FULL REPORT OF PRACTICUM
IRRIGATION AND DRAINAGE TECHNIQUE
(19G04130402)

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HASANUDDIN UNIVERSITY
MAKASSAR

2022

APPROVAL SHEET

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This Comprehensive Report is Prepared as One of the Requirements for Successfully Completing the Laboratory Examination of the Course Practical Irrigation and Drainage Techniques
(19G04130402)

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FOREWORD

Praises and gratitude are offered to the presence of the Almighty God, who has bestowed health and ease upon the writer to participate in all the experiments within the Irrigation and Drainage Techniques laboratory, enabling the completion of this comprehensive report. The writer extends thanks to the laboratory Assistants, Assistant Coordinator, and fellow members of Group 7 who provided invaluable assistance in finalizing this report.

May this comprehensive report serve as a source of benefit to its readers.

Makassar, Desember 12, 2022

Farhan

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ABSTRACT

Evapotranspiration refers to the total amount of water returned to the atmosphere from a water body, soil surface, and vegetation. Evapotranspiration can be measured using a lysimeter. A lysimeter is a container of a certain depth that is buried in the soil and used to collect the infiltrated water beneath it. Lysimeters can be used to measure both incoming and outgoing water. The purpose of the Plant Evapotranspiration Measurement laboratory work is to determine plant evapotranspiration through lysimeters and evaporating pans. The methods employed are direct measurement using lysimeters and evaporating pans. The results of the Plant Evapotranspiration Measurement laboratory work show that evapotranspiration varies at different times. Actual evapotranspiration (ETc) as well as potential evapotranspiration (ETo) exhibit fluctuating values. The conclusion drawn from the laboratory work is that the evapotranspiration process is influenced by factors such as soil texture, environmental temperature, and rainfall intensity. Higher environmental temperatures lead to greater evaporation, while higher rainfall intensity results in more water accumulating in water bodies.

Keywords: Water, Hydrology, Percolation.

INTRODUCTION

Background

The hydrological cycle is one of the processes through which surface water on Earth undergoes a continuous cycle. The hydrological cycle consists of various processes that contribute to the maintenance of ecosystems and life on Earth. As the hydrological cycle continues, the availability of water on Earth remains sufficient. Numerous processes are involved in the hydrological cycle, including evaporation, condensation, advection, precipitation, runoff, transpiration, infiltration, and percolation.

Evaporation refers to the process of water vaporizing from water bodies such as rivers or lakes into the atmosphere, forming clouds. Evaporation can be measured directly using an evaporating pan or through various calculation methods and their combinations. Transpiration refers to the water vapor released by plants. These two processes occur concurrently and are collectively referred to as evapotranspiration. The magnitude of evapotranspiration in arid regions is highly dependent on rainfall intensity. Evapotranspiration is influenced by factors like temperature, air pressure, solar radiation, wind speed, and soil water-holding capacity. Evapotranspiration can be measured using an instrument called a lysimeter.

A lysimeter is a device used to directly measure evapotranspiration. It consists of a container filled with soil, equipped with connected apparatus, and used to collect infiltrated water at the bottom of the lysimeter. The amount of water discharged from the lysimeter's tap can be measured using a container with a liter measurement. This measurement is typically taken in the late afternoon. Various hydrological processes or cycles occur in a lysimeter, including evapotranspiration, infiltration, and percolation.

Based on the above description, the Plant Evapotranspiration Measurement laboratory work is conducted to understand the working principles of lysimeters and evaporating pans, thereby determining the magnitude of evapotranspiration and percolation that occur in a land area.

Objective and Purpose Experiment

The objective of the Plant Evapotranspiration Measurement laboratory work is to determine plant evapotranspiration through lysimeters and evaporating pans.

The benefits of the Plant Evapotranspiration Measurement laboratory work include understanding the functioning of lysimeter systems, which can be utilized to provide water for agricultural cultivation.

LITERATURE REVIEW

Evapotranspiration

Evapotranspiration is one of the processes in the hydrological cycle and plays a crucial role in hydrology, agriculture, ecology, and other fields. Evapotranspiration refers to the transformation of water into vapor or water vapor and its movement from the evaporation area, which includes vegetation or plants and the soil surface, to the atmosphere. Evapotranspiration is essential for determining the consumptive water use for plants, the capacity of irrigation pumps, water availability analysis, reservoir capacity, and water conveyed through irrigation channels (Taolin et al., 2017).

Evapotranspiration represents the total amount of water returned to the atmosphere from a water body, soil surface, and vegetation. There are various types of evapotranspiration, including potential evapotranspiration, standard evapotranspiration, actual evapotranspiration, and plant evapotranspiration. The magnitude of evapotranspiration in arid regions depends greatly on the amount of rainfall. Evapotranspiration is influenced by factors such as temperature, air pressure, solar radiation, wind speed, and the water-holding capacity of soil and air. Temperature is one of the most dominant factors affecting the rate of evapotranspiration. Evaporation will increase or decrease with temperature, depending on whether the surface is cooler or warmer than the air. Evapotranspiration increases with greater solar radiation, humidity, wind speed, and temperature (Fibriana et al., 2018).

Potential evapotranspiration describes the energy received by a region from the sun. Additionally, potential evapotranspiration reflects the environmental, vegetation, or agricultural requirements for evapotranspiration, determined by factors such as leaf area, wind speed, air pressure, air temperature, and solar radiation. The value of evapotranspiration can be determined using various methods, such as the Penman-Monteith method. This method is relatively complex, requiring multiple climatic parameters and intricate unit conversions. The Penman-Monteith method utilizes several climatic parameters or meteorological variables, including solar radiation, air humidity, air temperature, and wind speed. The Penman-Monteith method is frequently used by researchers due to its accurate estimations (Fausan et al., 2021).

Evapotranspiration represents the total amount of water returned to the atmosphere from a water body, soil surface, and vegetation. There are various types of evapotranspiration, including potential evapotranspiration, standard evapotranspiration, actual evapotranspiration, and plant evapotranspiration. Lysimeter is a tool used to measure evapotranspiration in plants. Evapotranspiration is influenced by factors such as temperature, air pressure, solar radiation, wind speed, and the water-holding capacity of soil and air. Temperature is one of the most dominant factors affecting the rate of evapotranspiration. Evaporation will increase or decrease with temperature, depending on whether the surface is cooler or warmer than the air. Evapotranspiration increases with greater solar radiation, humidity, wind speed, and temperature (Kumar, 2017).

Infiltration

The hydrological cycle begins with the process of evaporating seawater, which then falls onto the ground as rain or snow. This phenomenon occurs continuously. If the rainwater that falls from the atmosphere is not captured by plants or vegetation, it will fall onto the earth's surface, and some of this water will evaporate, be absorbed into the soil, or be stored in depressions. Runoff includes the combination of surface flow, delayed flow in a basin, and subsurface flow (Rianto, 2021).

Infiltration is one of the processes in the hydrological cycle in which water flows into the soil, generally originating from rainfall. The amount of water entering the soil in a given time is referred to as the infiltration rate. Infiltration is a critical process in the hydrological cycle as it determines the amount of water present on the soil surface. However, not all water on the soil surface will be absorbed into the soil; some will stay in the top layer of the soil. This water will evaporate into the atmosphere. Soil moisture at the beginning, soil structure, organic matter content, soil texture, type and thickness of litter, biological activity, and vegetation type are among the factors that influence the amount of water entering the soil through infiltration, a process in the hydrological cycle (Dipa et al., 2021).

The litter layer and other ground cover plants contribute to increasing the capacity of infiltration within the soil, reducing the magnitude of surface runoff. When the infiltration capacity is smaller than the intensity of rainfall, flooding and erosion may occur. Infiltration rates will differ between locations. Soil infiltration rate is an essential process that affects the uniformity and efficiency of surface irrigation, as it distributes water from the surface to the soil profile (Patel et al., 2019).

The infiltration rate can be determined using the Horton equation. The Horton model is one of the infiltration models that describe how the infiltration capacity decreases with time until it approaches a constant value. The reduction in infiltration capacity is more influenced or controlled by surface factors than subsurface flow. The Horton model is relatively simple and suitable for experimental data (Susanawati et al., 2018).

The infiltration rate can also be determined using the Kostiakov model. The Kostiakov model describes the cumulative infiltration rate as a power function of time. The initial infiltration rate is infinite, and the rate increases over time until it approaches zero. The Kostiakov model is less ideal for vertical flow but is suitable for horizontal flow (Setiawan et al., 2022).

Conventional soil tillage dominates the improvement of soil porosity and water infiltration. Surface sealing tends to occur only a few days after soil tillage due to the immediate impact of raindrops on the soil surface. Limited vegetation cover on a soil surface, decreasing porosity, and reduced infiltration can lead to intensified erosion processes. Groundwater infiltration is influenced by several factors, including vegetation cover, soil tillage, porosity, surface roughness, soil density, groundwater content, and organic carbon content. When the soil has a coarse texture, the infiltration process is faster (Almeida et al., 2018).

High-intensity rainfall can destroy soil aggregates, leading to pore blockage and affecting soil texture, which can decrease infiltration rates. Ground cover vegetation will not grow well on soils with small pores. Infiltration is used to determine the amount of groundwater recharge beneficial for plants and to calculate runoff and aid in irrigation water management (Musdalipa et al., 2018)

Percolation

Percolation is one of the processes in the hydrological cycle where water enters and penetrates the soil layers down to the lower layers until reaching the saturated layer. Percolation measurement is conducted to determine the size of the infiltration area required for a specific soil type. If the soil's infiltration capacity is greater, then a smaller area of infiltration is needed. The type of soil used will affect the soil's infiltration capacity. Percolation capacity is defined as the maximum percolation rate possible, influenced by the unsaturated soil conditions in the non-saturated area. Percolation cannot occur until the unsaturated area reaches the field area. Percolation capacity is not significant in natural conditions due to stagnation in percolation caused by a semi-impermeable layer that leads to temporary retention in the unsaturated area. Several factors affect percolation, such as plant cover type, soil texture, soil depth, and soil permeability. Soil permeability is the ability of the soil to allow water seepage through soil pores over a certain time until saturation (Abbas & Takaendengan, 2021).

Movement through the soil is referred to as percolation, and the seepage out of the bottom is known as drainage. Many factors influence water movement, including gravity pulling water downward and capillary forces drawing water in along soil pores. Water only moves into the soil if the advancing front exceeds the field capacity. Actual water storage continues to decrease if it remains above the field capacity. If water is added, it won't be stored for long and will eventually flow down into the soil, undergoing percolation or evaporation processes (Sari & Prijono, 2019).

Lysimeter

Evapotranspiration can be measured using a lysimeter. A lysimeter is a container of a certain depth that is buried in the soil and used to collect the infiltrated water beneath it. Lysimeters can be used to measure both incoming and outgoing water. There are three processes or hydrological cycles that occur in a lysimeter: evapotranspiration, infiltration, and percolation. Each of these processes is influenced by various factors such as soil texture, soil structure, surrounding climate, and more (Sarminah et al., 2019).

Ombrometer

Evaporation occurring in a region can be measured using an evaporating pan. An evaporating pan is a device used to directly measure evaporation. Limited availability of evaporation data can occur due to instrument damage, measurement disturbances, and the absence of climatological stations. Measurements of evapotranspiration can be influenced by various factors such as rainfall and solar radiation. The greater the intensity of solar radiation, the greater the evaporation of water. Similarly, the greater the intensity of rainfall, the smaller the evapotranspiration value in an area due to occurring during rainy seasons with minimal solar radiation. Additionally, vegetation also plays a role. More vegetation leads to less water falling into lysimeters and evaporating pans as it is retained by plants. Rainfall can be measured using an ombrometer. This device is usually placed in an open area to directly collect rainfall. The unit of measurement is millimeters (mm). There are two types of rain gauges: recording and non-recording rain gauges. The Hellman rain gauge is an example of a recording rain gauge (Fadhilah et al., 2021).

Evaporation Pan

Evaporation is defined as the process of water vaporizing from surfaces like soil and water bodies. One instrument used to measure evaporation is the evaporating pan or open pan evaporimeter. An open pan evaporimeter is a large, round container made of iron. Conventional observations can yield more accurate data as they involve direct observation or measurement by an observer. Measurements with an evaporating pan involve placing rulers at four points. Typically, evaporating pan measurements are conducted over one day (Zubizarreta, 2020).

Plant Water Requirements

Plant water requirements refer to the amount of water needed for plants to grow and develop properly. The water requirement for red chili plants in each growth phase is related to the plant's coefficient. Variations in evapotranspiration values are caused by differences in rainfall and temperature. Evapotranspiration values are lower during the rainy season due to shorter sunlight duration and lower temperatures, leading to reduced transpiration from plant leaves to the atmosphere. Water requirements for plants at different age levels vary significantly based on the plant coefficient. Thus, the highest evapotranspiration values are obtained in the third month due to flowering, requiring more water. Additionally, plant water requirements are influenced by the extent of ground coverage by the canopy of leaves. The canopy area increases as the plant ages (Kusmali et al., 2015)."

METHODOLOGY OF PRACTICUM

Time and Location

The Practicum on Plant Evapotranspiration Measurement was conducted from Tuesday, October 26 to November 18, 2022, at the Agricultural Engineering Environment, Agricultural Engineering Study Program, Department of Agricultural Technology, Hasanuddin University, Makassar.

Tools

The equipment used in the Plant Evapotranspiration Measurement practicum includes lysimeters, buckets, measuring cups, nozzles, pumps, hoses, evaporating pans, rain gauges, control boxes, Microsoft Excel, and a smartphone camera.

Materials

The materials used in the Plant Evapotranspiration Measurement practicum include chili katokkon plants, wheatgrass, and water.

Experiment Procedure

The procedure for the Plant Evapotranspiration Measurement practicum is as follows:

1. Installing nozzles on each lysimeter.
2. Setting up the irrigation system and pump.
3. Set the automatic watering schedule using the timer setting on the pump.

4. Conduct measurements on the lysimeters by opening the percolation valve at 5:00 PM WITA (Central Indonesia Time) for 4 days.
5. Measuring evaporation in the evaporating pans at 5:00 PM WITA for 4 days.
6. Measuring rainfall using the rain gauge at 5:00 PM WITA for 4 days.
7. Processing data using Microsoft Excel.
8. Documenting the practicum

Formulas Used

The formulas used in the Plant Evapotranspiration Measurement practicum are as follows:

1. Actual Plant Evapotranspiration

$$ETc = Ir + R - P$$

Where :

ETc = actual plant evapotranspiration (mm/day)
Ir = Irrigation water (mm)
R = Rainfall (mm)
P = Percolation water

2. Evapotranspirasi Potensial Tanaman

$$ETo = \text{evaporation pan coefficient} \times \text{measured water height}$$

Where :

Eto = Potential plant evapotranspiration (mm/day)

3. Vaporation Pan Method

$$ETo = (h_0 - h_1) \times 0{,}7$$

Where :

ETo = Potential plant evapotranspiration (mm/day)
h_0 = Initial water height
h_1 = Final water height

4. Rainfall

$$CH = \frac{V}{A} \times 10$$

Where :

CH = Rainfall (mL/hari)
V = Measurement volume (cm^3)
A = Funnel area (cm^2)

RESULT AND DISCUSSION

Result

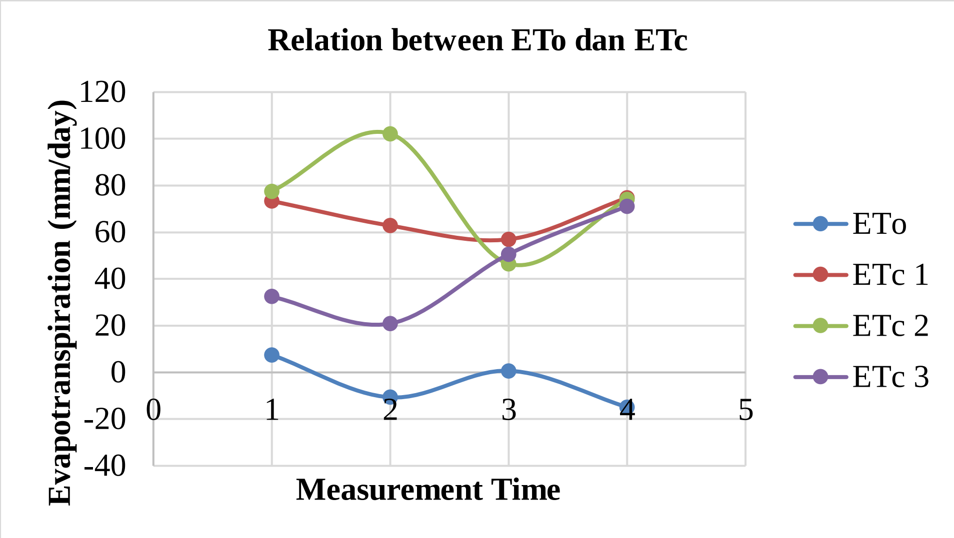

Figure 1. Relation between ETo dan Etc Graph

Discussion

Evapotranspiration refers to the process of water changing into vapor or water vapor and moving from its source, which can be vegetation or plants, and the soil surface to the atmosphere. Evapotranspiration is essential to determine the consumptive water use by plants, the capacity of irrigation water pumps, water availability analysis, reservoir capacity, and water conveyed through irrigation channels. Lysimeter is an instrument used to measure evapotranspiration in plants. It is a container with a specific depth buried in the soil to collect seepage underneath it. Lysimeters can be used to measure both the water entering and exiting the system, a phenomenon known as percolation. Percolation is a process in the hydrological cycle where water infiltrates the soil layers and reaches the saturated zone. Among the three lysimeters, lysimeters 2 and 3 exhibit the highest percolation rates because they are planted with wheatgrass, which has small leaves and absorbs less water. Lysimeter 1, planted with wider-leaved hot pepper plants, absorbs more water. Percolation measurements are conducted to determine the infiltration capacity required for specific soil types. The percolated water appears clear, as it has been filtered through gravel within the soil layers of the lysimeter. Several factors influence the amount of percolated water, with soil texture being one of them. Clayey soils tend to have smaller pores and therefore allow less water to exit. This aligns with the statement by Abbas & Takaendengan (2021) that various factors, such as vegetation cover, soil texture, upper soil layer thickness, and soil permeability, affect percolation.

Evaporation can be measured using equipment called an evaporative pan. Measurements are taken in the morning, noon, and afternoon to observe variations in the water level in the pan. This is done to account for factors like sunlight intensity, ambient temperature, and rainfall. Higher rainfall intensity leads to more water collected in the evaporative pan, while greater sunlight intensity increases the rate of evaporation. The graph depicts the relationship between ETo (potential evapotranspiration), and ETc (actual evapotranspiration). ETc represents the actual water loss from the surface through evaporation from water bodies and transpiration from plants. ETo, on the other hand, is the potential evapotranspiration or the atmospheric capacity to release water from surfaces through evaporation and transpiration. The graph demonstrates a fluctuating pattern between ETo and ETc due to variations in water level measurements from the evaporative pan, lysimeter, and rain gauge. Data might show an increase or decrease in subsequent measurements due to the ongoing evaporation process. When sunlight intensity is low, data values tend to be high, while high sunlight intensity accelerates evaporation due to increased temperature, resulting in lower data values. This explains the diverse range of evapotranspiration measurement data. This phenomenon is consistent with Kumar's statement (2017) that evaporation increases or decreases with temperature depending on whether the surface is cooler or warmer than the surrounding air.

CONCLUSION

Based on the conducted experiment, it can be concluded that evapotranspiration refers to the total amount of water returned to the atmosphere from a water body, soil surface, and vegetation. Evapotranspiration can be measured using lysimeters and evaporative pans. Several factors influence evapotranspiration, including temperature, air pressure, solar radiation, wind speed, and the water-holding capacity in both soil and air. Temperature is one of the most dominant factors affecting the rate of evapotranspiration. Evaporation will increase or decrease with temperature, depending on whether the surface is cooler or warmer than the air. The magnitude of evapotranspiration will increase when solar radiation, humidity, wind speed, and temperature become larger.

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APPENDIX

Appendix 1. CH Measurement Table, Evaporation and Lysimeter

Table 1. CH measurements and*Lysimeter*

Observation time	**Rainfall (mm)**	**Irrigation Water (L)**	***Lysimeter* 1(L)**	**ETc (mm)**	***Lysimeter* 2 (L)**	**ETc (mm)**	***Lysimeter* 3(L)**	**ETc (mm)**
06/11/2022	3,9	114	59.45	73,39	56,2	77,53	91.59	32.45
07/11/2022	18	114	78.8	62,84	47,9	102,20	111.7	20.93
08/11/2022	2,21	114	71	56.98	79,2	46,54	76	50,62
09/11/2022	23,8	114	74	74.75	74.5	74,12	76.8	71,19

Table 2. Evaporation Measurements

Measurement Day	**Initial Height (cm)**	**Final Height(cm)**	**Measurement Result (cm)**	**ETo**
1	5,625	4.55	1.075	7,525
2	4.55	6,075	-1.525	-10.675
3	6,075	5,975	0.1	0.7
4	5,975	8,1	-2.125	-14,875

Appendix 2. Documentation of Plant Evapotranspiration Measurement Practicum

Figure 2. Performing percolation water measurements

FIELD CAPACITY

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ABSTRACT

Field capacity is defined as the amount of water that a soil can retain under the influence of Earth's gravitational force. The water held by the soil is continuously taken up by plant roots or evaporates, causing the soil to gradually dry out. The purpose of the Field Capacity laboratory experiment is to understand the relationship between effective field capacity and soil water content, the methods employed, and the influencing factors. The experiment involves weighing soil and filter paper, saturating them with water, and allowing them to equilibrate until no more water drips out. Subsequently, the samples are oven-dried for 24 hours and weighed again. The result of the Field Capacity experiment indicates that the field capacity of the tested soil is 80.1%. The amount of water required by the soil to reach a 60% moisture content is 210 ml. Clayey soil possesses a higher water retention ability compared to sandy soil due to its tightly packed soil pores that hold water effectively. The conclusion drawn from the Field Capacity experiment is that the appropriate moisture content for different plants depends on their species. Horticultural plants such as vegetables and fruits require moderate water as they prefer slightly drier soil conditions. When plants receive sufficient water, their growth improves.

Keywords: Water, Clay, Soil

INTRODUCTION

Background

Plants can thrive and grow effectively when provided with appropriate care, including the right balance of nutrients and adequate water supply. Each plant has distinct water requirements that are adjusted according to the soil's water-holding capacity. Different soils possess varying water-holding capacities, influenced by soil moisture, saturated layer thickness, soil structure, soil texture, soil pores, bulk density, soil moisture content, and porosity. To determine a soil's water-holding capacity, measurement processes can be carried out using the field capacity calculation method.

Field capacity refers to the amount of water a soil can retain under the influence of various factors, such as Earth's gravitational force. Measuring the water content in soil can be done using a field capacity formula. Initially, dry soil paper is weighed, and then a soil sample weighing 100 grams is prepared. Subsequently, the soil sample is placed on filter paper, water is added, and the sample is allowed to reach a saturated condition. When no more water drips from the soil sample, another weighing process is conducted. Following this, the soil sample is oven-dried for a day and re-weighed to determine its final weight.

The soil moisture content can be measured using a soil moisture meter. A soil moisture meter is a tool utilized to measure the water content in the soil, capable of reading around 50% moisture content. The meter provides accurate measurements for soil up to a maximum depth of 10 cm. Soil samples used for measurement should either be dry or oven-dried before applying water. The addition of water is done until the desired moisture content is achieved. This process requires thorough mixing of water with soil to ensure uniformity, allowing consistent measurement data across all points. During soil moisture meter (SMM) measurements, the tool should not be moved or shaken to prevent soil from becoming exposed, which could allow air to enter and potentially affect measurement results.

Based on the aforementioned description, a Field Capacity experiment is conducted to determine the maximum amount of water soil can retain, thereby understanding how much water should be supplied to plants.

Objective and Purpose Experiment

The goal of the Field Capacity experiment is to establish the relationship between field capacity and soil moisture content, identify the methods used for calculating field capacity, and recognize the influencing factors.

The practical use of the Field Capacity experiment lies in understanding the soil's water-holding ability. This knowledge can be applied in agriculture to prevent overwatering or underwatering of plants. It also helps determine the suitable moisture content for the growing medium.

LITERATURE REVIEW

Soil

Soil is a component of the Earth's crust composed of minerals and organic materials. It serves as a growing medium for plants, and each type of soil possesses distinct characteristics and properties. Various types of soil exhibit different distributions and sizes of pores that can influence water availability within the soil. Soil texture significantly affects the soil's capacity to retain or store water. Clay-textured soil has a higher capacity for water retention compared to sandy soil. Finer soil textures correspond to greater soil water-holding capacities (Haridjaja et al., 2018).

The soil varies fundamentally from one location to another. This variation is characterized by both horizontal and vertical soil characteristics. Several factors contribute to soil formation, including organisms, parent materials, time, topography, and climate. Each formed soil can be classified using a soil classification system based on permanent soil characteristics, reflecting the soil's ability to support plant growth and development. Soil is a non-renewable resource with chemical, physical, and biological attributes. Different soil types exhibit varying fertility levels, affecting their capacity to support plant growth (Widiatmaka et al., 2015).

Soil type and environmental factors can influence the growth of plants. Peat soil, for instance, has a high pH value or acidity level, typically around 3-5, which is less favorable for plant growth. Elevated soil acidity poses a challenge to plant growth. However, this acidity can be mitigated in peat soil by adding dolomite as needed (Novara et al., 2021).

Soil Texture

Soil texture is defined as the degree of fineness of soil resulting from the varying composition of clay, silt, and sand fractions contained within the soil. Soil texture influences the rate of infiltration. Several factors impact infiltration rate, including soil structure, soil texture, soil moisture, soil depth, saturated layer thickness, rainfall intensity, ground cover vegetation, compaction due to rain, and physical properties of the soil. Finer soil textures make it more challenging for water to penetrate due to the compactness of soil pores. Conversely, coarser soil textures allow water to more easily penetrate the soil profile (Fadhli & Andayono, 2022).

The size of soil pores affects infiltration capacity. Larger soil pores result in greater infiltration capacity. Soils with larger pores struggle to retain water, leading to plant susceptibility to drought. Fragmented soil provides greater infiltration capacity compared to clay soil. Soil with water-saturated pores has a lower capacity than soil in a dry state. Sandy soil has good drainage pores, resulting in high infiltration rates but an inability to retain or bind water. Soil texture classes are grouped into five categories: t1, t2, t3, t4, and t5. Class t1 represents fine-textured soil, including dusty clay and clay. Class t2 comprises moderately fine-textured soil, such as clay-silt texture, sandy clay loam, silty clay loam, and dusty silty clay loam. Class t3 includes soils of moderate texture, including clay, dusty clay, and loam. Class t4 encompasses moderately coarse-textured soil, including sandy clay loam. Class t5 involves coarse-textured soil like sandy loam and sandy clay (Basir, 2019).

Soil quality and available water are key factors influencing harvest outcomes. Soil texture is an essential and variable component affecting the soil's ability to retain water, soil fertility, and crop production. Light soil provides better ventilation and permeability, but nutrient waste is higher. Heavy soil has higher microbial biomass, better water, and nutrient retention capability, and lower irrigation requirements, but poor ventilation and permeability (Hosseini et al., 2022).

Various soil types exist, such as gleysol, cambisol, alluvial gleysol, podzolic chromic, haplic oxisol, and others. Soil texture varies from fine to coarse classes. The texture change pattern from the soil surface to 100 cm deep does not show a decrease in clay content. Chemical properties of the soil include base saturation, organic matter, soil pH, cation exchange capacity, aluminum, and more. pH values range from acidic to highly acidic. Potassium is present in the soil in significant amounts, but only 2-10% is soluble and absorbed by roots (Sarminah et al., 2022).

Field Capacity

Field capacity is defined as the condition of soil being adequately moist, indicating the maximum amount of water soil can retain against gravitational force. The water held by the soil is continuously absorbed by plant roots or evaporates, resulting in the soil gradually drying out. When the roots of a plant can no longer absorb this water, it causes the plant to wilt. The optimal range of available soil moisture is between field capacity and permanent wilting point. Field capacity is determined through gravimetric methods. The difference between the moisture content at field capacity and the moisture content at air-dry soil conditions is used to calculate the required water for achieving field capacity. The amount of lost water is determined by weighing each pot after preparing the soil under field capacity conditions. The weight difference between wet soil and the container after watering represents the required amount of water for achieving the field capacity condition. Parameters observed include root length, plant height, wet weight of roots and canopy, dry weight of roots, and dry weight of canopy (Siregar et al., 2017).

Measurement of field capacity is conducted to determine the irrigation volume required for plants by saturating the planting medium in polybags until dripping occurs. Subsequently, the polybags are left undisturbed until no water drips from them. The polybags are weighed when wet, and their dry weights are determined after heating the planting medium in an oven at 100°C for 24 hours. The initial wet weight of soil in each polybag is maintained daily by weighing, and for subsequent watering, the polybags are re-weighed to calculate the amount of lost water. The plant is then watered according to the calculated water loss. Reduced water content within the plant can hinder cell division and cell enlargement, resulting in decreased plant height growth. However, this doesn't apply to horticultural plants that prefer slightly drier soil. Adequate water supply promotes better plant growth compared to water-deficient plants. Soil moisture availability affects the wet weight of the plant, yielding higher values. Optimal plant moisture content leads to increased photosynthesis and substantial dry-weight production. Water plays a critical role in plant growth, particularly in root development. Plants with limited or insufficient water availability exhibit smaller sizes compared to well-hydrated plants. Insufficient water supply obstructs nutrient transportation and photosynthesis in leaves. Water stress, characterized by inadequate water intake, hampers proper plant growth. Plants under water stress tend to elongate their roots in search of water, leading to reduced plant weight due to smaller leaves and diminished plant height (Novara et al., 2021).

Soil Moisture Measurement Tools

A soil moisture meter is a device used to measure the moisture content in a sample of soil. This tool is employed to assess the soil moisture level before the transplantation process. The LUTRON PMS 714 soil moisture meter is used to determine soil moisture content. The testing involves attaching or inserting the device into the soil sample and varying the moisture content. The moisture content value present in the soil is displayed on the device. The soil sample is continuously watered until the desired moisture content is achieved (Dewi et al., 2018).

Determining soil moisture is one of the most challenging measurements in hydrology. Tensiometers measure the capillary tension of soil water within the range of 0-1 atm. Tensiometers are particularly valuable as continuous reading instruments for estimating soil moisture content. Tensiometers do not operate effectively in drier soils under higher tension due to air entry through porous points. The gravimetric method is one of the techniques used to measure soil moisture content. Soil moisture content is calculated by weighing soil samples before and after drying. Direct gravimetric measurement of free soil moisture involves several processes, including sampling, drying, and weighing (Majhi & Sarkar, 2019).

METHODOLOGY OF PRACTICUM

Time and Location

The Field Capacity practical was conducted on Monday, September 5th, 2022, starting at 6:00 PM WITA and concluded at the Soil and Water Engineering Laboratory, Department of Agricultural Technology, Agricultural Engineering Program, Faculty of Agriculture, Hasanuddin University, Makassar.

Tools

The equipment utilized in the Field Capacity practical included Petri dishes, filter paper, funnels, an oven, beakers, and a weighing scale.

Materials

The materials employed in the Field Capacity practical comprised soil and water.

Practicum Procedure

Field Capacity Practical Procedure:

A. Gravimetric Method

1. Weigh each dry filter paper.
2. Fold the wet filter paper according to the folding instructions and place it inside the funnel as per the funnel's shape.

3. Weigh 100 grams of soil, then place the soil into the filter paper within the funnel.
4. Wet the soil in the funnel until the surface of the soil is moist, and allow it to stand until the water no longer drips and the soil is saturated with water.
5. After saturation, weigh the combined weight of wet soil and wet filter paper.
6. Place the samples in an oven at 105°C and leave them for 24 hours.
7. After 24 hours, take out the respective samples according to their groups and weigh them.
8. Calculate the field capacity of each soil using the predetermined formula.
9. Record the calculation results and document the practical.

B. Soil Moisture Meter (SMM) Method

1. Measure the soil moisture content using the SMM tool for a soil moisture level of 60%.
2. Homogenize the soil sample with water gradually.
3. Insert the SMM probe into the soil sample to a depth of 10 cm and read the measurement result.
4. Gradually add water until the soil moisture level reaches 30%.
5. Multiply the volume of water needed for the 60% soil moisture level by two.
6. Clean the tool using a tissue.

Formula Used;

$$KL = \frac{(c-b) - (d-a)}{(d-a)} \times 100\%$$

Where:

KL = Field Capacity (%)
a = Weight of dry soil and dry filter paper (gr)
b = Weight of wet filter paper (gr)
c = Weight of wet soil and wet filter paper (gr)
d = Weight of soil after being oven-dried for 24 hours (gr)

$$KA = \text{Persentase} \times KL$$

Where:

KA = Available Water (%)
Persentage = 40%, 60% dan 80%,
KL = Field Capacity (%)

RESULT AND DISCUSSION

Results

Table 3. Field Capacity Calculation Result Using Gravimetric Method

Soil Tekstur	Dry Soil Weight (gr)	Wet Soil and Filter Paper Weight (gr)	Dry Soil and Filter Paper Weight (gr)	KL (%)
Clay	100	106,79	95,77	80,1

Table 4. Calculation Results of Field Capacity Soil Moisture Content

KL	Available Water (%)		
	80%	60%	40%
80,1	64	48	32

Table 5. Calculation Results of Water Application using Soil Moisture Meter (SMM)

Massa (gr)	Kadar air (%)			
	100%	80%	60%	40%
500	350 ml	280 ml	210 ml	140 ml

Discussion

Soil field capacity is influenced by various factors such as soil structure, depth, and soil pores. Additionally, field capacity is also affected by the type and texture of the soil. Clay-textured soil has a greater capacity to retain water compared to sandy-textured soil. This is because clay soil has tightly packed pores that can hold more water, while sandy soil has more widely spaced pores, allowing water to flow through easily and making it difficult to retain. This aligns with the statement by Basir (2019) that soil with large pores struggles to retain incoming water, making plants prone to drought.

Field capacity is defined as the state of the soil being sufficiently moist, indicating the maximum amount of water the soil can retain against gravity. Water retained by the soil is continually absorbed by plant roots or evaporates, causing the soil to become progressively drier. Based on the conducted experiment, the calculation of field capacity water content was done using three treatments: 80%, 60%, and 40% water content. These three treatments were employed to determine which treatment was more effective. From the gathered data, it is evident that field capacity is directly proportional to water content. The higher the field capacity of the soil, the greater the water content. This corresponds with the statement by Siregar et al. (2017) that the sufficiently moist state of the soil, representing the maximum water it can hold, is known as field capacity, which is influenced by porosity, soil texture, and other factors.

In line with the experiment, measurements of water content were taken on soil samples until the desired water content was achieved. The weight of the soil samples used was 500 grams. These measurements were conducted to determine the amount of water required to reach water content percentages of 40%, 60%, 80%, and 100%. The amount of water needed to reach a water content of 60%, for instance, was 210 ml. The required amount of water for each percentage of water content varies due to factors such as soil type and texture. Based on existing literature, the optimal water content percentage for horticultural plants is around 60%. This aligns with the statement by Novara et al. (2021) that when plants receive sufficient water, their growth improves.

CONCLUSION

Based on the conducted experiment, it can be concluded that when the soil's field capacity is greater, the water content it can hold also increases. The effective methods used to calculate field capacity are the gravimetric method and the use of a soil moisture meter. Field capacity is influenced by various factors such as soil texture, soil pores, soil structure, and organic matter.

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APPENDIX

Appendix 3. Gravimetric Manual Calculations

$$KL = \frac{(c\text{-}b) - (d\text{-}a)}{(d\text{-}a)} \times 100\%$$

$$KL = \frac{106{,}79 - 95{,}77}{106{,}79} \times 100\%$$

$$= 80{,}1\%$$

Appendix 4. Manual Calculation of Percentage of Moisture Content in KL

Where :
KL = 80,1%
Inquired: KA 80%, 60% dan 40%...?

KA 80% $= \text{Persentase} \times KL$

$$= \frac{0}{100} \times 80{,}1\%$$

$$= 64\%$$

KA 60% $= \text{Persentage} \times KL$

$$= \frac{0}{100} \times 80{,}1\%$$

$$= 48\%$$

KA 40% $= \text{Persentage} \times KL$

$$= \frac{0}{100} \times 80{,}1\%$$

$$= 32\%$$

Appendix 5. Field Capacity Practicum Documentation

Figure 3. Measurement of soil dry weight


Figure 4. Soil moisture meter tools

DRIP IRRIGATION

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ABSTRACT
Drip irrigation is defined as a method of directly delivering water to plants in the root area or on the soil surface through slow and continuous water droplets. In drip irrigation systems, only a portion of the root zone is wet, but all the provided water can be absorbed more quickly in conditions of low soil moisture. The purpose of the Drip Irrigation practicum is to study drip irrigation systems, understand their working principles, and assess the efficiency of drip irrigation installations. The method used involves direct measurements conducted twice a week over a span of 13 weeks. The results obtained from the Drip Irrigation practicum indicate that the coefficient of uniformity for water distribution along each lateral remains below the standard, resulting in uneven water distribution and causing instability in plant growth. The conclusion drawn from the Drip Irrigation practicum is that the efficiency of the implemented installation is still suboptimal due to values of distribution efficiency and application efficiency falling below the standards. This could be attributed to various factors including the diameter of emitter holes, water pressure, pipe slope, pipe length, and type of tubing used.

Keywords: Water, Horticulture, Irrigation.

INTRODUCTION

Background

Water is one of the essential natural resources for human life. It can be used for various daily needs. Additionally, water is crucial for irrigating plants to support their healthy growth. Each plant has different water requirements, influenced by factors such as soil texture, soil porosity, soil structure, plant type, and more. Watering plants can be done directly or through irrigation techniques. Irrigation refers to the effort of supplying water to agricultural land from sources like rivers.

Irrigation is a method or technique of providing water to fulfill the water needs of plants through land irrigation. Plants require adequate irrigation not only during the initial planting phase but throughout their growth period. There are various types of irrigation commonly used in Indonesia, including sprinkler irrigation, surface irrigation, subsurface irrigation, pump irrigation, and drip irrigation. Drip irrigation is a type of irrigation that distributes water to the land using pipes or hoses with adjustable pressure. Water emerges from the pipes in droplets directly onto the plant roots. Drip irrigation is considered superior to other irrigation methods because it delivers water directly to the plant root area, minimizing water wastage and runoff. The advantages of drip irrigation include its suitability for early-stage plant growth, areas with limited water availability, promoting rapid plant adaptation to the soil, efficiency, and water conservation.

Horticultural plants are those that can be cultivated in gardens or yards. They encompass a variety of plants such as flowers, vegetables, fruits, and medicinal plants.

Examples like chili peppers and eggplants are commonly grown horticultural plants due to their health benefits, such as cardiovascular health and blood sugar control. Horticultural plants are typically cultivated in residential gardens or yards using irrigation systems. Water is directed from the water source to the plants in controlled amounts based on their water requirements.

Based on the above description, a Drip Irrigation practicum is conducted to understand how to create a drip irrigation system and comprehend its operational principles, which can then be applied in the field of agricultural cultivation.

Objective and Purpose Experiment

The purpose of the Drip Irrigation practicum is to study the drip irrigation system, understand its operational principles, and learn about the efficiency of drip irrigation installation.

The significance of the Drip Irrigation practicum lies in the application of drip irrigation within agricultural cultivation fields for irrigation systems.

LITERATURE REVIEW

Horticulture Plant

Horticulture refers to plants that can be cultivated for various purposes such as ornamental plants, medicinal plants, vegetables, and fruits. Horticultural plants have multiple functions, including decoration, medicinal use, and as a source of food. Horticulture plants have a promising development prospect due to their high economic value. Additionally, there is a broad market potential both domestically and internationally. According to Lihiang et al. (2022), vegetable plants can be classified based on the consumed part, including:

1) Stem vegetables. Asparagus is an example of above-ground stem vegetables without starch. Potatoes and taro are examples of below-ground stem vegetables with starch.
2) Root vegetables. Carrots are root vegetables with a swollen taproot. Cassava and sweet potatoes are examples of root vegetables with lateral root enlargement.
3) Leafy vegetables. This category includes various types like moringa and spinach.

Bird's eye chili, scientifically known as *Capsicum annuum L.*, is one of the horticultural plant types with high vitamin C content. Bird's eye chili offers numerous health benefits, such as boosting immune function. With the increase in population, the demand for chili supply has also risen. Therefore, farmers engage in continuous chili cultivation, often disregarding environmental factors. Influencing factors include high water evaporation due to high air temperature, low soil fertility, and pest and weed infestations. Soil quality is determined by organic matter content. Soil is classified as poor if it contains less than 1% organic matter. It is considered moderate if the organic matter content is around 2-3%, and it is considered good if the organic matter content is around 3-5%. Chili cultivation must be carefully managed from land preparation since it impacts plant growth and production outcomes. This is due to the continuous use of inorganic fertilizers, which affect soil structure. Organic fertilizers can enhance agricultural productivity and reduce environmental pollution (Polii et al., 2019).

Irrigation

Irrigation refers to activities related to obtaining water to support agricultural activities such as plantations, fields, and paddy fields. This involves creating irrigation facilities and infrastructure such as buildings and canal networks that distribute and allocate water systematically to irrigation plots for plant needs. The provision of water has several purposes, including preventing soil erosion, breaking up soil clods, incorporating water into the soil for plant growth, cooling the soil and atmosphere to create a favorable environment for plant growth, and more. According to Hariyanto (2018), irrigation networks can be classified into three categories based on regulation methods, water flow measurement, and the completeness of facilities:

a) Technical Irrigation

Technical irrigation involves separating drainage networks from irrigation networks. This means that drainage channels and irrigation channels function independently from the source to the outlet. Irrigation channels deliver water to the fields, while drainage channels transport excess water from the fields to natural drainage ditches leading to the sea. Tertiary plots play a central role in technical irrigation networks, with a maximum area of 150 ha. Water distribution within tertiary plots is managed by farmers. Tertiary and quarter networks convey water to the fields, and excess water is collected in tertiary and quarter drainage networks before being directed to the primary drainage network. This irrigation network efficiently distributes water, accounting for diminishing water availability over time.

b) Non-Technical Irrigation

Non-technical irrigation involves distributing water without regulation or measurement, with excess water flowing into natural drainage channels. Typically, the water supply is abundant and the slope ranges from moderate to steep. Consequently, intricate techniques or methods for water distribution are not required. Non-technical irrigation has drawbacks, including high costs for numerous taps due to each village creating its network. Additionally, water wastage occurs because water networks are usually located in higher areas, and excess water doesn't reach the lower, more fertile regions. Infrastructure in non-technical irrigation systems has a short lifespan as it's not permanent or fixed.

c) Semi-Technical Irrigation

Semi-technical irrigation includes a dam on the river with downstream intake and measurement structures. Water distribution methods are typically similar to those of simple networks. Intake structures serve larger areas compared to simple networks. Thus, costs are shared across multiple regions. If the permanent structure involves a river intake, government involvement is needed.

Irrigation is a crucial agricultural practice for producing crops in semi-arid and arid regions. Efficient water usage and management are essential considerations in Australia. Most irrigation water comes from rivers and dams, conveyed through open channels or pipes to irrigation areas for storage before being used or directly applied to plant roots. Irrigation often using groundwater has storage tanks. In agriculture, common irrigation methods or systems include sprinkler irrigation, surface irrigation, and drip irrigation. Sprinkler irrigation delivers water in the form of spray using sprinklers. Sprinkler irrigation is also called pressurized irrigation because it operates under low pressure, often involving various pump forms (Koech & Langat, 2018).

Drip Irrigation

Drip irrigation is defined as a method of providing water directly to plants either at the root area or on the soil surface through slow and continuous water droplets. The advantages of using the drip irrigation system include reducing the risk of plant salinity due to effective salt accumulation control around the root zone. Drip irrigation is suitable for sandy soils, dry climates, and areas with limited water resources. In the drip irrigation system, only a portion of the root area is moistened, but all the provided water can be quickly absorbed in low-moisture soil conditions. Water delivery in drip irrigation is limited and achieved through a container that serves as a temporary water reservoir with holes underneath. Water is released slowly in droplet form onto the soil. Efficient water use can be optimized through appropriate irrigation techniques, and drip irrigation can maintain soil moisture around field capacity and permanent wilting point. Using drip irrigation is necessary to achieve water use efficiency, thus reducing water loss due to high-temperature evaporation (Witman, 2021).

Drip irrigation is one of the water supply systems that involve releasing water through pipes around or along plant rows. The drip irrigation system is composed of several components, including the irrigation water source, power source, pump, and pipeline network. According to Udiana et al. (2014), the components of a drip irrigation pipe network include:

1) Lateral, which refers to pipes where emitters are installed. Lateral pipes are made of PVC or PE and have diameters ranging from ½ inch to 1 ½ inch.
2) Emitter, a component that delivers water from the lateral pipe to the soil around the plant continuously at low flow rates.
3) Main pipe, which conveys water from a water source to the distribution pipes in the drip irrigation network. Main pipes are typically made of PVC or a combination of cement and asbestos, with diameters ranging from 7.5 to 25 cm.
4) Sub-main pipe, distributing water to lateral pipes, usually made of PVC with diameters of 2 to 3 inches.
5) Supporting components such as filters, valves, flow regulators, pressure regulators, control systems, chemical tanks, and more.

Drip irrigation offers numerous advantages, including higher water use efficiency, water savings, and improved plant quality. The primary approach for efficient water use involves increasing beneficial usage, avoiding water loss, and reducing non-beneficial water consumption. Sustainable water use and improved irrigation efficiency are top priority issues. Plant water productivity is an essential index for evaluating water savings and obtaining higher output or value for each water droplet used (Çetin & Kara, 2019).

Applying water through drip irrigation can save water usage by around 87% - 95%. Furthermore, the drip irrigation system reduces labor requirements. Drip irrigation saves water by minimizing losses through processes like evaporation, percolation, and surface runoff, making it suitable for water-scarce areas (Widiastuti & Wijayanto, 2018).

Factors Influencing Drip Irrigation System

Various factors affect the efficiency of the drip irrigation system, such as rainfall, plant water requirements, and others. Effective rainfall is the amount of rainfall useful for plant water needs. Plant water requirements refer to the amount of water needed for plant evapotranspiration to ensure proper growth. Irrigation systems often involve energy losses. Energy losses occur in pipes and pumps. Pump energy losses can be determined by assessing pipe energy losses. Pipe energy losses include minor losses and major losses. Minor losses occur due to pipe shape resistance, such as valves, expansions, contractions, and bends. Major losses result from frictional forces within pipes in the drip irrigation system. Pipe shape resistance energy losses include valve losses, contraction losses, and expansion losses (Udiana et al., 2014).

Droplet uniformity is a crucial factor in drip irrigation planning. The irrigation system must deliver the same volume of droplets to each emitter. Emitters located closer receive higher pressure, resulting in higher droplet flow compared to emitters farther away. Variable flow rates in lateral pipes indicate the performance of the drip irrigation system. Higher emitter droplet uniformity values indicate better irrigation system performance. Several factors influence emitter droplet size, including emitter hole diameter, pipe slope, and lateral pipe length. Emitter flow decreases with longer lateral pipes. A steeper pipe slope increases droplet flow. There is also a relationship between flow duration and droplet flow or uniformity. Longer flow duration results in smaller emitter droplet flow, but better droplet uniformity. Shorter flow durations lead to lower uniformity. Conversely, longer flow durations lead to increased uniformity (Saidah et al., 2014).

Emitter uniformity is vital as it determines the suitability of a drip irrigation system or installation. Emitter uniformity testing involves flowing water through a drip irrigation setup and collecting water from each emitter. The Coefficient of Uniformity (CU) is a measurement parameter representing the uniformity level of the drip irrigation system. A CU value above 85% indicates the suitability of the drip irrigation installation. Application Efficiency (EA) represents how well an irrigation installation functions. Distribution Efficiency (ED) assesses how efficiently water is distributed in the irrigation system. Good ED and EA values for a drip irrigation installation are above 90% (Putra et al., 2017).

METHODOLOGY OF PRACTICUM

Time and Location

The Drip Irrigation Experiment was conducted on Tuesday, October 26th, 2022, starting at around Agricultural Engineering Environment, Agricultural Engineering Study Program, Department of Agricultural Technology, Faculty of Agriculture, Hasanuddin University, Makassar.

Tools

The equipment used in the Drip Irrigation practical includes emitters, water manometer, a pump, measuring cup, water container (tank), a stopwatch, planter bags, pipe adhesive, pipe insulation, ½ inch pipes, external ½-inch hose couplings, ½ inch pipe end caps, ½ inch hoses, nails, spades, support wood, plant markers, shading net, bamboo, beams, pump, electrical installation, measuring cup, and pipe insulation.

Materials

The materials used in the Drip Irrigation practical include eggplant seedlings, water, soil, and compost fertilizer.

Laboratory Procedure

The procedure for the Drip Irrigation practical is as follows:

1. Prepare the equipment and materials required for the practical.
2. Assemble and set up the equipment for a drip irrigation installation.
3. Install emitters laterally at three points, with the end point of the hose positioned at predetermined intervals.
4. Test the created drip irrigation installation by measuring the flow rate of each emitter.
5. Adjust the drip rate of the emitters according to the predetermined plant water requirements.
6. Test the uniformity of the drip system after transplanting the seedlings, conducting the test weekly to evaluate the performance of the drip system's water droplets twice a week.

7. Measure the uniformity of the drip system by turning on the pump and directing water to the drip irrigation installation.
8. Start the stopwatch for 10 minutes when the water reaches the end of the drip irrigation installation.
9. Prepare a spade and a glass of mineral water.
10. Calculate the volume of water collected in the glass from the emitters using the spade.
11. Record the water volume for each emitter.
12. Documentation of experiment

Formula Used

Formulas used in Drip irrigation Experiment:

1. Emitter Flow Rate

$$Q = \frac{V}{t}$$

Where :
Q = Flow rate (L/hr)
V = Volume (L)
t = Time (hr)

2. Uniformity Coefficient

$$Cu = 100 \left\{1 - \frac{\sum [x_i - x]}{\sum x_i}\right\}$$

Keterangan:
Cu = Uniformity Coefficient (%)
x_i = Individual Measurement Value
x = Mean Measurement Value
$\sum[x_i-x]$ = Sum of Absolute Deviations from The Mean

3. Distribution Efficiency

$$ED = 100 \left\{1 - \frac{\sigma q}{q\ average}\right\}$$

Where:
ED = Distribution efficiency (%)
σq = Average deviation of flow rates
q Average = Average flow rate

4. Application Efficiency

$$EA = 100 \left(\frac{q\ min}{q\ average}\right)$$

Where :
EA = Application efficiency (%)
q min = Minimum emitter flow rate (L/hr)
q rata-rata = Average emitter flow rate (L/hr)

RESULT AND DISCUSSION

Result

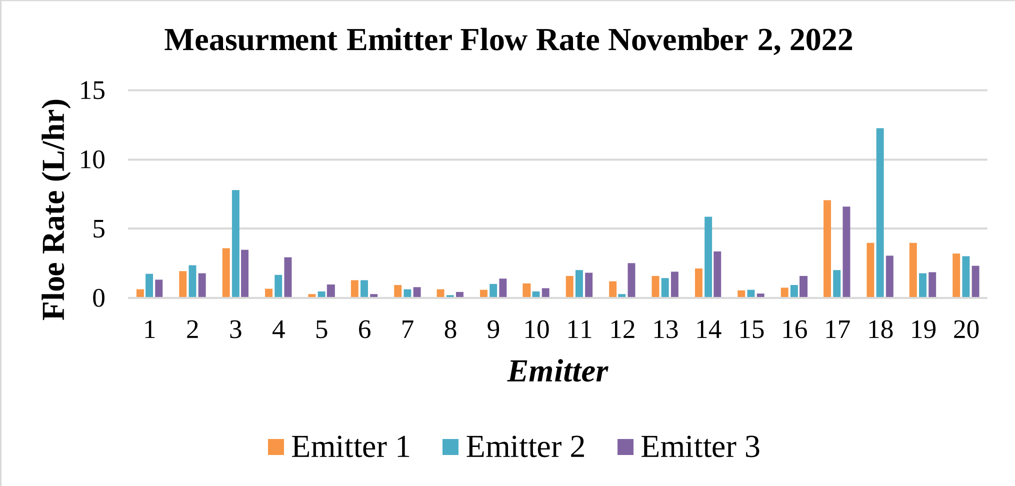

Figure 5. Emitter Flow Rate Graph on November 2, 2022

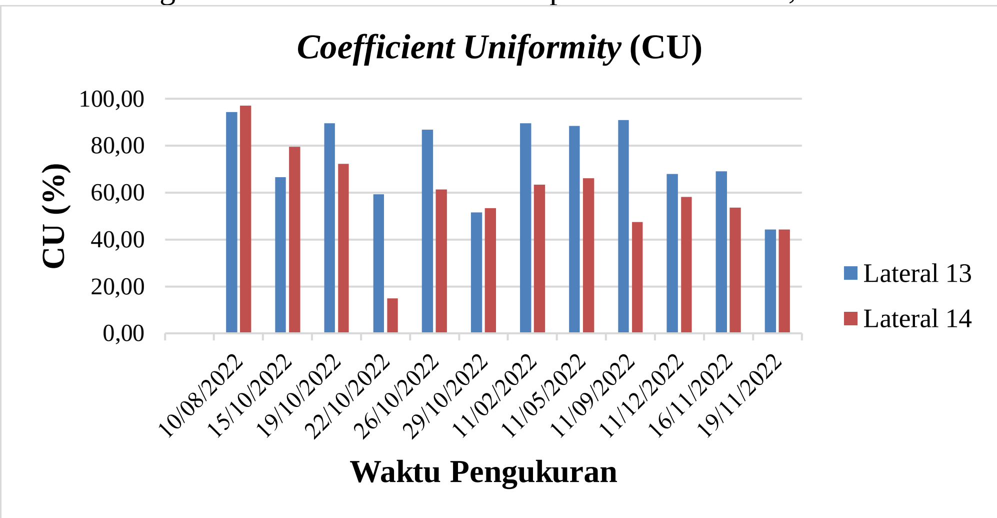

Figure 6. Coefficient Uniform (CU) Graph

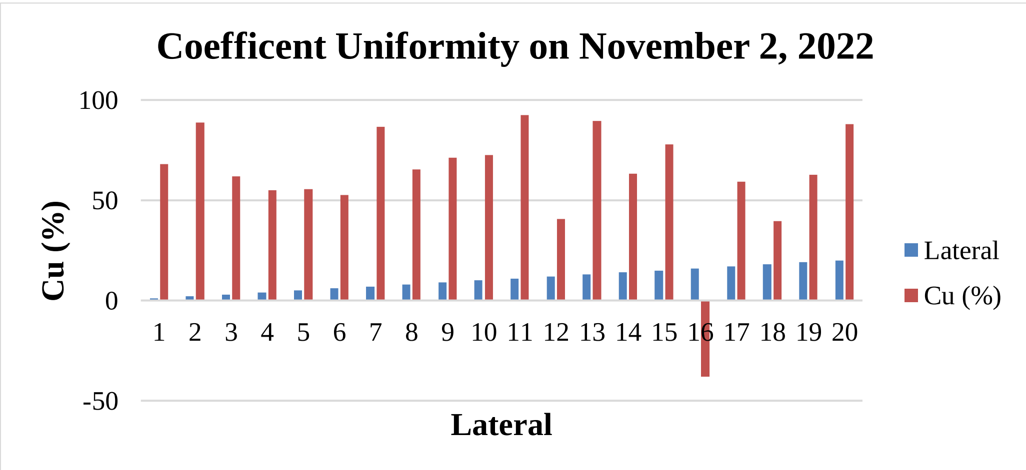

Figure 7. Coefficient Uniform Graph on November 2, 2022

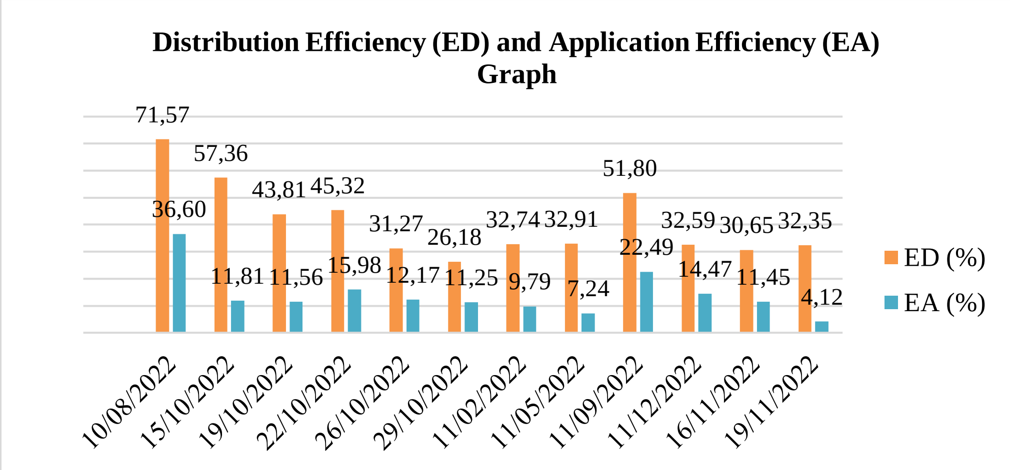

Figure 8. Distribution Efficiency (ED) and Application Efficiency (EA) Graph

Pembahasan

Based on Figure 1, the emitter flow rate graph on November 2, 2022, shows varying flow rates for each lateral. The drip irrigation system consists of 20 laterals, and lateral 18 exhibits the highest emitter flow rate. This variation is attributed to leakage in the hose used. The choice of hose type is a factor affecting the drip irrigation system as this type of hose is prone to leakage and does not meet the standard requirements for drip irrigation hose. Additionally, emitter flow rates are influenced by factors such as emitter rotations, hose length, hose straightness, pipe installation slope, and lateral distance from the water tank. Lateral 18 has emitters with varying hole diameters, resulting in non-uniform water output or flow rate. This aligns with Saidah et al.'s statement (2014) that droplet uniformity is crucial in drip irrigation planning.

Based on Figure 2, the coefficient of uniformity (CU) graph for lateral 13 and lateral 14 shows varying values during each measurement time. CU is a coefficient indicating the uniformity of water distribution in an irrigation system. Each lateral has 3 emitters per plant. Uniform water output from the emitters is necessary to ensure a consistent water supply to each plant for proper growth and development. The graph reveals that at measurement times 2, 4, 6, 10, 11, and 12, CU values fall below 85%, indicating poor uniformity in water distribution. This is influenced by water pressure, hose type, and emitter factors. Figure 3 displays the coefficient uniform graph on November 2, 2022, also showing varied values. The lowest CU value is found in lateral 16 with a value of -37.9%. This value indicates that the irrigation system in lateral 16 is not suitable for use. Insufficient or excessive water supply to plants can lead to growth problems or even death, emphasizing the importance of water use efficiency in drip irrigation systems. This aligns with Witman's statement (2021) that water use efficiency can be optimized through proper irrigation techniques, maintaining soil moisture within the field capacity and permanent wilting point range.

Based on Figure 4, the distribution efficiency (ED) and application efficiency (EA) graph are displayed. Application efficiency signifies the effectiveness of an irrigation installation system. Distribution efficiency assesses the efficiency and effectiveness of water distribution in the irrigation system. When plant water requirements are met, plant growth and development are accelerated. The success of the drip irrigation system is indicated by the growth of chili and eggplant plants in planter bags. If plants in each planter bag exhibit healthy growth, the drip irrigation system is considered suitable. A good value for ED and EA is above 90%. The graph shows that ED and EA values for each measurement are below 90%. ED values below 90% indicate uneven water distribution across plant areas. EA values below 90% indicate suboptimal or inadequate installation of the drip irrigation system. Leakage in the hose is a contributing factor to the reduced efficiency. This is consistent with Udiana et al.'s statement (2014) that energy loss is often present in irrigation systems.

CONCLUSION

Based on the conducted practical experiment, it can be concluded that drip irrigation involves the direct application of water to plant roots or the soil surface through slow and continuous water droplets. In a drip irrigation system, only a portion of the root area is wet, but all the water provided can be absorbed more quickly in low-moisture soil conditions. Water is limitedly applied through containers that temporarily hold water, releasing it in droplets through holes at the bottom. The created irrigation system is not yet efficient as water distribution to each plant is uneven, resulting in inadequate growth and development of some plants.

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APPENDIX

Appendix 6. Observation Data of Drip Irrigation Practicum

Table 6. Observation Results on November 2, 2022

Lateral	No. Emitters	Volume(L)	Time interval (Hours)	Q(L/Hr)	|Xi-X|	CU (%)	ED (%)	EAs (%)
	1	0.107	0.167	0.642	0.592			
1	2	0.29	0.167	1.74	0.506	68.02		
	3	0.22	0.167	1.32	0.086			
	1	0.32	0.167	1.92	0.11			
2	2	0.395	0.167	2.37	0.34	88,83		
	3	0.3	0.167	1,8	0.23			
	1	0.6	0.167	3,6	1.36			
3	2	1,3	0.167	7,8	2.84	61,83		
	3	0.58	0.167	3.48	1.48			
	1	0.11	0.167	0.66	1.104			
4	2	0.28	0.167	1.68	0.084	55,10		
	3	0.492	0.167	2,952	1.188			
	1	0.047	0.167	0.282	0.294			
5	2	0.081	0.167	0.486	0.09	55,56		
	3	0.16	0.167	0.96	0.384			
	1	0.215	0.167	1.29	0.336			
6	2	0.216	0.167	1,296	0.342	52,62		
	3	0.046	0.167	0.276	0.678			
	1	0.155	0.167	0.93	0.156			
7	2	0.104	0.167	0.624	0.15	86.56		
	3	0.128	0.167	0.768	0.006			
	1	0.105	0.167	0.63	0.204			
8	2	0.034	0.167	0.204	0.222	65,26		
	3	0.074	0.167	0.444	0.018			
	1	0.095	0.167	0.57	0.43			
9	2	0.17	0.167	1.02	0.02	71.33		
	3	0.235	0.167	1.41	0.41			
	1	0.175	0.167	1.05	0.306			
10	2	0.081	0.167	0.486	0.258	72.58		
	3	0.116	0.167	0.696	0.048		32,74	9.79
	1	0.268	0.167	1,608	0.2			
11	2	0.335	0.167	2.01	0.202	92.55		
	3	0.301	0.167	1,806	0.002			
	1	0.2	0.167	1,2	0.126			
12	2	0.045	0.167	0.27	1.056	40,57		
	3	0.418	0.167	2,508	1,182			

	1	0.2641	0.167	1.5846	0.0534	
13	2	0.2389	0.167	1.4334	0.2046	89.50
	3	0.316	0.167	1,896	0.258	
	1	0.352	0.167	2,112	1,664	
14	2	0.976	0.167	5,856	2.08	63,28
	3	0.56	0.167	3,36	0.416	
	1	0.091	0.167	0.546	0.052	
15	2	0.101	0.167	0.606	0.112	77,87
	3	0.055	0.167	0.33	0.164	
	1	0.126	0.167	0.756	0.344	
16	2	0.159	0.167	0.954	2,244	-37.94
	3	0.265	0.167	1.59	1,964	
	1	1.175	0.167	7.05	1,826	
17	2	0.337	0.167	2,022	3,202	59,14
	3	1,1	0.167	6,6	1.376	
	1	0.66	0.167	3.96	2.47	
18	2	2,044	0.167	12,264	5,834	39,51
	3	0.511	0.167	3,066	3,364	
	1	0.66	0.167	3.96	1.42	
19	2	0.3	0.167	1,8	0.74	62,73
	3	0.31	0.167	1.86	0.68	
	1	0.535	0.167	3,21	0.35	
20	2	0.505	0.167	3.03	0.17	87,88
	3	0.39	0.167	2.34	0.52	

Table 7. Debt Data

Lateral	Volume(ml)			Time (t)	Discharge (L/Hour)		
	Emitter 1	**Emitter 2**	**Emitter 3**		**Emitter 1**	**Emitter 2**	**Emitter 3**
	880	771.2	880	10	5,28	4.6272	5,28
	520	520	1040	10	3,12	3,12	6,24
	220	266	297	10	1.32	1,596	1,782
	134	140	318	10	0.804	0.84	1,908
	269	292	372	10	1,614	1,752	2,232
	350	160	98	10	2,1	0.96	0.588
13	264,1	238.9	316	10	1.5846	1.4334	1,896
	310	270	220	10	1.86	1.62	1.32
	259	220	286	10	1,554	1.32	1,716
	220	360	150	10	1.32	2,16	0.9
	400	200	220	10	2,4	1,2	1.32
	126	90	340	10	0.756	0.54	2.04
	855	812	880	10	5,13	4,872	5,28
	530	980	740	10	3,18	5.88	4,44

14	359	713	440	10	2.154	4,278	2.64
	220	1210	164	10	1.32	7,26	0.984
	330	1100	660	10	1.98	6,6	3.96
	220	713	326	10	1.32	4,278	1,956
	352	976	560	10	2,112	5,856	3,36
	440	1100	650	10	2.64	6,6	3,9
	287	1100	459	10	1,722	6,6	2,754
	310	1010	540	10	1.86	6.06	3,24
	305	1100	540	10	1.83	6,6	3,24
	261.5	1280	550	10	1,569	7,68	3,3

Table 8. Coefficient Uniformity (CU) on 2 November 2022

Lateral	CU (%)
1	68.0173
2	88.8342
3	61,828
4	55.102
5	55.5556
6	52.6205
7	86.5633
8	65.2582
9	71.3333
10	72.5806
11	92.5516
12	40.5732
13	89.4994
14	63.2768
15	77.8677
16	-37,939
17	59.1373
18	39.5127
19	62.7297
20	87.8788

Table 9. Calculation of Distribution Efficiency (ED) and Application Efficiency (EA)

Date Measurement	ED (%)	EAs (%)
10/08/2022	71.57	36,60
15/10/2022	57,36	11.81
19/10/2022	43,81	11.56
22/10/2022	45,32	15.98
26/10/2022	31,27	12,17
29/10/2022	26,18	11.25

11/02/2022	32,74	9.79
11/05/2022	32,91	7,24
11/09/2022	12.58	14.38
11/12/2022	32.59	14,47
16/11/2022	30.65	11.45
19/11/2022	32.35	4,12

Appendix 7. Drip Irrigation Manual Calculations

a. Flow rate

$$Q = \frac{V}{t}$$

$$Q = \frac{0,2641\ L}{0,16667\ hour}$$

= 1.5846 L/hour

b. Uniformity Coefficient

the the $CU = 100\left\{1- \frac{\sum[x_i-x]}{\sum x_i}\right\}$ $CU = 100\left\{1- \frac{(0,0534)+(0,2046)+(0,258)}{(1,5846)+(1,4334)+(1,896)}\right\}$

= 89.4994%

c. Distribution Efficiency

$$ED = 100\left\{1- \frac{\sigma q}{q\ average}\right\}$$

$$ED = 100\left\{1- \frac{1,40086}{2,0829}\right\}$$

= 32.7447%

d. Application Efficiency

$$EA = 100\left(\frac{q\ min}{q_{average}}\right)$$

$$EA = 100\left(\frac{0,204}{2,0829}\right)$$

= 9.7940%

Appendix 8. Drip Irrigation Practicum Documentation

Figure 9. Installation of a drip irrigation system hose

IRRIGATION SPRINKLER

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ABSTRACT

Irrigation sprinkler is defined as a process of providing water to plants in the form of water droplets, resembling rain, and this water application process is carried out by flowing water from a water source to an irrigation system which is then broken down into water droplets by nozzles. The objective of the Irrigation Sprinkler practicum is to determine the efficiency of each type of sprinkler used, flow distribution, uniformity coefficient, and factors influencing water distribution from each type of sprinkler. The method employed in the Irrigation Sprinkler practicum involves direct field measurements using different types of sprinklers including the 360-degree sprinkler, 2-nozzle sprinkler, 3-nozzle sprinkler, and 4-nozzle sprinkler. The results of the Irrigation Sprinkler practicum show that the water distribution pattern of each sprinkler type is not uniform, as some areas did not receive water due to factors such as wind, water pressure, water flow rate, and the type of sprinkler used. The conclusion drawn from the Irrigation Sprinkler practicum is that the irrigation system created is not suitable for use in a cultivation area, as it exhibits a uniformity coefficient of less than 85% and a distribution uniformity of less than 25%.

Keywords: Water, Irrigation, Nozzle, Sprinkler.

INTRODUCTION

Background

Plants have varying water requirements. Each plant is provided with water using various methods, whether directly by watering the plants or through irrigation methods. Irrigation is the process of providing water to plants in a controlled amount, sourced from water bodies such as rivers, lakes, and others.

Irrigation is defined as a process or activity of supplying water to plants to ensure their growth and development. There are various irrigation methods used in agriculture, such as surface irrigation, pump irrigation, drip irrigation, furrow irrigation, subsurface irrigation, sprinkler irrigation, and more. Each irrigation method has its specifications, including water application, irrigation system design, and compatibility with specific plant types.

Sprinkler irrigation is employed in extensive agricultural fields. In this method, nozzles break down the water into droplets. Besides water application, sprinkler irrigation is also used for fertilization processes. Sprinkler irrigation systems are suitable for all soil types, especially those with low water-holding capacity or infiltration rate.

The working principle of a sprinkler irrigation system involves spraying water like rain. Water is conveyed and then released through nozzles that break it into droplets. The water is supplied to the nozzle using pump pressure, pushing water through pipes and out of the nozzles. There are various types of sprinklers, such as the 360-degree sprinkler, 2-nozzle sprinkler, 3-nozzle sprinkler, and 4-nozzle sprinkler. Each type of sprinkler has a different water distribution pattern, typically influenced by water flow rate, water pressure, and wind speed. If the area experiences high wind speed, the distribution pattern may not be uniform.

Based on the description above, the Irrigation Sprinkler practicum is conducted to understand the working principles of sprinkler irrigation, learn about the water distribution patterns of each type of sprinkler, and identify the factors influencing the process. This knowledge can be applied in agricultural cultivation areas.

Objective and Purpose Experiment

The purpose of conducting the Irrigation Sprinkler practicum is to determine the efficiency of each type of sprinkler used, water distribution, uniformity coefficient, and the factors influencing water distribution from each type of sprinkler.

The utility of the Irrigation Sprinkler practicum is to identify the types of sprinklers that are suitable for cultivation in agricultural fields.

LITERATURE REVIEW

Irrigation

Water is defined as a crucial natural resource essential for the survival of all living creatures. Water availability is limited, while the water demand has been increasing in terms of quality, quantity, and various types of needs. Water constitutes one of the most vital human necessities, used for drinking, washing, bathing, and various other purposes. For plant water needs, an irrigation and dam system needs to be established. Irrigation is defined as the activity of providing drainage and regulating irrigation water to support agriculture. Irrigation water is typically sourced from reservoirs, rivers, tidal systems, and groundwater. The required water quantity in an irrigation area varies and is adjusted accordingly. Excess water in a water distribution project will flow to disposal points like drains. Knowledge of irrigation water requirements is essential as it is a crucial and necessary step in the management and planning of irrigation systems.

There are several functions of irrigation, such as moistening the soil, regulating soil temperature for optimal plant growth, saturating the soil with water from rivers, increasing groundwater availability, cleansing the soil to eliminate pests and unnecessary substances, channeling excess water to drainage channels, and reducing excessive water to prevent soil damage and waterlogging. Irrigation management involves various technical aspects, including water application in fields, distribution of irrigation water from its source to agricultural land, managing the flow and disposal of excess water to agricultural fields, and the development and provision of water sources for agricultural land purposes (Sari & Sulaeman, 2020).

Irrigation water requirements for plants significantly influence their production outcomes. The quality of irrigation water affects plant growth, and soil quality, and poor irrigation water quality has negative impacts on crop productivity, agricultural produce quality, and the health of individuals and farmers who come in direct contact with irrigation water. The availability of irrigation water has a positive impact on farmers, as it enables them to decide when to plant and manage crops without relying on rainfall. Irrigation water is often cited as a cause of crop failure. However, various factors contribute to this, such as quality, quantity, and timing of water supply. In conventional paddy cultivation, the water requirement typically ranges around 1 liter/ha. There are several risks or negative impacts associated with poor water quality, including high salinity. Irrigation water with high sodium content can lead to soil salinization and dissolved carbonates. The high magnesium content in irrigation water can also cause alkalinity. Elevated salinity can hinder plant growth processes and water absorption by roots due to high osmotic pressure. This is because of the high concentration of dissolved ions in the water around the root zone (Adhitiya et al., 2018).

Irrigation is defined as the utilization of various water sources that can be controlled promptly to enhance crop production outcomes. Irrigation involves the conveyance of water through an irrigation system during the planting season, land preparation, pre-irrigation, weed control, harvesting, and leaching salts from a root zone. Groundwater exploitation can release contamination from natural geogenic sources, such as arsenic, from solid phases into groundwater. Reusing wastewater can escalate pesticide concentration and the emergence of other contaminants in irrigation water. The increased utilization of irrigation water has led to a decline in the quality of irrigation water from the ground (Malakar et al., 2019).

Irrigation Sprinkler

Sprinkler irrigation is defined as a process of providing water to plants in the form of water droplets, similar to rain. The process of water delivery is carried out by flowing water from a water source to an irrigation system, which is then broken down into droplets by nozzles. The distribution of water is assisted by pressure originating from a pump. The selection of operational pressure, sprinkler size or type, and spacing between sprinklers is necessary to achieve uniform flow. The design and layout planning of sprinklers in this irrigation system involves considerations such as plant water requirements, plant quantity, lateral pipe spacing, and sprinkler spacing planning. Subsequently, the suitable type of sprinkler for cultivation areas can be determined (Julia et al., 2021).

Inadequate management of water resources can lead to water crisis conditions and impact food security. Manual management of irrigation water is not feasible, necessitating an effective and more efficient irrigation water supply system. One way to meet plant water needs is by implementing an automated sprinkler irrigation system. The sprinkler irrigation system consists of various components, including pumps and power sources such as pressure sources, water sources, lateral pipes, main pipes, and sprinklers. The sprinkler irrigation system uses pressurized pipes and nozzles to deliver water to plants in cultivation areas. The sprinkler irrigation system is classified into traveling irrigators, permanent systems, portable systems, semi-portable systems, and linear move systems (Sirait et al., 2020).

Sprinkler irrigation is a method that employs specialized equipment to deliver pressurized water to land for uniform spraying. The main factors in evaluating sprinkler irrigation quality are the rate of water application and the uniformity of sprinkler irrigation. The distribution of water in sprinkler irrigation is a fundamental aspect of the planning and design of the system. Water distribution in a specific area often involves a combination of several sprinklers that depend on the water distribution of one sprinkler, operational pressure, slope of the land, wind direction and speed, humidity, temperature, and more. A sprinkler type is considered suitable if the water spray distance can reach the plants and the received water flow is in line with their needs. Additionally, leak-free installation and a consistent pattern of water uniformity at each point are also determining factors. The viability of a sprinkler is determined through performance tests, observing distribution patterns, volume, range, and water flow (Yan et al., 2020).

Performance of Sprinkler Irrigation System

The diameter of water droplets is a crucial parameter for evaluating the performance of a sprinkler irrigation system and directly affects the efficiency of water utilization and the kinetic energy of droplets on the ground. The diameter of water droplets is closely related to parameters such as the rate of water application, coefficient of uniformity, water utilization coefficient, and misting rate. A droplet distribution model based on the least squares method provides an important theoretical foundation for predicting water distribution and determining the coefficient of uniformity for sprinkler irrigation. When water droplets are too small, they can be carried away by the wind, and when they are too large, water distribution becomes uneven as not all plants are reached (Yan et al., 2020).

In sprinkler irrigation systems, overlapping irrigation between adjacent sprinklers is sometimes necessary to improve irrigation uniformity. Sprinkler spacing tests are related to the coverage capacity and required discharge of the irrigation network. The results of testing the influence of various pipe transmission slope variations (10°, 20°, 30°, and 40°) on the uniformity and radius of irrigation from perforated pipe sprinklers showed a minimum uniformity value of 85% and a maximum value of 95%, with spray capacities of 2.66 m and 2.40 m. Sprinkler irrigation offers the advantage of water savings of up to 50%. Several factors influence water distribution in sprinkler irrigation systems, including the uniformity coefficient, irrigation radius, water discharge, flow rate, wind speed, and water pressure. The uniformity coefficient, also known as the coefficient of uniformity of irrigation water distribution, is affected by nozzle size, water pressure, sprinkler spacing, wind speed, and direction. The sprinkler irrigation radius refers to the coverage area achieved by the sprinkler and is circular. This data is used to determine the coverage area achievable by the sprinkler. Water discharge affects the volume of water emitted from the nozzle. If the water discharge is large and the hose used is long, the water pressure will decrease, resulting in a smaller coverage area for a given type of sprinkler. Large plant spacing requires higher pressure. Additionally, the height of the sprinkler stick also affects the coverage area's uniformity coefficient. A higher stick height leads to a lower uniformity coefficient, affecting the stick spacing (Negara et al., 2021).

Sprinkler irrigation systems can enhance irrigation uniformity and efficiently use irrigation water, supplying more than 85%. Sprinkler irrigation can be applied to flat or sloping terrain. This method is suitable for dry or water-deficient land. Volume and irrigation water application rates are provided by sprinklers with varying sprinkler spacings. The distribution pattern must remain consistent for a specific nozzle shape, pressure, and wind conditions during operation. The design of sprinkler irrigation is aimed at preventing surface runoff. Evaluating sprinkler irrigation performance is influenced by wind direction and speed, water pump pressure, land topography, and sprinkler spacing. Higher water pressure ensures uniform water distribution from the nozzle for a given sprinkler specification. Wind speed carries water droplets away, leading to uneven water distribution. Smaller water droplets fall closer to the sprinkler, while larger ones fall farther away. Large water droplets can have negative impacts on plants and lead to splash erosion, compacting the soil. However, excessively small water droplets may evaporate, resulting in water wastage and low irrigation system efficiency. The coefficient of uniformity and uniformity distribution are two factors influencing the success of a sprinkler irrigation system. If the coefficient of uniformity value is above 80%, it indicates good uniformity of water distribution from the sprinklers. A low coefficient of uniformity value indicates poor water distribution to plants. This leads to uneven water supply to plants. If the distribution uniformity value is less than 25%, it indicates poor uniformity of water distribution (Fajar et al., 2019).

The coefficient of uniformity can be determined through direct field measurements by placing containers at specific distances. The amount of water collected in these containers is measured using measuring cups or a spoid. Irrigation storage efficiency refers to the ratio of beneficial water supply to plants to the total water provided, calculated as a percentage (%). Factors affecting irrigation storage efficiency include soil texture, soil preparation, and soil permeability. The available water capacity in the soil increases with finer-textured soils. Evaluating the efficiency of sprinkler irrigation usage involves calculating stored water, the coefficient of uniformity, and lost water. Factors influencing the efficiency of sprinkler irrigation usage include soil physical properties, soil preparation, moisture in the root area, water application techniques, irrigation system layout, and weather and climate conditions. Sprinkler irrigation should be operated when there is no rain to prevent water loss. This emphasizes that groundwater availability is a factor affecting water supply (Sudirman et al., 2022).

Types of Sprinklers

Sprinklers are devices used in irrigation systems to distribute water to plants in the form of droplets, broken down by nozzles. One of the types of sprinklers is the rotary ace sprinkler. The rotary ace sprinkler has three water outlets and is designed to provide water to large areas with a 360° rotation angle (Julia et al., 2021).

The Mini 24D Netafim sprinkler is another type used for irrigation in limited spaces. With a radius of about 5 m-6 m, it's suitable for smaller areas. The coefficient of uniformity for a Mini 24D Netafim sprinkler irrigation system can be determined by varying the distance and height of the sprinkler stick, with a duration of around 15 minutes. This method can also identify the optimum irrigation radius suitable for agricultural cultivation (Negara et al., 2021).

Irrigation networks consist of various components such as lateral pipes, main pipes, manifold pipes, pumps, and sprinklers. According to Widianto (2018), three common types of sprinklers are Sellery Round sprinklers, Aldo Garden 302 sprinklers, and Wipro 5-pattern sprinklers. Sellery round sprinklers rotate due to the torque generated by water leaving the sprinkler, breaking the water into droplets, and distributing it in a circular pattern. Aldo Garden 302 sprinklers utilize the impact of water jets to change the sprinkler's direction and have striker fins to break the water, enabling the sprinkler's rotation. Wipro 5-pattern sprinklers operate without moving parts and feature half-circle water-breaking fins.

Surfer

In the context of Surfer, a grid refers to vertical and horizontal lines forming quadrilaterals used as a basis for contour creation. The intersection points of vertical and horizontal lines represent elevation or depth points. The process of forming an organized Z-value arrangement from XYZ data is known as gridding. Bathymetric data displayed in in-depth contours is used to visualize the underwater topography, and contour mapping is based on Surfer. Surfer is software used to create contour maps based on grids, capable of representing surface fields, generating 3D and isoline maps, and calculating volumes, and areas. The creation of such maps involves algorithms that prepare input data for 3D visualization in the form of maps. Surfer uses grids to process insufficient input XYZ data and prepares it for visualization modules. During data preparation, it's possible to preview the estimated shape of the 3D map that has been created (Litwin et al., 2017).

Infiltration Rate and Irrigation Rate

The infiltration rate refers to the decrease or capacity of water flow into the soil. Irrigation rate, or application rate, involves the process of water distribution emitted by a sprinkler. A sprinkler irrigation system should be designed to have a rate lower than the infiltration rate and irrigation rate of the soil to prevent runoff or surface flow. The irrigation rate in a sprinkler system should use less water than the soil's infiltration rate and conclude before the entire shallow soil surface is saturated with enough depth to cause accumulated surface flow. The highest infiltration rate occurs initially and gradually decreases. In homogeneous deep soils, the basic infiltration rate is equal to the soil's saturated hydraulic conductivity. Surface flow occurs if the surface depressions continue to fill with water and have enough depth to cause accumulated flow, dependent on vegetation amount (Fajar et al., 2019).

METHODOLOGY OF PRACTICUM

Time and Location

The Irrigation Sprinkler Experiment was conducted on Tuesday, November 8th, 2022, starting at 10:00 AM WITA and concluded at the Volleyball Court, Agricultural Engineering Study Program, Department of Agricultural Technology, Faculty of Agriculture, Hasanuddin University, Makassar.

Tools

The equipment used in the Sprinkler Irrigation laboratory includes a 2-nozzle sprinkler, 3-nozzle sprinkler, 4-nozzle sprinkler, 360-degree sprinkler, tripod, cans, measuring tape, scissors, screwdriver, pliers, cans, hose, spoid, digital pressure gauge, stopwatch, Microsoft Excel, Surfer software, and anemometer.

Materials

The material used in the Sprinkler Irrigation laboratory is water.

Laboratory Procedure

The procedure for the Sprinkler Irrigation laboratory is as follows:

7. Prepare the equipment and materials to be used.
8. Place cans in the designated area with a distance of 1 meter between each can, totaling 64 cans. Adjust the distribution of the cans.
9. Install the 2-nozzle sprinkler irrigation system using a tripod.
10. Measure the water pressure using a digital pressure gauge.
11. Measure the water discharge that will flow to the sprinkler for 1 minute.
12. Turn on the pump to start operating the sprinkler for 10 minutes.
13. Observe the water distribution pattern and sprinkler wetting pattern.
14. Measure the wind speed using an anemometer during the sprinkler operation.
15. Turn off the pump after the sprinkler operation time is completed.
16. Measure the water collected in each can using a spoid.
17. Record the measurement data in tabular form.
18. Repeat steps 3-11 for the 3-nozzle, 4-nozzle, and 360-degree sprinklers.
19. Process the data using Microsoft Excel to determine the values of Cu and Du for each sprinkler.

20. Create 2-dimensional and 3-dimensional contour maps of the water distribution uniformity using Surfer software.
21. Document the laboratory activity.

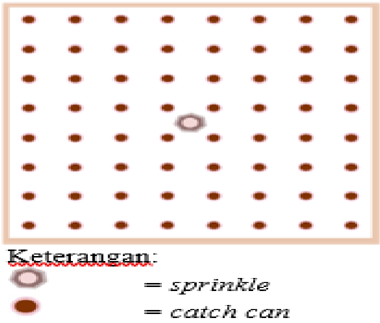

Figure 10. The layout of Sprinkler Irrigation Network Configuration

Formula Used

Formulas used in Sprinkler irrigation Experiment:

5. Water Flow Rate

$$Q = \frac{V}{t}$$

Where :
Q = Flow rate (L/hr)
V = Volume (L)
t = Time (hr)

6. Uniformity Coefficient

$$Cu = 100 \left\{ 1 - \frac{\sum [x_i - x]}{\sum x_i} \right\}$$

Keterangan:
Cu = Uniformity Coefficient (%)
x_i = Individual Measurement Value
x = Mean Measurement Value
$\sum[x_i - x]$ = Sum of Absolute Deviations from The Mean

7. Uniformity Distribution

$$Du = \frac{\frac{1}{4} \times \text{mean of lowest volume}}{\text{mean of catchment volume}} f \times 100\%$$

Where:
Du = Uniformity Distribution (%)

RESULT AND DISCUSSION

Result

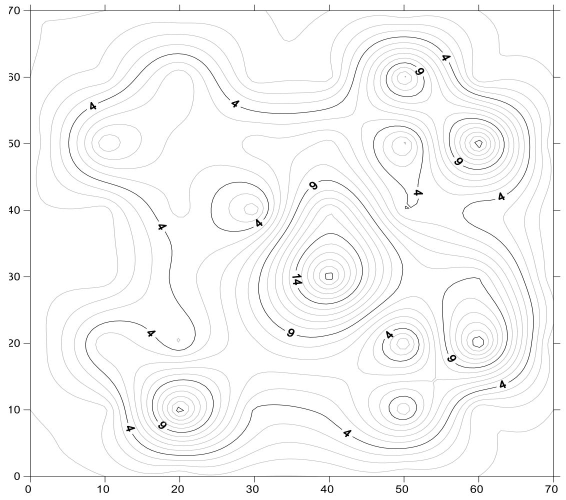

Figure 11. 2D Contour of 360-degree Sprinkler

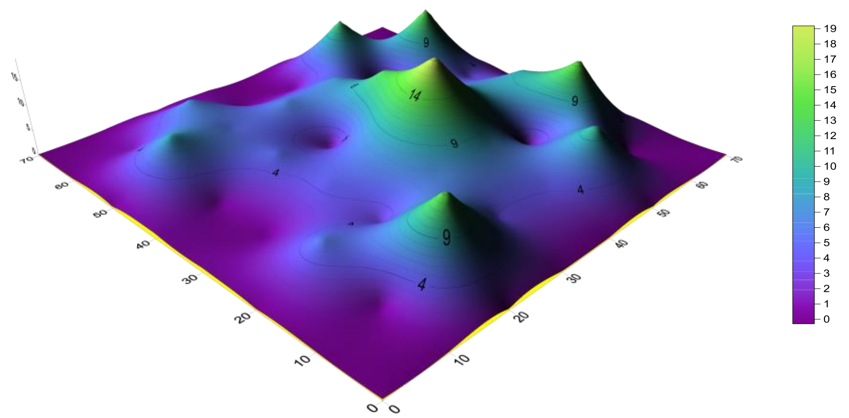

Figure 12. 3D Contour of Distribution Uniformity for 360-degree Sprinkler

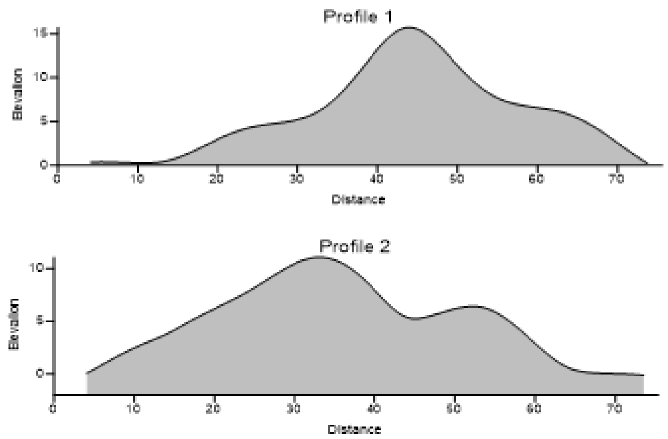

Figure 13. Depth of Water Volume for 360-degree Sprinkler from x and y sides

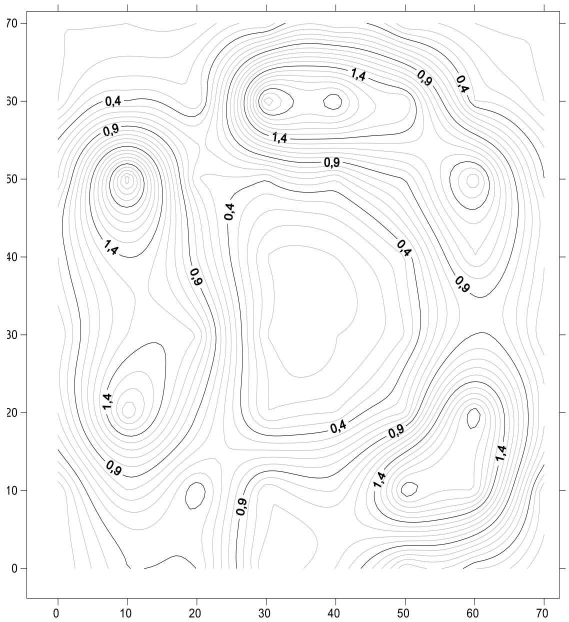

Figure 14. 2D Contour of 2-nozzle Sprinkler

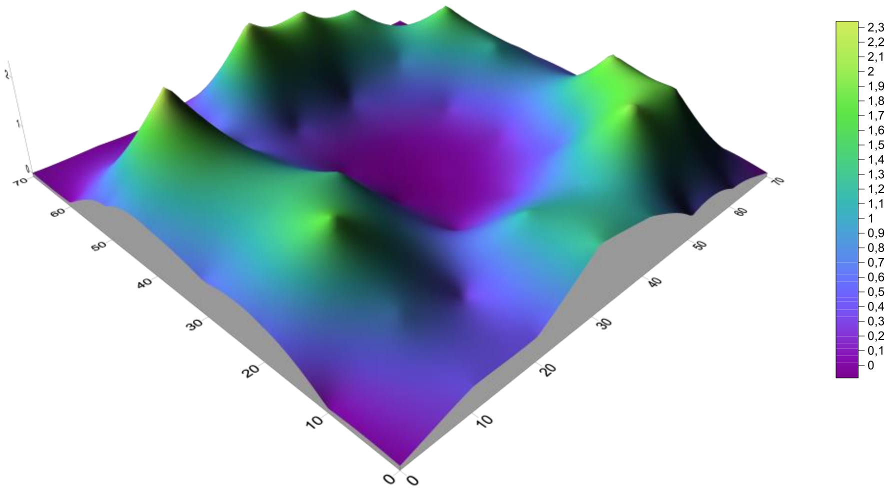

Figure 15. 3D Contour of Distribution Uniformity for 2-nozzle Sprinkler

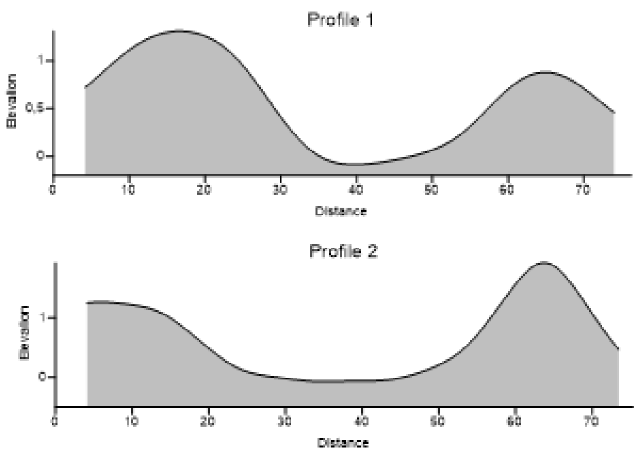

Figure 16. Depth of Water Volume for 2-nozzle Sprinkler from x and y sides

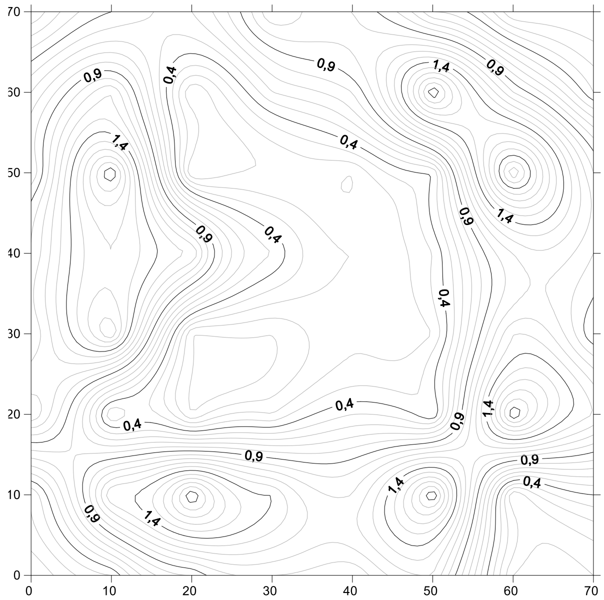

Figure 17. 2D Contour of 3-nozzle Sprinkler

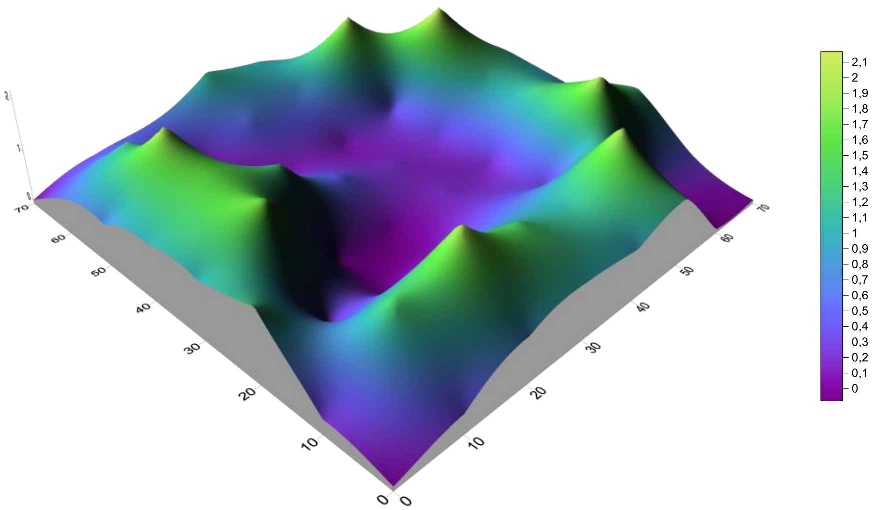

Figure 18. 3D Contour of Distribution Uniformity for 3-nozzle Sprinkler

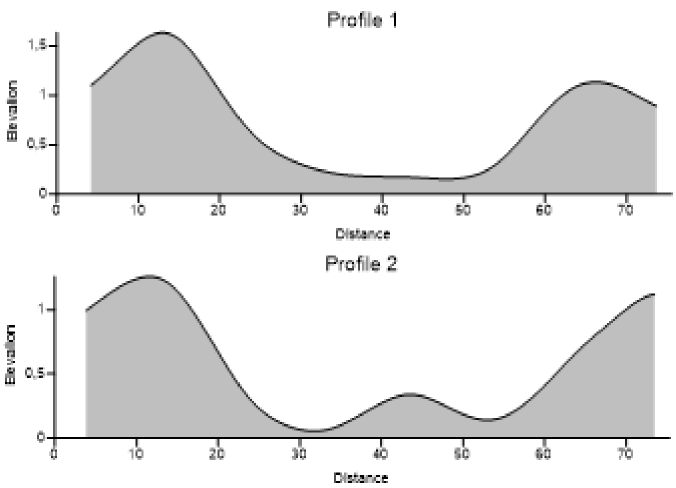

Figure 19. Depth of Water Volume for 3-nozzle Sprinkler from x and y sides

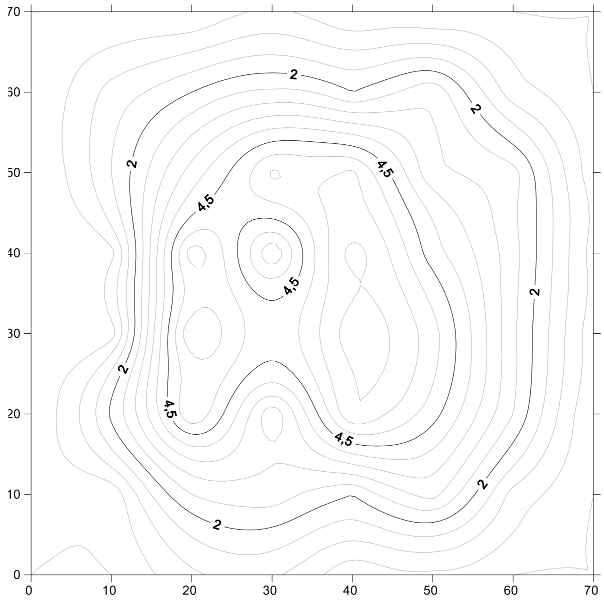

Figure 20. 2D Contour of 4-nozzle Sprinkler

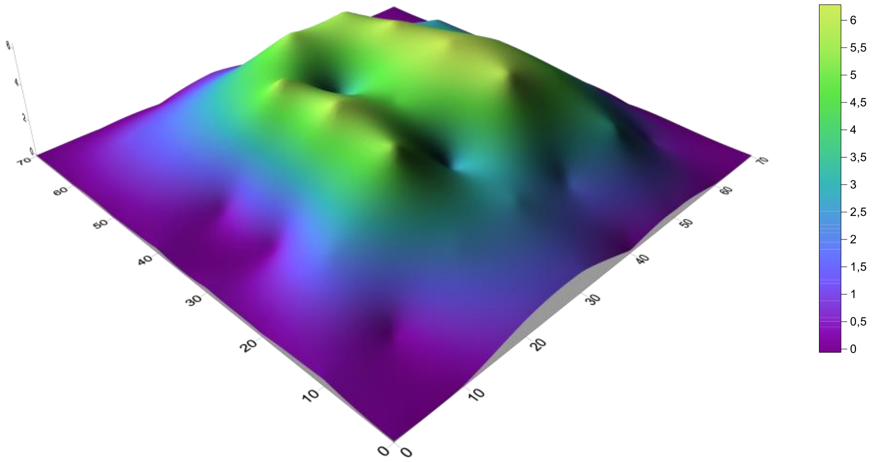

Figure 21. 3D Contour of Distribution Uniformity for 4-nozzle Sprinkler

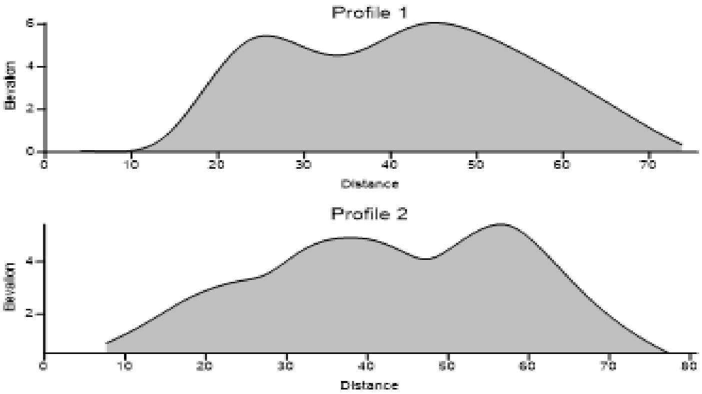

Figure 22. Depth of Water Volume for 4-nozzle Sprinkler from x and y sides

Table 10. Measurement Data for Sprinkler Irrigation Experiment

Sprinkler Types	Flow Rate (L/hr)	Pressure (bar)	Wind Speed (m/s)	Du (%)	Cu (%)
360	8,4	0	0	0	-15,73
2 *nozzle*	4,7	10	1,3	2,01	19,04
3 *nozzle*	4,7	10	1,4	5,05	26,59
4 *nozzle*	8,9	1,4	1,1	0	6,28

Discussion

Sprinkler irrigation is defined as a process of delivering water to plants in the form of droplets similar to rain. The water delivery process is achieved by flowing water from a water source through an irrigation system that breaks the water into droplets using nozzles. The irrigation water requirement for a plant significantly affects its productivity. Poor irrigation water quality can have negative impacts on plant growth, soil quality, and the overall health of both the produce and the farmers who are in direct contact with irrigation water. Availability of irrigation water makes it easier for farmers to determine the optimal planting times, as they are less reliant on rainfall, in line with Adhitiya et al. (2018), who noted that the availability of irrigation water positively impacts farmers by allowing them to plan their planting and crop management activities independently of rainfall.

A sprinkler irrigation system comprises several components, such as a pump and a power source for pressure, a water source, lateral pipes, main pipes, and sprinklers. The system delivers water to plants using pressurized pipes through nozzles. In the conducted experiment, the sprinklers were placed at the center of arranged catch cans, with a 1-meter spacing between each can. During the uniformity measurement of the irrigation water, it was observed that not all catch cans were filled with water; only a majority of them were. This uneven distribution is due to various factors, including water pressure, hose length, sprinkler type, and wind speed. Higher wind speeds around the irrigation system area lead to uneven water distribution as the water droplets can be carried away by the wind, as stated by Fajar et al. (2019).

Based on the experiment, measurements were taken to determine the amount of water released by the sprinkler nozzles into the catch cans. The results were processed to create plots using Surfer software, specifically Figures 3, 6, 9, and 12. These plots depict uneven water distribution patterns, resulting in the observed up-and-down distribution trends. Rising patterns indicate greater water depth in the catch cans. This uneven distribution is a result of low water pressure through the hose to the nozzles, causing some catch cans to remain empty. The 3D contour plots for each sprinkler type show dominant green and purple shades. Catch cans located further from the sprinkler have lower water volumes compared to those located closer, as small water droplets from the nozzles are easily carried away by the wind. This corresponds with Yan et al.'s (2020) statement that when water droplets are too small, they are prone to be carried away by the wind, while larger droplets fail to cover all plants effectively.

Through the experiment's data processing, the uniformity coefficient (Cu) and the distribution uniformity (Du) were calculated to assess the performance of the sprinkler irrigation system. The four nozzle types produced different Cu values, allowing a comparison of their performance. Among them, none achieved a satisfactory results. The 360-degree sprinkler had a Cu value of -15.73%. The 2-nozzle sprinkler had a Cu value of 19.04%. The 3-nozzle sprinkler had a Cu value of 26.59%. The 4-nozzle sprinkler had a Cu value of 6.28%. These Cu values indicated that the irrigation system did not evenly distribute water to plants, as their uniformity coefficients were below 85%. Similarly, the Du values were calculated: 0% for the 360-degree sprinkler, 2.01% for the 2-nozzle sprinkler, 5.05% for the 3-nozzle sprinkler, and 0% for the 4-nozzle sprinkler. These Du values reflected poor water distribution uniformity, being less than 25%. Both Cu and Du values were influenced by water pressure and wind speed in the measurement area, in line with Fajar et al.'s (2019) If the coefficient of uniformity (Cu) value is less than 85% and the distribution uniformity (Du) value is less than 25%, it can be concluded that the irrigation system is not effective in delivering water to plants due to the uneven amount of water received and the inadequate distribution of water.

CONCLUSION

Based on the conducted experiment, it can be concluded that sprinkler irrigation refers to a process of delivering water to plants in the form of droplets, resembling rainfall. This water delivery process involves flowing water from a water source to an irrigation system, which then breaks the water into droplets using nozzles. The pattern of irrigation water distribution is influenced by several factors such as water pressure, hose length, sprinkler type, water flow rate, spacing between plants, the height of the sprinkler stick or tripod, and the impact of wind direction and speed in the area where the sprinkler irrigation system is set up.

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APPENDIX

Appendix 9. Table of Calculations for Sprinkler Irrigation Practicum

Table 11. XYZ Sprinkler 360 data

X	Y	Z
0	0	0
10	0	0.4
20	0	0.4
30	0	1,3
40	0	1,1
50	0	0.4
60	0	0.3
70	0	0
0	10	0
10	10	0.8
20	10	0.3
30	10	1,2
40	10	1
50	10	2
60	10	1,8
70	10	0.1
0	20	0.6
10	20	1,8
20	20	0.9
30	20	0.1
40	20	0.2
50	20	0.6
60	20	2
70	20	0.6
0	30	0.6
10	30	1,3
20	30	1,3
30	30	0
40	30	0
50	30	0.2
60	30	0.9
70	30	0.4
0	40	0.8
10	40	1,4
20	40	0.8
30	40	0
40	40	0

50	40	0.3
60	40	1,2
70	40	0.5
0	50	0.6
10	50	2,4
20	50	0.5
30	50	0.4
40	50	0.5
50	50	0.9
60	50	1,7
70	50	0.4
0	60	0
10	60	0.4
20	60	0.2
30	60	2,2
40	60	2
50	60	1,6
60	60	0.3
70	60	0
0	70	0
10	70	0
20	70	0
30	70	0.2
40	70	0.4
50	70	0.1
60	70	0
70	70	0

Table 12. XYZ Sprinkler 2 Nozzle data

X	Y	Z
0	0	0
10	0	0.4
20	0	0.4
30	0	1,3
40	0	1,1
50	0	0.4
60	0	0.3
70	0	0
0	10	0
10	10	0.8
20	10	0.3

30	10	1,2
40	10	1
50	10	2
60	10	1,8
70	10	0.1
0	20	0.6
10	20	1,8
20	20	0.9
30	20	0.1
40	20	0.2
50	20	0.6
60	20	2
70	20	0.6
0	30	0.6
10	30	1,3
20	30	1,3
30	30	0
40	30	0
50	30	0.2
60	30	0.9
70	30	0.4
0	40	0.8
10	40	1,4
20	40	0.8
30	40	0
40	40	0
50	40	0.3
60	40	1,2
70	40	0.5
0	50	0.6
10	50	2,4
20	50	0.5
30	50	0.4
40	50	0.5
50	50	0.9
60	50	1,7
70	50	0.4
0	60	0
10	60	0.4
20	60	0.2
30	60	2,2

40	60	2
50	60	1,6
60	60	0.3
70	60	0
0	70	0
10	70	0
20	70	0
30	70	0.2
40	70	0.4
50	70	0.1
60	70	0
70	70	0

Table 13. XYZ Sprinkler 3 Nozzle data

X	Y	Z
0	0	0
10	0	0.3
20	0	0.8
30	0	1
40	0	0.9
50	0	1,2
60	0	0
70	0	0
0	10	0.2
10	10	1,4
20	10	2
30	10	1,4
40	10	1,1
50	10	2
60	10	0
70	10	0.4
0	20	1,3
10	20	0.2
20	20	0
30	20	0.2
40	20	0.5
50	20	0.3
60	20	2
70	20	1,3
0	30	1
10	30	1,8

20	30	0
30	30	0
40	30	0.2
50	30	0.2
60	30	1,3
70	30	0.8
0	40	1
10	40	1,6
20	40	1,3
30	40	0.5
40	40	0.2
50	40	0.3
60	40	1,1
70	40	1
0	50	0.7
10	50	2
20	50	0
30	50	0.1
40	50	0.1
50	50	0.4
60	50	2,2
70	50	1
0	60	0.6
10	60	1,2
20	60	0
30	60	0.6
40	60	0.8
50	60	2
60	60	1
70	60	0.3
0	70	0
10	70	0.4
20	70	0.6
30	70	1,2
40	70	1
50	70	0.5
60	70	0
70	70	0

Table 14. XYZ Sprinkler 4 Nozzle data

X	Y	Z
0	0	0
10	0	0
20	0	0.9
30	0	1,1
40	0	0.1
50	0	0.4
60	0	0
70	0	0
0	10	0.3
10	10	0.1
20	10	2,5
30	10	2,8
40	10	2
50	10	3,2
60	10	0.8
70	10	0
0	20	0.1
10	20	2,1
20	20	5,5
30	20	2,6
40	20	6
50	20	4,7
60	20	2,5
70	20	0
0	30	0.2
10	30	0.2
20	30	6
30	30	4,6
40	30	6,3
50	30	5,2
60	30	2,6
70	30	0.2
0	40	0.2
10	40	0.3
20	40	5,8
30	40	3
40	40	6,2
50	40	4,2
60	40	2,7

70	40	0.3
0	50	0
10	50	1.5
20	50	3,7
30	50	5,6
40	50	5,6
50	50	3,1
60	50	2,7
70	50	0.2
0	60	0
10	60	1,2
20	60	2
30	60	2,6
40	60	2
50	60	2,9
60	60	0.7
70	60	0
0	70	0
10	70	0
20	70	0
30	70	0.6
40	70	0
50	70	0
60	70	0
70	70	0

Table 15. Data of Cu and Du Sprinkler 360

Catchcan	**Water volume(mm)**	**1/4 smallest volume (mm)**	**[xi-x] (mm)**
1	0	0	0.89
2	0	0	0.89
3	0	0	0.89
4	0	0	0.89
5	0	0	0.89
6	0	0	0.89
7	0	0	0.89
8	0	0	0.89
9	0	0	0.89
10	0.16	0	0.73
11	3.84	0	2.95
12	0.99	0	0.10
13	1.14	0	0.25

14	2.86	0	1.97
15	0	0	0.89
16	0	0	0.89
17	0		0.89
18	1.56		0.67
19	0.73		0.16
20	1.77		0.88
21	2.08		1.19
22	0.21		0.68
23	3.95		3.06
24	0		0.89
25	0.16		0.73
26	0.08		0.81
27	1.19		0.30
28	2,18		1.29
29	5,14		4,25
30	2,29		1.40
31	2.34		1.45
32	0		0.89
33	0.21		0.68
34	0.13		0.76
35	1.40		0.51
36	0.31		0.58
37	3.38		2.49
38	1.04		0.15
39	0.78		0.11
40	0		0.89
41	0		0.89
42	2.34		1.45
43	1.40		0.51
44	1.71		0.82
45	1.92		1.03
46	0.13		0.76
47	3.90		3.01
48	0		0.89
49	0		0.89
50	0.34		0.55
51	1.82		0.93
52	0.10		0.79
53	0.16		0.73
54	3,22		2,33

55	0		0.89
56	0		0.89
57	0		0.89
58	0		0.89
59	0		0.89
60	0.05		0.84
61	0		0.89
62	0		0.89
63	0		0.89
64	0		0.89

Table 16. Cu and Du Sprinkler 2 Nozzle Data

Catchcan	**Water volume(mm)**	**1/4 smallest volume (mm)**	**[xi-x] (mm)**
1	0	0	0.17
2	0.10	0	0.07
3	0.10	0	0.07
4	0.34	0	0.17
5	0.29	0	0.11
6	0.10	0	0.07
7	0.08	0	0.09
8	0	0	0.17
9	0	0	0.17
10	0.21	0	0.04
11	0.08	0	0.09
12	0.31	0	0.14
13	0.26	0	0.09
14	0.52	0	0.35
15	0.47	0.03	0.30
16	0.03	0.03	0.15
17	0.16		0.02
18	0.47		0.30
19	0.23		0.06
20	0.03		0.15
21	0.05		0.12
22	0.16		0.02
23	0.52		0.35
24	0.16		0.02
25	0.16		0.02
26	0.34		0.17
27	0.34		0.17
28	0		0.17
29	0		0.17
30	0.05		0.12

31	0.23		0.06
32	0.10		0.07
33	0.21		0.04
34	0.36		0.19
35	0.21		0.04
36	0		0.17
37	0		0.17
38	0.08		0.09
39	0.31		0.14
40	0.13		0.04
41	0.16		0.02
42	0.62		0.45
43	0.13		0.04
44	0.10		0.07
45	0.13		0.04
46	0.23		0.06
47	0.44		0.27
48	0.10		0.07
49	0		0.17
50	0.10		0.07
51	0.05		0.12
52	0.57		0.40
53	0.52		0.35
54	0.42		0.24
55	0.08		0.09
56	0		0.17
57	0		0.17
58	0		0.17
59	0		0.17
60	0.05		0.12
61	0.10		0.07
62	0.03		0.15
63	0		0.17
64	0		0.17

Table 17. Data of Cu and Du Sprinkler 3 Nozzles

Catchcan	**Water volume(mm)**	**1/4 smallest volume (mm)**	**[xi-x] (mm)**
1	0	0	0.19
2	0.08	0	0.11
3	0.21	0	0.02
4	0.26	0	0.07
5	0.23	0	0.04

6	0.31	0	0.12
7	0	0	0.19
8	0	0	0.19
9	0.05	0	0.14
10	0.36	0	0.17
11	0.52	0	0.33
12	0.36	0	0.17
13	0.29	0.03	0.09
14	0.52	0.03	0.33
15	0	0.05	0.19
16	0.10	0.05	0.09
17	0.34		0.14
18	0.05		0.14
19	0		0.19
20	0.05		0.14
21	0.13		0.06
22	0.08		0.11
23	0.52		0.33
24	0.34		0.14
25	0.26		0.07
26	0.47		0.27
27	0		0.19
28	0		0.19
29	0.05		0.14
30	0.05		0.14
31	0.34		0.14
32	0.21		0.02
33	0.26		0.07
34	0.42		0.22
35	0.34		0.14
36	0.13		0.06
37	0.05		0.14
38	0.08		0.11
39	0.29		0.09
40	0.26		0.07
41	0.18		0.01
42	0.52		0.33
43	0		0.19
44	0.03		0.17
45	0.03		0.17
46	0.10		0.09
47	0.57		0.38
48	0.26		0.07

49	0.16		0.04
50	0.31		0.12
51	0		0.19
52	0.16		0.04
53	0.21		0.02
54	0.52		0.33
55	0.26		0.07
56	0.08		0.11
57	0		0.19
58	0.10		0.09
59	0.16		0.04
60	0.31		0.12
61	0.26		0.07
62	0.13		0.06
63	0		0.19
64	0		0.19

Table 18. Data of Cu and Du Sprinkler 4 Nozzles

Catchcan	**Water volume(mm)**	**1/4 smallest volume (mm)**	**[xi-x] (mm)**
1	0	0	0.49
2	0	0	0.49
3	0.23	0	0.25
4	0.29	0	0.20
5	0.03	0	0.46
6	0.10	0	0.38
7	0	0	0.49
8	0	0	0.49
9	0.08	0	0.41
10	0.03	0	0.46
11	0.65	0	0.16
12	0.73	0	0.24
13	0.52	0	0.03
14	0.83	0	0.34
15	0.21	0	0.28
16	0	0	0.49
17	0.03		0.46
18	0.55		0.06
19	1.43		0.94
20	0.68		0.19
21	1.56		1.07
22	1.22		0.73
23	0.65		0.16

24	0	0.49
25	0.05	0.44
26	0.05	0.44
27	1.56	1.07
28	1.19	0.71
29	1.64	1.15
30	1.35	0.86
31	0.68	0.19
32	0.05	0.44
33	0.05	0.44
34	0.08	0.41
35	1.51	1.02
36	0.78	0.29
37	1.61	1,12
38	1.09	0.60
39	0.70	0.21
40	0.08	0.41
41	0	0.49
42	0.39	0.10
43	0.96	0.47
44	1.45	0.97
45	1.45	0.97
46	0.81	0.32
47	0.70	0.21
48	0.05	0.44
49	0	0.49
50	0.31	0.18
51	0.52	0.03
52	0.68	0.19
53	0.52	0.03
54	0.75	0.27
55	0.18	0.31
56	0	0.49
57	0	0.49
58	0	0.49
59	0	0.49
60	0.16	0.33
61	0	0.49
62	0	0.49
63	0	0.49
64	0	0.49

Appendix 10. Distribution of Water on the Sprinkler

Figure 23. Distribution of 360 sprinkler water

Figure 24. Distribution of 2 nozzle sprinkler water

Figure 25. Distribution of 3 nozzle sprinkler water

Figure 26. Distribution of 4-nozzle sprinkler water

Appendix 11. Documentation of Sprinkler Irrigation Practicum

Figure 27. Measuring the discharge of water in a can