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UNIFORMITY OF DRIP IRRIGATION SYSTEM WITH LIQUID PEAT ON DIFFERENT SLOPES

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1 ABSTRACT

The use of liquid peat is an alternative to use of mineral fertigation However, it is necessary to monitor the uniformity of this organomineral fertilizer in order to obtain its adequate use, so the organomineral fertilizer can produce better quality crops. This study aimed to evaluate the uniformity of a drip fertigation system with liquid peats on different slopes. The experiment was carried out on a test bench, where the flow rate of the drippers was determined and subsequently its uniformity was calculated using the Christiansen uniformity coefficient (CUC) fot the treatments in level (0%), uphill (2%) and downhill (2%). The experimental statistics were performed by analysis of variance (ANOVA) and Tukey's test at 5% probability to compare uniformity, in addition to the analysis of the process by Shewhart and CUSUM control charts. Liquid peat showed excellence in its uniformity (>90%) while used for drip irrigation systems. The liquid peat applied at the level slope was the most uniform, followed by upslope and downslope treatments, respectively. Through Shewhart and CUSUM control charts, it was possible to affirm that fertigation with liquid peat in level obtained a better performance.

Keywords: control chart, uniformity, organomineral fertilizer, microirrigation.

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2 RESUMO

O uso da turfa líquida é uma alternativa ao uso da fertirrigação mineral. No entanto, é necessário o monitoramento da uniformidade deste fertilizante organomineral para obter seu uso adequado, assim o fertilizante organomineral pode produzir culturas de melhor qualidade. O objetivo deste estudo foi avaliar a uniformidade de um sistema de fertirrigação por gotejamento com turfa líquida em diferentes inclinações. O experimento foi conduzido em uma bancada de

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testes, onde a vazão dos gotejadores foi determinada e consequentemente sua uniformidade pelo Coeficiente de uniformidade de Christiansen (CUC) para os tratamentos em nível (0%), aclive (2%) e declive (2%). A estatística experimental foi determinada pela análise de variância (ANOVA) e teste de Tukey a 5% de probabilidade na comparação da uniformidade, complementando os gráficos de controle de Shewhart e CUSUM. A turfa líquida apresentou excelência na sua uniformidade (> 90%) em sistemas de irrigação por gotejamento. A turfa aplicada em nível (0%) foi a mais uniforme, seguido pelos tratamentos em aclive e declive, respectivamente. Através dos gráficos de controle de Shewhart e CUSUM foi possível afirmar que a fertirrigação em nível obteve uma melhor performance.

Palavras-chave: gráficos de controle, uniformidade, fertilizante organomineral, microirrigação.

3 INTRODUCTION

Among the various types of fertilizers used in fertigation, those of organic origin have been used as highly valuable supplements due the low profitability of agricultural activities and the concern with sustainable agriculture so that it is necessary to define a system able to obtain higher yield linked to efficiency, improving nutrition and crop development (LANA; RAMPIM; VARGAS, 2014).

The liquid form of organomineral fertilizers falls into the categories of biological activators, stimulants and growth regulators, sources of low concentration of mineral nutrients, conditioners and wetting agents. This type of product is relatively new and remains little studied (OLIVEIRA et al., 2018).

Liquid peat is the best among the liquid organic mineral fertilizers. Liquid peat is a pure source of humic substances, which are molecular aggregates that constitute the main part of natural organic matter. Two main components of liquid peat are humic and fulvic acids, which are derived from Australian Leonardite. Humic acids act indirectly, by altering the microbial dynamics of the rhizosphere, or by stimulating the exudation of organic acids and sugars from the roots; In this way, it acts as a source of energy for soil microorganisms and increases the availability of nutrients in soil (PUGLISI et al., 2013).

Uniformity is a measure of the capacity of an irrigation system to apply the same amount of water everywhere in the irrigated area (MOHAMED et al., 2019). Several factors affect the uniformity of an irrigation system: variation in flow and pressure, obstruction of emmiters and variations in temperature and topography.

A concept to be interpreted with caution is that the uniformity of emission of the irrigation system is influenced by the different slopes. According to Zhang, Hui and Chen (2018), the water distribution in irrigation in sloping areas is very different from the distribution in irrigation in flat areas and understanding spatial patterns based on topographic information and their interactions can provide opportunities for specific irrigation management applications (MAZARON; TURCO; SILVA, 2016).

The monitoring of uniformity in drip irrigation system is even more important. Problems may arise while applying fertilizers in the field. Owing to the small diameter of the emitters, there is a possibility of clogging, which influences uniformity (HERMES et al., 2018).

For the analysis of irrigation parameters, such as uniformity, statistical process control (SPC) techniques can be used, such as Shewhart and CUSUM control charts (ANDRADE et al., 2017). According to Chinchilla et al. (2018), SPC is a useful tool in monitoring irrigation systems to establish corrective measures timely , and the use of control charts proved to be efficient for monitoring the uniformity of drip irrigation (LOPES et al., 2020).

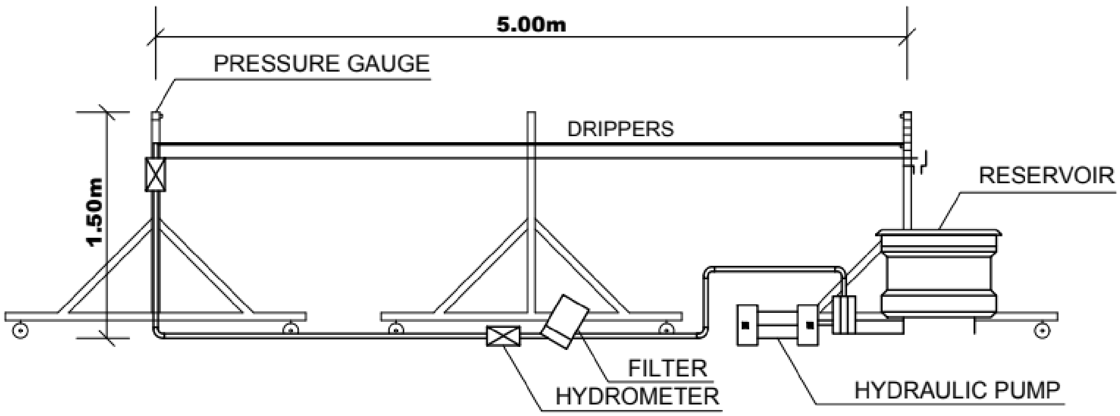
As there is a lack of evaluation of drip fertigation systems with liquid peat, this study is significant in fertigation systems. This work evaluates the uniformity of the flow rate in drip fertigation system with liquid peat at different slopes.

4 MATERIAL AND METHODS

This study was conducted at the Irrigation and Fertigation Laboratory, Experimental Center for Agricultural Engineering, State University of Western Paraná, that is located in the municipality of Cascavel, State of Paraná, Brazil (latitude 24º 58' S and longitude 53º 27' W).

The experiment was carried out on a 5 m test bench, with four lateral lines. The pulley system makes a turn with the lateral line to obtain a 10 m long lateral line. Figure 1 shows the design of the test bench. The test bench consists of an Acquapump (Ferrari), 0.5 hp engine, maximum flow (Q) of 1.8 m^3 h^{-1}, total head of 22 m, control head with 120 mesh disk filter, and BERMAD pressure controller model 0075 PRVy, as recommended by the manufacturer of the drippers.

Figure 1. Illustration of the test bench used.



The drippers from the brand IRRITEC, model P1, were tested. These drippers are designed for surface and subsurface irrigation and consists of labyrinth-type turbulent flow with emmiters spaced by 0.50 m and attached to the tubing wall with a mechanism against the suction of debris. The dripper has nominal diameter of 16 mm, maximum working pressure of 80 kPa, proportionally coefficient of the emitter equation (K) of 1.26 and discharge exponent (x) of 0.48.

In the tests, the liquid peat *Ultra Solo* was used, which is a liquid organomineral fertilizer, formed by compounds of organic matter, humic and fulvic acid and organic carbon (N = 2.0 %; P_2O_5 = 2.0 %; K_2O = 2.0 %; Ca = 1.0 %; Mg = 1.0 %; S = 1.1 %; Zn = 0.10 %; Mn = 0.10 %; Fe = 0.10 %; B = 0.03 %; Mo = 0.01 %; pH = 6.0; relative density = 1.20 g cm^{-3}). Before the beginning of the tests, the dilution of the liquid peat in the reservoir was performed manually, using a commercial recommendation of mixing 5L of liquid peat to 100L of water (BORSSOI et al., 2012).

The flow rate was determined for each test, according to the methodology proposed by Keller and Karmeli (1975). This methodology consists of determining four emitters per lateral line; that is, in the first dripper, the drippers are located at 1st, 7th (1/3 of length), 13th (2/3 of length) and last positions.

The flow rate of the drippers was measured by the gravimetric method to obtain greater precision in the determination. With the volume collected in the emitters for 3 min as recommended by NBR 9261 (ABNT, 2006), the flow of the emitters was determined.

Twenty-five tests were performed for each slope: level (0%), uphill of 2% and downhill of 2% (AMERICAN SOCIETY OF AGRICULTURAL AND BIOLOGICAL ENGINEERS, 1996). The number of tests mentioned above is recommended by Montgomery (2016) for quality control tests. After the end of the tests for each slope, a backwash was performed in the system with water.

To evaluate the irrigation system, the Christiansen uniformity coefficient (CUC) was used, according to Equation 1 (CHRISTIANSEN, 1942).

$$CUC = \left(1- \frac{\sum_{i=1}^{n}|qa-qi|}{nqa}\right) \text{ x } 100 \quad (1)$$

Where:
qi = flow of each emitter (L h^{-1});
qa = arithmetic mean of flows (L h^{-1})
n = number of emitters.

The classification of CUC data was performed as suggested by Frizzone et al. (2012), who considered uniformity as 90%-100% (excellent), 80%-90% (good), 70%-80% (regular), 60%-70% (bad) and <60% (unacceptable).

To analyze CUC, Shewhart control charts were built. These charts are used to investigate the parameters during testing, and making it necessary to calculate the upper control limit (UCL) and ower control limit, using Equations 2 and 3, respectively.

$$UCL = \bar{\bar{x}} + 3\ \frac{\overline{MR}}{d_2} \quad (2)$$

$$LCL = \bar{\bar{x}} - 3\ \frac{\overline{MR}}{d_2} \quad (3)$$

Where:
$\bar{\bar{x}}$ = average;
$\overline{MR}$ = mobile range of observations;
d_2 = predetermined value (tabulated = 3.931) (MONTGOMERY, 2016).

In addition to Shewhart control chart, the CUSUM control chart was used, where deviations from the mean are accumulated over time, described in Equation 4:

$$C_i = \sum_{j=1}^{i}(x_j - u_0) \quad (4)$$

Where:
x_j = mean of the j-th sample;
C_i = cumulative sum up to the i-th sample;
u_0 = target, that in this research was the mean of the treatment.

In the case of CUSUM control charts, these accumulate deviations above and below the target value are called respectively upper and lower CUSUM, being expressed by Equations 5 and 6:

$$C_i^+ = \max\ [0;\ x_i - (u_0 + K) + C_{i-1}^+] \quad (5)$$

$$C_i^- = \max\ [0;\ (u_0 + K) - x_i + C_{i-1}^-] \quad (6)$$

Where:
x_i = time observation;
K = compensation value, being used in this research the value of 0.5.

For better visualization of the flow in the test bench, spatial analysis was performed.

The interpolation of the drip flow data was performed using the statistical model Inverse of Distance, described in Equation 7:

$$z = \frac{\sum_{i=1}^{n} \frac{1}{d_i} z_i}{\sum_{i=1}^{n} \frac{1}{d_i}} \quad (7)$$

Where:

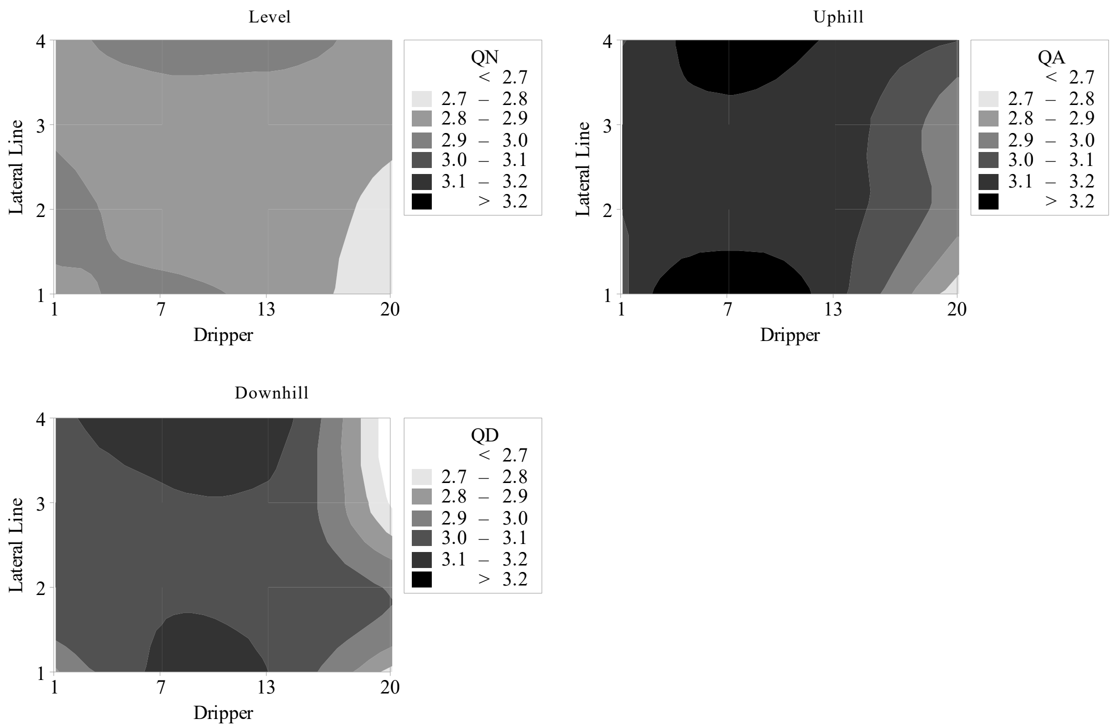
z = estimated value for point z;
n = number of observations;
z_i = observed values;
d_i = distances between observed and estimated values (z_i and z).

Data were submitted to ANOVA, using the F-test at 5 % probability. The comparison of means was performed using the Tukey test at 5% significance. All statistical, graphical, and control charts were performed using MINITAB 18 software.

5 RESULTS AND DISCUSSION

Figure 2 shows the contour graph of flow rates with liquid peat, in level, uphill and downhill. There is a similarity in uphill and downhill irrigation systems, with the highest flow rates at the beginning of the lateral lines, which gradually decreases until the end of the lateral lines. This decreasing rate of flow in the irrigation system occurs due to the pressure drop during the stretch (ALVES et al., 2015). Marcuzzo and Wendland (2011) also observed a concentration of the highest flows at the center of the first and last lateral line in case of upslope and downslope irrigation systems with liquid peat as the pressure until the end of the pipe.

Figure 2. Spatial distribution of the flow rate of liquid peat in: level (A), upslope (B) and downslope (C)



It is verified that in all situations, the highest flows are located in the 7th dripper of the 1st lateral line and the 7th dripper in the 4^{th} lateral line, which means that the flow increases and then decreases after the 7th dripper till the end of lateral line. Variations in land level and pressure losses have an important effect on this variation in the flow of drippers in irrigation because the operating pressure loads of the drippers are low (FRIZZONE et al., 2012).

By conducting the F-test, it was found that there was a statistical difference between the groups analyzed. Therefore, a comparison of the CUC results was performed using the Tukey test (Table 2), which showed that the liquid peat in downslope had the lowest average uniformity (95,23%). Ella, Reyes and Yoder (2009), when studying the uniformity of water distribution in a low-cost drip irrigation system with different slopes and hydraulic heads, found that the uniformity decreased with the increase in slopes. In areas of rugged topography, there are marked variations in system pressure, causing the flow differences, which reduce uniformity (LIMA et al., 2003).

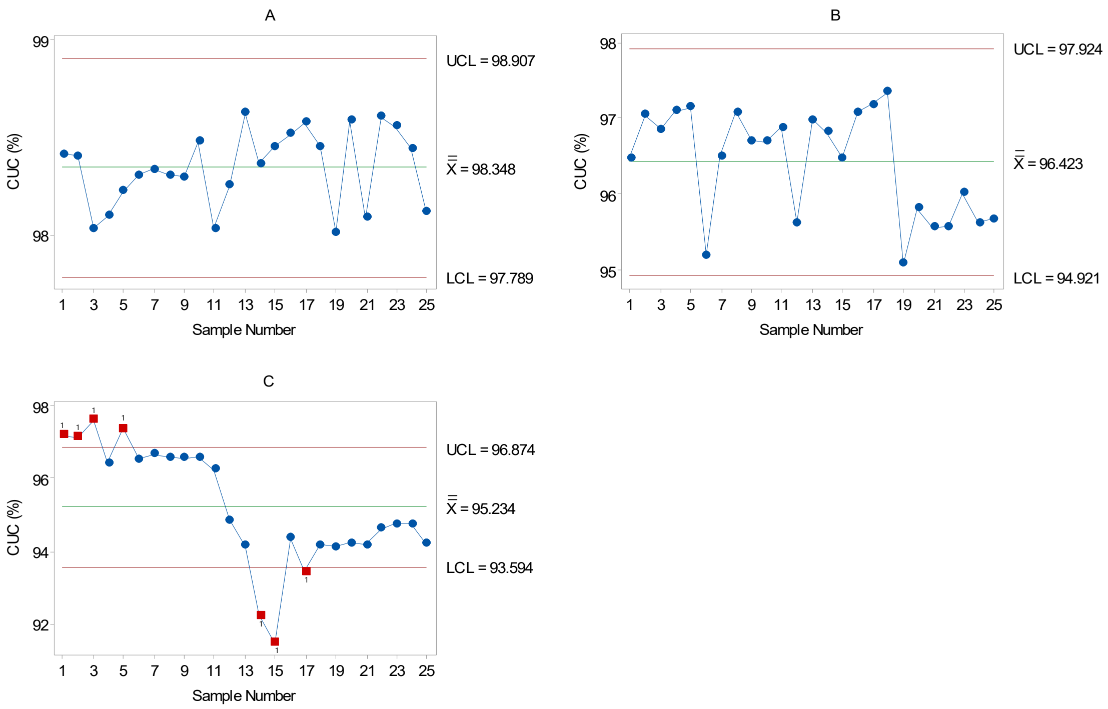
Table 2. Simple-effect analysis and comparison of using liquid peat in lateral line slopes.

Slopes	CUC	SD	Variance	CV (%)	Minimum	Maximum	Q_1	Q_3
Level	98.34^{a}	0.19	0.03	0.20	98.02	98.63	98.17	98.50
Uphill	96.42^{b}	0.70	0.49	0.73	95.09	97.34	95.65	97.06
Downhill	95.23^{c}	1.64	2.69	1.72	91.49	97.63	94.18	96.61

Means followed by least one lowercase letter in the columns do not differ by test of Tukey ($P < 0.05$).
Notes: SD: Standard deviation; CV: Coefficient of variation; Q_1: First quartile; Q_3: Third quartile.

In Figure 3, the Shewhart control charts for CUC of the liquid peat are shown. For liquid peat, the Shewhart control chart shows that the process was under statistical control for level and for level and uphill slopes. The process is out of statistical control when points are detected outside the limit of statistical control and/or when there is a sequence of points above or below the midline, confirming the observations already made (FERREIRA; NOMELINI; OLIVEIRA, 2016).

Figure 3. Shewhart control charts for the CUC with liquid peat in level (A), uphill (B) and downhill (C).

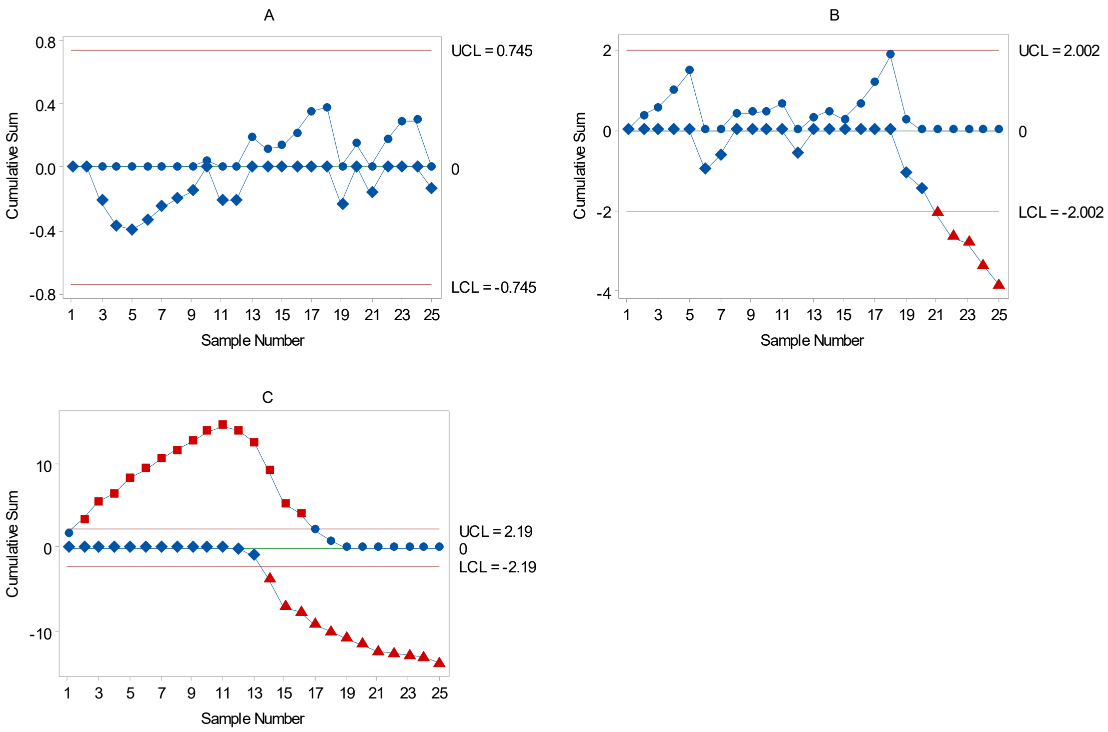


For the downhill system, there is a downward trend in values throughout the process, which keeps the causes values below the lower control limit (LCL = 93.59).

Justi and Saizaki (2016) previously reported the presence of isolated points while monitoring the irrigation and fertigation processes with Shewhart control chart. The isolated points can be caused by the destabilization of the pressure (SILVA et al., 2015). Szekut et al. (2018) reported that lateral lines positioned on downhill indicate better operating conditions compared to level and uphill systems.

As in the Shewhart control chart, the level system remained under statistical control in the CUSUM control chart (Figure 4). In uphill system, from trial 19 to 25 (end of monitoring), the data represent a sequence of consecutive points, decreasing and below the lower control limit (LCL); therefore, this process was considered outside the statistical quality control. Lopes et al. (2019) tested different slopes in irrigation uniformity with CUSUM control chart, and also obtained uphill and downhill results outside the statistical control. When a drip irrigation system is used, there is an accumulative increase in the variation of its flow, which affects its uniformity (SILVA et al., 2015).

Figure 4. CUSUM control charts for the CUC with liquid peat in level (A), uphill (B) and downhill (C).



The existing flow variations are easily observed by the CUSUM control chart, Andrade et al. (2017) found that CUSUM control chart was also decisive in the determination of the moment of the occurrence of the process variability, when compared to Shewhart control chart.

6 CONCLUSIONS

For drip irrigation systems, liquid peat showed excellence in its uniformity, as the dripper flow increased or decreased during the lateral line when using liquid peat on all slopes tested.

For drip irrigation with liquid peat, the level 0% slope was the most uniform, followed by an uphill and downhill 2% slopes, respectively.

The control charts were adequate to diagnose the treatments under control, through Shewhart and CUSUM control chart, it was possible to affirm that fertigation with liquid peat in level 0% slope obtained better performance.

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