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Consistent Distribution of Irrigation Water On Vertical Gardens (With Water As Content Sample)

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Abstract

As the population increases and infrastructure development continues to increase, the need for green open space is decreasing. A vertical garden is an efficient solution with a vertically modern garden concept that the functions of green open spaces can be fulfilled. The irrigation system in a vertical garden gives a major role because plants can be grown well if they have a great irrigation system. Drip irrigation is one type of irrigation system that is widely applied and the best method that has been used in the world because it is considered more efficient with a small discharge, can reduce runoff, and can reduce water loss due to evaporation. This study aims to analyze the uniform of water distribution in the drip irrigation system and the average variation of water distribution in the row and column direction using a statistical test with Kruskal-Wallis. Based on the statistical analysis, it is obtained the coefficient of variation (Cv) of 0.27, the uniformity statistic (Us) of 73.2%, and the coefficient of uniformity (Uc) of 71.7% which means that the three parameters are categorized as good and acceptable while for statistical tests Kruskal-Wallis has a difference in the average variation of water distribution for the row and column groups.

Keywords: Drip irrigation system, Green open space, Kruskall-wallis test, Vertical garden,

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1. Introduction

Currently, urban infrastructure development is one of the causes of environmental damage. Along with the increasing population and infrastructure development which continues to increase every year the need for green open space is decreasing. Green open space has changed its function into a built area, where most of its surface is covered by roads, buildings and other infrastructure.

Green open space has an important role in the spatial planning of a city. Ecologically, the main function of this green open space is to absorb air pollution, improve the air quality of the city and at the same time reduce the temperature of the city. Law Number 26 of 2007 concerning Spatial Planning states that the proportion of green open space is a minimum of thirty percent of the city area, so it becomes a challenge in a dense urban and built area to be able to utilize the remaining land as a substitute for green open space.

Vertical gardens are an efficient solution so that the needs and functions of green open spaces in an urban area can be met. Vertical garden is a modern garden concept that is made vertically or vertically and is an innovation for future urban planning. Vertical gardens can give a natural impression in the urban environment in creating elements of beauty and comfort from a garden (Widiastuti et al., 2014).

The main factors in planning a vertical garden according to Mulyadi (2012) include the selection of planting media, the selection of plant types and supporting structures for the vertical garden as well as planning an irrigation system or providing water and nutrients to vertical garden plants.

The irrigation system in a vertical garden consists of constituent components, namely a network of pipes, water sources, and pumps so that water can be distributed to plants through emitters. The use of a pump is used because the water flow system in the vertical garden is carried out from the bottom up so that the pump can adjust the pressure required at

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vertical garden that is 0.8 bar to 1 bar. Meanwhile, if the drainage is carried out from top to bottom, it is influenced by gravity so that it affects the volume obtained and the required water distribution, namely the higher the elevation, the smaller the volume accommodated.

In the field implementation, the bottom-up drainage method is more effective to obtain an even distribution of water in each row because the higher the elevation, the smaller the volume of water, so that it can assist in the placement of plant species according to the characteristics of their water needs. Types of plants that need a lot of water can be placed at the lowest elevation, while the types of plants that need less water can be placed at a higher elevation. When viewed in terms of the vertical garden frame structure, the higher the elevation, the smaller the volume of water accommodated and the larger the volume of water is proportional to the weight of the water and the weight is calculated as a load on the modeling of the vertical garden frame structure causing the load received at the upper elevation to be smaller and vice versa. at the lower elevation has a large load so as to produce a vertical garden structure that is more stable, safe and does not roll over and the use of steel material in the vertical garden frame can use a smaller profile dimension at a lower cost.

One type of irrigation system that is widely applied to vertical gardens according to Alabas (2013) is to use drip irrigation. Drip irrigation is considered to be more efficient than other irrigations because it gives water to plants with a small amount or discharge so that water use is more efficient, can reduce runoff and can reduce water loss due to evaporation. The most important thing to note in this drip irrigation system is the value of uniformity of water distribution obtained from the discharge of each emitter used so that it can assess the performance of the drip irrigation system based on the classification for micro irrigation systems (Adhiguna & Rejo, 2018).

In calculating the average value of the variation in water distribution or water discharge, it is obtained from each sample pot or water content sample. Water content samples are several samples or samples taken in an experiment or experiment that can represent the surrounding conditions. The calculation of the average variation in water distribution is carried out to determine the classification of the value of uniformity of water distribution or the performance of the drip irrigation system used. Meanwhile, to obtain a group with an average distribution of water or water discharge that is significantly different, statistical tests can be used, namely the analysis of variance or ANOVA.

In previous studies conducted by several previous authors regarding irrigation systems in vertical gardens or green walls, they were able to provide an overview for the research carried out. The following are some of the studies that have been carried out including:

a. Segovia-Cardozo et al. (2019) conducted research on living walls with an area of 4.44 m2 $^{\text{consisting}}$ of two zones, namely at the top (12% of the total area) and the bottom (88% of the total area) with 168 pots arranged in a matrix of 14 columns and 12 rows. This study takes into account the estimated water requirements of plants determined from the water balance in the form of evapotranspiration, precipitation and irrigation depth. Each row and column consists of water content samples arranged diagonally and then statistical tests are carried out to determine the uniformity of water in the drip irrigation system.

b. Raphael et al (2018) conducted a study on drip irrigation. This research is more focused on evaluating the use of emitters in drip irrigation, namely the calculation of the average discharge for each emitter so that the coefficient of flow variation in the emitter can be obtained. This study also uses statistical analysis, namely analysis of variance (ANOVA) by assuming that the variation in water distribution in the two sections is the same.

c. Prodanovic et al. (2019) conducted a study on the daily water retention capacity of green walls for each plant pot consisting of five types of plant species. This study was conducted using the IBM SPSS 25 statistical test for differences in uniformity variations, but in this study the sample pot or water content sample representing other pot conditions was used only one column in the vertical direction. In this study, there are two methods to determine the amount of water retention capacity, namely the weight method and the volume method.

d. Mistry et al. (2017) conducted a study on the evaluation of drip irrigation systems with variations in pressure from the emitter. In this study, the water discharge obtained from each emitter is used to assess the performance of the micro irrigation system in this case using a drip irrigation system.

e. El-Nemr (2012) explains the calculations and equations used in drip irrigation. Statistical calculations on the drip irrigation system presented in a spreadsheet in Microsoft Excel are also used to assess the performance of the drip irrigation system.

In the drip irrigation system, it is necessary to calculate the value of uniformity of water distribution obtained from the discharge of each emitter used so that it can assess the performance of the drip irrigation system based on the classification for micro irrigation systems. In the drip irrigation system, it is also necessary to calculate the average value of the variation in water distribution or water discharge from each sample pot (Water Content Sample).

The uniformity of the drip irrigation system aims to see the level of distribution of water flowing in each emitter in a system. The parameters used in drip irrigation are as follows.

The discharge calculation for each emitter can be calculated using the storage volume data per unit time as follows.

$$Q = \frac{V}{t} \quad (1)$$

Where:

Q = discharge at each *emitter* (L/h)
V = storage volume of each pot (Liters)
t = holding time 2 minutes (seconds)

The average emitter water discharge can be calculated by the equation below.

$$Qa = \frac{1}{n} \sum_{i=1}^{n} Qi \quad (2)$$

Where:

Qa = average emitter discharge (m3/s) or (l/h)
Qi = discharge at emitter (m^3/s) or (l/h)
n = number of emitters

As for the standard deviation emitter discharge can be calculated by the following equation.

$$S = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(Qi - Qa)^2} \quad (3)$$

Where:

S = standard deviation

So that the coefficient of variation of flow at the emitter can be calculated by dividing the standard deviation by the average flow rate at the emitter.

$$Cv = \frac{S}{Qa} \quad (4)$$

For the classification of the coefficient of variation of flow at the emitter can be seen in Table 1.

Table 1. Classification of Coefficient of Variation (Cv)

Coefficient of variation (Cv)	Classification
0.4	Unacceptable
0.4- 0.3	Low
0.3- 0.2	Acceptable
0.2- 0.1	very good
0.1	Excellent

Furthermore, uniformity statistics (Us) are used to determine the uniformity of the micro irrigation system, as follows.

$$Us = 100\,(1 - Cv) \quad (5)$$

Where:

Us = Uniformity stats
Cv = Coefficient of variation

Emitter uniformity (UE) is determined as a function of the relationship between 25% of the lowest or minimum discharge and the average emitter discharge.

$$E_u = 100\,\frac{\bar{Q}_{25\%\,min}}{\bar{Q}a} \tag{6}$$

Where:

Eu = Emitter *uniformity*

For the comparison classification between US and EU values for planning, see Table 2.

Table 2. Classification of Us and EU values

Classification	Us(%)	EU (%)
Excellent	90	94 – 100
good	80 - 90	81 - 87
Fair	70 - 80	68 - 75
poor	60 - 70	56 - 62
Unacceptable	60	50

Source: Field Evaluation of Drip Irrigation Systems in Raphael, 2018

The uniformity coefficient (UC) is the uniformity of flow obtained from the drip irrigation system with the following equation.

$$UC = 100\left[1 - \frac{1}{n\,x\,Qa}\sum_{i=1}^{n}|Qi - Qa|\right] \tag{7}$$

Table 3. Classification of the Uniformity Coefficient

Uniformity Coefficient UC (%)	Classification
Above 90	Excellent
80 - 90	good
70 - 80	Fair
60 - 70	poor
60	Unacceptable

Source: Field Evaluation of Drip Irrigation Systems in Raphael, 2018

ANOVA (analysis of variance) is a statistical analysis test that serves to distinguish between the mean of more than two groups of data by comparing the variances. While the *one way* ANOVA test is part of the ANOVA test which has an average or treatment effect of one factor or there is only one independent or independent variable which is divided into several groups and one dependent or dependent variable (Hanief & Himawanto, 2017).

The alternative ANOVA test was carried out if the data were not normally distributed and homogeneous. If using data transformation still does not change the data to be normally distributed, then an alternative ANOVA test is needed, namely using the Non-Parametric statistical test. Non-parametric statistical test is a statistical test that does not require the assumption that the data distribution is normally distributed. The non-parametric statistical test which is an alternative to the one-way ANOVA test is to use one-way analysis of variance based on ranking, namely the Kruskal-Wallis test (Anwar, 2009).

The Kruskal-Wallis test is part of the Non-Parametric statistical test for independent samples, namely comparing a variable measured in a sample of more than two groups (Yuantari & Handayani, 2017).

The general equation for the Kruskal-Wallis test is as follows.

$$H = \frac{12}{N\,(N+1)} \sum_{i=1}^{k} \frac{R_i^2}{n_i} - 3\,(N+1) \quad (8)$$

Where :

N = number of samples
Ri = number of ranks in group i
ni = number of samples in group i

In the Kruskal-Wallis test, if obtained from the calculation results there is a significant difference, then it is continued with the further Kruskal-Wallis test, including the Dunn-Boferroni test. Dunn-Boferroni follow- up test was conducted to determine which groups had significant differences.

The purpose of this study was to analyze the uniformity of water distribution by measuring the discharge in the drip irrigation system and to analyze the average variation of water distribution in the horizontal (row) and vertical (column) directions using statistical tests.

The scope of this research is carried out at the Hydraulics Laboratory, the movement of water in the vertical garden only moves in a vertical direction or only moves in the pot, measuring the volume of water in the vertical garden using a water content sample so that unknown pots can be interpolated based on the value of the nearest pot sample. (above and below), testing the average variation of the uniformity of water distribution using a statistical test of analysis of variance that is comparing plants in the horizontal and vertical directions and further testing is carried out if there is a difference in the average water distribution or discharge of each pot in the horizontal direction and vertical.

2. Methodology

2.1. Research Stages

In this study, for measuring water discharge using a water content sample in a vertical garden drip irrigation system in determining the classification of the value of uniformity of water distribution and the average variation of water distribution in the horizontal (row) and vertical (column) directions with statistical tests, the research stages are carried out like the following flow chart in Figure 1.

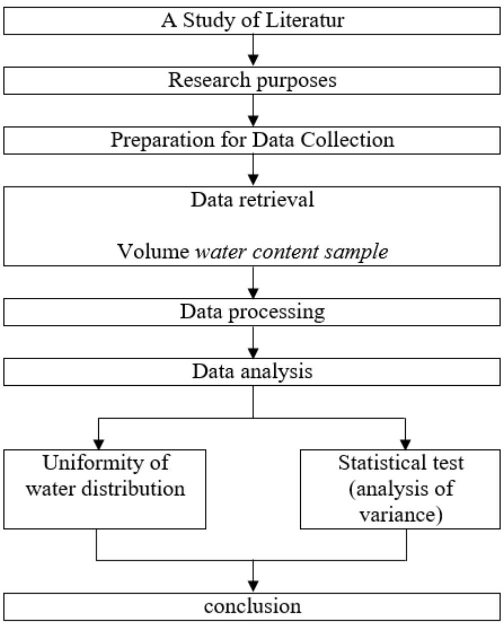

Figure 1. Research flow chart

The stages of data analysis for uniformity of water distribution and statistical tests with analysis of variance can be seen in the flow chart below.

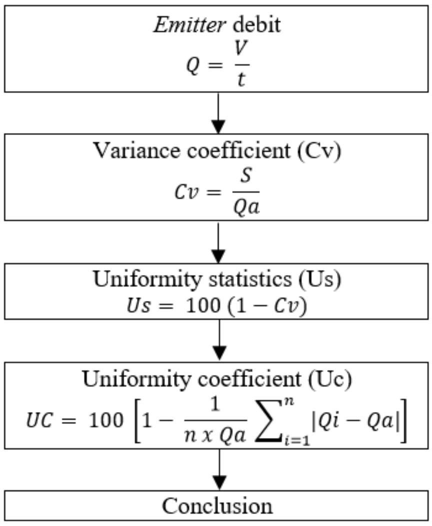

Figure 2. Flowchart of analysis of uniformity of water distribution

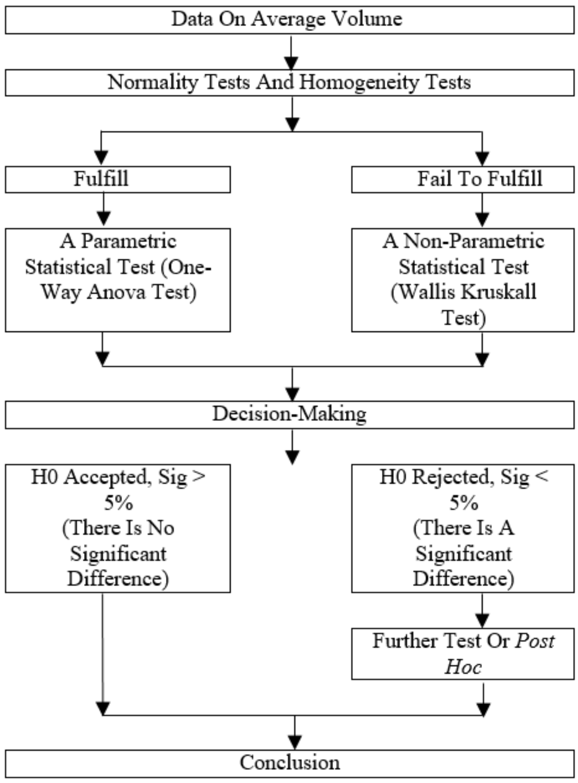

Figure 3. Flowchart of analysis of variance

2.2. Method of collecting data

In this study, data collection was carried out at the Hydraulics Laboratory by measuring the volume of the water content sample in the vertical garden. This research was conducted from September 1 to September 30, 2020 for four days a week, namely Tuesday, Wednesday, Thursday and Friday. So the total is 18 days of data collection. Data were collected once a day and started at 10 am after watering at 8 am. After 2 hours of waiting time until the water no longer comes out of the emitter the volume of water in the water content sample. Furthermore, the water content sample or measuring cup is taken from the vertical garden to read the volume and then place it on a flat place so that the water volume reading is precise and correct.

3. Results and Discussion

3.1. Value of Water Distribution Uniformity

Classification of the value of uniformity of water distribution in drip irrigation aims to classify the performance of the drip irrigation system used and the level of water distribution in each emitter. The determination of the classification of the uniformity value of water distribution is determined by three parameters, namely the classification of the coefficient of variation (Cv), the comparison classification between the statistical uniformity values (Us) and emitter uniformity (Eu) and the uniformity coefficient classification (UC). The following table summarizes the performance classification of drip irrigation systems in vertical gardens.

Table 4. Recapitulation of drip irrigation system performance classification

Parameter	Score	Classification
Coefficient of Variation	0.27	OK/Accepted
Uniformity Statistics	73.2%	OK/Accepted
Coefficient of Uniformity	71.7 %	OK/Accepted

So based on the table 4, it can be concluded from the three parameters, namely the classification of the coefficient of variation (Cv), the classification of the comparison between the value of statistical uniformity (Us) and the uniformity of the emitter (Eu) and the classification of the uniformity coefficient (UC) which is used to assess the performance of drip irrigation in vertical gardens. good and acceptable.

3.2. Statistical Test (Analysis of Variance)

The statistical test used in this research is analysis of variance. Analysis of variance serves to determine whether there is a difference in the average uniformity of water distribution between data groups, namely data groups in the horizontal direction (between rows) and the vertical direction (between columns). This statistical test was carried out with the help of the SPSS (Statistical Product and Service Solution) program.

In the normality and homogeneity test above, the data obtained are not normally distributed and not homogeneous, then the analysis of variance that can be used is using non-parametric statistical tests with the Kruskal-Wallis test. The Kruskal-Wallis test was chosen because it is an alternative test to the one-way ANOVA test which functions to compare between each group with one influencing factor and has more than two groups being compared.

The results of non-parametric statistical tests using the Kruskal-Wallis test in the row and column groups can be seen in Tables 5 and 6.

Table 5. Test Kruskal-Wallis group line

Statistics Test	Storage volume
Chi-Square	63.629
df	11
asymp. Sig.	1.95E-09

Table 6. Kruskal-Wallis test *for* column groups

Statistics Test	Storage volume
Chi-Square	69.644
df	13
asymp. Sig.	9.33E-10

In table 5, the Chi-Square value for the row group is 63.629 with a degree of freedom (df) 11 while in the Chi-Square table for the degree of freedom (df) 11 and a 95% confidence level, the Chi-Square table value is 4.575. So that the Chi-Square value calculated is greater than the Chi-Square table value, which means that it is in the area of rejection of

Ho (initial hypothesis), that is, there is a difference in average uniformity. Meanwhile, the significance value for the row group is smaller than 5 %, namely 1.95E-09, which means that for decision making on the Kruskal-Wallis test, the initial hypothesis is rejected and the alternative hypothesis is accepted, which means that there is a difference in the average uniformity of water distribution in the vertical garden.

In Table 6, the Chi-Square value for the column group is 69.644 with a degree of freedom (df) 13 while in the Chi-Square table for a degree of freedom (df) 13 and a 95% confidence level, the Chi-Square table value is 5.892 so that the Chi-Square value calculated is greater than the Chi-Square table value, which means that it is in the area of rejection of Ho (initial hypothesis), that is, there is a difference in average uniformity. Meanwhile, the significance value for the row group is smaller than 5%, namely 9.33E-10, which means that for decision making on the Kruskal-Wallis test, the initial hypothesis is rejected and the alternative hypothesis is accepted, which means that there is a difference in the average uniformity of water distribution.

Based on the decision making in the Kruskal-Wallis test, there is a significant difference between the average uniformity of water distribution in the vertical garden both in the row group (horizontal direction) and column group (vertical direction) so that further tests are needed on non-parametric statistics using the test Dunn-Bonferroni on SPSS to obtain groups that experienced a significant difference in mean

Based on the results of the significance value in the Kruskal-Wallis further test or the *Dunn-Bonferroni test* for the row group, it is obtained:

1) Group row 1 against row 9, row 10, row 11, row 12
2) Group row 2 against row 10, row 11, row 12
3) Group on row 3 against row 11, row 12

As for the column group obtained:

1) Group column 1 against column 11,
2) Group column 7 against column 13,
3) Group column 8 against column 13,
4) Column group 9 against column 13, column 14
5) Group column 10 against column 13, column 14,
6) Column group 11 against column 13 and column

Having a significance value of less than 5% means that there are differences in the average distribution of water. As for the others, there is no difference in the average distribution of water.

4) Conclusion

Based on the results of the research conducted, the following conclusions can be obtained:

1) The classification of water distribution uniformity by measuring water discharge using a water content sample in a vertical garden drip irrigation system is based on three parameters, namely the coefficient of variation (Cv), statistical uniformity (Us) and uniformity coefficient (Uc) which are categorized as good and acceptable.

2) Based on the results of statistical tests, the average value of water distribution in the horizontal row group is 77.03 mL to 157.49 mL and in the vertical column group it is 68.99 mL to 160.83 mL and the statistical test decision making is significant differences between each row group and column group so that further tests were carried out to obtain the group that had the significant difference.

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