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# Hydraulic evaluation of drip irrigation with autonomous and direct photovoltaic pumping

## *Avaliação hidráulica da irrigação por gotejamento com bombeamento fotovoltaico autônomo e direto*

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## ABSTRACT

The combination of high-quality irrigation technologies, especially in terms of uniformity, with pumping energy from renewable sources can solve problems in regions without electricity, prolonged droughts or even supplementary irrigation systems. Therefore, to improve the autonomous and direct photovoltaic pumping system for drip irrigation, statistical quality control was used, since the variation of radiation throughout the day affects the energy supply, the water pumping flow rate and, consequently, uniformity. In view of the potential of this statistical technique, we sought to investigate the variations in application uniformity of three irrigation systems that differed according to the manufacturer and, above all, the thickness of the hose. The results indicate that a thicker-walled hose stabilizes the system's characteristic fluctuating pressure. In addition, hydraulic power values in conjunction with application uniformity values should be taken into account when deciding on the choice of emitter for a drip irrigation project.

**Keywords:** Solar energy; Localized irrigation; Application uniformity; Statistical control; Hydraulic power.

## RESUMO

A combinação de tecnologias de irrigação de alta qualidade, especialmente no que diz respeito à uniformidade, com energia para bombeamento proveniente de fontes renováveis, pode resolver questões em regiões sem eletricidade, secas prolongadas ou até mesmo para sistemas de irrigação complementar. Portanto, buscando o aperfeiçoamento do sistema de bombeamento fotovoltaico autônomo e direto para irrigação por gotejamento, utilizou-se o controle estatístico de qualidade, uma vez que, a variação na radiação ao longo do dia afeta o suprimento de energia, o fluxo de bombeamento de água e, consequentemente, a uniformidade. Tendo em vista o potencial desta técnica estatística, buscou-se investigar as variações na uniformidade de aplicação de três sistemas de irrigação que diferiam conforme o fabricante e, principalmente, a espessura da mangueira. Os resultados indicam que, uma mangueira de parede mais grossa estabiliza a pressão flutuante característica do sistema, além disso, valores de potência hidráulica em conjunto com valores de uniformidade de aplicação devem ser considerados, na tomada de decisão da escolha do emissor para um projeto de irrigação por gotejamento.

**Palavras-chave:** Energia solar; Irrigação localizada; Uniformidade de aplicação; Controle estatístico; Potência hidráulica.

## INTRODUCTION

Promoting environmentally friendly and low-energy operation of irrigation systems to save water has become an unavoidable requirement for sustainable agricultural production (Zhang et al., 2013). Photovoltaic technology in rural activities is becoming an alternative to provide higher yields for producers (Das et al., 2017; Nasir, 2019), due to its potential for expansion and the high investments made, energy generation through solar panels is seen as one of the most promising areas in the clean energy sector (Sampaio & González, 2017).

One way of increasing the efficiency of water use with energy has been the use of water pumping in irrigation systems (Bernardo et al., 2008). In this sense, autonomous photovoltaic pumping stands out as emerging and challenging and can be used in various scales of energy production Mittal et al. (2012).

However, it is worth noting that one of the challenges of this pumping technique is that its energy varies over time (Pande et al., 2003). This can affect the efficiency of drip irrigation systems, as the power of the pump is directly influenced by the amount of sunlight available.

In addition to this temporal variability, another challenge is the diversity of drip hoses available on the market. There are emitter tubes with thicknesses varying between 100 and 250 microns, also varying spacings, from 0.1 m to 1.0 m between emitters, different technologies in the production of emitters, such as different labyrinth designs, or the format in which the emitters are attached to the hoses. All these variables combined compromise the quality of the product (Saad & Jefery, 2015).

Several studies involving hydraulic evaluation of drip tubes have already been carried out. Dalri et al. (2015) evaluated the technical and hydraulic characteristics of seven emitting tubes, determining parameters such as manufacturing variation coefficient; coefficients of the dripper characteristic equation; dripper tube wall thickness; tube internal diameter; spacing between emitters. (Fischer Filho et al., 2018) observed satisfactory results for uniformity when investigating the hydraulic performance of four drippers as a function of the manufacturing variation coefficient. While Saad & Jefery (2015) found that drip hoses with different wall thicknesses presented different flow rates for the same pressure.

Given these results, the opportunity to understand how the choice of hose thickness can interfere with the behavior of irrigation with autonomous photovoltaic pumping stands out. Therefore, the hypothesis of this work is that varying the wall thickness of the hose, as well as the model of emitter used, can alter the hydraulic behavior of drip irrigation with autonomous photovoltaic pumping, to the point where one model is more suitable when considering the final quality of the water application.

Thus, in order to improve the autonomous photovoltaic pumping system for drip irrigation, statistical quality control was used, which is a technique that consists of analyzing the process, establishing standards, comparing performance, verifying and studying deviations, seeking and implementing solutions and analyzing the process again after modifications, with the aim of improving the system as a whole (Montgomery, 2016).

The performance of new irrigation system configurations can be assessed by applying statistical process control (SPC) techniques (Kepp et al., 2023). Some studies such as (Campana et al., 2013; Reca et al., 2016; Haupenthal, 2019; Zavala et al., 2020), have been carried out to improve the autonomous photovoltaic system for irrigation through the evaluation of uniformity and simulation models for the optimization and operation of the system, since the variation in radiation throughout the day affects the energy supply, the water pumping flow and, consequently, the uniformity of the irrigation system (Andrade et al., 2017).

In addition, other studies, such as those by (Frigo et al., 2016; Hermes et al., 2015; Zocoler et al., 2015; Andrade et al., 2017; Siqueira et al., 2018) and (Lopes et al., 2021), have used this technique to understand the behavior of different irrigation projects.

Therefore, in view of the potential of autonomous photovoltaic drip irrigation systems, the objective was to investigate, using statistical process control, the variations in the behavior of the application uniformity of three irrigation systems that differ by manufacturer and mainly by hose thickness.

## MATERIAL E METHODS

### Characterization of the research location

The experiment was conducted at the Irrigation and Fertigation Laboratory (LIF), at the Agricultural Engineering Experimental Center (NEEA), of the State University of Western Paraná, Cascavel, Brazil at the geographical coordinates 24° 54' 0" South and 53° 31' 48" West, with an average daily solar irradiance of 4.96 KWh $m^{-2}$ $day^{-1}$ on the inclined plane at an angle equal to latitude (25° North), with climate classification Cfa (Köppen & Geiger, 1928), in the months of October to December 2022, during the day, 9 am to 5 pm.

### Irrigation system

The irrigation test was carried out on a 5 m drip irrigation bench with the following characteristics: pulley system with lateral line return, obtaining a length of 10 m; bench width of 1.55 m, with four lateral lines; gutters for water return to a 100-liter reservoir. Figure 1 shows the layout of the test bench.

Three dripper models were tested, P1 Irritec, with emitters spaced 0.5 m apart and an average flow rate reported by the manufacturer of 2.10 L h-1 at 10 mca. The emitter used is characterized by an internal diameter of 16 mm, a thickness of 0.2 mm, a maximum working pressure of 8 mca, a proportionality coefficient of the emitter equation (K) of 0.69, a discharge exponent (x) of 0.48 and recommended filtration of 120 mesh; followed by the P1 Irritec model, with emitters spaced at 0. 20 m and an average flow rate reported by the manufacturer of 1.1 L $h^{-1}$ characterized by an internal diameter of 16 mm, a thickness of 0.2 mm, a maximum working pressure of 8 mca, a proportionality coefficient of the emitter equation (K) of 0. 38 and discharge exponent (x) of 0.48 and recommended filtration of 120 mesh; ending with the Aries 16200 emitter, Netafim, spaced at 0.40 m and with an average flow rate reported by the manufacturer of 1.5 L $h^{-1}$, characterized by an internal diameter of 15. 5 mm, a thickness of 0.5 mm, a maximum working pressure of 24.5 mca, a proportionality coefficient of the emitter equation (K) of 0.52, a discharge exponent (x) of 0.46 and recommended filtration of 200 mesh.

An Irritec® model FLD 120 mesh disc filter and two INSTRUTEMP® model 8215 digital pressure gauges (100 mwc) were installed at the beginning of the irrigation system and at the end of the last line to measure the initial and final pressure of the drip system, where data was collected at the beginning (t=0 min), middle (t= 2min) and end (t= 4min) of the test, establishing an average for the initial and final pressure.

## Characteristics of the photovoltaic panel and motor pump

The irrigation test was carried out using an installation system powered by solar energy, with a polycrystalline silicon module, power 150 Wp, brand Resun Solar, model RS6E 150P, directed towards the Equator (True North), The system was installed at an inclination corresponding to the latitude of the location, 24º 58", since the angle of inclination of the photovoltaic generator must be equal to the latitude of the location where the system will be installed (Pinho & Galdino 2014), in order to maintain the highest average annual irradiance. Table 1 describes the specifications of the photovoltaic panel.

The system was connected directly to a Solarjack submerged diaphragm pump, model SDS-D-228, with a maximum flow rate of 342 L h-1, which recharged the irrigation platform.

## Experimental design

The experiment was conducted in a completely randomized design, in which three dripper models (P1 by Irritec 2.1 $L.h^{-1}$; Aries by Netafim and P1 by Irritec 1.1 $L.h^{-1}$) powered by solar energy were evaluated.

**Table 1.** Characteristics of the RS6E 150P photovoltaic module.

| Maximum power | 150 W |
|---|---|
| Open circuit voltage | 22.3 V |
| Short-circuit current | 8.82 A |
| Maximum power point voltage | 17.91 V |
| Maximum power point current | 8.38 A |
| Efficiency (module area) | 15.29% |
| Number of cells | 36 [4×9 (156 × 156 mm)] |
| Cell type | Polycrystalline. 4 or 5BB |
| Module dimensions | 1487 × 666 × 35mm |

All electrical characteristics parameters are tested under STC conditions: 1000W/$m^2$, AM1.5, 25 °C. Source: Resun Solar Energy (2024).

A total of 25 trials were carried out for each treatment; this number of samples is recommended by Montgomery (2016) for quality control tests. The treatments were therefore arranged as follows: T1 - P1 Irritec 2.1 $L.h^{-1}$; T2 - Aries Netafim 1.5 L $h^{-1}$, and T3 - P1 Irritec 1.1 $L.h^{-1}$

It should be noted that the collection took place during periods of clear skies, cloud cover and overcast periods, in order to assess whether climate change presents any significant alteration to the uniformity coefficients; according to the manufacturer, the pump used in the experiment works even on rainy days. In addition, care was taken to clean the photovoltaic module before any collection procedure to avoid the effect of external components.

## Test procedures

Irradiation levels were recorded by an Instrutherm model MÊS-100 portable solar energy meter during the irrigation system's flow collection period. Exploratory data analysis made it possible to statistically explore and investigate water pumping behavior

Hydraulic power values were calculated using Equation 1, given by (Protogeropoulos & Pearce, 2000):

$$Pot_h = \rho \, x \, g \, x \, Q \, x \, H \quad (1)$$

where: $Pot_h$ - Hydraulic power (W), ρ - Specific mass of water (Kg. $m^{-3}$); g - gravity (m. $s^{-2}$), Q - flow rate (m. $s^{-1}$), and H - height in (m.c.a.).

To obtain the irrigation system's application uniformity, the collectors were positioned close to the outlets determined by the Keller & Karmeli (1974) methodology. This methodology consists of determining the flow rate in 4 emitters per lateral line, i.e. the first dripper, the drippers located at 1/3 (7th dripper) and 2/3 (13th dripper) of the length of the lateral line and the last dripper (20th) in 4 lines. With the volume collected from the emitters within the range of 09:00 to 17:15 hours, in order to obtain equality within the collection period, the flow measurement with an interval of 45 min between each collection.

The flow rate of the drippers was measured using the gravimetric method, which consists of weighing a given volume

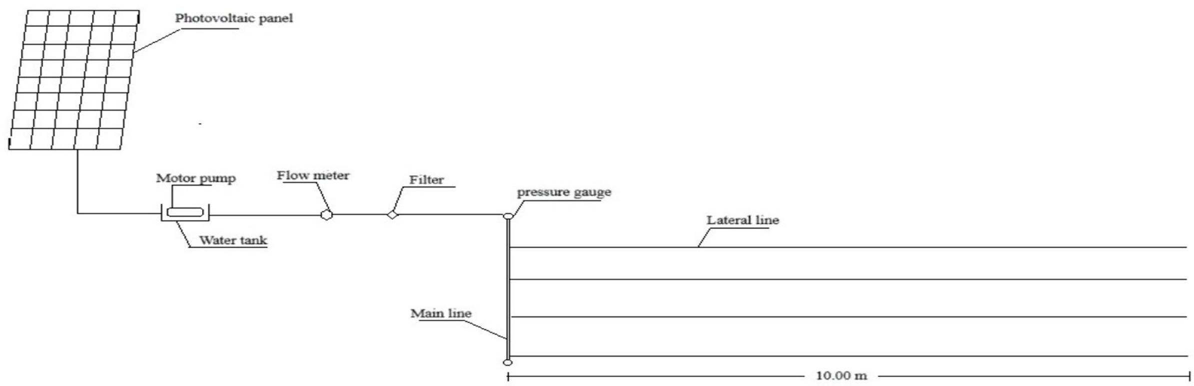


**Figure 1.** Illustration of the drip irrigation test bench.

of water over a given time in order to obtain greater precision in determining the volume. As recommended by NBR 9261 (Associação Brasileira de Normas Técnicas, 2006), the emitter flow rate was determined using Equation 02:

$$q = \frac{v}{1000xt} x 60 \quad (2)$$

where q - Dripper flow rate, L h-[1]; v - volume of solution collected, mL; t - collection time, min.

Based on the flow rate of the 16 drippers per test, the Distribution Uniformity (UD) proposed by Merrian & Keller (1978) was used, as shown in Equation 3.

$$\text{UD} = 100\left(\frac{q_{25}}{q_a}\right) \quad (3)$$

where q25 - average of the lower quartile of volumes of water in the collectors (mm); qa: overall average of the volume of water collected (mm).

(Frizzone et al., 2012) proposed the classification of the UD (%) according to the values obtained in order to identify the efficiency of the irrigation system, which is shown in Table 2.

Shewhart Control Charts were used to monitor UD (%) with a focus on individual averages, following the methodology proposed by Montgomery (2016). In the analysis of the behavior of some processes, the sample size is n = 1, which means that the sample consists of a single individual unit. In general, these graphs use the moving range of two consecutive observations as the basis for estimating the variability of the process. The moving range is defined as MR and is calculated by $MRi = |xi - xi\text{-}1|$, where i is an integer representing the point being observed (Montgomery, 2016).

To create and interpret these graphs, the Upper Control Limit (UCL) and Lower Control Limit (LCL) are calculated using Equations 4 and 5 (Montgomery, 2016).

$$UCL = \overline{\overline{X}} + L\frac{\text{MR}}{d_2} \quad (4)$$

$$LCL = \overline{\overline{X}} - L\frac{\text{MR}}{d_2} \quad (5)$$

where $\overline{\overline{X}}$ - Mean of the averages; L - Distance from the control limits to the central line, expressed in standard deviation units; MR - Mean of the data amplitudes; d_2 - A constant equal to 1.128 when the number of observations is n = 2, considering individual measurements, according to tabulated values described by Montgomery (2016).

In general, Shewhart control charts are usually calculated considering L = 3, which represents approximately 370 samples collected, so that a point can indicate a change in the monitored statistic when the process is outside the control limit (Montgomery, 2016). The author adds that the definition means that 99.7% of the samples will be within the control limits, as long as only common causes are acting on the system and the distribution is normal.

**Table 2.** Classification of UD for drip irrigation systems.

| Classification | UD (%) |
|---|---|
| Excellent | > 90 |
| Good | 90-80 |
| Regular | 80-70 |
| Fair | 70-60 |
| Poor | <60 |

**Source:** Frizzone et al. (2012).

However, in this study, L = 2 was used, and this value is justified by the fact that the number of samples collected was only 25. This value represents approximately 22 samples collected, so that one point can indicate a monitored statistical change, i.e. out-of-control behavior.

Statistical comparison techniques and Shewhart control charts were calculated using MINITAB software, version 16.

## RESULTS AND DISCUSSION

Figure 2 shows the graphs for the behavior of the emitter flow rates in relation to the working pressure for the tests involving the three hoses Figure 1b and for the data supplied by the manufacturer Figure 1a. It can be seen that, at a 5% significance level, the exponential model q=k.h^x correctly specifies the relationship between flow rate and service pressure. It is worth noting that in all the regressions the S value was close to zero, which demonstrates the quality of the data description for the proposed models.

Comparing the coefficients of the field data models with the manufacturer's data, it can be seen that the angular coefficients decreased with the application of direct and autonomous photovoltaic pumping for all the hoses studied. One hypothesis to justify this behaviour lies in the system's fluctuating pressure; under photovoltaic pumping conditions there are abrupt variations in energy over a short period of time, so when the pump receives more energy from the system, the pressure at the main line inlet rises before the system's average flow rate, because it takes longer for the entire system to fully pressurize and stabilize. Therefore, under fluctuating pressure, even before the pressure stabilizes, the pump starts operating with less energy and the flow rate does not reach its maximum values.

Figure 3 shows the graphs relating to the behavior of emitter flow in relation to irradiance, considering the three dripper models. It can be seen that, at a 95% confidence level, the Michaelis-Menten non-linear model accurately demonstrated the relationship between flow rate and irradiance for all the treatments tested. That said, it was possible to ascertain that the maximum flow rate of the P1 - 2.1 $L.h^{-1}$, Aries - 1.5 $L.h^{-1}$ and P1 - 1.1 $L.h^{-1}$ emitters stabilizes at 2.1 $L.h^{-1}$, 1.4 $L.h^{-1}$ and 0.8 $L.h^{-1}$, respectively.

Evaluating the system's working pressure for each treatment, shown in Figure 4, it can be seen that the pressure was higher when the 1.1 $L.h^{-1}$ Irritec P1 emitter was used (T3), and lower when the 2.1 $L.h^{-1}$ Irritec P1 emitter was used (T1). It can be seen that the lower the dripper's nominal flow rate, the higher the system's working pressure. This behavior indicates that the sizing of the solar pumping power must be carried out carefully, because in addition to achieving the designed flow rate, the pumping must deliver the service pressure recommended by the manufacturer, or even a higher pressure, so that the system does not operate at a pressure below the reference at times of low irradiance, to the point of interfering with the quality of the irrigation.

The hydraulic power of the system is an important variable to consider when choosing an emitter for a drip irrigation project with direct and autonomous photovoltaic pumping. This is because pressure is inversely proportional to flow. In other words, an

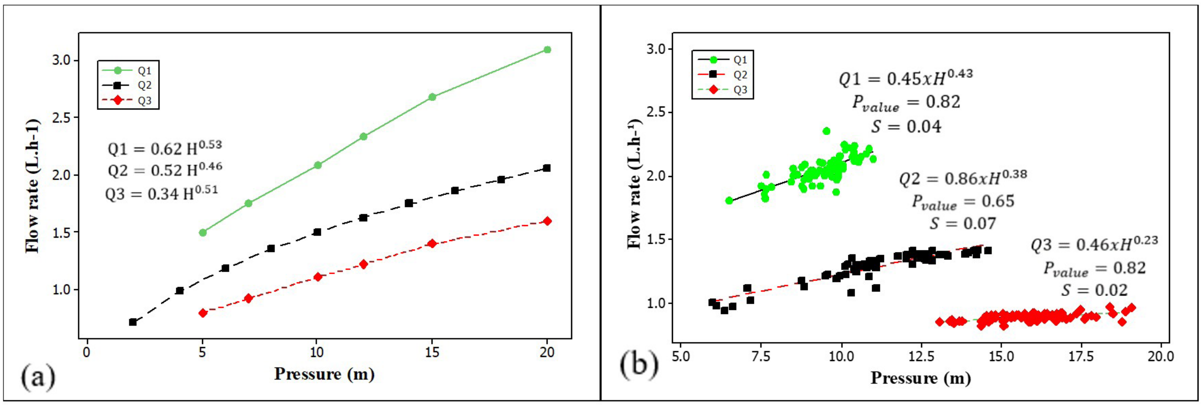


**Figure 2.** Flow rate (Q) x working pressure, (a) according to the manufacturer and for the (b) tests with the three hoses.

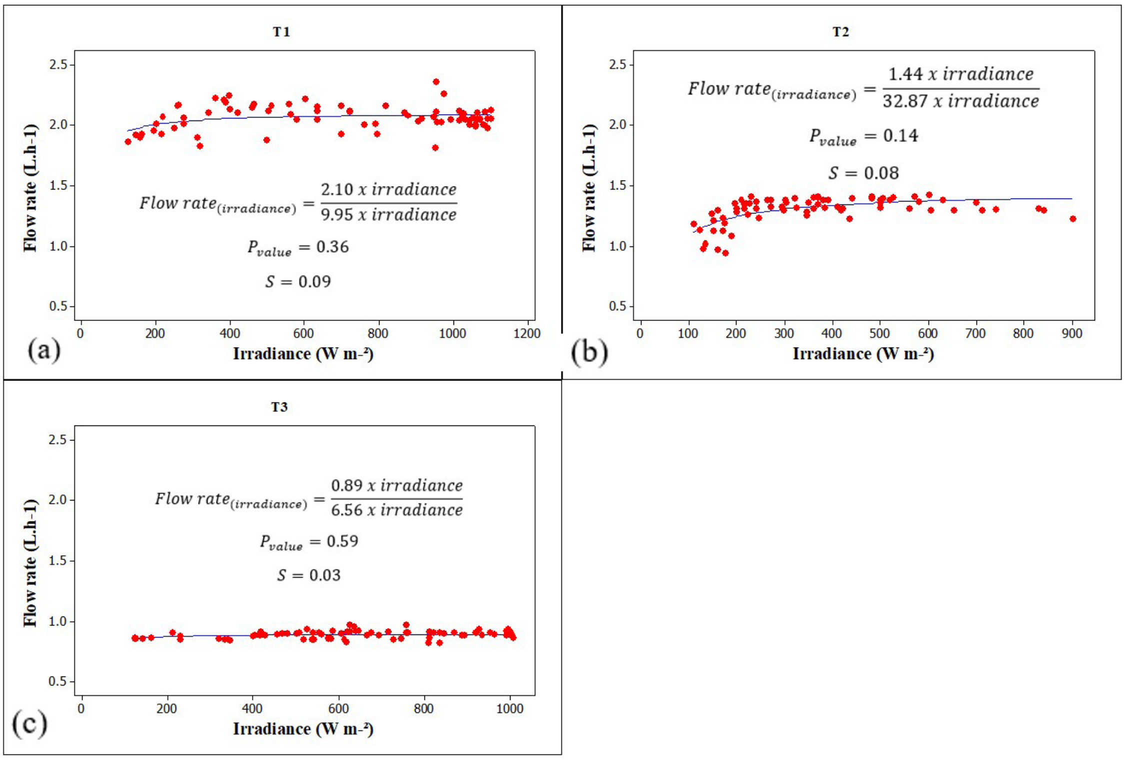


**Figure 3.** Flow rate x irradiance for the three dripper models (a) T1 - Irritec 2.1, (b) T2 - Netafim, (c) T3 - Irritec 1.1.

emitter with a higher nominal flow rate will operate at a lower pressure than an emitter with a lower nominal flow rate. Figure 5 shows the hydraulic power of the 75 trials of each drip irrigation system carried out with each of the three emitters.

Figure 5 shows that the treatment with the 2.1 $L.h^{-1}$ Irritec P1 emitter had the highest hydraulic power, with an average of 5.3 W, while the other treatments had an average hydraulic power of 3.9 W. It should also be noted that the points below the control limits are explained by the low irradiance at the time of collection.

Also, Figure 5 shows that the hydraulic power was higher for the treatments operating with the emitter with the highest nominal flow rate. However, care should be taken when using this information alone to decide which emitter to choose, as the quality of the irrigation could be compromised.

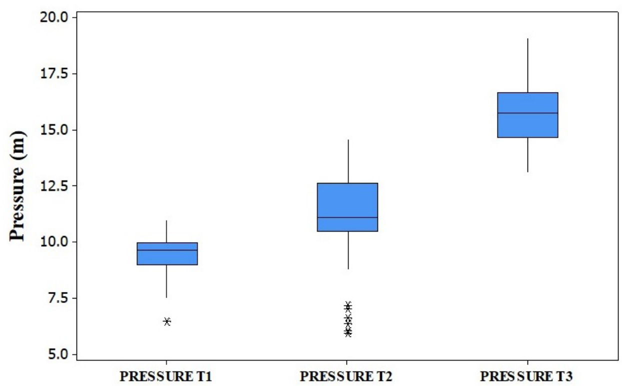


**Figure 4.** Working pressure for the three dripper models T1 (Irritec 2.1 $L.h^{-1}$), T2 (Netafim 1.5 $L.h^{-1}$), T3 (Irritec 1.1 $L.h^{-1}$).

Therefore, an alternative to help with decision-making is to carry out a complementary analysis of the distribution uniformity of the applied blade. Figure 6 shows the behavior of the irrigation system, UD (%) for the three treatments. The graph shows that the average application uniformity of the treatment involving the 2.1 L.h-1 Irritec P1 dripper was the lowest, with an average of 87%, as well as the high amplitude of the data. The low uniformity is explained by the pressure values; although the average operated under the manufacturer's conditions, the fluctuating pressure characteristic of solar pumping means that it operates at times under a lower pressure than the average, which is reflected in the irrigation application uniformity.

The disparity in uniformity found in the treatment involving the P1 Irritec - 2.1 $L.h^{-1}$ emitter is reinforced by other research. Fischer Filho et al. (2018), when investigating the UD (%) of irrigation with a 1.5 $L.h^{-1}$ Irritec P1 hose, under constant pressure, reached values of 96%.

With regard to studies involving application uniformity in photovoltaic and autonomous drip irrigation systems, other works also highlight how timely this project is can be. Pande et al. (2003), for example, recommended a design dimension based on the uniformity of an application. Reca et al. (2016) and Zavala et al. (2020) investigated the multisectoral application of this irrigation model, also using UD (%) as a validator.

Cervera-Gascó et al. (2020) set out to develop mathematical models based on uniformity to design drip irrigation systems conditioned to this energization system.

(Cossich et al., 2024) when investigating the uniformity of application of a pulsating drip irrigation system, i.e. also under fluctuating pressure, showed that the greater the variation in pressure, the greater the drop in UD (%) in the system.

Comparing the treatment with the Aries Netafim hose - 1.5 $L.h^{-1}$ and P1 Irritec - 1.1 $L.h^{-1}$, it can be seen that although the average pressure was lower, the uniformity values were higher for the Netafim dripper, which can be explained by the hose's greater wall thickness. According to Saad & Jefery (2015), the thicker the wall, the less sensitive the flow rate is to changes in pressure. In other words, in the application of direct and autonomous photovoltaic pumping, a thicker-walled hose stabilizes the fluctuating pressure characteristic of the system which implies higher raw material requirements and higher costs.

The initial investment in implementing a drip irrigation system using thicker hoses varies depending on the longevity and characteristics of each project. A study by Melo et al. (2019) showed that thin-walled hoses suffer greater load losses, which limits their hydraulic efficiency and useful life.

Thus, although more expensive, thicker tubes offer better performance and durability, justifying the initial investment in autonomous photovoltaic systems. This corroborates the data presented in Table 2 on wall thickness values for different brands of drip tubing.

In addition to the costs related to the drip tubes, Table 3 presents information on different solar pumping kits, listing the total value and the savings generated by excluding the controller from the irrigation system. One of the most immediate advantages of not using the controller is the reduction in initial investment costs, which can reach up to 44.3% depending on the brand and model chosen (Table 4). The MPPT controller represents up to 35% of the cost of a solar pumping kit. Its exclusion makes the system

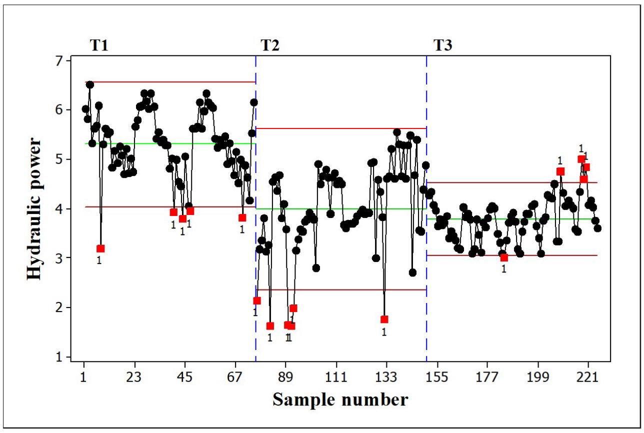


**Figure 5.** Shewhart control chart for hydraulic power.

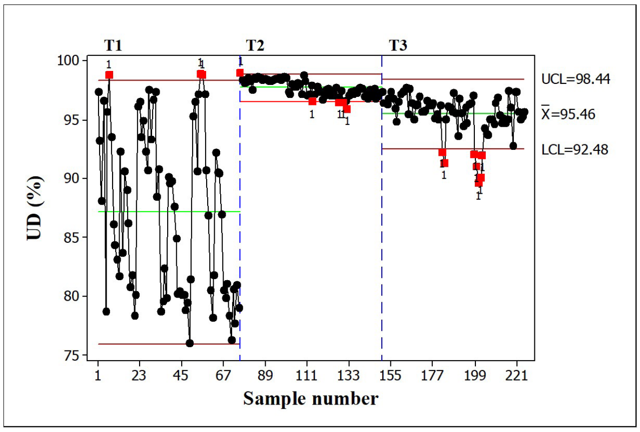


**Figure 6.** Shewhart chart for UD (%).

**Table 3.** Brands and models of drip lines.

| Brand/Model | DL (m) | NP (mca) | Pipe diameter (mm) | | T (mm) | Flow ($Lh^{-1}$) | Value (R$) | |
|---|---|---|---|---|---|---|---|---|
| | | | internal | external | | | total | meter |
| Netafim Aries 16200 | 900 | 25 | 15.5 | 16.5 | 0.50 | 1.50 | 1092.48 | 1.21 |
| Netafim Drip netpc | 800 | 25 | 15.5 | 16.5 | 0.50 | 1.60 | 1888.99 | 2.36 |
| Irritec P1 | 3500 | 8 | 16.1 | 16.5 | 0.20 | 2.10 | 1168.00 | 0.33 |
| Rivullis | 1000 | 10 | 15.5 | 16.0 | 0.20 | 1.50 | 603.00 | 0.60 |
| NaanDanJain | 3000 | 9 | 16.0 | 16.4 | 0.20 | 1.60 | 1264.15 | 0.42 |
| Brasil Drip Pantanal | 1000 | 10 | 16.0 | 16.4 | 0.20 | 2.00 | 845.00 | 0.84 |

DL: drip tape length; NP: nominal pressure; T: Wall thickness.
**Source:** Elaborated by the author.

**Table 4.** Brands and models of solar pump kits.

| Solar pump kit with controller | Power required (W) | Daily flow rate (L/day) | Type of solar pump | Value | Controller | Value | *Savings without controller (%) |
|---|---|---|---|---|---|---|---|
| ZTROON - 3ZTPC5-45-48-500W | 500 | 30.000 | Centrifugal submerged | 2,819.00 | ZTROON MPPT 48V | 1,249.00 | 44.3 |
| ZTROON - 3ZTPC5.2-75-96-750W | 750 | 31.200 | Centrifugal submerged | 3,789.00 | ZTROON MPPT 96V | 1,349.00 | 35.6 |
| ZTROON – 3ZTPC6-125-96-1500W | 1500 | 36.000 | Centrifugal submerged | 5,659.00 | ZTROON MPPT 96V | 1,349.00 | 23.8 |
| ZTROON – 3ZTS2.0-150-48-750W | 750 | 12.000 | Helicoidal | 3,529.00 | EPEVER MPPT 12/24/36/48V | 1,199.00 | 34.0 |

*Represents the economic benefit resulting from the absence of the controller in the system, allowing a comparative analysis of the financial impact of its inclusion or exclusion.
**Source:** Neosolar (2025).

more economically viable for small farmers (García Reca et al., 2018). However, the author points out that for systems of more than two hectares, the absence of electronic control compromises hydraulic performance and makes modular expansion difficult. It is therefore essential to consider the specific characteristics of each system before opting to include or exclude the controller.

## CONCLUSIONS

When designing a drip irrigation system with direct and autonomous photovoltaic pumping, it is advisable to design a higher working pressure than that recommended by the manufacturer.

Hoses with greater wall thickness are more recommended for drip irrigation with direct and autonomous photovoltaic pumping.

When deciding whether to choose a drip irrigation system with direct and autonomous photovoltaic pumping, the hydraulic power values must be considered together with the application uniformity values.

## DATA AVAILABILITY STATEMENT

Research data is available in the body of the article.

## ACKNOWLEDGEMENTS

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Marcio Antonio Vilas Boas: Supervision, investigation, methodology, formal analysis, revision and editing, validation, acquisition of financing.

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