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Economic evaluation of solar energy for crop production under dry land area of Kassala, Sudan

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Abstract: Two trails were conducted under Kassala State conditions. The First trail was conducted to evaluate the solar energy in comparison with electricity for cucumber production under greenhouse condition. The second trail was conducted in a private farm in the Atbara River area during 2021 and 2022 to evaluate the effect of using solar energy compared to fuel (diesel) for banana production. In experiment one the treatments (solar energy and electricity) were conducted the in same greenhouse in the two seasons. Solar energy was used in the first season and electricity was used in the second season. The measured parameters were; fruit weight (g), fruit length (cm) and total yield (t/306m2). Trail two was carried out in banana orchard established in 2020. Banana crop was planted at a spacing of 3×3 meter. The farm was divided into two equal parts, each part was 1ha and irrigated by (7.5Hp) pump. Surface irrigation was used in the two parts and the irrigation was applied every 5-7 days according to farmers' practice. Solar energy was used in the first part. The solar energy system consisted of solar panels and an inverter, which is sufficient to operate the irrigation pump. An electric generator was used in the second part for operating the irrigation pump. Yield and yield components were measured. The profitability of the solar energy compared to electricity and electric generator in the two experiments were calculated. The results revealed that there were no significant differences in yield and yield components of banana and cucumber between solar energy compared to electricity and electric generator in the two experiments. The highest value of net benefit ratio of cucumber greenhouse was obtained under solar energy compared to electricity. Moreover, banana under solar energy is the most economic and had higher net benefit compared to fuel.

Keywords: Solar energy, electricity, surface irrigation, cucumber, banana.

I. INTRODUCTION

Energy is an essential factor in stimulating and supporting the economic agricultural development (ElZubeir, 2016). The supply of electricity in Sudan is becoming scarce. Similarly, Sudan's energy infrastructure too is suffering, with currently only 30% of the population mainly in urban areas have access to electricity (Omer, 2013). On the other hand, electricity use has been growing at about 13% per year despite the fact that only 47% of the country's rural population is currently connected to the electric grid (UNDP, 2020). So far, the expansion of the residential sector continues, despite significant increases in electricity prices (Wubeshet-Zegeye and Kahubire, 2019).

Sudan is largely dependent on imported fossil fuels for power generation. Thus, a plan must be drawn to benefit from renewable energies and to reduce dependence on fossil fuels. Sudan faces many energy development challenges brought about by high electricity subsidy levels and climate-induced impacts on hydroelectric generation which has been decreasing at a rate of about 4% per year. Improving access to modern and affordable energy is a development priority for Sudan (Karekezi, et al., 2012). The level of solar radiation in Sudan is promising, with a solar energy density of 436-639W/m2. According to Abdeen (2009) Sudan has been considered as one of the best countries for exploiting solar energy since its average sunshine duration ranges from 8.5 to 11 hours a day.

Sudan has abundant wind and solar energy resources, but it largely lacks the ability to use these resources for power generation (ElZubeir, 2016). Solar energy can supply and or supplement many agricultural energy requirements. It offers farmers an opportunity to cut down their energy expenses. In addition to this, it is also a predictable energy source, which means that farms need not be concerned about potential power outages (Intermountain Wind and Solar, 2015). On the other hand, extensive use of solar water pumps in irrigation would therefore lead to substantial greenhouse gas emission reductions (ElZubeir, 2016). The significant increase in electricity prices, as well as the frequent cuttings on a daily basis for several hours, necessitates the use of other alternative energy. Moreover, El Zein (2017) reported that in the neighboring countries many successful solar projects were implemented and that should be encouraging the Sudan to follow the same way and solve to problem that the spread of solar energy. Wamalwa, et al (2024) mentioned that there are reveals considerable potential for solar irrigation, with profitability and viable cropland areas that vary according to crop type, irrigation system cost scenarios, and soil fertility levels. Research should be focused on the renewable energy development to make it economically more competitive with other fossil fuels. Since there are no research results available

for the use of solar energy in irrigation. Objective of the study was to evaluate solar energy in comparison with electricity and fuel for cucumber yield under greenhouse conditions and for banana production under surface irrigation.

2. MATERIALS AND METHODS

Two trails were conducted. The first trail was carried out at the greenhouses in the farm of the Horticultural Department, Ministry of Production and Economic Resources, Kassala State, during March and August of 2019 and 2020. The objective of the study was to evaluate solar energy in comparison with electricity for cucumber yield under greenhouse conditions. The greenhouse is a plastic tunnel with an area 306m2 (34m×9m) located in North-South directions with temperature 24-31°C and humidity 80-90%. Irrigation was applied by drip irrigation system every 3 days at the rate of 2.5 liter/plant according to Mohamed and Ahmed, (2009). Seeds of the most cultivated cucumber hybrid (Fatin) were planted at an intra-row spacing of 40 cm with inter-row (beds) spacing of 50 cm as recommended by Khalifa et al. (2016). Seeds were sown as one seed per hole on both sides. Soluble fertilizer (NPK/20:20:20) was fertigated at a rate of 13kg/fed/week for the first 2 weeks after planted. All cultural practices i.e., hoeing and weeding were carried out during the growing season as recommended. The greenhouse consists of 2 fans, each one (3.5 HP/hr), as well as two pumps, the first for irrigation and the second for cooling, each one (1HP/hr). The greenhouse was divided to the 5 parts each part (bed or mastaba) was 10 m length. The treatments (solar energy and electricity) were conducted in same greenhouse in two seasons. Solar energy was used in the first season and electricity was used in the second season. The solar energy system consists of solar panels and an inverter for operate the greenhouse. The measured parameters were; fruit weight (g), fruit length (cm) and total yield (t/306m2).

Power cost was calculated according to the following equation:

Power cost (SDG) = Engine capacity (KW/hr) × Operation (hr/day) × Season length (day) × Cost of electricity (SDG/KW).

Trail two was conducted in a private farm in the Shalaki village at Atbara River area in Halfa locality, Kassala State during 2021 and 2022 to evaluate the effect of using solar energy compared to fuel (diesel) for banana production. The soil at the experimental site is silty clay with high silt content. The banana orchard was established in 2020 and banana cv. "Dowarf Cavidish", was planted in the field at a spacing of 3×3 meter (1111 mother plants/ha) as recommended by Hamid (1995a). Three months after planting, two suckers were left giving 2222 plants/ha. The recommended dose of fertilizer (400g/urea/mat/year split in two doses in December and June was applied according to Hamid, (1995b). Special horticultural practices, viz, weed control, leaf removal, mulching, desuckering, bunch propping, removal of male bud, wind breaks, etc. were carried out as recommended. The farm was divided in two equal parts; each part was 1ha. Surface irrigated from a well with 7.5HP submersible pump. Irrigation was applied every 5-7 days according to farmers' practice. Solar energy was used in the first part consisted of solar panels and an inverter, which was sufficient to operate the irrigation pump alternatively. 10KW electric generator was used in the second part to operate the irrigation pump.

Mature bunches were harvested when they reached full three-quarter shape. Yield and yield components were taken, with ten centimeters of the stalk left with the bunch to facilitate handling. Second hand of freshly harvested bunch was used to measure the fruit characteristics according to Dadzie and Orchard (1997).

The profitability of the solar energy compared to electricity and electric generator in the two experiments were calculated based on the field information and data collected according to CIMMYT (1988).

GraphPad statistical package was utilized for analysis of data and t- test was used for means separation.

3. RESULTS AND DISCUSSION

Effect of solar energy in comparison with electricity on fruit weight, fruit length and number of fruits per plant and yield of cucumber under greenhouse conditions:

Results revealed that there was no significant difference between solar energy and electricity of cucumber yield and yield components under greenhouse (Table 1). The higher yield was obtained with solar energy compared to electricity this might be due solar energy was used in the first season. This means that the greenhouse cooling efficiency was higher in the first season (Table 1). The use of solar energy was for irrigation only, and its impact was noticeable on the economic impact. These results are in agreement with those reported by Xie and Hossain (2012) who reported that there was keen interest in investing in solar energy to support the development of irrigated agriculture promoting solar irrigation in sub-Saharan Africa. Moreover, Dinara et al. (2014) found that pumping cost was the deciding factor in the analysis of the costs of water pumping systems.

Table 1. Effect of solar energy in comparison with electricity on fruit weight, fruit length, number of fruits per plant and yield of cucumber under greenhouse conditions.

Treatments	Fruit weight (g)	Fruit length (cm)	Number of fruits per plant	Yield (t/306m^2)
Solar energy	148	15.2	21	6.1
Electricity	144	15.0	20	5.8
SE$^{\pm}$	4.7	0.49	1.64	1.92
T. value	0.73	0.41	0.73	0.52
Significance level	NS	NS	NS	NS

NS indicate not significant.

Effect of solar energy in comparison with electricity on economic analysis of cucumber under greenhouse conditions:

Initial cost under solar energy was higher compared to electricity. Fixed costs and variable costs of greenhouse were also equaling (Table 2). Total cost under solar energy was lower compared to electricity because there was an additional cost of power with electricity (Table 2). The results showed that benefit cost ratio under solar energy was more economic and had higher net benefit compared with electricity (Table 2). Similar results were observed by Dinara et al. (2014) who reported that the system run under solar energy is more economical. Moreover, Dinara et al. (2014) found that system for pumping water that used solar energy had lower total costs and lower overall energy consumption. The pumping cost was the deciding factor in the analysis of the costs of water pumping systems.

Table 2. Initial cost, total cost and benefit cost ratio of solar energy in comparison with electricity on number of fruits per plant and yield of cucumber under greenhouse conditions.

Particulars	Treatments	
	Solar energy	Electricity
Initial cost (SDG/306m^2)	500000	156000
Power cost (SDG/year)	0	324000
Rent of counter (SDG/year)	0	60000
Fixed cost of greenhouse (SDG/306m^2)	140000	140000
Variable cost (SDG/306m^2)	340000	340000
Total cost (SDG)	980000	1020000
Yield (t/306m^2/year)	18.3	17.4
Gross return (SDG/306m^2/year)	4575000	4350000
Net benefit (SDG/306m^2/year)	3595000	3330000
Benefit cost ratio	3.7	3.3

The price of one ton cucumber equal 250000 and 1USD=550SDG

Effect of solar energy in comparison with fuel on yield and yield components of banana:

Yield and yield components of banana showed no significant differences between solar energy and fuel (Table 3). This is normal due to the absence of a difference in the application of cultural practices and in the amount of irrigation water applied between the two treatments. The difference is only in the way the pump or power source is operated, and this will appear in the economic analysis (Table 3). Similar results were recorded by Korpalea et al. (2016) who reported that the performance of solar powered water pump was equal to the conventionally power pump.

Table 3. Effect of solar energy in comparison with fuel on total yield, number of hands per bunch and number of fingers per hand of the mother plant and first ratoon crops of banana.

Treatments	Total yield (ton/ha)		No. of hands per bunch		No. of fingers per hand	
	MP	FR	MP	FR	MP	FR
Solar energy	19.2	25.0	8.8	9.8	129	141.8
Fuel	18.4	24.2	8.6	9.6	127	141.0
SE$^{\pm}$	1.27	0.92	0.71	0.63	1.99	1.09
T. value	0.63	0.87	0.28	0.32	0.91	0.74
Significance level	NS	NS	NS	NS	NS	NS

MP= Mother plant.

FR= First ratoon crops.

NS indicate not significant.

Effect of solar energy in comparison with fuel on economic analysis of banana:

Variable costs and total cost of the fuel and solar energy of banana are shown on Table 4. Total cost was higher with fuel compared to solar energy due to cost of the oil, spare parts, filters, fuel cost and fuel transportation (Table 4). These results are in agreement with those reported by Korpalea et al. (2016) who found that the system using solar energy had the lowest total cost because it did not have pumping cost, i.e., the consumed energy was only solar energy while diesel consumption was accounted during the entire lifetime of the other system, and this expenditure surpassed other costs. The highest net benefit of banana was obtained with solar energy (4.83 Mill SDG) compared to (1.029 Mill SDG) under fuel (Table 4). The highest value of benefit cost ratio was recorded with solar energy (6.91) compared to fuel (0.24) which in additional to that mean solar energy was most economical for banana irrigation (Table 4). Similar results were reported by Dinara et al. (2014) who reported that the system with solar energy was more economical when compared with the system running on diesel.

Table 4. Economic analysis of solar energy in comparison with fuel of banana.

Particulars	Treatments	
	Solar energy	Fuel
Initial cost (SDG)	500000	175000
Oil spare parts and filters (SDG)	0	250000
Maintenance (SDG)	200000	200000
Fuel cost (SDG)	0	3600000
Fuel transportation (SDG)	0	60000
Empty drams (SDG)	0	30000
Total cost (SDG)	700000	4315000
Yield (t/ha)	69.2	66.8
Gross return (SDG/ha)	5536000	5344000
Net benefit (SDG/ha)	4836000	1029000
Benefit cost ratio	6.91	0.24

The price of one ton banana equal 80000 and 1USD=550SDG

4. CONCLUSION

The highest benefit cost ratio of cucumber greenhouse and banana were obtained under solar energy compared to fuel and electricity.

5. RECOMMENDATION

Based on the above findings, the Authors request the National Crop Husbandry Committee to use the solar energy for crop production under Kassala conditions.

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