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Original Article

Development of a solar photovoltaic backpack sprayer

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Abstract

Backpack solar photovoltaic sprayers have appeared in the market with the aim of improving spraying quality and reducing physical effort for the operator. Queries related to the duration and how to charge batteries are very common and in general they become a barrier for using this equipment in the field. With the objective to better such sprayers, this work has aimed to develop and evaluate a solar photovoltaic backpack sprayer. An electric backpack sprayer MTS brand, model Spritz 18, was used. An aluminum structure was designed and built for fixing two photovoltaic cells, Kyocera brand, model KS5. The evaluation of equipment was made for the instantaneous power generated by the photovoltaic panel with the operator in movement and with the sprayer in static, as well as the potential use of the system. At the end it was verified that the average of the instantaneous power generated was of 1.4 and 2.18 W, for in movement and in static respectively. It was observed that the developed system has wide applicability. It may be applied for field use; it may also optimize the duration of the battery up to 45% and make possible the use of backpack electric sprayers in remote or distant locations, where there is no electric supply system, once it makes possible charging the batteries just using solar energy.

Keywords: agrochemicals application technology, instant power, photovoltaic panel

Desenvolvimento de um pulverizador costal elétrico fotovoltaico

Resumo

Pulverizadores costais elétricos têm surgido no mercado visando melhorar a qualidade das pulverizações e reduzir o esforço físico do operador. Indagações quanto à duração e formas de carregar a bateria são comuns e no geral torna-se um obstáculo em campo para se utilizar estes equipamentos. Com o objetivo de melhorar tais pulverizadores, objetivou-se com este trabalho desenvolver e avaliar um pulverizador costal elétrico fotovoltaico. Utilizou-se um pulverizador costal elétrico da marca MTS, modelo Spritz 18, projetou e construiu uma estrutura em alumínio para fixar duas células fotovoltaicas, marca Kyocera, modelo KS5. Posteriormente prosseguiu a avaliação do equipamento quanto à potência instantânea gerada pelo painel fotovoltaico com o operador em movimento e com o pulverizador estático, bem como o potencial uso do sistema. Ao final verificou-se que em média a potência instantânea gerada por cada painel foi de 1,4 W e 2,18 W, em movimento e estático, respectivamente. Observou-se que o sistema desenvolvido possui grande aplicabilidade, podendo ser aplicado a campo, otimiza a duração da bateria em até 45% e possibilita o uso dos pulverizadores costais elétricos em locais remotos ou distantes, em que não há rede de energia elétrica, pois possibilita o carregamento da bateria apenas com energia solar.

Palavras-chave: painel fotovoltaico, potência instantânea, tecnologia de aplicação de agrotóxicos.

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Introduction

The use of pesticides is an integrant part of the modern agriculture and contributes to productivity and quality of crop grown (Hilz & Vermeer, 2013). Oerke (2006) reports that the use of pesticides prevents yield losses up to 45 % of the of the world food supply. However, the pesticides must be applied with care in order to achieve the objective of the pesticides application technology, which consists in pest and diseases control with minimal environmental contamination and without leaving residues on foods.

Several aspects should be taken into account at the spraying time, as the product choice, weather conditions, spray volume, as well as the correct selection, regulation and calibration of the equipment are fundamental factors that define the pesticides application quality. Although these factors are known, in outdoors conditions leave the control only by operators' responsibility becomes a complicating factor, since there are many factors. Thus, many technologies have been researched and incorporated into sprayers.

Between the knapsack sprayers, the knapsack electric sprayer has gained prominence. Unlike the normal knapsack sprayers, those devises have an ergonomic advantage since there is no need to do repetitive efforts. Another advantage is that these devices allow to work in a constant pressure, which provides greater pesticides application quality, since the pressure changes the droplet spectrum (Nuittens et al., 2009; Fernandes et al., 2007), the spray pattern quality (Cunha & Silva, 2010), the uniformity of liquid distribution (Sasaki et al., 2011) and the potential risk of drift (Costa et al., 2012; Viana et al., 2010).

In spite of these advantages, these equipments are less spread nowadays. Queries in relation to the battery length and how to charge them, have become a key in these sprayers, once in field conditions, there are cases in which the access to electric energy is precarious or are so distant from places in which the operation of pulverization is being made.

Na alternative source of energy is the solar energy, thus it is a clean type, does not emits carbon dioxide, has flexibility of use and is of simple operation and maintenance (Dinçer, 2011). Solar energy also may be easily used in remote places, or places of difficult access.

The hypothesis of this work is that if the use of photovoltaic cells for electric backpack sprayer can optimize the battery duration of these equipment. Therefore this work has aimed to develop and evaluation a system to ease battery charging in conditions of field and optimizing its duration in electric backpack sprayers using photovoltaic panels.

Material and Methods

During all the research, a backpack electric sprayer brand MTS, model SPRITZ-18, was used. This equipment has a 12 volts battery with capacity for 9 A h^{-1}, diaphragm pump, 18 L tank and pressure sensor.

Initially, using a multimeter, brand Minipa, model ET 2510, it was determined the power required by the portable electric sprayer pump using four spraying bits (XR 110 02 VK, AXI ISO 110 03, AXI ISO 110 04 and AXI ISO 110 05), in pressure of 300 kPa.

A structure was designed using the software SolidWorks v. SW2012, and later it was built in aluminum in the form of a "tilt window" in order to permit the alteration of the solar panel, aiming a maximum efficiency of it. The structure was designed for fixing two panels of 5Wp, brand Kyocera, model KS5. After the support was built, it was fixed in the electric backpack sprayer.

In the evaluation of the solar panel, using a multimeter brand Minipa, Model ET 2030A and other brand Minipa, model ET 2510 the instant potencies generated by the panel, with and without the sprayer in movement.

The evaluation of the instant power with the sprayer in movement is a hard task, once factors such as place relief, characteristics of the local and the culture and the position of the operator may affect the efficiency of the solar panel. In order to minimize these errands, and not to favor operator position in relation to the sun, a plain area was demarcated in a circle which ray was of 3 meters, measuring the instant power, in 24 points, during this trail. This procedure was made with the panel in angles of 90, 45 and 20°C in relation to the horizon plan.

For evaluating the static sprayer, the equipment was placed on a table at the height of approximately 0.6 m in relation to the soil and measured instant potencies in four cardinal points (North, South, East and West), as well as in angulations of 90, 45 and 20 □C, in relation to the horizon plan.

For placing the sprayer in the due cardinal points and angulations, a round ruler and a compass were used.

Data were collected in 4 randomized days, 28/05 (13:05 at 14:00); 29/05 (09:50 at 10:45); 31/05 (08:05 at 9:00); 04/06 (08:35 at 9:30), in which the local radiation in the moment of the collection were 2004.5; 1582; 1304; 1301 kJ m^{-2}, respectively, according to information supplied by the INMET. In all the tests, temperature of panels was measured using a digital thermometer brand ICEL Manaus, Model TD – 890. Later the data were analyzed, in statistic delineation in randomized blocks design.

After data collection, analysis and some simulations were made as follows:

Calculation of the percentage of optimization for duration of the battery to an operator which every hour of work stopped for refilling the tank, 30 minutes resting and one hour for lunch.

Time for recharging the battery using the photovoltaic cells with state of battery of (100, 75, 50 e 20%), using one or two photovoltaic panel.

Cost of system implementation.

Statistic analysis were made using the software Assistat v. 7.6 beta and simulations by means of Microsoft Excel.

Results and Discussion

The electric portable sprayer related din this study has a diaphragm pump. During the tests it was observed that the demand of power is proportional to liquid flow (Figure 1).

It was observed that in flows tested, the power varied from 13.2 to 28.3 W. with these data, it was verified that it is possible to use photovoltaic cells in these sprayers following hence the design and building of the prototype (Figure 2).

All the structure was built in aluminum, with dimensions of 0.42 m in the base and 0.49 m height, weight of 1.5 kg and two photovoltaic panels, with approximately 2.2 kg, totalizing 3.7 kg.

In the essays for generated power, temperature of panels remained from 24.7 to 34.5 °C.

In the evaluation of the instant power generated with the operator in movement, it was verified that, either the position of the operator in relation to the sun, as the angle of the panel altered the energy generated (Figure 3).

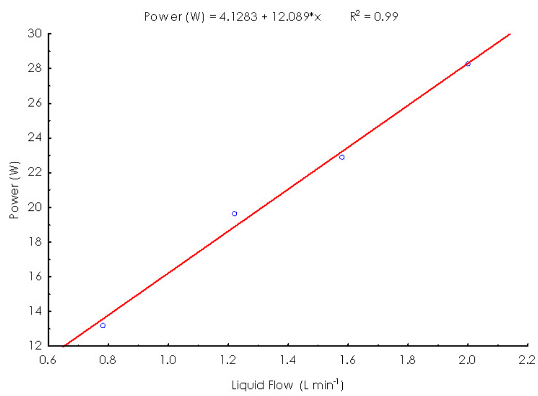
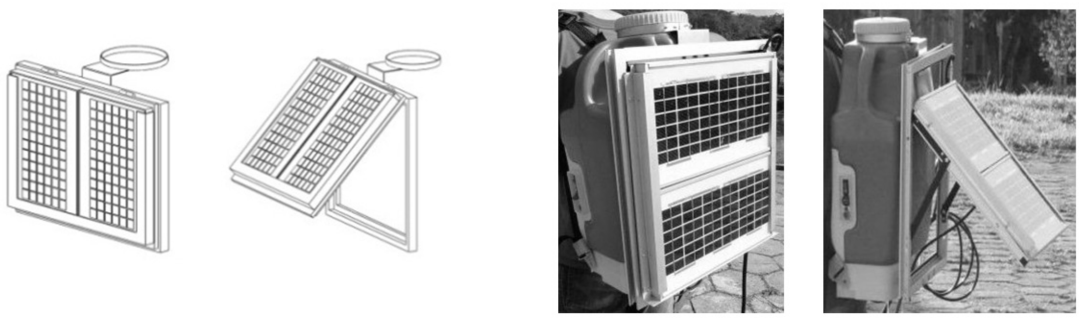


Figure 1. Demands of power in relation to the flow. *p<0.05.



(a) (b)

Figure 2. Prototype. (a) Project in SolidWorks; (b) Construction of the prototype.

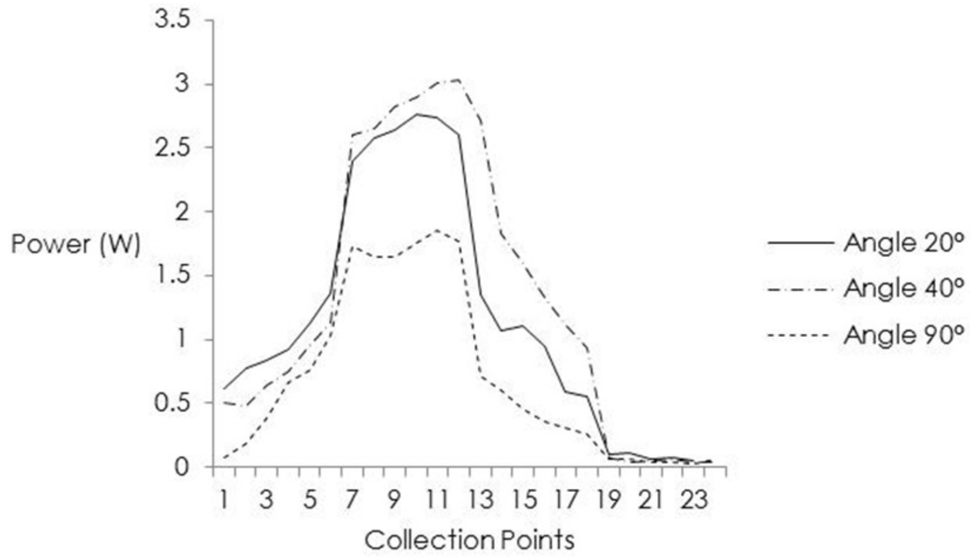


Figure 3. Average instant power (W) generated with the operator in movement.

Wade & Short (2012) reported that energy produced by photovoltaic panels is dependent of solar radiation and temperature, corroborating with the present result, or else, the incidence of radiation on the panel sometimes being favored, other times not favored.

With the operator in movement, it was evaluated the best panel angle in relation to the horizon plan. For such analysis we worked with the average used by both photovoltaic modules. It was observed that the energy generated varied according to the panel inclination. Angles of 20 and 40° produced greater amounts of energy, when compared with angles of 90° (Table1).

Table 1. Average Power generated in function of the angle of the photovoltaic module in relation to the horizon plan.

Angle of panel (degrees)	Power (W)
40	1.401 a
20	1.201 ab
90	0.837 b

Averaged followed by the same letter in the column do not differ among itself by Tukey test ($p<0.05$).

This result may be attributed to the fact that when altering the angle, it was also altered the amount of energy received by the photovoltaic module. Soto et al. (2005) assure that the angle determines the incident radiation, and affects the amount of energy transmitted and then converted into electricity by the cell. These authors also assure that meaningful effects happen when the angle is greater than 65°.

In this work, the alteration of the solar panel angle is of extreme importance. According to Gnoatto et al. (2008) the alteration of the angle may optimize the system according to the demand of the charge attached to the modules, the kind of application and the function of this with the climate behavior along the year. During the spraying, the equipment enables to the operator to position the panel according to the hour of the day, season, place of work, enabling hence a greater efficiency in energy production.

During the evaluation with the equipment static, it was verified that the power varied according to the position and panel angle (Table 2).

Table 2. Average power generated with static equipment.

Face	Power (W) in different angle		
	20°	40°	90°
North	1.227 bA	1.112 abA	0.422 abA
South	0.173 bA	0.0818 bA	0.038 bA
East	2.133 aA	2.184 aA	2.004 aA
West	0.539 bA	0.419 bA	0.310 bA

Averages followed by the same capital letter in the column and lower case letters in the line, do not differ among themselves by Tukey test ($p<0.05$).

It was verified that the power was favored, when the panel was turned with the face to the East. This result may be attributed to the fact that the evaluations were made, mainly in the morning period, when the solar radiation concentrates in this face.

For generating energy with the

photovoltaic cells, the recommendation is that the panel is installed turned to the North face and in the local latitude. If possible the angle may be adjusted monthly for obtaining a maximum efficiency in the production of energy (Gunerhan & Hepbasli, 2007; Yakup & Malik, 2001). In this equipment, due to the easy handling of the panel, whenever it was used in static mode, it is recommended to adjust it in order to let it capture the most energy as possible.

All the energy generated by the solar panel should be directed to the sprayer battery, which stores it for later use. It is recommended to use a charge which restrain an overcharging of the battery and increase its lifespan (Karthik et al., 2012).

In simulation 1, it was considered that, in average, the Power generated with the operator in movement and with the static equipment was of 1.4 and 2.0 W, respectively. It was verified that in this condition of work, it is possible to generate a charge of 1.54 A h^{-1}, for each panel used, optimize the length of the battery in up to 45.4% (Table 3).

Table 3. Simulation of the of optimization of the battery length using photovoltaic cells

Flow (L min^{-1})	Consumed charge (A h^{-1})	% Optimized	
		1 Panel	2 Panels
0.8	6.78	22.714	45.428
1.2	9.72	15.844	31.687
1.6	11.58	13.298	26.598
2.0	13.92	11.063	22.126

These results demonstrate the potential use of the system. In this condition of work using the flow of 0.8 L min^{-1}, probably the operator will not have problems in relation to the length of the battery, once itself has operational capacity enough for performing the operation along a day.

However, in case the operator increases the flow or the time of spraying, the battery may end before the end of day. Yet with the use of photovoltaic cells, occurs the increase of the sprayer autonomy, reducing the probability of the battery ending up in the field.

It is known that in spraying, whenever it is possible, it is common to apply low volume of spray, in order to increase the operational capacity of the sprayer and reduce production costs. However, this reduction of volume demands the optimization of application technology for assuring the maintenance of application efficiency (Souza et al., 2012).

In remote places or with difficult access to electric power net, it is possible to use the photovoltaic system for charging these sprayers. Using only the solar energy, with power generated of 2 W, the charging time of the battery is proportional to its state of charge (Table 4).

Table 4. Time for charging the battery using the photovoltaic cells

Estate of charge (%)	Charging time (hour)	
	(1 Panel)	(2 Panels)
100 (Complete)	0	0
75	11.45	5.73
50	22.90	11.45
20	36.64	18.32
0 (Empty)	45.80	22.90

It was observed that the necessary time for charging the battery using only photovoltaic cells is high, with time of 45.8 and 22.9 hours with 1 and 2 panels, respectively. It is recommended to smaller rural workers, to let the equipment exposed to the sun, aiming to charge the battery in days which they are not spraying, aiming to always keep the battery charged for later use.

In a closer future, with the use of new technologies, such as multiple cells with different bands and also light concentrators, it may be possible to enhance the efficiency of solar panels (Meral & Dinçer, 2011), reducing hence, the time for charging the sprayer battery.

In relation to the cost of the present prototype, when using a panel, the cost is approximately R$ 270.00; with two panels, it costs R$ 410.00 (Table 5).

Table 5. Costs of system implementation

Items	1 Panel (R$)	2 Panels (R$)
Photovoltaic cells	120	240
Metallic structures	70	90
Charge controller	80	80
Total (R$)	270	410

Actually, the value of an electric portable sprayer is of approximately R$600.00. The cost is still very high, representing an added value of 45 and 68% to the sprayer, when using one panel instead of two, respectively. However, advantages such as easy installation, increase in the quality of spraying, possibility of use in remote locations, make the equipment attractive.

With the use of new Technologies, allied to a high efficiency of conversion, low consumption of material, use of low cost material, innovations in fabricating it, mass production and optimized technologies systems may make solar panels more viable (Dinçer, 2011).

Conclusion

The system has a great potential for use.

The maximum instant power generate in each panel is 1.4 and 2.18 W with the equipment in movement and static, respectively.

The panel angle changes the instant power generated.

In simulated condition, the system optimizes the duration of the battery up to 45%.

The system enables the use of electric backpack sprayers in remote locations or in locations not supplied with electric energy.

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References

Costa, A.G.F., Velini, E.D., Rossi, C.V.S., Corrêa, M.R., Negrisoli, E., Fiorini, M.V., Cordeiro, J.G.F., Silva, J.R.M. 2012. Efeito de pontas e pressões de pulverização na deriva de glyphosate + 2,4-D em condições de campo. *Revista Brasileira de Herbicidas* 11: 62-70.

Cunha, J.P.A.R., Silva, R.A.M. 2010. Uniformidade de distribuição volumétrica de pontas de pulverização em função da pressão de trabalho e altura da barra. *Bioscience Journal* 26: 52-58.

Cunha, J.P.A.R., Teixeira, M.M., Fernandes, H.C. 2007. Avaliação do espectro de gotas de pontas de pulverização hidráulica utilizando a técnica da difração do raio laser. *Engenharia Agrícola* 27: 10-15.

Dinçer, F. 2011. The analysis on photovoltaic electricity generation status, potential and policies of the leading countries in solar energy. *Renewable and Sustainable Energy Reviews* 15: 713-720.

Fernandes, A.P, Parreira, R.S., Ferreira, M.C, Romani, G.N. 2007. Caracterização do perfil de deposição e do diâmetro de gotas e otimização do espaçamento. *Engenharia Agrícola* 27: 728-733.

Gnoatto, E., Dallacort, R., Ricieri, R.P., Silva, S.L.; Ferruzi, Y. 2008. Eficiência de um conjunto fotovoltaico em condições reais de trabalho na região de Cascavel. *Acta Scientiarum Technology* 30: 215-219.

Gunerhan, H., Hepbasli, A. 2007. Determination of the optimum tilt angle of solar collectors for building applications. *Building and Environment* 42: 779–783.

Hilz, E., Vermeer, A.W.P. 2013. Spray drift review: The extent to wich a formulation can contribute to spray drift reduction. *Crop Protection* 44: 75-83.

Karthik, M., Jothibasu, M., Pradeep, E., Ganeshmurthy, R., Arun Kumar, N. 2012. Design and Development of Solarised Agro Sprayer for Rural Applications. In: International Conference on Computing, Electronics and Electrical Technologies. *Papers*… Tamil Nadu, Índia. p.389-393.

Meral, M.E., Dinçer, F. 2011. A review of the factors affecting operation and efficiency of photovoltaic based electricity generation systems. *Renewable and Sustainable Energy Reviews* 15: 2176–2184.

Nuyttens, D., Schampheleire, M.De., Verboven, P., Brusselman, E., Dekeyser, D. 2009. Droplet size and velocity characteristics of agricultural sprays. *Transactions of the ASABE* 52: 1471-1480.

Oerke, E.C. 2006. Crop losses to pests. *The Journal of Agricultural Science* 144: 31-43.

Sasaki, R.S., Teixeira, M.M., Alvarenga, C.B., Quirino, A.L.S., Tiburcio, R.A.S. 2011. Uniformidade de distribuição volumétrica de pontas de pulverização hidráulica em diferentes condições operacionais. *Engenharia na Agricultura* 19: 541–547.

Soto, W.De., Klein, S.A., Beckman, W.A. 2005. Improvement and validation of a model for photovoltaic array performance. *Solar Energy* 80: 78-88.

Souza, L.A., Cunha, J.P.A.R., Pavanin, L.A. 2012. Deposição do herbicida 2,4-D Amina com diferentes volumes e pontas de pulverização em plantas infestantes. *Revista Ciência Agronômica* 43: 78-85.

Viana, R.G., Ferreira, L.R., Ferreira, M.C., Teixeira, M.M., Rosell, J.R., Tuffi, S.L.D., Machado, A.F.L. 2010. Distribuição volumétrica e espectro de gotas de pontas de pulverização de baixa deriva. *Planta Daninha* 28: 439–446.

Wade, N.S., Short, T.D. 2012. Optimization of a linear actuator for use in a solar powered water pump. *Solar Energy* 86: 867-876.

Yakup, M.A.B.H.M., Malik, A. Q. 2001. Optimum tilt angle and orientation for solar collector in Brunei Darussalam. *Renewable Energy* 24: 223-234.