MOBILE SPRINKLER PERFORMANCE FOR SMALL AREAS AND GARDENS

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ABSTRACT

Purpose: was to evaluate the coefficients of uniformity of alternative mobile sprinkler, small size, working in a static way, as well as wind effect and static quality control, in order to enable small producers to have access to the use of irrigation equipment with low cost and quality in the efficiency of water application.

Method/design/approach: Uniformity tests of irrigation lasted one hour and were performed with a small mobile sprinkler, determining the volumes in different grids (mesh and cross), spacings (0.25 and 0.50 m) and periods (morning, afternoon and night). The analyses of the irrigation quality control process were performed from control charts for individual measures, adopting the Shewhart charts.

Results and conclusion: The Grids did not influence the uniformity coefficients; The spacing between collectors of 0.50 m provided the best values for the uniformity coefficients; The wind speed directly affected the uniformity coefficients; Most of theif within the limits of quality.

Research implications: The variations observed in the uniformity coefficients throughout the tests are associated with climatic variations. Thus, local climatic conditions should be monitored so that there is no interference in the uniformity of water application by the sprinkler irrigation system.

Originality/value: This study indicates that the evaluated sprinkler can be used obtaining high values of uniformity and within the quality limits.

Keywords: Uniformity of Application, Irrigation, Sprinkling, Wind Speed.
DESEMPENHO DE ASPERSOR MÓVEL PARA PEQUENAS ÁREAS E HORTAS

RESUMO

Objetivo: buscou-se avaliar os coeficientes de uniformidade de aspersor móvel alternativo de pequeno porte, trabalhando de modo estático, bem como o efeito do vento e controle estático de qualidade, a fim de possibilitar que pequenos produtores tenham acesso à utilização de equipamentos de irrigação com baixo custo e com qualidade na eficiência de aplicação de água.

Referencial teórico: A revisão bibliográfica demonstrou a importância da uniformidade como parâmetro para qualidade da irrigação.

Método: Ensaios de uniformidade da irrigação duraram uma hora e foram realizados com aspersor móvel de porte pequeno, determinando-se os volumes em diferentes Grides (malha e em cruz), espaçamentos (0,25 e 0,50 m) e períodos (manhã, tarde e noite). As análises do processo de controle de qualidade da irrigação foram realizadas a partir de gráficos de controle para medidas individuais, adotando os gráficos de Shewhart.

Resultados e conclusão: Os Grids não influenciaram os coeficientes de uniformidade; O espaçamento entre coletores de 0,50 m proporcionou os melhores valores para os coeficientes de uniformidade; A velocidade do vento afetou diretamente os coeficientes de uniformidade; Grande parte dos dados situaram-se dentro dos limites de qualidade.

Implicações da pesquisa: As variações observadas nos coeficientes de uniformidade ao longo dos ensaios estão associadas as variações climáticas. Desta forma, deve-se monitorar as condições climáticas locais para que não ocorra interferência na uniformidade de aplicação de água pelo sistema de irrigação por aspersão.

Originalidade/valor: Este estudo indicou que o aspersor avaliado pode ser utilizado obtendo-se valores elevados de uniformidade e dentro dos limites de qualidade.

Palavras-chave: Uniformidade de Aplicação, Irrigação, Aspersão, Velocidade do Vento.

1 INTRODUCTION

The territorial expansion of irrigated agriculture in search of higher yields results in an increased demand for water, and thus it is of great importance that irrigation systems are regulated to meet crop needs, as well as reducing water waste, whether by climatic factors or even by surface runoff.

Among the irrigation methods, sprinkling in a special way, presents the application of water artificially simulating rain, since it sprays on the soil droplets of water that will later be made available to the plant (Alencar, Cunha, Ramos, Soares, Pizziolo & Oliveira, 2007). As advantages of adopting good management of irrigation by sprinklers there are the savings of water, electricity, durability and good functioning of the equipment (Miranda & Rosal, 2018).

The parameters used in the determination of uniformity and management of irrigation present important foundations for the optimization of water use, like the direct participation in productivity efficiency (Carrión, Tarjuelo & Motero, 2001). The uniformity of water application is an important management parameter, as it can be adapted in several cultures (Mantovani, Bernardo & Palaretti, 2012). Besides being one of the main ways of establishing whether the irrigation system is efficient or not (Brennan, 2008).
Factors such as climate and wind can interfere with the efficiency of the water slide application (Oliveira, Colombo & Faria, 2009), but these factors can decrease the impacts at night, because in this period, there is a lower occurrence of these impacts on the sites, and thus results in higher quality of irrigation (Frigo, 2014). According to Justi, Vilas Boas and Sampaio (2010), when verifying the interference of these factors, from control graphs, observed that they proved to be viable and adequate, identifying the variations in the process and the efficiency of irrigation.

In this context, new irrigation equipment has been developed for the rational use of water. In view of the importance of water in agriculture and the uniformity of water distribution is essential for the management of irrigation in Brazil, this study aimed to evaluate the Coefficients of Christiansen Uniformity (CUC), Distribution Uniformity (CUD) and Statistical Uniformity (CUE) of a small alternative mobile sprinkler, working in a static way, as well as wind effect and static quality control, in order to enable small producers to have access to the use of irrigation equipment with low cost and quality in water application efficiency.

2 THEORETICAL FRAME

The rational use of water resources has been the subject of the United Nations (UN) Global Agenda 2030, in the face of the challenge of the availability of water for the survival of the inhabitants of the Earth. The same time that water stress (the relationship between water demand and availability) is identified as one of the main bottlenecks for sustainable economic growth (Rosa, Costa, Silva, Lunkes, Gomes, Rodrigues & Ribeiro, 2023).

Water is abundant in nature, with many sources that humans can use to meet their daily water needs. Water is an obligatory component in human survival. Every day humans use water for many things to meet their needs. Humans make use of water sources from existing nature, to then process it into water suitable for their use (Fikri, Fauzi, & Firmansyah, 2023).

Irrigated agriculture is the main source of water consumption in the river basins, with abstractions exceeding 60% (ANA, 2019). Thus, studies of irrigation techniques are essential for increasing productivity in cultivated areas, particularly in regions where the precipitated volumes are not sufficient to supply the crop's water demand.

The sprinkler irrigation method is the one most used in Brazil, since most soils and topographies are adaptable (Allen & Macadam, 2020). For irrigation to be efficient, water must be distributed evenly and in the quantity demanded by the crop. Therefore, studies that aim to improve the performance of irrigation are important for guaranteeing good productivity and the efficient management of water resources.

In this sense, performance indicators were created to ensure the quality of irrigation, and uniformity of water application, one of the most important indicators and used for this analysis in sprinkler irrigation systems (Mendoza & Frizzone, 2013).

The uniformity of water application is an index related to the variability of the application of the irrigation blade added to the average value, which demonstrates the existence or not of deviations from the average blade distributed in the wet area (Frizzone, Freitas, Rezende & Faria, 2012), that is, the uniformity indicator is able to characterize the irrigation system and demonstrate the regularity in which the water is distributed, considering the overlap of the spray jets (Frizzone & Dourado, 2003). ISO 15886-3 (2012) indicates that there is no ideal way to express uniformity of distribution, but suggests four coefficients, at least one of which should be used to express the results of application uniformity testing (Camargo, Molle, Tomas, Pinto & Frizzone, 2014).

The most commonly used quality index is the Christiansen Coefficient of Uniformity (CUC) (Frizzone, 2017), whose value must be higher than 85% for the system to be considered...
excellent and, when below 70%, indicates an inadequate uniformity of the irrigation system (Mantovani, Bernardo & Palaretti, 2007).

However, in the CUC assays there are a number of factors that can intervene in the results, ranging from soil and climate influences to execution errors. Moreover, these are time-consuming and costly. Thus, simulating uniformity is a feasible alternative for solving this problem, including the selection of sprinklers in the design phase may be an alternative.

Although there is a standard that determines the spacing between the collectors (0.5 m) in carrying out the tests of the water distribution profile, there is no scientific basis for such information, and studies are needed to determine the appropriate spacing. In addition, ISO 15886-3 (2012) recommends that the reconstituted validation be carried out in each test, where the maximum deviation should be 5% (sprinklers with flow greater than 507.6 L h\(^{-1}\)) or 7% (sprinklers with flow less than 507.6 L h\(^{-1}\)).

3 METHOD

The tests of uniformity of irrigation were conducted at the State University of the West of Paraná - Cascavel Campus, located at 24°59'16.3" S; 53°26' 55.4''O and altitude of 780 m. The climate of the region is mesothermic temperate, subtropical, super humid; presenting annual accumulated precipitation of 1822 mm and annual average relative humidity of 75% (IAPAR, 2019).

The Agropolo NY-25 mobile sprinkler, small in size, with a flow rate of 0.860 m\(^3\) s\(^{-1}\) and a range of 26 m, was used when using the orange x gray nozzles at a working pressure of 20 mca. This sprinkler was parked at the site of the experiment and coupled by means of a 50 m hose, the beginning of which was fitted with a manometer and connected to a half-inch tap for the evaluation of the tests.

Two different samples were collected, called Grid 1 and Grid 2 (Figure 1), and the water collected with Becker type collector with a capacity of 1000 m, installed at ground level. In Grid 1, mesh, 25 tests were carried out from 0.25 m and another 25 to 0.50 m for the distribution of the sprinkler. In Grid 2, cross tests were carried out 25 tests from 0.25 m and 25 more for 0.50 m. The tests lasted about one hour in both tests, the aim of which was to maintain the same characteristic operating conditions between the tests, as recommended by Montgomery (2001).

Figure 1 shows the arrangement of the collectors and sprinkler car in Grid1 and Grid 2

![Figure 1: Arrangement of the Collectors and Sprinkler Carrier on Grid1 and Grid 2](image)

Source: Prepared by the authors

In Grid 1 (Figure 2), 27 beckers were installed in position 1 (left) of the sprinkler and 27 in position 2 (right), totaling 54 collectors spaced 0.25 and 0.50 m between each, aiming to collect all rainfall within the action dimensioning of the mobile sprinkler.
To visualize possible differences in water application quality during applications, the 25 tests were performed at different times of the day, with nine during the morning period (Trials 1, 2, 3, 4, 5, 14, 15, 16 and 17), six in the afternoon period (Trials 6, 7, 18, 19, 20 and 21) and ten in the evening period (Trials 8, 9, 10, 11, 12, 13, 22, 23, 24 and 25).

Figure 2 shows the sketch of Grid 1, with collectors and sprinkler car.

![Sketch of Grid 1](image)

**Figure 2:** Sketch of Grid 1, with manifolds and sprinkler.

*Source:* Prepared by the authors (2023)

In Grid 2 (Figure 3) 36 collectors and the mobile sprinkler were used, nine beckers in position 1 (left), nine in position 2 (right), nine in position 3 (front) and nine more in position 4 (back), with spacing of 0.25 and 0.50m between each. Twenty-five trials were conducted, of which 10 were conducted during the morning period (Trial 3, 4, 5, 6, 15, 16, 17, 18, 24 and 25), 9 during the afternoon period (Trial 7, 8, 9, 10, 19, 20, 21, 22 and 23) and six during the evening period (Trials 1, 2, 11, 12, 13 and 14), with the aim of showing changes during the day-long applications.
Figure 3: Croqui Grid 2 with collectors and sprinkler car.

Source: Prepared by the authors

The evaluation of water distribution and the irrigation quality control process was carried out by determining the Christiansen Coefficient of Uniformity (CUC), Coefficient of Uniformity of Distribution (CUD) and Coefficient of Statistical Uniformity (CUE).

The Christiansen coefficient of uniformity (1942), classified as the main parameter describing the uniformity of irrigation, was determined by Equation 1:

\[
CUC = 100 \left(1 - \frac{\sum_{i=1}^{n} |x_i - x_{med}|}{n \cdot x_{med}}\right)
\]  \hspace{1cm} (Eq. 1)

Where:

- CUC - Christiansen Coefficient of Uniformity, in %;
- \(x_i\) - Individual values of water volume contained in collectors, in mm;
- \(x_{med}\) - Overall average of the values of the collected water volumes, in mm;
- \(n\) - Number of collectors in the test area.

The distribution coefficient (CUD) relates the fourth part of the total area that receives less water to the mean lamina applied in the total area (CRIDDLE et al., 1956), and is determined according to Equation 2:

\[
CUD = 100 \left(\frac{x_{25}}{x_{med}}\right)
\]  \hspace{1cm} (Eq. 2)

Where:

- CUD - Coefficient of uniformity of distribution, in %;
- \(x_{25}\) - Average of the smallest quartile of volumes of water contained in the collectors, in mm;
- \(x_{med}\) - Overall average of the values of volumes of water collected, in mm.
Wilcox and Swailes (1947) indicated a coefficient of uniformity using the standard deviation as a dispersion measure, determining the Coefficient of Statistical Uniformity according to Equation 3

\[
CUE = 100 \times \left(1 - \frac{sd}{Qmed}\right) \quad (Eq. 3)
\]

Where:

CUE: Statistical Uniformity Coefficient (%); Sd - standard deviation of precipitation values, in \((Lh^{-1})\); Qmed - mean of the collected sprinkler flows in the sub-area \((Lh^{-1})\).

Thus, from the results calculated from the Equations, it becomes possible to classify the efficiency of the irrigation system, as values presented in Table 1:

<table>
<thead>
<tr>
<th>RATING</th>
<th>CUC (%)</th>
<th>CUD (%)</th>
<th>CUE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>&gt; 90</td>
<td>&gt; 84</td>
<td>90 - 100</td>
</tr>
<tr>
<td>Good</td>
<td>80-90</td>
<td>68-84</td>
<td>80-90</td>
</tr>
<tr>
<td>Fair</td>
<td>70 - 80</td>
<td>52-68</td>
<td>70 - 80</td>
</tr>
<tr>
<td>Bad</td>
<td>60 - 70</td>
<td>36-52</td>
<td>60 - 70</td>
</tr>
<tr>
<td>Unacceptable</td>
<td>&lt; 60</td>
<td>&lt; 36</td>
<td>&lt; 60</td>
</tr>
</tbody>
</table>

Source: Mantovani (2001)

Analysis of the irrigation quality control process was performed from control charts to individual measurements, adopting Shewhart charts. The graphs are used to detect the lack of control in a given process and their systematic use is quite relevant, as it can identify and reduce variability (Opazo, Shikida & Behr, 2005).

Shewhart graphics are used for individual measurements, and are easy to handle and understand. For its use in the construction of Shewhart quality statistical control charts, it is necessary to calculate the lower and upper limit, obtained by Equations 4 and 5:

\[
LSC = \bar{X} + 3 \frac{MR}{d_2} \quad (Eq.4)
\]

\[
LIC = \bar{X} - 3 \frac{MR}{d_2} \quad (Eq.5)
\]

Where:

LSC- Lower control limit; LIC- Upper control limit; \(\bar{X}\)- Mean of averages; \(MR\)- Mean of the moving amplitudes of the data; \(d_2\)- constant used for moving amplitude for \(n = 2\) \((d_2 = 1.128)\), described by Montgomery (2009).

The experimental design used was the 2x2 factorial, with the factor 1 composed of the Grids (Grid 1 and Grid2) and the factor 2 corresponding to the spacing of the sprinkler with the collecting glasses (0.25 and 0.50 cm). The wind was determined by means of an anemometer. The data were submitted to the assumptions of normality by the Shapiro - Wilk test. The results were submitted to the analysis of variance and, when significant, were compared by Tukey’s test at 5% probability. The statistical analysis was carried out using the statistical program RStudio (RStudio Team, 2015) and the graphs were drawn up by the SigmaPlot® software, version 12.
4 RESULTS AND DISCUSSIONS

Proper water management in irrigated agriculture production is essential to reduce water waste as well as scarcity.

4.1 Analysis of Variance

In Table 2, the analysis of variance (ANOVA) is presented, in which it is possible to observe that there was no significant interaction between the Grid x spacing factors, but, in isolation, there was a significant effect for the spacing factor, and there was no effect for the Grid factor.

Table 2. Analysis of variance (ANOVA), coefficient of variation (CV), mean and standard deviation for the coefficients of uniformity as a function of the sample grids and spacing between the collectors of the 25 tests.

<table>
<thead>
<tr>
<th>FV</th>
<th>CUC</th>
<th>CUD</th>
<th>CUE</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid</td>
<td>0.9899*</td>
<td>0.7591*</td>
<td>0.0986*</td>
<td></td>
</tr>
<tr>
<td>Spaces</td>
<td>0.0176*</td>
<td>0.0367*</td>
<td>0.0092*</td>
<td></td>
</tr>
<tr>
<td>Grid x Spacing</td>
<td>0.8698*</td>
<td>0.6703*</td>
<td>0.8533*</td>
<td></td>
</tr>
<tr>
<td>CV (%)</td>
<td>9.97</td>
<td>16.71</td>
<td>10.97</td>
<td></td>
</tr>
</tbody>
</table>

Of which: FV - Sources of Variation; *m - not significant (p>0.05); *-significant (p<0.05); CUC - Christiansen Coefficient of Uniformity; CUD - Coefficient of Distribution Uniformity and CUE - Coefficient of Static Uniformity.

Source: Prepared by the authors (2023)

Also in Table 2, it is possible to verify that the coefficients of uniformity (CUC, CUD and CUE) presented higher values when the greater spacing between the sprinklers was used. Note that the collectors spaced at 0.25 m showed CUC, CUD and CUE equal to 77.4, 57.58 and 71.66%, respectively, while the collectors spaced at 0.50 m showed 81.22, 72.54 and 75.95%, respectively.

Results obtained are in accordance with ISO 15886-3 (2012), which recommends 0.5 m spacing in water application uniformity assessments, indicating that smaller spacing does not improve application uniformity. Also, Charles et al. (2020) analyzing five spacings between collectors (0.125; 0.25; 0.50; 0.75; 1.0 m) and two models of sprinklers (sprinkler with flow of 1.4 and 3.0 m³ h⁻¹, respectively), observed that the higher CUC values for spacings greater than 0.50 m, corroborating the results of this work. Figure 4 shows the average tests for the coefficients of uniformity as a function of the spacing between the collectors.
Knowing that the coefficients of uniformity are classified as excellent, good, reasonable, poor and unacceptable (Mantovani, 2001; Asaber, 2008), it was found that for the spacing between 0.25 m collectors in Grid 1 resulted in CUC, CUD and CUE "reasonable", while the 0.50 m spaced collectors obtained "good" as a rating for CUC and CUD, and "reasonable" rating for CUE. For Grid 2, the spacing between collectors of 0.25 m obtained "reasonable" for CUC and CUE and "good" for CUD, while for spacing 0.50, the answers were: "good" for CUC and CUD and, "reasonable", for CUE.

In order for irrigated agriculture to be beneficial for plants and also for the reduction of costs with the systems, it is fundamental that the irrigation project be dimensioned with criteria and respect for hydraulic principles. A poorly sized project results in a low efficiency in water application, which will imply increased pumping costs and, mainly, reduced productivity (Nascimento, Feitosa & Soares, 2017).

4.2 Effect of Wind Speed

In Figure 5A, it is possible to observe that in the trials using Grid 2 for the spacing between collectors of 0.25 m, in the morning period (tests 3 to 6, 15 to 18, 24 and 25) the CUC varied from 73 to 89%, wind speed ranged from 0 to 3.18 m s\(^{-1}\), in the afternoon period (tests 7 to 10 and 19 to 23) with CUC of 64 to 70%, and 3.80 to 5.03 s to 85\% and at night (trials 1, 2 and 11 to 14), to 75 to 91% 0 to 2.77 m s\(^{-1}\) the afternoon from 2.36 to 4.21 m s\(^{-1}\) to CUC 68 to 77% and night from 0 to 1.95 m s\(^{-1}\) with results from CUC 79 to 93%. Simil

ar results found by Justi et al. (2010) in which there was a tendency in CUC to decrease with increasing wind speed, where most of the trials were conducted with wind speed between 1.5 to 3 m s\(^{-1}\).
Azevedo, Bernardo, Ramos, Sediyama and Cecon (2000) conducted the study in which it was found that interference of climatic factors in a sprinkler irrigation system. In that study, the wind speed interfered with the process analyzed, reducing the CUC from 83 to 42%, when the wind speed increased from 1 to 7 m s\(^{-1}\).

![Figure 5](image)

**Figure 5.** Wind speed for the *Grids* cross (A) and mesh (B) for 25 repeats.  
**Source:** Prepared by the authors (2023)

The results showed that at night the wind speed is lower for both *Grids* and spacing between collectors. Thus, it may be an indication that the determination of uniformity of water application by the sprinkler irrigation system through the coefficients (CUC, CUD and CUE) in the night period may have less influence of wind speed, in view of, that the system simulates the action of rain. This condition corroborates with Faria, Beskow, Colombo and Oliveira (2012), because the distribution of water by the sprinkler irrigation system is directly affected by the wind.

Wind conditions directly affect water distribution, so it is suggested that irrigation be carried out when wind speed is less than 2.5 m s\(^{-1}\) (Dukes, 2006). In addition, water losses caused by drift (wind) significantly reduce water efficiency (Maroufpoor, Sanikhani, Emamgholizadeh & Kişi, 2018).
4.3 Statistical Quality Control

The study based on static quality control (control chart) allows the researcher to reduce the variability of the data allowing a production of products aimed at a given need, for example, specifications of irrigation projects (MONTGOMERY, 2017).

It is observed, in Figure 6A, that the CUC in Grid 1 and spacing between collectors of 0.25 m, presented 72% of the values are within the limits of quality control, as well as another 16% below and 12% above. In Figure 6B, CUD showed 80% of the values within the limits, 16% below and 4% above. For CUE, 100% of the values are within the limits of quality control (Figure 6C).

Figure 6. Static Quality Control for the uniformity coefficients CUC (A), CUD (B) and CUE (C) considering Grid 1 (mesh) with 0.25 m spacing between collectors, in 25 repetitions.

Source: Prepared by the authors (2023)
In Figure 7A it is possible to observe that the CUC using *Grid 1* with 0.50 m spacing between collectors was equal to that obtained in the 0.25 m spacing. However, in Figure 7B, it is observed that 84% of the values for CUD are within the limits and, 16% below the limit, while for CUE (Figure 7C), 96% of the values are within the limits and 4% below the quality control limit.

Values that remained above the control limit, and within the control limit Figure 6 and 7, were collected in the night and day periods, where climatic factors did not interfere in the collections, since the points that remained below the control limit, collections carried out in the afternoon when the wind factor was high 5.03 m s⁻¹. Results found by Justi et al. (2010) in studies conducted with 25 trials, it was found that one of the collections was above the control limit and the others within the control limit.
The Grid 2 with 0.25 m spacing between collectors resulted in 88% of the values for CUC within the limits, 8% below and 4% above the quality control limit (Figure 8A). In Figure 8B, it is noted that 76% of the CUD values are within limits and 20% below and 4% above the quality control limit. Regarding CUE (Figure 8C), it is observed that 84% of the values are located within the limits, 8% below and above the quality control limit.

Figure 8. Static Quality Control for the uniformity coefficients CUC (A), CUD (B) and CUE (C) considering the Grid 2 (cross) with spacing between collectors of 0.25 m 25 repetitions.

Source: Prepared by the authors (2023)

Figure 9 shows the quality control for CUC, CUD and CUE considering the Grid 2 with 0.50 m spacing between collectors. Analyzing the dispersion of the data, it is noted that 96% were within the control limits and 4% were below the quality control limit for CUC (Figure 9A). The CUD presented 84% of the values within the control limits and 16% was below the...
control limit, while the CUE obtained 92% was within the control limits and 8% was above the control limit.

Figure 9. Static Quality Control for the uniformity coefficients CUC (A), CUD (B) and CUE (C) considering Grid 2 (cross) with spacing between 0.50 m and 25 repeats collectors. 
Source: Prepared by the authors (2023)

As noted in the statistical quality control charts, it is noted that some of the trials showed CUC, CUD and CUE values below the quality limit. For Grid 2 (test 21) and Grid 1 (tests 18 to 21), both in the afternoon and with 0.25 m spacing between collectors, a higher wind speed value was observed, which corresponded to 5.03 m s⁻¹ and a lower value for the respective coefficients of uniformity, thus demonstrating the influence of wind on the determination of the coefficients in the afternoon period.
In a study conducted by Frigo (2012) it was found that wind negatively influenced the coefficients of uniformity, resulting in values below the quality control limit. In addition, Montgomery (2009) adds that values outside the limits of quality control require further study. On the other hand, values above the control limit should be considered as "acceptable", because the higher the value of the coefficient, the greater will be the uniformity of water application, i.e., greater water saving (Frigo, 2012).

The variations observed in the coefficients of uniformity throughout the trials are associated with climatic variations, as the trials were conducted at different times of day. Thus, the irrigator and/or technician must monitor local climatic conditions, mainly wind speed so that there is no interference in the uniformity of water application by the sprinkler irrigation system.

According to Frigo (2014), when using water distribution uniformity data in his sprinkler irrigation system, applying the Shewart control charts, he found that wind is a factor that can directly influence CUC. Thus, Frigo, Villas Boas, Frigo and Frigo (2016) reports that the Shewart control chart for individual measurements has proven to be better, as it presents better results for evaluating sprinkler irrigation in the presence of self-correlated data.

Studies by Bishaw and Olumama (2015) and Norenberg, Faria, Rettore Neto, Beskow, Colombo, Timm and Manke (2017) show the negative effect of wind speed greater than 2 m s\(^{-1}\) on water application via sprinkler irrigation systems, where the higher the wind speed, the lower the values of the uniformity coefficients.

Based on the results presented by Darko, Shouqui, Junping, Haofang and Xingye (2017), they suggest that irrigation does not neglect the effect of wind speed at the time of irrigation, and it is also necessary to adopt water application management strategies, so that the uniformity of sprinkler irrigation systems is not compromised.

5 FINAL CONSIDERATIONS

For the conditions of the experiment and according to the results obtained, it was concluded that:

There was no significant effect on the comparison of sample grids. The Grids did not influence the uniformity coefficients, represented by CUC, CUD and CUE; the 0.50 m manifold spacing provided the best values for the uniformity coefficients; Wind speed directly affected the uniformity coefficients, with values from 3.80 to 5.03 m s\(^{-1}\); The study of static quality control made it possible to observe the variability of the data throughout the tests and, in general, a large part of the data was within the quality limits, since it was observed that wind is a variable that directly influences the application efficiency and this, in turn, is represented by the uniformity coefficients; The afternoon period proved less favorable for the determination of the coefficients, since the trials in this period were below the lower limit of the control chart for Grid 1, CUC 73.01, CUD 58.99 and CUE 62.39 and, for Grid 2, CUC 65.85, CUD 52.98 and CUE 62.07.

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