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Techno-economic evaluation of solar pump using surface and subsurface drip fertigation in brinjal (*Solanum melongena* L.) crop

Gevariya SA and Rank HD

Abstract
A field experiment was conducted to study the techno-economic evaluation of solar pump using surface and subsurface drip fertigation in brinjal (*Solanum Melongena* L.) crop during November 2019 to April 2020. The solar photovoltaic pumping system was having solar panel area of 28.8 sqm, power capacity of 4.8 kw and 5 hp AC submersible pump. The brinjal crop response to surface and subsurface drip irrigation having fertigation level of 60%, 80% and 100% RDF were assessed. The brinjal crop was transplanted at 0.6 m p/p x 0.3 r/r x 1.2 pr/pr spacing. The drip system were having inline lateral of 4 lph dripper at 0.6 m spacing. The each lateral was kept at 1.8 m spacing, each one served a pair of rows. The irrigation was scheduled at IW/ETc of 1.0. The maximum yield of brinjal was found to be 37940 kg/ha under subsurface drip irrigation with 80% RDF, while in surface drip irrigation it was found 33558 kg/ha with 100% RDF. The maximum benefit cost ratio of 9.07 was found under subsurface drip irrigation with 80% RDF.

Keywords: Solar photovoltaic pump, brinjal, surface drip irrigation, subsurface drip irrigation

1. Introduction
Gujarat is the extreme western state of India. The western peninsular regions of Gujarat are known as Saurashtra and Kutch (22.74° N latitude and 69.95° E longitude). Junagadh is part of Saurashtra region located at 21.50° N latitude and 70.10° E longitude with an altitude of 60 meter above mean sea level.

Photovoltaic water pumping system is one of the best alternative methods for irrigation. Solar energy is the most abundant source of energy in the world. Photovoltaic generation is an efficient approach for using the solar energy. The cost of solar panels has been constantly decreasing which encourages its usage in various sectors. One of the applications of this technology is used in irrigation systems for farming. Solar powered irrigation system can be a suitable alternative for farmers in the present state of energy crisis in India. In rural areas where adequate electrical power is not available for water pumping, in such places agriculture is fully depend on hand pumps or water from distant rivers. At that time the best solution is water pumping using solar energy and this pumping can also be done using the diesel powered motors.

Brinjal is one of the most common vegetables grown throughout the country for its purple, green and white pendulous vegetable. It is the member of the Solanaceae family and is closely related to potato and tomato. Brinjal is popular vegetable and is native of India. It can be grown throughout the year in almost all the states of India except at higher altitudes. According to Horticultural Statistics - 2018 India produces about 12.8 Million ton of brinjal from an area of 0.73 Mha (Million ha) with an average productivity of 17.53 t/ha. The brinjal producing states are West Bengal, Orissa, Gujarat, Madhya Pradesh, Bihar, Chattishgarh, Karnataka, Andhra Pradesh, Maharashtra and Haryana (Anon., 2004). In Gujarat, brinjal is grown in 0.071 Mha area with production of 1.423 Million ton with 11.89% share of India and productivity of 21.14 t/ha (Anon., 2018). The major brinjal producing belts in West Bengal are Hoogly, 24-Paraganas and Burdwan. This paper presents economical analysis of solar pump installed in Gujarat.

2. Methodology
A field experiment was conducted at the Research-cum-Demonstration Farm, Center of Excellence on Soil and Water Management, Research Testing and Training Centre, CAET, Junagadh Agricultural University, Junagadh during the years 2019-2020.

One-month old seedlings of the brinjal variety GJLB - 4 were transplanted at a spacing of 0.6 m p/p x 0.3 r/r x 1.2 pr/pr on 30 November 2019. The net plot size was 25.2 m x 12 m. The experiment was laid out in the completely randomized design with 4 replications and 7 treatments were taken as follows: T1- Surface drip + 60% RDF, T2-Surface drip + 80% RDF, T3-Surface drip + 100% RDF, T4-Subsurface drip + 60% RDF, T5-Subsurface drip + 80% RDF, T6-Subsurface drip + 100% RDF, T7-Farmers practices as control (Surface irrigation) + 100% RDF.

Surface and subsurface drip installation

Surface and subsurface drip irrigation systems were installed using 16 mm inline laterals with emitters of 4 lph discharged spaced at 60 cm. Furrows of 20 cm depths and 12 m lengths were made using a tractor drawn furrow opener. For the subsurface drip irrigation system the laterals were buried at 20 cm depth and were covered with the soil.

Table 1: Solar panel specification coefficients were calculated as per the formulae suggested by Falconer (1981) [4]

Sr. No.	Particulars	Values	Unit
1	Number of cells	1200	No.
2	Cell area	15.24 × 15.24	Cm^2
3	Number of Panel	20	No.
4	Panel area	1.44	m^2
5	Maximum Power (Pmax)	240	W
6	Maximum Power Voltage (Vmp)	29	V
7	Maximum Power Current (Imp)	8.28	A
8	Short Circuit Current (Isc)	8.89	A
9	Open Circuit Volt (Voc)	36	V
10	Maximum System Voltage	1000	V

Following assumption were made to carried out the economic analysis of the system.

1. Operating life of the PV panels was assumed to be 20 years and life of the drip irrigation system assumed to be as 10 years.
2. The interest rate on capital assumed as 8%. (Karni, 2012)

The cost economics calculation of brinjal cultivation includes the total cost of cultivation and total return per unit area. The total cost of cultivation was computed using the following equation;

$$TCC = CCC + CSPS + CT + FCDI + CF + CH$$

Where,
TCC = Total cost of cultivation (₹/ha/season),
CCC = Common cost of cultivation of brinjal (₹/ha/season),
CSPS = Cost of solar pumping system (₹/ha/season),
CT = Cost of trench preparation (₹/ha/season), FCDI = Fixed cost of drip irrigation (₹/ha/season),
CF = Cost of fertigation (₹/ha/season), CH = Cost of harvesting (₹/ha/season)

Total fixed cost was amortized over the life of the pump by the following relationship. (Raju and Vishnushekar, 2002) [4].

$$Scsps = [PVSPS \times i \times (1+i)m] / [\{A \times s\}[(1+i)m - 1\}]$$

$$Scdis = [PVDIS \times i \times (l+i)n] / [\{s\} \{(l+i)n - 1\}]$$

Where,
Scsps = Seasonal cost of solar pumping system (₹/ha/season),
Scdis = Seasonal cost of drip irrigation system (₹/ha/season),
m = Life of the solar pumping system,
i = Prevailing rate of interest,
A = Total area (ha) commanded by the pumping system in a Season (ha),
s = Number of season in a year for which the pumping system/ irrigation system used,
P = present value of the drip irrigation system (₹/ha), n = Life of the drip irrigation system,
PVDIS = present value of the drip irrigation system (₹/ha),
PVSPS = Present value of the solar pumping system (₹)

3. Results and discussion

Solar panel output in form of watt is continuously increased with increase in solar radiation. Power output from a panel directly varies with solar intensity. Maximum of monthly average power of 3986.31 W per 28.8 m2 (136.68 W/m2) was obtained in April-2020 at 01:00 pm. Minimum of monthly average power of 1122.34 W per 28.8 m2 (38. 97 W/m2) was observed in December-2019 at 05:00 pm. The same result was obtained by Buni *et al.* (2018) [3] also.

Common cost of cultivation (CCC)

After economic analysis of two irrigation methods (surface and subsurface drip) separately, a common cost of cultivation of ₹ 19296/ha/season was obtained for surface and subsurface drip irrigation.

Cost of solar pumping system

Seasonal cost of solar pumping system was calculated using equation 3.16 and was obtained as ₹ 8269.52.

Cost of trenching

Cost of making 20 cm depth trench was ₹ 1,500/ha/season for sub surface drip irrigation.

Cost of fertigation

Cost of fertigation for 100% RDF, 80% RDF and 60% RDF were calculated separately to get the total cost of cultivation for each treatment. Cost of fertigation was obtained as ₹ 12160/ha/season, ₹ 9728/ha/season and ₹ 7296/ha/season for 100% RDF, 80% RDF and 60% RDF respectively.

Fixed cost of drip irrigation

The fixed cost of drip irrigation system was calculated considering the 10 years life of system serving for 2 seasons. It was found as ₹ 68648 per ha for 1.8 m lateral spacing. The seasonal cost of drip irrigation system (for 3 ha and 2 seasons) was calculated using the equation 3.17 and was obtained as ₹ 4998/ha/season.

Total cost of cultivation (TCC)

The highest and lowest total cost of cultivation was obtained as ₹ 64409.52/ha/season and ₹ 54,175.52/ha/season, respectively under treatments I2F3 and I1F1 as shown in the Table 2.

Gross return (GR)

The market price of brinjal prevailed during the season was ₹15 per kg. The highest and lowest gross income was found as ₹ 5,69,100/ha/season and ₹ 4,29,480 /ha/season respectively under treatments I2F2 and I1F1 as shown in Table 2.

Net return (NR)

The highest and lowest net return was found as ₹ 5,06,228.48/ha/season and ₹ 3,75,304.48/ha/season respectively under treatments of I2F2 and I1F1.

Benefit-cost ratio (BCR)

It can be seen from the table that, highest BCR was obtained under the treatment T5 (9.07) followed by the treatment T6 (8.45). Lower BCR was recorded in treatment T1 (7.93).

Table 2: Economics of brinjal cultivation for each treatment

Treatments		Yield (kg/ha)	TCC (₹/ha/ season)	GR (₹/ha/ season)	NR (₹/ha/ season)	BCR	Additional net return over control (₹/ha/season)
T1	I1F1	28632	54175.52	429480	375304.48	7.93	-46382
T2	I1F2	31324	57953.52	469860	411906.48	8.11	-9780
T3	I1F3	33558	61502.52	503370	441867.48	8.18	20181
T4	I2F1	32306	57512.52	484590	427077.48	8.43	5391
T5	I2F2	37940	62761.52	569100	506338.48	9.07	84652
T6	I2F3	36372	64409.52	545580	481170.48	8.47	59484

4. Conclusion

In short, the economic analysis showed that, subsurface drip irrigation with 80% RDF yields more benefits and higher benefit cost ratio 9.07 obtained in this treatment also.

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