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Increasing water use efficiency in agricultural systems is critical as it results in economic and environmental cost reductions, especially in localized irrigation, which depends on a number of factors, especially the flow rate of the emitters and proper uniformity of water distribution, both with respect to direct with the pressure of the emitters For this evaluation the use of coefficients of water uniformity, it is essential to indicate the best wetness management. The experiment was carried out in the Irrigation laboratory, in a test stand, using Christiansen uniformity coefficient - CUC, distribution uniformity coefficient - CUD and statistical uniformity coefficient - CUE. In the irrigation line, four pressures on the drip emitter (5, 10, 15 and 20 mca) were applied. The pressure variations obtained did not reduce the efficiency of the uniformity of water distribution by the drip system, falling into high efficiency ranges for all evaluated coefficients, representing adequate wetting rates.

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Increasing water use efficiency in agricultural systems is critical as it results in economic and environmental cost reductions, especially in localized irrigation, which depends on a number of factors, especially the flow rate of the emitters and proper uniformity of water distribution, both with respect to direct with the pressure of the emitters For this evaluation the use of coefficients of water uniformity, it is essential to indicate the best wetness management. The experiment was carried out in the Irrigation laboratory, in a test stand, using Christiansen uniformity coefficient - CUC, distribution uniformity coefficient - CUD and statistical uniformity coefficient - CUE. In the irrigation line, four pressures on the drip emitter (5, 10, 15 and 20 mca) were applied. The pressure variations obtained did not reduce the efficiency of the uniformity of water distribution by the drip system, falling into high efficiency ranges for all evaluated coefficients, representing adequate wetting rates.

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1. Introduction

The use of irrigation techniques, especially localized irrigation, requires the application of evaluations that may indicate the efficient use of water by the system (uniformity of water distribution), which brings, among other benefits, lower cost of energy use or even reduction in environmental impact.
Uniformity of water distribution is an essential evaluation in localized irrigation systems, both in the initial phase of the project and in post-implementation performance [1], which is reinforced by the growth of areas irrigated by this system.

Several factors are responsible for the reduction or lack of uniformity in water distribution in localized irrigation systems, such as: pressure difference in the drip line, due to the resulting pressure losses and also the terrain unevenness, variation of the hydraulic characteristics involved in the irrigation, system, obstructions, clogging, poor quality control adequacy in the manufacturing uniformity of the emitters, place of water application, or also by the flow variation in the emitters [2] and [3].

In particular, the variation in the flow rate of the emitters is a major factor in the uniformity of water distribution, since according to [4], it is dependent on manufacturing variations, total use time, pressure and temperature. Therefore, it is essential to determine the flow rate of the emitters and their uniformity, using coefficients such as the Christiansen - CUC uniformity coefficient, which adopts the average deviation for the dispersion measurement [5] and [6].

The variation of the drip flow rate is dependent on the inlet pressure in the lateral line emitters, which is regulated by the self-compensating system, thus the emitters tend to operate within the recommended limit, with a maximum drip flow variation of 10% [7].

In addition to CUC, water distribution uniformity can be expressed by some indices, such as distribution uniformity coefficient - CUD [8] and statistical uniformity coefficient – CUE [9], most commonly used to evaluate the uniformity of water application [10]. Thus, the objective was to determine the CUC, CUD and CUE in a drip irrigation system under increasing pressures.

2. Material and Methods

The experiment was carried out at the Irrigation Laboratory of the Department of Rural Engineering, Faculty of Agronomic Sciences FCA-UNESP Campus Botucatu, located at coordinates 22 ° 51'10 " S and 48 ° 25'51 " W, with Cfa climate. - humid warm (mesothermal) temperate climate, with the warmest month average temperature over 22 ° C [11] (Figure 1).

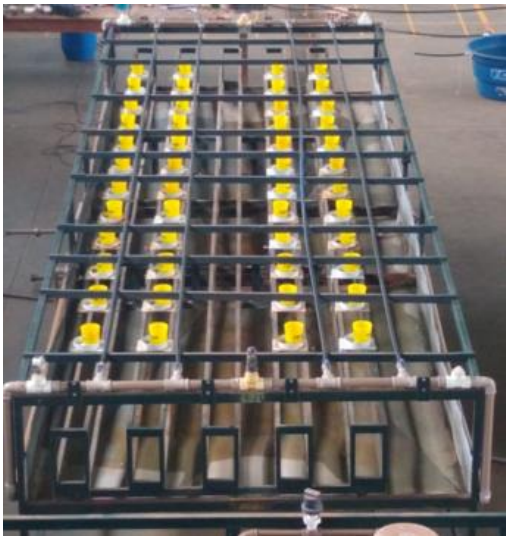

Figure 1. Irrigation Laboratory - Dripper test bench.

For dripper evaluation for CUC, CUD and CUE coefficients, the drip bench was used. This bench has a 300 liter capacity water tank and Schneider brand BC 92S AV 2CV three-phase 60 HZ 220/380 motorcycle pump set for pressurizing water through 1 ¼ inch PVC pipes with a filter. of 120 mesh discs.

The length of the lateral lines is 6m and the width 1.86 m having two air outlet valves and also two Bourdon pressure gauges (Figure 2) that were used to regulate the uniformity test pressures at 5, 10, 15 and 20 mca.

Figure 2. Bourdon type digital and analog pressure gauge.

During the dripper evaluation test, each dripper was strictly observed, so that there was no interference of flow from the connection. The flow was determined by the gravimetric method in order to obtain better accuracy in the volume measurements (ml) collected from each dripper. The volume of water emitted by the drippers was stored in collectors with a capacity of 300 ml for a period of four minutes and weighed in a FILIZOLA® precision scale as shown in Figure 3.

Figure 3. Weighing dripper uniformity test volume.

The percentages of CUC, CUD and CUE were estimated through equations (1), (2) and (3) and evaluated according to Table 1, Table 2 and Table 3 respectively.

2.1 Christiansen Uniformity Coefficient (CUC -%)

Such a coefficient may be expressed by the following mathematical expression:

$$CUC = 100\left\{1 - \frac{\sum_{i=1}^{n}|x_i - x_{med}|}{n.x_{med}}\right\} \quad (1)$$

where,

CUC - Christiansen uniformity coefficient (%);
n - number of samples in the lateral line;
x_i - measured flow rate of each emitter $(L.h^{-1})$;
x_{med} - med - average drip flow $(L.h^{-1})$.

Table 1 presents the criteria for classification of the Christiansen uniformity coefficient in irrigation systems.

Table 1. Christiansen uniformity coefficient classification (CUC).

CUC (%)	Classification
> 90	Excellent
80 - 90	Good
70 - 80	Reasonable
60 - 70	Bad
< 60	Unacceptable

Source: [12].

2.2 Uniformity of distribution coefficient (CUD -%)

Proposed by [8], the distribution uniformity coefficient (CUD) is based on the ratio of 25% smaller experimentally measured flow values in relation to the average observed flow rates, being expressed by the following equation:

$$CUD = 100.\frac{q_n}{\bar{q}} \quad (2)$$

where,

CUD − Coeficient of distribution uniformity;
q_n − Average of 25% lower flow rates values;
$\bar{q}$ − Average observed flow rates.

Table 2 presents the quantitative and qualitative classifications of the distribution uniformity coefficient.

Table 2. Classification of distribution uniformity coefficient (CUD).

CUD (%)	Classification
87-100	Excellent
75-87	Good
62-75	Reasonable
50-62	Bad
< 50	Unacceptable

Source: [13].

2.3 Coefficient of statistical uniformity (CUE -%)

The statistical uniformity coefficient (CUE) developed by [9] refers to the coefficient of variation of the applied water depth.

This model can be implemented for drip irrigation systems, provided that the values measured by the sprinklers are replaced by the values emitted by the emitters. Thus, the statistical uniformity coefficient can be expressed by the following mathematical equation:

$$CUE = \left(1 - \frac{\sigma}{\overline{q_m}}\right) \qquad (3)$$

where,

$CUE -$ Coeficient of statistical uniformity (%);
$\sigma -$ Standard deviation of the sample;
$\overline{q_m} -$ Mean observed flow rates $(L.h^{-1})$.

The Table 3 presents the statistical uniformity coefficient classifications.

Table 3. Classification of the statistical uniformity coefficient (CUE).

CUE (%)	Classification
90-100	Excellent
80-90	Good
70-80	Reasonable
60-70	Bad
< 60	Unacceptable

Source: [14].

3. Results and Discussion

The uniformity coefficients obtained by the dripper test are presented in Table 4. Four pressures (20, 15, 10 and 5 mca) were analyzed in the four lines as seen in Figure 1, seeking to verify the dripper evaluation at different service pressures.

Table 4. Dripper uniformity test under increasing pressures.

PRESSURE	LINE	CUC[1]	CUD[2]	CUE[3]
20	1	98,15	97,74	97,81
20	2	97,98	97,67	97,67
20	3	98,30	97,90	97,94
20	4	98,18	97,49	97,83
15	1	98,87	98,26	98,51
15	2	98,19	98,08	97,80
15	3	98,23	97,86	97,82
15	4	98,72	98,78	98,33
10	1	98,53	98,08	98,34
10	2	98,14	97,62	97,92
10	3	98,00	97,69	97,83
10	4	98,45	97,99	98,30
5	1	98,83	97,86	98,43
5	2	98,47	97,93	98,10
5	3	98,64	98,29	98,37
5	4	98,62	98,15	98,34

[1]Christiansen uniformity coefficient. [2]Efficiency of distribution uniformity. [3]Statistical uniformity coefficient.

The Table 5 shows the mean values resulting from each pressure in relation to the repetitions for the dripper uniformity test.

Table 5. Values of uniformity coefficients of water distribution of drippers under increasing pressures.

Pressure	CUC[1]	CUD[2]	CUE[3]
20	98,15	97,70	97,81
15	98,50	98,24	98,11
10	98,28	97,85	98,10
5	98,64	98,06	98,31

[1]Christiansen uniformity coefficient. [2]Efficiency of distribution uniformity. [3]Statistical uniformity coefficient.

For the four pressures established in the dripper test, the Christiansen uniformity coefficient (CUC) remained constant in the 98% range so in the range considered excellent according to [12]. CUC values between 84 and above 90% are considered to be adequate for irrigation systems [15] and [16].

For pressures of 10 and 20 mca the values obtained by the coefficient Uniformity of distribution (CUD) showed similar behavior, with values in the range of 97%, while for pressures of 5 and 15 mca the values are in the range of 98%.

All CUD values obtained are classified as excellent according to [13] as well as for [12] where values below 36% are considerable as unacceptable and over 84% as excellent. In addition, the CUD is the most widely used coefficient in system evaluation, as it has sensitivity, and allows better evaluation in irrigation systems considering the ratio between the lowest average quartile value and the average water depth collected [17] cited by [18]. The values observed for CUD, when low, may indicate water loss by deep percolation, when the minimum applied blade is equivalent to the required blade, or even emitters unevenness [19] and [18].

For the pressures of 15, 10 and 5 mca, the values obtained by the statistical uniformity coefficient (CUE) presented similar behavior with values in the range of 98%, with no large variations, however, for the pressure 20 mca the behavior was in the range of 97%. % being lower than other pressures. In this work all values related to (CUE) are classified as excellent, since they are above 90% [10] and [14].

It is noteworthy that the uniformity of water distribution during the experiment remained with (CUC), (CUD) and (CUE) with values above 97%, thus being classified according to the literature as excellent [20], [21] and [12].

4. Conclusion.

The pressure variations obtained did not reduce the efficiency of the uniformity of water distribution by the drip system, falling into high efficiency ranges for all evaluated coefficients, representing adequate wetting rates.

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