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Development of Solar Powered Micro-irrigation Applicator for Dryland Agriculture

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Authors' contributions

This work was carried out in collaboration among all authors. Author MLM developed the machine whereas author IL managed the literature searches, helped in field data acquisition and wrote the first draft of the manuscript. Author MJ evaluated the machine and tabulated the results. All authors read and approved the final manuscript.

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ABSTRACT

In India, 58% of net sown area is under dryland agriculture, where rain is the only source of irrigation water. Sowing is usually done in dryland whenever the ground is wet due to rainfall. But, if there is no rainfall within 30-40 days after sowing, the crop will be under severe dry spell condition and many a times the crop fails due to which the farmer incurs heavy losses. To solve this problem, a solar operated micro-irrigation applicator was developed and tested at *Chaudhary Charan Singh Haryana Agricultural University* (CCSHAU), Hisar, Haryana, India. The machine consists of body structure with inbuilt 500 litres capacity water storage tank, solar panels, battery, solar charger, mono-block pump set with DC motor, transportation wheel and drip irrigation system. Water has to be taken from the pond where rain water has been stored during rainy season. The machine works on solar power and can be installed anywhere in remote area. In the last week of January, 2019, at CCSHAU, Hisar, the average solar insolation was 948 W/m^2 and the average voltage developed by the solar panels was 12.86 V. The average discharge rate

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of dripper and sprinkler were 79.9 and 640.2 ml/minute, respectively. The performance of the machine was evaluated in bottle gourd and it was found to be satisfactory to save the crop under dry spell conditions.

Keywords: Solar panel; micro-irrigation; drip; dryland agriculture; sprinkler; insolation.

1. INTRODUCTION

India is basically an agricultural nation with about 58% of net sown area under dryland agriculture [1]. Rain is the only source of irrigation water. Sowing is dependent on rain. But, if there is no rainfall within 30-40 days after sowing, the crop will be under severe dry spell condition and many a times the crop fails due to which the farmer incurs heavy losses and it of great concern and needs immediate attention. This is a great challenge to save the crops under dryland agriculture in order to meet food security requirements as well as the declining trend in the growth of agriculture sector. Also, in order to enhance productivity and profitability of famers as well as eradicate rural unemployment, there is an urgent need to find a solution.

Since, water is the limiting factor in dryland, it can be harvested and kept for irrigation through drip or micro sprinkler. Drip irrigation applies water slowly and directly to the plant root zone through emitters. Whereas, micro sprinklers are used to spray the water at low height [2]. Drip irrigation is preferred as evaporation losses are much less as compared to micro sprinklers. Without significantly affecting the crop yield, water saving to the extent of 30 to 70% and about 35% in drip and sprinkler irrigation, respectively can be achieved [3]. Moreover, drip irrigation is more suitable with solar pump as it requires 1-2 metre head as compared to micro sprinkler which requires 10-20 metre head [4] which may not be possible and therefore not viable. The concept of drip irrigation can easily be installed and adopted to small land holding and can be handled by a single house hold. The installation for small plots is also very simple and there is no need to go for underground system for main pipeline. Drip irrigation is an extremely efficient mechanism for delivering water and fertilizers directly to the plant root [5]. It increases yield and allows for introduction of potentially high value crops in regions where they could not be sustained due to dry spell conditions. Solar powered (Photovoltaic or PV) pumps work smoothly and save potential hours of labour in rural area. Therefore, development of a solar operated micro-irrigation applicator as a crop saver under rainfed farming system has been undertaken. As India receives solar energy in the range of 5 to 7 kWh/m^2 for about 300 to 330 days in a year [6], the use of machine along with technology can bring revolution in dryland agriculture. The use of photovoltaic system reduces the load of increasing electric demand on government as an alternative for conventional energy in agriculture sector [7]. Thus, the development of this machine will not only lead to prosperity of farmers and development in our country speedily, but can generate employment through custom hiring system and self employment by taking land on contract basis especially near the cities to grow high value crops and earn substantial income from agriculture. This is an assured system in which dependency upon electricity or diesel engine or gen-set can be avoided.

2. MATERIALS

The availability of irrigation water at right time and at right stage has to be ensured, particularly when the crop is under dry spell conditions so that productivity does not reduce drastically. Initially, the farmers may adopt water conservation practices by making bund of at least one feet height along the boundary of the farm as well as deep ploughing of more than 10 cm on the farm. This will help to conserve 90% of rain water in the field. The problem of dry spell conditions of crop can be handled through use of Solar Operated Micro- Irrigation Applicator (Fig. 1) coupled with drip irrigation system (Fig. 2). Soil under dryland farming system is hungry for nutrients. This problem can be sorted out through green manuring as well as application of micro nutrients according to soil health card and using solar operated micro irrigation applicator [8].

Sowing on raised bed with proper placement of seed or plants can give best results of productivity beside reduction in cost of cultivation and alleviation of drudgery associated with various farm operations through use of improved implement.

The output required from solar pumping drip irrigation system depends upon good system

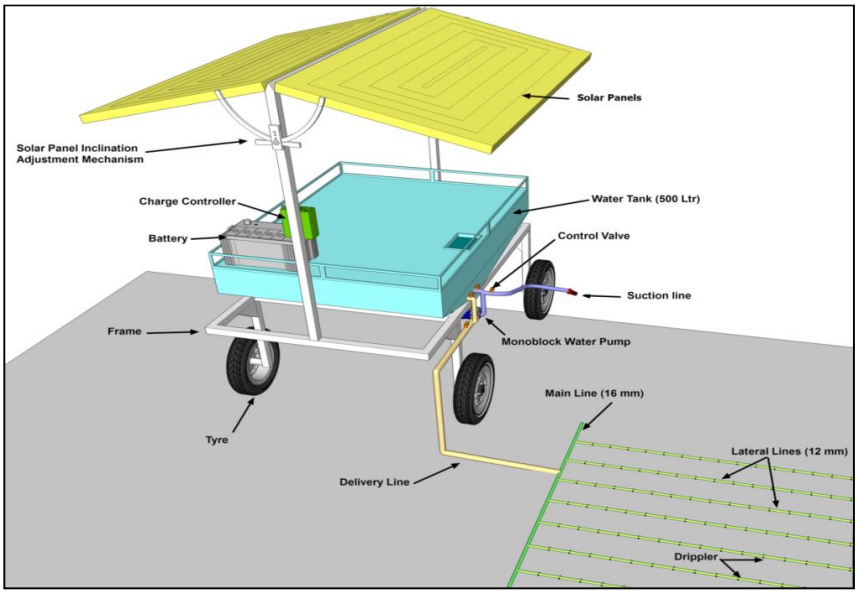

Fig. 1. A view of solar operated micro irrigation applicator

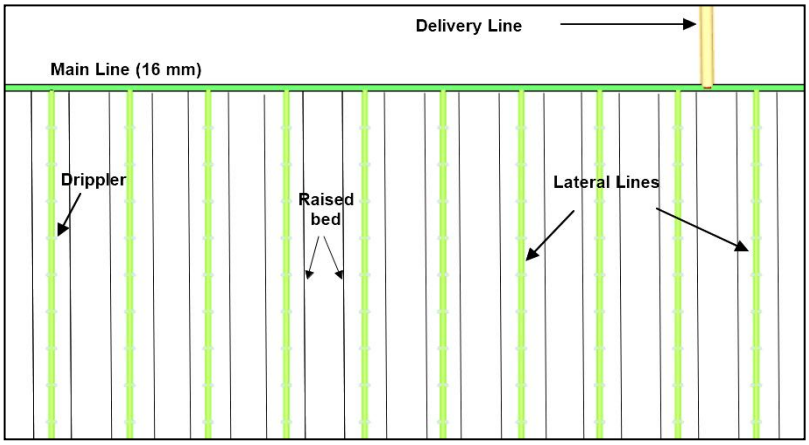

Fig. 2. Schematic installation of drip irrigation system

design derived from actual site conditions, water requirements of different crops, frequency of irrigation, raised bed technology, deep tillage and bunding around the farm before commencement of rainy season etc.

The drip irrigation application in the developing world has been limited in the absence of reliable access to water. Therefore, solar operated pumps with assured water storage tank can be a boom for the farmers besides low maintenance, increase in income, increase in yield etc. [9]. Moreover, the quantity of water that is required by the crop to meet out the evapo-transpiration can be applied with the help of drip irrigation system. The solar operated pumps and low pressure drip irrigation system make an ideal pairing from the technical point of view. This system is suitable with less repair and maintenance.

The application efficiency of water is 85% in drip system and 70% in micro sprinkler system. Small scale drip irrigation system typically uses a small water storage tank of 500 litres capacity with 40 feet main pipe line of 32 mm size, 900 feet lateral pipeline of 16 mm size and emitter/drippers as per crop requirements. Emitters are provided on the laterals at a distance as per plant to plant distance already available on the bed. The crop is sown on raised bed and lateral lines with emitters are provided along with each plant root.

The water is supplied with pressure by a DC motor with mono block pump from the storage tank through solar energy fed battery to ensure regular supply of irrigation water, even if sun light is not sufficient.

3. METHODOLOGY

The machine was fabricated as per the details given under the sub-section technical details. The DC mono-block pump had two suction pipes operated by a one way valve. One suction pipe is connected to the water storage tank of the machine, whereas the other suction pipe is a flexible pipe which can be used to draw water from the water source e.g. pond etc. One way valve is used to select one suction pipe at one time. For filling water in the tank, the machine was deployed near the rain water pond. Generally, it took 8 to 10 minutes to fill the tank of 500 litres depending upon the depth of water source.

To evaluate the performance of the machine, the following parameters were recorded using the instruments given Table 1.

After preliminary trials, the machine was evaluated in bottle gourd crop at CCSHAU, Hisar.

3.1 Technical Details

A solar operated micro irrigation applicator was developed for dry season water application (Fig. 1) in rainfed areas to deal with severe moisture stress conditions in crops. Front and rear view of the fabricated machine is depicted in Fig. 3. The machine consists of solar panel, storage battery, DC motor with monoblock pump, solar battery charger controller, chassis with water storage tank, hitching system and transport wheel. The machine can be transported by single bullock or two persons or tractor through proper hitching system.

It works as a crop-saving machine for crops in dryland agriculture. Moreover, it utilizes solar power to operate the system. The machine can be used anywhere in rural/remote area to avoid crop failure in dryland agriculture. The machine encourages to generate employment through custom hiring system for high value crops such as vegetables, floriculture etc. to generate more income in agriculture.

The machine can be suitably parked near the field in such a way that solar panel works efficiently. The DC motor operated mono block pump fitted with water storage tank supplies water with pressure to the drip irrigation system in order to give irrigation water to the roots of individual plants.

Solar Operated Micro Irrigation Applicator converts grid operated pump into solar operated pump which provides high and reliable output even in remote area. Moreover multi crops can be grown, because of availability of assured water supply throughout the year with low maintenance cost, long life, no fuel or electricity cost and zero pollution. The details of different components used in the machine are given below:

1) Solar panel
2) Solar battery charger/ controller
3) Mono block pump set with DC motor.
4) Storage battery
5) Water storage tank
6) Drip irrigation system
7) Body structure
8) Hitching system

1) Solar panels

Solar panel or photovoltaic (PV) panels (made up of solar cells) are used as alternate source of energy to produce sufficient and reliable electricity, directly from solar radiation (sun light) to power source (battery) and then for operation of irrigation pump for suction and delivery of water to drip irrigation system. The use of alternate energy source is highly desired for promotion of dryland agriculture, as a profitable enterprise. The flow rate of water and pump out time is determined by both the intensity of solar energy available and the size of PV array used to convert that solar energy into direct current (DC) electricity. In this machine a battery of 12V 155 AH was used to store the electricity. The DC motor coupled with pump is operated from battery source. The solar panels can be adjusted manually (0° to 90°) with the help of angle adjusting frame to obtain maximum solar insolation.

Solar Panel size

Length (mm)	: 1640
Width (mm)	: 990
Thickness (mm)	: 6.5
No. of panel	: 2
No. of cell	: 60
Power per panel	: 250 watt
Total power available	: 500 watt

Table 1. The performance of the machine in different parameters

Parameters	Unit	Name of the instrument	Make and model	Range and accuracy
Solar insolation	W/m^2	Solar radiation meter	PCE SPM1	0-2000 W/m^2 ± 5%
Voltage	V	Digital DC isolated voltmeter	YB 20V	0-20 V 0.01V
Volume	ml	Graduated cylinders	Fisher	100/500/1000 ml
Stop watch	sec	Digital stopwatch	RACER	1/100 s

Fig. 3. Front and rear view of developed experimental machine

Table 2. The average discharge rate of dripper and sprinkler operated with the solar powered micro-irrigator applicator

Test No.	Discharge rate (ml/minute)	
	Dripper	Sprinkler
1	73.0	614.0
2	74.0	614.5
3	79.5	637.0
4	86.5	658.5
5	88.8	663.0
6	87.5	660.0
7	87.5	655.0
8	73.0	628.0
9	75.5	633.0
10	74.0	639.0
Average ± S.D	79.9 ± 6.85	640.2 ± 18.33

Source: Anonymous (2019) [10]

Solar panel angle adjusting flat size

Length (mm) : 1010
Width (mm) : 40
Thickness (mm) : 6
No. of holes : 3
Dia. of hole (mm) : 14
Hole to hole distance (mm): 178

2) Solar battery charger controller

This is a voltage or current regulator to charge the battery and to save it from over charging. The charge controller lowers the voltage and current as soon as the battery becomes full. These are smart charger, microprocessor controlled compact unit. A wide range of 12V battery chargers are available in the market. Now-a-days, smart chargers often have 5-9 stage charge profile which help to extend life of the battery instead of 3 stage which were earlier used. The multipurpose charger can be used for 12V battery and is smart enough to recognize the type of lead acid battery connected to it and avoids overcharging or undercharging of the battery.

3) Mono block pump set with DC motor

Solar panels produce DC electricity and stores in battery. The DC motor operates the pump-set through battery and supplies irrigation water with

Table 3. The average solar insolation and the voltage developed

Time	W/m^2	Voltage (V)	
		Solar panel	Battery
9:00 AM	600	12.4	12.01
9:30 AM	840	12.5	12.02
10:00 AM	874	12.5	12.02
10:30 AM	933	12.6	12.08
11:00 AM	990	12.7	12.15
11:30 AM	1010	12.9	12.55
12:00 PM	1045	13.4	12.69
12:30 PM	1053	13.4	12.74
1:00 PM	1052	13.4	12.65
2:00 PM	1042	13.4	12.47
2:30 PM	1021	13.0	12.31
3:00 PM	1019	12.9	12.17
3:30 PM	915	12.6	12.06
4:00 PM	876	12.4	12.01
Average±S.D	947.86 ± 124.3	12.86 ± 0.40	12.28 ± 0.28

Source: Anonymous (2019) [10]

pressure to drip irrigation system. The main specifications are:

Make :Perceptual Motor Development Lab (PMDL)
DC motor capacity : 500W
RPM : 3200
Inlet diameter (mm): 32.5
Outlet diameter (mm): 32.5
Voltage : 12V

4) Storage battery

Type : Lead acid
Capacity : 155 AH
Size (mm) : 500 × 220 × 210
Voltage : 12V
Method of fixing: U – clamp with bracket and welded with water storage tank

5) Water storage tank

Type : Rectangular type flat
Material : MS sheet
Size (mm) : 1680 × 1265 × 235
Filling Cap (mm) : 245 × 245 Square type
Ground clearance (mm) : 880
Capacity : 500 litres

6) Drip Irrigation system

Diameter of main pipe (mm) : 32
Diameter of lateral pipe (mm): 16
Material of pipe : LDPE

7) Transport wheels

Type : Pneumatic
Size (inches) : 5× 19
Total no. : 4
Ply rating : Front 10; Rear 6

8) Body structure

Main Frame : MS Box Type
Ground Clearance (mm) : 720
Material of construction : MS pipe, MS sheet, angle iron, axle, beam, hitching system, nut and bolt.
Overall Dimensions (mm) (L×B×H) : 4080 × 4570 × 2320
Mass (kg) : 435

9) Hitching system

It can be transported by one bullock with suitable beam of size 2400 × 73 mm or two persons or tractor with suitable trailed type hitching system.

3.2 Testing and Evaluation

The machine was tested by CCS Haryana Agricultural University, Hisar in the last week of January, 2018. The average discharge rate of dripper and sprinkler is given in Table 2. The average solar insolation and the voltage developed in the solar panel and voltage across the battery terminals is given in Table 3. The performance of the machine using drip irrigation was evaluated in bottle gourd and it was found to be satisfactory to save the crop under dry spell conditions.

4. CONCLUSIONS

- A solar powered micro-irrigation applicator was developed for water application in rainfed areas to save the crop from severe moisture stress conditions.
- It was evaluated in bottle gourd and the performance was found to be satisfactory.

- Thus, the machine will be useful for all the farmers' especially marginal (< 1 ha area) and small farmers (1-2 ha area) of rainfed area and save their crops when it is under severe moisture stress conditions.
- The solar operated micro irrigation applicator can be useful for other purposes e.g., lighting, music system, mobile charging, drinking and bathing of animals etc.
- The innovation will help towards more crop per drop through drip irrigation technology and doubling of income of the farmers as per agenda of the government.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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