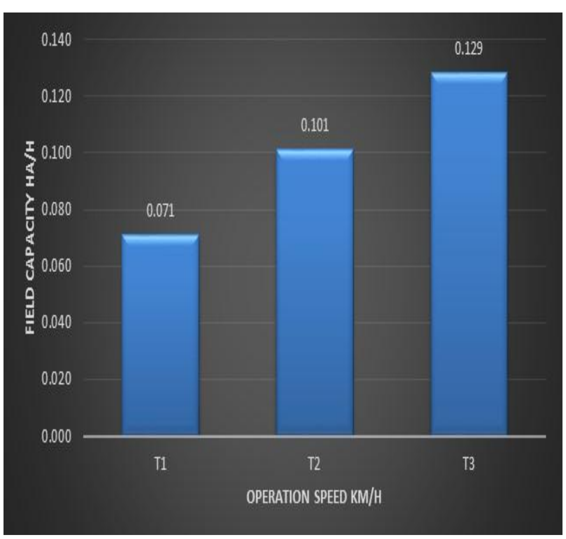


Fig. 10. Graphical representation of field capacity Vs speed of operation

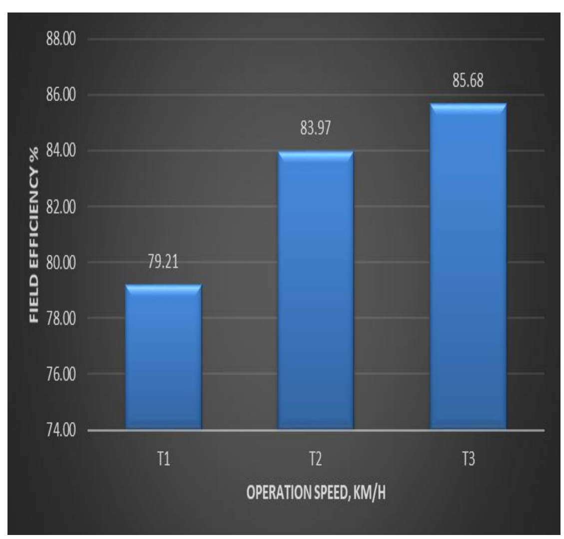


Fig. 11. Graphical representation of Field efficiency Vs speed of operation

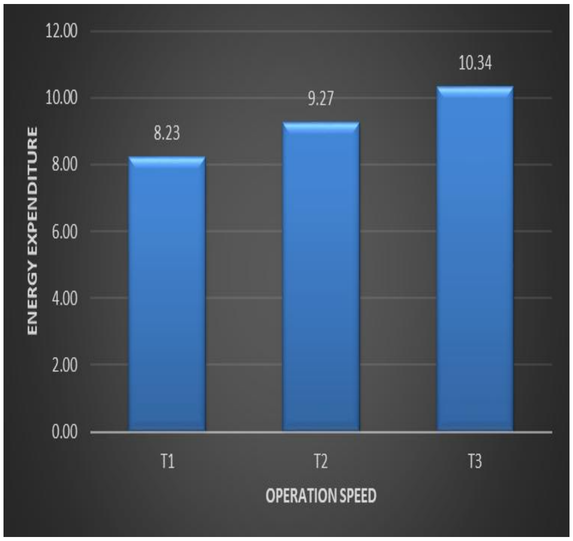


Fig. 12. Graphical representation of Energy expenditure rate Vs speed of operation

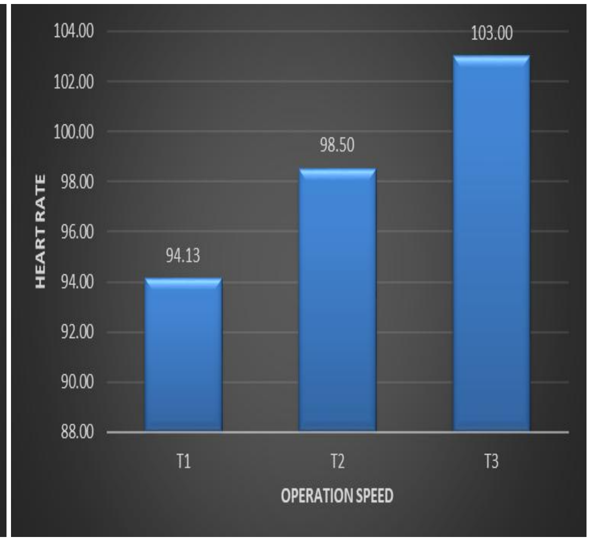


Fig. 13. Graphical representation of Heart rate Vs speed of operation

Table 10. ANOVA showing effect of forward speed on field efficiency

Source	DF	SS	MSS	CAL F	TAB F	TEST	SEM	CD
Treatment	2	179.779	89.89	3.54	3.47	**	1.783	5.242
Error	21	533.795	25.42	-	2.76	CV % =	0.760	
Total	23	713.574	-	-	-			

Table 11. ANOVA showing effect of forward speed on energy expenditure rate

Source	DF	SS	MSS	CAL F	TAB F	TEST	SEM	CD
Treatment	2	17.93	8.97	15.54	3.47	**	0.27	0.79
Error	21	12.11	0.58		2.76	CV % =	0.102	
TOTAL	23	30.04						

Table 12. ANOVA showing effect of forward speed on heart rate

Source	DF	SS	MSS	CAL F	TAB F	TEST	SEM	CD
Treatment	2	17.93	8.97	15.54	3.47	**	0.27	0.79
Error	21	12.11	0.58	-	2.76	CV % =	0.102	
Total	23	30.04	-	-	-			

4. CONCLUSIONS

Weeding and intercultural are the critical management practices which have proportionate effect on soil moisture conservation, nutrients loss and finally affect the crop yield significantly. Though manual, bullock drawn and mechanical weeding methods are available but the availability, efficiency and prevailing operational charges discourages the farmers to take up these methods. In our country 98% of the contemporary machines use the power by burning of fossil fuels to run IC engines or external combustion engines.

1) The developed solar operated walking type power weeder was tested in field and it has worked satisfactorily. The parts and components were strong enough to work with higher efficiency. The developed solar operated walking type power weeder was found best and safe for weeding operation.
2) Discharging time during simultaneous charging and discharging of battery was obtained 7.38 h at operating speed of 2.5 km/h. The effective field capacity and field efficiency were obtained 0.129 ha/h at 2.0 – 2.5 km/h and 85.68% respectively.

3) For three different forward speed of operation 1.0 – 1.5, 1.5 – 2.0 and 2.0 – 2.5 km/h, Plant damage was observed as 7.40, 7.86 and 8.45 respectively. For the three different speed of operation 1-1.5, 1.5-2.0 and 2.0-2.5 km/h , weeding efficiency were found to be 90.24, 84.69 and 83.50% respectively
4) It seems to be higher energy requirement in moving the machine at higher forward speed. The results revealed that energy expenditure for all three speed 1.0 – 1.5, 1.5 – 2.0 and 2.0 – 2.5 km/h was 8.13, 9.27 and 10.34 kJ/min.
5) Heart rate of operator found at 1.0 – 1.5, 1.5 – 2.0 and 2.0 – 2.5 km/h was 94.13, 98.50 and 103 bpm. Fabrication cost of rotary weeder was worked out as 62140. The operational cost was determined as 61.09 /h. The benefit cost ratio and payback period were found as 2.76 and 3.61 year.
6) From the result, higher weeding efficiency and lesser plant damage was observed at the forward speed of 1.5 km/h. At this speed, better weeding was observed without clod formation, plant damage and better inversion of uprooted weeds.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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