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Development A Knapsack Sprayer Powered by Photovoltaic Panel

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ABSTRACT

Spraying pesticides are important to protect crops from insects consequently to obtain the highest production yield. The manual or battery knapsack sprayers are dominant in the Egyptian market. However, the first type depends on the operator skill and for the second type; the battery charge is not constant throughout the operating period. Therefore, the research aimed to develop a knapsack sprayer powered by solar energy that operates throughout the day at constant flow rate pressure. This was achieved by manufacturing the developed sprayer from local materials, and by providing it with a solar pump powered by a battery, the photovoltaic panel and an electronic circuit in which the spray pressure can be controlled from 0 to 4 bars. The amount of pesticide can be controlled according to the age of the plant, as well as, the uniformity of pesticide distribution identified using constant pressure throughout the spray period and thus ensuring the fairness of pesticide distribution and not relying on lobar experience. The results indicated that the number of operating hours for the developed sprayer reaches more than 8 hours per day with constant pressure compared to using the battery-powered sprayer only, which operates from 1.5 to 3 hours only with no pressure stability at a flow rate 600 to 1000 ml/min. On the economic side, the cost of spraying from the developed sprayer is 54.37 L.E/fed compared with (102.50 and 79.70 LE /fed) for manually sprayer and battery sprayer, respectively. Therefore, a developed sprayer is high economic and practical value in the agricultural sector.

Keywords: solar energy; pesticide; knapsack sprayer.

INTRODUCTION

Spraying of pesticides is an important task in agriculture for protecting the crops from insects. Farmers still use traditional techniques to spray pesticides or liquid fertilizers, such as manual knapsack or self-power sprayer. The use of a manual knapsack sprayer leads to a decrease in worker productivity from time to time, and thus a decrease in work and production efficiency, and therefore the distribution of pesticides or liquid fertilizers is irregular throughout the field and depends on the experience of the worker. *Kumawat et al. (2018)* showed that, maintenance of the solar sprayer is easy and less vibration, and the operation of solar-powered pumps is economical due to the lower costs of operation and maintenance and its environmental impact is less than the internal combustion engine (ICE) pumps. Solar pumps are useful when the electricity source and alternative sources are not particularly available compared to the gasoline sprayer.

The farmer can do the spraying himself without involving the workers, thus increasing the spraying efficiency

On the other side, *Krishna et al. (2017) and Charvani et al. (2017)* specified that fuel is expensive and it is not available in many places. If hand operated spray systems are used, the productivity of labor decreases and the efficiency will be low. Also, *Khan (2014)* establishes that the solar panel could generate a higher voltage, power and current in inclined position than in horizontal position, under operated with a solar pump to supply pressure for spray fluid of 0.5 to 1.5 kg/cm^2. Also, *Sasaki et al. (2014)* added that solar photovoltaic sprayer can be used for reducing the physical effort of the operator and increasing the spraying quality. *Patil et al. (2014) and Ismail (2007)* recommended that sprayer could run from 2.5 to 5 hours at full operation in full solar intensity and the rate of liquid flow through sprayer was influenced by the liquid head. The sprayer was capable of spraying the liquid 90 l/h at an operator speed of 2.52 km/h. *Varikuti et al. (2013) and Rao et al. (2013)* found that the time taken to charge the full battery of capacity 12V with 7A was 16.67 h and fully charged battery could be used to spray 575 l pesticides per approximately 5-6 acres. Consequently, if we charge the battery per day, then it covers approximately 200 liters of pesticides which in turn covers 2 to 2.5 acres of land.

So, the knapsack sprayer powered by solar energy is an alternative solution to these problems and limitations. The main advantages of the development sprayer are the running cost reduces and consumes less time. It was fabricated and developed by considering parameters like desired spraying capacity, low cost, high operating time, and faster coverage of the area. Thus, the sprayer was fabricated to be a value for the agricultural sector.

MATERIAL AND METHODS

Field experiments were conducted at Etay El-Baroud agricultural Research Station Beheira Governorate, on eggplant crop planted in rows per inter-row distance of a meter. The field testing of the sprayer was carried out from 19th to 21st June 2019. Various operating standards for the field spray test were recorded using Ridomil plus (50% wp) at the concentration of 300g/100 L water. The

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laboratory evaluations of developed sprayer powered by solar energy were done at Tractor and Farm Machinery Test and Research Station –Alexandria governorate.

Solar knapsack sprayer configuration

The solar knapsack sprayer designed as shown in Fig (1) consists of:-

– The solar panel (0.40 * 0.55 m) was connected with the sprayer to charge the battery and output order of 12 Volts and 25 Watts,

– The charging unit (10) Amp, 12 volts was delivers a signal to charges battery,

– The battery sealed lead acid battery 12V - 9 Amp,

– D.C. pump 12 Volt 15 Watt,

– Aluminum frame with dimensions, height 1.00 m, width 0.40 m and breadth 0.20 m,

– The fluid tank 20 liters with dimensions 0.47 × 0.40 × 0.17 m,

– The electronic circuit as shown in Fig (2) was controlled the pressure of spray from 0 to 4 bar according to control volts, this controller specification [working voltage of DC 3 to 30 V control power of 0.01- 100 W and outline size of 4 × 6 × 2.8 cm with weight of 30 g.

– Sectorial mist nozzle of flow rate 0.5 to 1.0 L/min and

– Spray lance, hose pipe and two on/off switch.

Working principle

The battery is charged by the charging regulator connected to the solar cell and the pump pressure is adjusted by the designed electronic circuit, the pump runs and thus the liquid is sprayed from the tank through the spray. The block diagram of the solar knapsack sprayer is shown in Fig. (3). It is economical for the farmers and it is very easy to work, which has one more advantage that the sprayer can use the power that save in the battery and it can used to light the LEDs at night in house (lamp 8 watts for 8 hours) and the solar sprayer mass of 27kg compared with 23kg of manual sprayer.

1	Photovoltaic panel
2	Charging unit
3	Aluminum frame
4	Nozzle
5	Hose pipe
6	On/off switch
7	D.C. pump
8	On/off switch
9	Fluid tank
10	Contents box
11	Electronic circuit
12	Battery

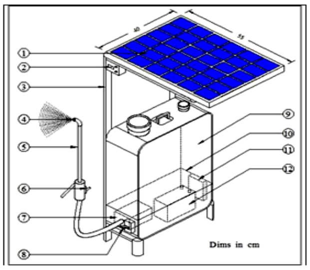

Fig .1. Solar knapsack sprayer

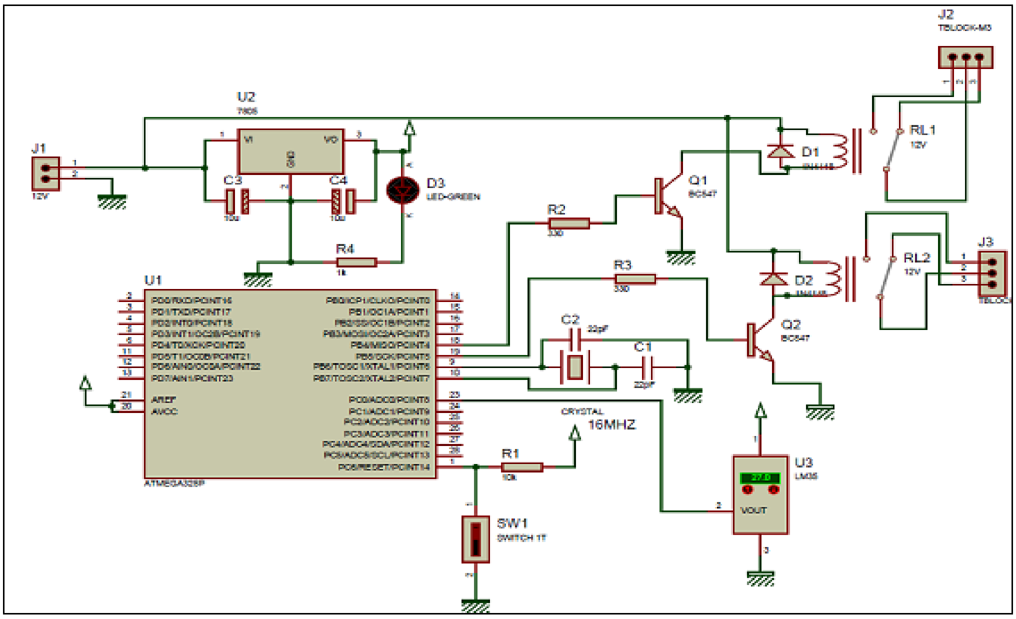

Fig .2. Circuit diagram connected with solar sprayer to change the pressure

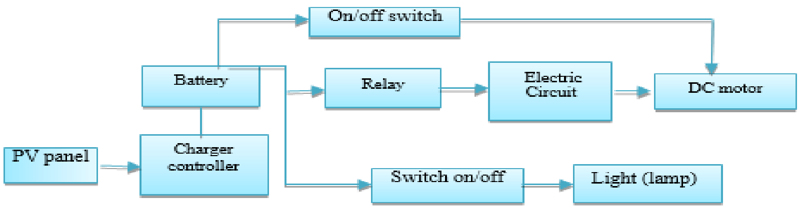

Fig .3. Block diagram of the solar knapsack sprayer

Sprayer battery discharging

The battery discharge characteristics of the sprayer have been tested to determine the discharge time and reduction of the battery voltage. The sprayer panel is covered with a dark cloth and the sprayer motor operates to discharge the fully charged battery. Different parameters such as battery current, time, discharge rate and battery voltage for each 15-minute interval were measured. The reduction of voltage was observed at three pressures until the battery was fully discharged, and the pump stopped working. Three replications were performed and the average value was recorded.

Sprayer battery charging

The charge characteristics of the sprayer battery have been tested to determine the charging time and rise of battery voltage at the non-working time of the pump. The photovoltaic panel has been exposed to sunlight to charge the battery. Different parameters such as panel voltage, battery voltage, panel current, ambient temperature and solar radiation (SI) were measured 15 minutes interval. The battery was charged until it reaches 12V. Three replications were performed and the average value was recorded.

Simultaneous sprayer battery charging and discharging

The sprayer battery charging and discharging were tested to determine the sprayer total operating time. A photovoltaic panel charged the battery which, was fully exposed in sunlight and the battery was used simultaneously for working the pump of the sprayer. The measurements required to determine the sprayer performance are solar radiation, battery current, battery voltage, ambient temperature, panel current and panel voltage were measured per 30 minutes intervals. The reduction of voltage was observed at three pressures until the battery was fully discharged, and the pump stopped working. Three replications were performed and the average value was recorded.

Spray volume requirement

The liquid volume requirement was carried out by measuring 4 × 4 m at the open field. The tank (20 liters) was filled up with liquid. The solar sprayer was turned on and the worker speed was 2.52 km/h throughout the field. Treatments were replicated three times per each flow rate (Q1, Q2, and Q3) (1000, 800 and 600 mL/min) at three different pressures (1.8, 1.4 and 1.0 bar), respectively. So, the spray volume at liter/fed was calculated.

Field testing

Before starting the field experiment, the conditions of the field were recorded such as the condition of the field and area. Also, the crop parameters were recorded such as spacing of the row, the crop height, the name of crop and spacing between plants. The following field parameters were determined during the experiment. Treatments were replicated three times per each flow rate (Q1, Q2, and Q3) (1000, 800 and 600 ml/min)

Effective field capacity

The effective field capacity (EFC) was calculated from the total time required for the field operation.

$$EFC = \frac{A}{T} \text{ Fed/h} \quad \text{.......... (1)}$$

Where: A = field area, fed

T = Total working time, h.

Theoretical Field Capacity

Theoretical Field Capacity is the area covered by sprayer at its rated width and at rated speed. Theoretical field capacity was determined by the formula,

$$TFC = \frac{W \times S}{4.2} \quad \text{.......... (2)}$$

Where: TFC = Theoretical Field Capacity, fed/hr

W= Effective operating width, m

S= operating Speed, km/h

Field Efficiency (FE)

It is the ratio between the effective field capacity and the theoretical field capacity

$$FE = \frac{EFC}{TFC} \times 100 \quad \text{.......... (3)}$$

Economics of solar sprayer

To determine the Economics of solar sprayer, the following calculation are used.

Sprayer cost (S_C)

$$D\,r\,(LE/h) = \frac{S_C - S_r}{T_L - H_S} \quad \text{.......... (4)}$$

Where: S_C = sprayer cost, LE.

H_S= sprayer Annual use, hr

T_L = Total life of sprayer, yr

S_V = Salvage value, LE.

Dr = depreciation rate LE/hr

Variable Cost

Labor working cost (LE /hr)= labor Wage / operating hours

Maintenance and repair (LE /hr) = 5 % of sprayer cost

Total Variable cost = Operators cost (LE /hr) + Maintenance and repair (LE /hr)

Operating cost = Fixed Cost + Variable Cost

The tools and devices that used at the field experiments are as given below:

- Measuring tape was used to measure effective operating width, the dimensions and the height and spacing plants.
- A stop watch was used to record the time during the test.
- Clamp ampere (digital) was used to measure the battery voltage and current and also to measure PV panel voltage and current.
- 2000 ml Measuring cylinder was used to determine the flow rate of the solar sprayer.

RESULTS AND DISCUSSIONS

Sprayer battery discharging

The sprayer was operated at different flow rates and the battery discharging recording. As shown in Figs. 4, 5 and 6 the battery voltage and ampere were measured with time at different flow rate 1000, 800 and 600 ml/min, respectively.

The discharge rate of sprayer battery (12 V) released at three levels of flow rates. The battery voltage reduces gradually with reduction of flow rate up to (530, 350 and 210 ml/min) at Q_1, Q_2 and Q_3, respectively.

The average sprayer working time was established to be (3.0, 2.5 and 1.5 hours) at flow rate 1000, 800 and 600 ml/min, respectively. It was exposed that the battery used only as a source of the power reduced the efficiency of all systems due to operating voltage was a reduction. Also, the results, from Figure 5 and 6 indicate that when controlling and reducing the voltage to change the spray pressure, it leads to increase the current consumption of the battery and therefore the time of battery operating decreased by using the electric circuit to 2.5 and 1.5 hours at 800 and 600 ml/min

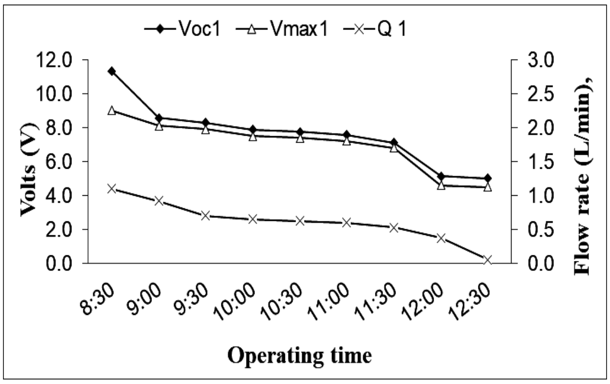

Fig. 4. Battery discharging of the sprayer at Q_1 (1000 ml/min)

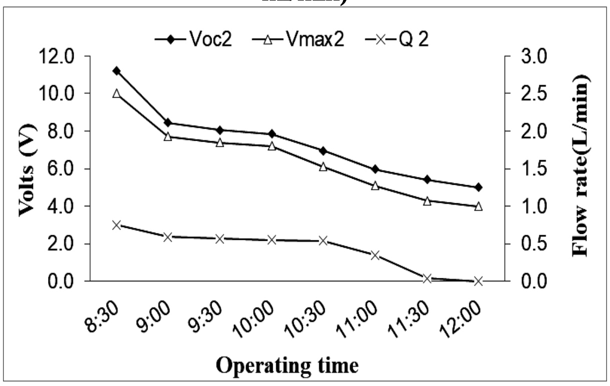

Fig. 5. Battery discharging of the sprayer at Q_2 (800 ml/min)

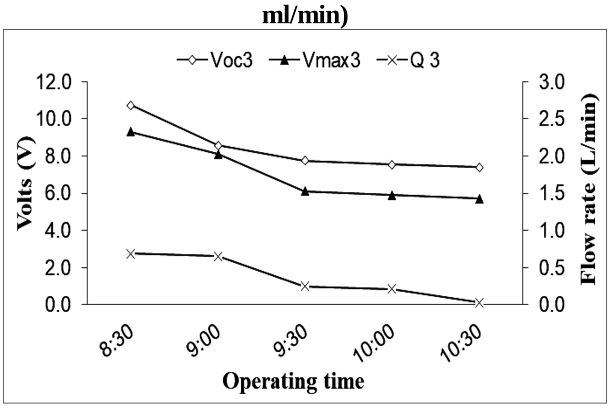

Fig. 6. Battery discharging of the sprayer at Q_3 (600 ml/min)

Sprayer battery charging

The sprayer battery charging was tested to find out the charging time and the voltage of the battery throw the period of charging when the sprayer was in non-working time. The photovoltaic panel was exposed to sunlight on 1st June 2019. The photovoltaic panel charged the battery till the volt reaches up to 12 V. The variation of panel voltage, solar radiation, and battery voltage with time is shown in Fig.7. It was found that, the time required for battery charging preparatory was found to be 5.5 hours to reach full voltage (12.8 V); the charging regulator disconnects the battery. The average solar radiation was ranged from 300 to 1100 W.h/m^2 during the experiment. The output Photovoltaic panel voltage was varied from 11.6 to 18.9 volt through the experiment.

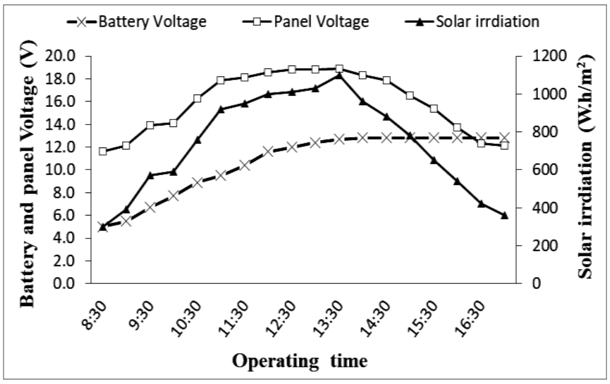

Fig. 7. Battery Charging with solar panel

Simultaneous battery charging-discharging

The sprayer operated and the photovoltaic panel charging the battery at the same time and the total operating period of the sprayer was measured. The battery discharging and charging of solar sprayer was recorded at different pressures as shown in (Fig. 8). The battery was charged by the photovoltaic panel which, was fully exposed to sunlight and consecutively the solar sprayer was operating by the battery.

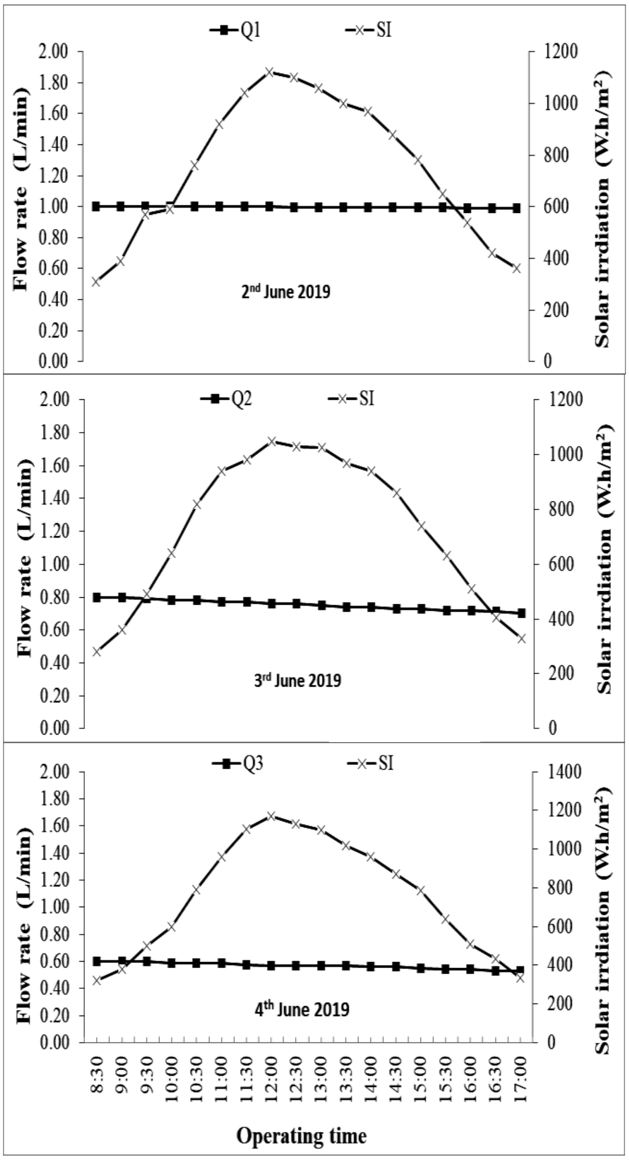

Fig. 8. Battery charging-discharging of the sprayer

The photovoltaic panel was exposed to sunlight on 2nd June 2019. The average solar radiation ranged from 310 to 1120 W.h/m^2. During the test, the sprayer operated continuously for 8 hours and 30 minutes from 8.30 a.m. to 17:00 without a stoppage due to the availability of power from solar Photovoltaic panel at flow rate 1000 ml/min. The battery voltage varied from 11.60 to 10.90 V during the working time. The sprayer flow rate was varied from 1000 to 900 ml/min during the test. It was exposed that sprayer hours continuously operate 3 hours only without photovoltaic panels.

Also, from the results, the photovoltaic panel was exposed to sunlight on 3rd June 2019. The average solar radiation ranged from 280 to 1050 W.h/m^2. During the test, the sprayer operated continuously for 8 hours and 30 min from 8.30 a.m. to 17:00 without a stoppage due to the availability of power from a solar panel at a flow rate of 800 ml/min. The battery voltage varied from 11.32 to 10.30 V during the working time. The sprayer flow rate was varied from 800 to 620 ml/min during the testing. It was revealed that the sprayer hours continuously operate 2 hours and 30 minutes only without a Photovoltaic panel.

Also, from the results, the solar panel was exposed to sunlight on 4th June 2019. The average solar radiation ranged from 320 to 1170 W.h/m^2. During the test, the sprayer worked continuously for 8 hours and 30 min from 8.30 a.m. to 17:00 without a stoppage due to the availability of power from a photovoltaic panel at a flow rate 600 ml/minute. The battery voltage varied from 11.22 to 10.00 V during the working time. The sprayer flow rate was varied from 600 to 460 ml/min during the testing. It was revealed that the sprayer hours continuously operate 1.5 hours only without Photovoltaic panel.

Field performance of the sprayer

The results obtained are shown in Table 1. It was observed that the spray volume requirement of the sprayer per fed was 100, 80 and 60 lit/fed at a flow rate 1000, 800 and 600 lit/mint respectively. Also, the sprayer effective field capacity was varied from 0.40 fed. /h. to 0.46 fed/h at flow rate 600 and 1000 ml/min. The maximum field efficiency of the sprayer was 77% at a flow rate 600 and the minimum field efficiency was 0.66 % at the flow rate of 1000 ml/min.

Table1. Field performance of the sprayer

Items	1000 ml/min	800 ml/min	600 ml/min
Spray volume lit/fed.	100	80	60
Operator speed, km/h	2.52	2.52	2.52
E FC, fed./h	0.40	0.43	0.46
T F C, fed./h	0.59	0.59	0.59
F E, %	0.66	0.71	0.77

Economics of sprayer

The sprayer economic evaluation at flow rate of 1000 ml/min and the sprayer operated manually were calculated. The results are shown in Table 2, the manually operated knapsack sprayer had lower field capacity than a solar sprayer. The field capacity of sprayer was 0.4 fed/h at the flow rate of 1000 ml/min. In case manual operated sprayer, field capacity was found 0.2 fed/h. It was indicated that the minimum operational cost per fed for the development solar sprayer was found to be 53.75 LE/fed compared with (102.50 and 78.75 LE/fed) for manually sprayer and battery sprayer, respectively. Thus, the sprayer performance at a flow rate of 1000 ml/min is cheap than a manually operated sprayer.

Table2. Economics of the sprayer

Sr. no.	Description	Solar sprayer	Battery sprayer	Manually sprayer
I	Fixed cost			
I	Cost of sprayer, LE.	1500	1000	500
Ii	Depreciation, LE. /h	0.75	0.50	0.25
	Total fixed cost	0.75	0.50	0.25
II	Variable cost, LE/h			
Iv	Operator cost, LE/h	20	20	20
	Repair and maintains, LE/h	0.75	0.50	0.25
	variable cost LE/h	20.75	20.50	20.25
Vi	No. of labor /fed.	1	1	1
Vii	Operating time of Spraying, h/fed.	2.5	3.75	5
Viii	Field capacity, fed./h	0.4	0.27	0.2
Ix	Operational cost LE/fed.	53.75	78.75	102.50

CONCLUSION

The main results in the present study can summarize in the following points:

1- The sprayer worked continuously for 3 hours only without photovoltaic panel (with battery only) and the solar sprayer was worked for 8 hours and 30 minutes continuously with Photovoltaic panel.
2- The flow rate of a solar sprayer was values from 1000 ml/min (11.60 V) to 900 ml/min (10.90V) after 8 hours and 30 minutes, compared with the sprayer with battery without solar panel, the battery voltage reduces gradually with reduction of flow rate up to 530 from 1000 ml/min
3- Manually operated knapsack sprayer had lower field capacity than solar sprayer. The field capacity of a solar sprayer 0.4 fed/h at a flow rate of 1000 ml/min. In case manual operated sprayer, field capacity was found 0.2 fed/h
4- The minimum operational cost per fed for the development sprayer was found to be 53.75 LE/fed compared with (102.50 and 78.75 LE/fed) for manually sprayer and battery sprayer, respectively.

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تطوير رشاشة ظهرية لتعمل بالألواح الكهروضوئية

محمد عبدالجواد أحمد ابوعجيله ، محمد ابراهيم سعد المعداوى ، اسلام محمد السيد السباعى و وليد البندارى الفخرانى
معهد بحوث الهندسة الزراعية – مركزالبحوث الزراعية - جيزة

في قطاع الزراعه تعد عمليه رش المبيدات مهمه لحمايه المحاصيل من الحشرات للحصول علي أعلي انتاج. وبالرغم من الانتشار الواسع للرشاشات الظهرية اليدوية وكذلك الرشاشة التى تعمل على بطارية سبق شحنها ، حيث يعتمد النوع الأول على مهارة المشغل والنوع الثاني يعتمدعلى شحن البطارية الذى يكون غير ثابت طوال فترة التشغيل، مما يؤدى الى عدم انتظام توزيع المبيد أو الاسمدة السائلة فى الحقول وبالتالى انخفاض كفاءة التشغيل والانتاجية. لذلك كان الهدف من البحث هو تطوير رشاشة ظهرية لتعمل بالطاقة الشمسية طوال اليوم وبضغط ثابت. وتم تحقيق ذلك عن طريق تطوير الرشاشة الظهرية من خامات محلية، وتزويدها بطلمبة تعمل ببطارية عن طريق الخلية الشمسية ودائرة الكترونية يمكن من خلالها التحكم فى ضغط الرش من 0.0 حتى 4.0 بار وبالتالى يمكن التحكم فى كمية المبيد من خلالها علي حسب عمر النبات، وايضا انتظامية توزيع المبيد عن طريق استخدام ضغط ثابت طوال فترة الرش وبالتالى ضمان عداله توزيع المبيد وعدم الاعتماد على خبرة العامل. أوضحت النتائج ان عدد ساعات التشغيل للرشاشه المطورة يصل الي أكثرمن 8 ساعات يوميا مع ثبات الضغط بالمقارنة باستخدام الرشاشة التى تعمل بالبطارية فقط والتى تعمل من 1.5 الى 3.0 ساعات مع عدم ثبات الضغط عند معدلات التصرف المستخدمة من 600 الي 1000 مليلتر/دقيقه. ومن الناحيه الاقتصاديه تكلفه رش الفدان بالرشاشه التى تعمل بالطاقة الشمسية 53.75 جنيه/ فدان مقارنه بالرشاشه اليدوية والرشاشة التى تعمل ببطارية (102.50 و 78.75 جنيه/ فدان) على التوالى. لذلك تكون الرشاشة المطورة ذات قيمة اقتصادية وعملية عالية فى القطاع الزراعي، وخاصة في المواقع الصحراوية حيث لا يوجد مصدر للطاقة والعمالة المدربة.