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Biohole Effectiveness Analysis Through The Distribution Pattern Of Microbes At Each Depth In Real Time On Alluvial Soil

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ABSTRACT

This research was conducted on alluvial soils, especially for plantations, with the aim of not only restoring the health and fertility of the soil due to the use of chemical fertilizers and pesticides as well as seeing the pattern of EC distribution at each depth from the center of the biohole based on the time of observation. Through controlled microbial activity, its spread through two types of biohole, namely horizontal and vertical biohole. This research observes in real time through soil parameter sensors connected to the micro controller to changes in soil acidity, infiltration rate, conductivity electrolyte level and porosity level through soil infiltration rate.

Through simulations with 2 types of biohole, it can be seen the increase in EC in each depth to the time of observation in real time. From the observations of graphs and EC standards, it can be seen that the ability of the soil to provide nutrients in the root growth zone to support the schedule and distribution patterns of planting both during vegetative growth and generative growth periods. So that we will know the proper biohole distance and spacing in order to be able to provide vegetative and generative mass nutrition based on nutrient values monitored through sensors that change the analog parameters in the micro posesor into digital information transmitted by wifi in real time.

Alluvial soil fertility simulation based on the number of microbial populations = 10^{8} / cfu with **variable 1**: using the vertical type Biohole with a diameter of 30 cm and a depth of 80 cm, has an effective zone for root growth at a depth of between 20 to 40 cm, **Varibale 2** = using a horizontal type Biohole with a diameter of 25 cm and a depth of 40 cm, has an effective zone for root growth at a depth between 15 to 30 cm. On both types the initial nutrient condition before simulating the soil fertility value with the Electrolyte Conductivity (EC) parameter is 420 uS / cm.

1. Introduction

The potential of alluvial land is very large for agricultural business, but the structure of this soil layer is also easily damaged if managed incorrectly. The ability of farmers also needs to be improved, especially in understanding the characteristics of this soil. So that with Biosoildam technology it will save fertilizer use and increase crop production while preserving natural resources through soil and water conservation.

The current decline in carrying land capacity continues to expand (*environement degradation*) . One of the main contributing factors is the decrease in the soil fertility, health and absorption (infiltration rate), triggered by excessive use of inorganic fertilizers (pesticides) (Nugroho Widiasmadi, 2019). To restore the land's capacity quickly and measurably and to restore soil productivity as well, infiltration is not enough. Biological agents (biofertilizer) are needed to support soil and water conservation. However, so far, there has not been any periodical and continuous/real-time measurement of the monitoring & assessment system of agricultural cultivation. Thus, accurate information on a soil parameter in achieving a harvest target is needed.

Infiltration is the process of water flowing into the soil which generally comes from rainfall, while the infiltration rate is the amount of water that enters the soil per unit time. This process is a very important part of the hydrological cycle which can affect the amount of water that is on the surface of the soil. Water on the surface soil will enter the soil and then flow into the river (Sunjoto, S., 2011). Not all surface water flows into the soil, but some portion of the water remains in topsoil to be further evaporated back into the atmosphere through the soil surface or soil evaporation (Suripin, 2013).

Infiltration capacity is the ability of the soil to absorb large amounts of water into the ground and influenced by the microorganism activities in the soil (Nugroho Widiasmadi, 2020). The large infiltration capacity can reduce surface runoff. The reduced soil pores, generally caused by soil compacting, can cause a decreased infiltration. This condition is also affected by the soil contamination (Nugroho Widiasmadi, 2020) due to excessive use of chemical fertilizers and pesticides which hardens the soil as well.

Smart-Biosoildam is a Biodam technology development that involves microbial activity in increasing the measured and controlled inflation rate. Biological activities through the role of microbes as agents of biomass decomposition and soil conservation become important information for soil conservation efforts in supporting healthy food security (Nugroho Widiasmadi, 2020). Such development has used a microcontroller to effectively monitor the activities of the said agents through the electrolyte conductivity parameter as an analogue input of EC sensors embedded in the soil and further converted to digital information by the microcontroller (Nugroho Widiasmadi, 2020).

To control the activities of biological agents, other variables are needed, such as information on pH, humidity (M) and soil temperature (T) obtained from pH sensors, T sensors, M sensors. These sensors are connected to a microcontroller which can be accessed through a pin that functions as a GPIO (General Port Input Output) in the ESP8266 Module so as to provide the additional capability of a WIFI-enabled microcontroller to send all analogue responses to digital in real-time, every second, minute, hour, day and monthly. Furthermore, we can display this data in infographics and numeric tables to be stored and processed in the WEB (Sigit Wasisto, 2018)

2. Methodology

To maximize yields, optimal soil nutrient content is required ranging from vegetative growth to generative growth so as to save the use of organic fertilizers and other nutrients. This research is to observe the number of microbes that spread radially through the horizontal & vertical biohole as the center of microbial distribution which is observed in real time using soil parameter sensors. This research will show soil characteristics in its ability to increase natural fertility and the ability to nourish the soil from toxins that come from water and air pollution.

The study was conducted on alluvial land which for decades has been the source of livelihood for the community of Korowelang Anyar Village Cepiring District Kendal Regency. Land management lacks soil and water conservation. People use chemical fertilizers & pesticides excessively which harden the soil texture, acidify the soil and decrease the yields. Hardened agricultural land also triggers floods, since the soil's ability to absorb decreases. This research that took place from April – November 2019, intends to restore the carrying capacity of the land.

Tools and materials used in research are: Mikrokontroler Arduino UNO,Wifi ESP8266, Soil parameter sensor : Temperature (T) DS18B20, humidity (M) V1.2, Electrolit Conductivity (EC) G14 PE, Acidity pH) Tipe SEN0161-V2 , LCD module HD44780 controller, Biohole as *Injector fotr Biosoildam*, *Biofertilizer* Mikrobia Alfafaa MA-11, red union straw as microbia nest , Abney level, , Double *Ring Infiltrometer*, Erlemeyer, ruler, *Stop watch* , plastic bucket , *tally sheet,* measuremet glass, micro scale , hydrometer dan water (*Douglas, M.G. 2018)*.

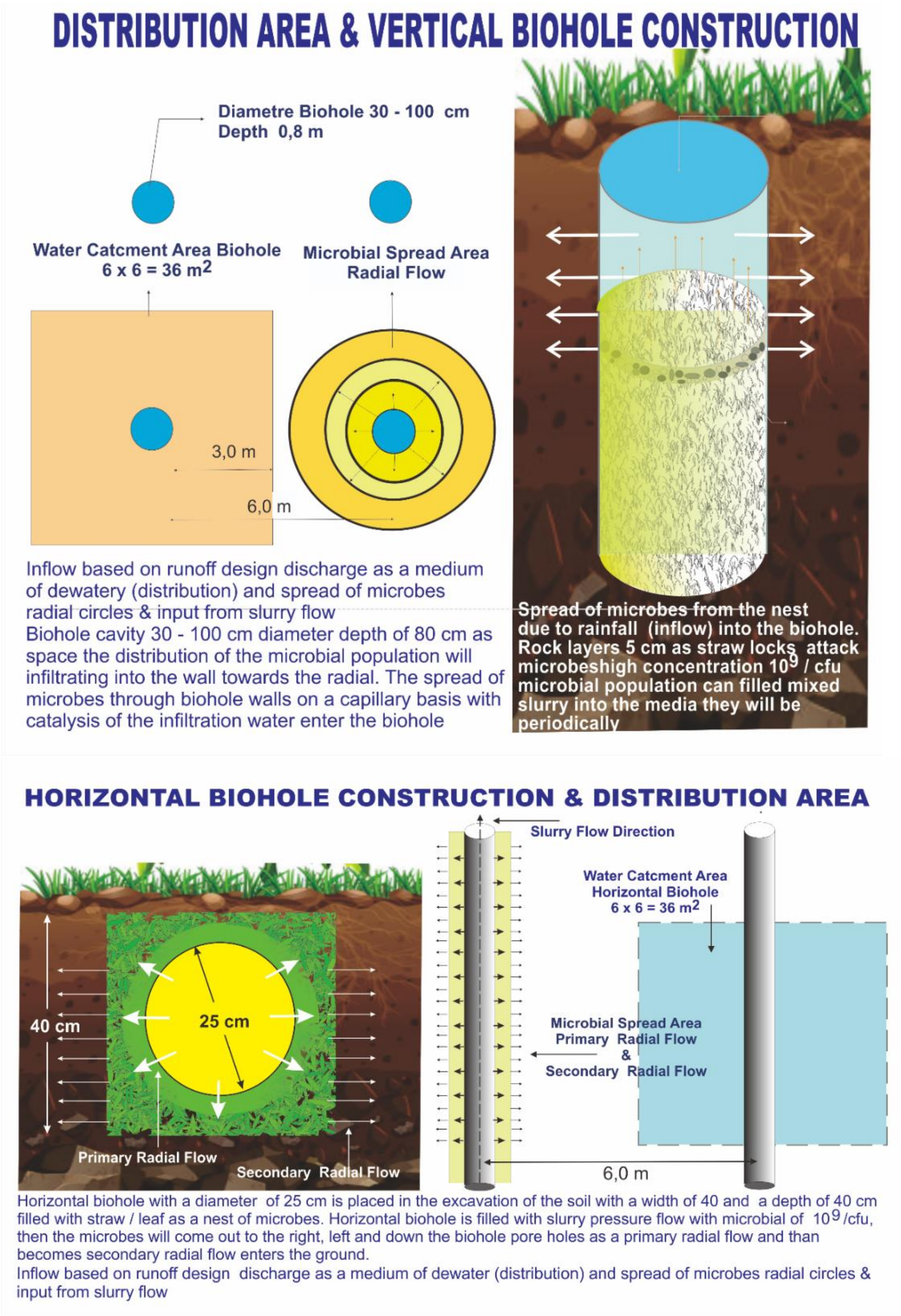
2.1. Determining plot and sensor points

To determine plots and sensors, this study uses purposive sampling at distances 3 metre from the center of Biohole with a diameter of 0,25 & 0,3 meter as the central radial distribution of the biological agent Microbe Alfaafa MA-11 through the water injection process. Infiltration rate and radial biological agent distribution can be controlled in real-time through measurement sensors with parameters: EC/salt ion (macronutrients), pH, humidity and soil temperature. And as a periodical control, the infiltration rate with a Double Ring Infiltrometer on the variable distance from the center of the Biohole are manually measured. Next, soil samples are also taken to analyze their characteristics, such as soil texture, organic material content and bulk density (Douglas, M.G. 2018).

Figure 1: Double Ring Infiltrometer & Sensors

Figure 2: Instalation of Double Ring Infiltrpmeter

Figure 3. Alluvai Soil Layers



Inflow based on runoff design discharge as a medium of dewatery (distribution) and spread of microbes radial circles & input from slurry flow

Biohole cavity 30 - 100 cm diameter depth of 80 cm as space the distribution of the microbial population will infiltrating into the wall towards the radial. The spread of microbes through biohole walls on a capillary basis with catalysis of the infiltration water enter the biohole

Spread of microbes from the nest due to rainfall (inflow) into the biohole. Rock layers 5 cm as straw locks attack microbeshigh concentration 10^9 / cfu microbial population can filled mixed slurry into the media they will be periodically

Horizontal biohole with a diameter of 25 cm is placed in the excavation of the soil with a width of 40 and a depth of 40 cm filled with straw / leaf as a nest of microbes. Horizontal biohole is filled with slurry pressure flow with microbial of 10^9/cfu, then the microbes will come out to the right, left and down the biohole pore holes as a primary radial flow and than becomes secondary radial flow enters the ground.

Inflow based on runoff design discharge as a medium of dewater (distribution) and spread of microbes radial circles & input from slurry flow

Figure 4. Distributiom & Biohole Structure

2.2. Data Processing

2.2.1. Catalysis Discharge

Smartbiosoildam innovation uses runoff discharge as a media for biological agents distribution through the inlet/inflow (Biohole) as a centre for the microbial populations distribution with water. The runoff discharge calculation as a basis for the Inflow Biosoildam formula requires the following stages:

1. conducting a rainfall analysis,
2. calculating the catchment area, and
3. analyzing the soil/rock layers.

Biosoildam structure can be made with holes in the soil layer without or using water pipes/reinforced concrete pipes (RCP) with perforated layer that will let microbes to spread radially. We can calculate the discharge entering Biohole as a function of the catchment characteristic with a rational formula:

$$Q = 0{,}278\ CIA \qquad (1)$$

where C is the runoff coefficient value, I is the precipitation and A is the area (Sunjoto, S. 2018). Based on this formula, the Table presents the results of runoff discharge.

2.2.2. Infiltration

Infiltration is the process by which water on the ground surface enters the soil. It is commonly used in both hydrology and soil sciences. The infiltration capacity is defined as the maximum rate of infiltration. It is most often measured in meters per day but can also be measured in other units of distance over time if necessary. The infiltration capacity decreases as the soil moisture content of soils surface layers increases. If the precipitation rate exceeds the infiltration rate, runoff will usually occur unless there is some physical barrier. Infiltrometers, permeameters and rainfall simulators are all devices that can be used to measure infiltration rates. Infiltration is caused by multiple factors including; gravity, capillary forces, adsorption and osmosis. Many soil characteristics can also play a role in determining the rate at which infiltration occurs.

The spread of microbes as a biomass decomposting agent can be controlled through the calculation of the infiltration rate at point radius from Biohole as the centre of the spread of microbes. by using the Horton method. Horton observed that infiltration starts from a standard value **fo** and exponentially decreases to a constant condition **fc**. One of the earliest infiltration equations developed by Horton is:

$$f(t) = f_c + (f_o - f_c)e^{-kt} \qquad (2)$$

where :

k is a constant reduction to the dimension [T -1] or a constant decreasing infiltration rate.

fo is an infiltration rate capacity at the beginning of the measurement.

fc is a constant infiltration capacity that depends on the soil type.

The **fo** and **fc** parameters are obtained from the field measurement using a double-ring infiltrometer. The **fo** and **fc** parameters are the functions of soil type and cover. Sandy or gravel soils have high values, while bare clay soils have little value, and for grassy land surfaces, the value increases (Nugroho Widiasmadi 2019).

The infiltration calculation data from the measurement results in the first 15 minutes, the second 15 minutes, the third 15 minutes and the fourth 15 minutes at distance from the centre of Biohole are converted in units of cm/hour with the following formula:

Infiltration rate = (ΔH/t x 60) (3)

where: ΔH = height decrease (cm) within a certain time interval, T = the time interval required by water in ΔH to enter the ground (minutes) (Huang, Z, and L Shan.2011). This observation takes place every 3 days for one month.

2.2.3. Soil Characteristics

The porosity of soils is critical in determine the infiltration capacity. Soils that have smaller pore sizes, such as clay, have lower infiltration capacity and slower infiltration rates than soils that have large pore size, such as sands. One exception to this rule is when clay is present in dry conditions. In this case, the soil can develop large cracks which leads to higher infiltration capacity.

Soil compaction is also impacts infiltration capacity. Compaction of soils results in decreased porosity within the soils, which decreases infiltration capacity. Hydrophobic soils can develop after wildfires have happened, which can greatly diminish or completely prevent infiltration from occurring.

Soil moisture content : Soil that is already saturated has no more capacity to hold more water, therefore infiltration capacity has been reached and the rate cannot increase past this point. This leads to much more surface runoff. When soil is partially saturated then infiltration can occur at a moderate rate and fully unsaturated soils have the highest infiltration capacity.

Organic materials in soils

Organic materials in the soil (including plants and animals) all increase the infiltration capacity. Vegetation contains roots that extent into the soil which create cracks and fissures in the soil, allowing for more rapid infiltration and increased capacity. Vegetation can also reduce surface compaction of the soil which again allows for increased infiltration. When no vegetation is present infiltration rates can be very low, which can lead to excessive runoff and increased erosion levels.[3] Similarly to vegetation, animals that burrow in the soil also create cracks in the soil structure.

2.2.4. Microbial Population

This analysis uses MA-11 biological agents that have been tested by the Microbiology Laboratorium of Gadjah Mada University based on Ministerial Regulation standards: No 70/Permentan/SR.140/10 2011, includes:

Table 2.1: Microbes Analysis

No	Population Analysis	Result	No	Population Analysis	Result
1	Total of Micobes	18,48 x 10^8cfu	8	Ure-Amonium-Nitrat Decomposer	Positive
2	Selulotik Micobes	1,39 x 10^8cfu	9	Patogenity for plants	Negative
3	Proteolitik Micobes	1,32 x 10^8cfu	10	Contaminant E-Coly & Salmonella	Negative
4	Amilolitik Micobes	7,72 x 10^8cfu	11	Hg	2,71 ppb
5	N Fixtation Micobes	2,2 x 10^8cfu	12	Cd	<0,01 mg/l

6	Phosfat Micobes	1,44 x 10^8cfu	13	Pb	<0,01 mg/l
7	Acidity	3,89	14	As	<0,01 ppm

(Nugroho Widiasmadi, 2019)

ts application in Biosoildam is concentrating the microbes into "population media", as a source of soil conditioner for increasing infiltration rates and restoring natural fertility.

2.2.5. Microcontroller against Nutrient Content, Acidity, Temperature & Soil Moisture

Indications of microbial activity on fertility can be controlled through acidity. The number of nutrients contained in the soil is an indicator of the level of soil fertility due to the activity of biological agents in decomposing biomass. Important factors that influence the absorption of nutrients (EC) by plant roots are the degrees of soil acidity (soil pH), temperature (T) and humidity (M). Soil Acidity level (pH) greatly influences the plant's growth rate and development (Boardman, C. R. and Skrove, J.W., 2016).

Microbial activity as a contributor to soil nutrition from the biomass decomposition results can be controlled through the salinity level of the nutrient solution expressed through conductivity as well as other parameters as analogue inputs. Conductivity can be measured using EC, Electroconductivity or Electrical (or Electro) Conductivity (EC) is the nutrients density in solution. The more concentrated the solution is, the greater the delivery of electric current from the cation (+) and anion (-) to the anode and cathode of the EC meter. Thus, it results in the higher EC. The measurement unit of EC is mS/cm (millisiemens) (John M Lafle, PhD, Junilang Tian, Professor ChiHua Huang, PhD,2011).

This study uses an Arduino Uno microcontroller which has 14 digital pins, of which there are 6 pins used as Pulse Width Modulation or PWM outputs, namely the pins D.3, D.5, D.6, D.9, D.10, D.11, and 6 analogue input pins for these soil parameter elements, namely EC, T, pH, M. Analog input on Arduino Uno uses C language and for programming uses a compatible software for all types of Arduino (Samuel Greengard 2017). Arduino Uno microcontroller can facilitate communication between Arduino Uno with computers including smartphones. This microcontroller provides USART (Universal Synchronous and Asynchronous Serial Receiver and Transmitter) facilities located at the D.0 (Rx) pin and the D.1 (Tx) pin.

This research uses the ESP8266 data transmission system with the firmware and the AT Command set that can be programmed with Arduino. The ESP8266 module is an on-chip system that can be connected to a WIFI network. Besides, several pins function as GPIO (General Port Input Output) to access these ground parameter sensors that are connected to Arduino, so that the system can connect to Wifi (Klaus Schwab, 2018). Thus, we can process analogue inputs of various soil parameters into digital information and process them via the web.

3. Results And Discussion

3.1. Rainfall Design and Frequency Duration Intensity (FDI)

The rainfall design intensity was determined using rainfall data from Kendal Station in 2010-2018 Statistical analysis was performed to determine the distribution type used, which in this study was the Log Person III's. Distribution checking on whether rain opportunities can be accepted or not is calculated using the Chi Square test and the Kolmogorov Smirnov test. Next, the design rainfall intensity is calculated using the mononobe formula.

3.2. Discharge Plan

The discharge plan as a MA-11 microbial catalyst uses the rainfall intensity for 1 hour since it is estimated that the most predominant rainfall duration in the area studied is 1 hour. The runoff coefficient for various surface flow coefficients is 0.70 - 0.95 (Suripin 2013), while in this study we use the smallest flow coefficient value, which is 0.70.

The discharge plan has various catchment areas, between 9 m^2 to 110 m^2 with a proportional relationship. The larger the plot, the greater the plan discharge generated as a biohole inflow.

The depth of Biohole in the study area in the 25-year return period ranges from 0.80 m to 1.50 m.

The absorption volume will determine the maximum capacity of water contained in Biohole. The greater the volume of Biohole is, the greater the water container is.

3.3. Biohole Design

a) **Vertical Biohole** walls use natural walls with a 0.3 m diameter and a 0.8 m depth or the storage area of 36 m^2. Organic material (slurry combined with solid pressed red onion straw waste) is used as a place for microbial populations/microbial sources. The top is installed pipe from ground tank to slurry flow from digester. Thus, when filled with organic material water, it remains stable to maintain the radial spread of microbes. The Biohole volume capacity for that dimension is 0.157 m^3, with a catchment of 36 m^2 and the 25 year-discharge = 0.0000841 m^3/sec and will be fully filled in about 15 to 20 minutes. This figure considers natural resources in the form of rainfall intensity of the study area which adjusted to the spread of microbes. Therefore, the water-emptying phase and the microbial population formulation phase can take place optimally.

b) **Horizontal Biohole** walls use natural walls with a 0,25 m diameter and a 0.4 m depth or the storage area of 36 m^2. Organic material (solid pressed padi straw waste) is used as a place for microbial populations/microbial sources. The top is coated with a 5 cm thick rock which acts as an energy-breaking medium. Thus, when filled with organic material water, it remains stable to maintain the radial spread of microbes (Nugroho Widiasmadi, 2019). The Biohole volume capacity for that dimension is 0.125 m3, with a catchment of 36 m2 and the 25 year-discharge = 0.0000841 m^3/sec and will be fully filled in about 15 to 20 minutes. This figure considers natural resources in the form of rainfall intensity of the study area which adjusted to the spread of microbes. Therefore, the water-emptying phase and the microbial population formulation phase can take place optimally.

3.4. Soil Coating Effect on Biohole

If land is covered by impermeable surfaces, such as pavement, infiltration cannot occur as the water cannot infiltrate through an impermeable surface This relationship also leads to increased runoff. Areas that are impermeable often have storm drains which drain directly into water bodies, which means no infiltration occurs.

Vegetative cover of the land also impacts the infiltration capacity. Vegetative cover can lead to more interception of precipitation, which can decrease intensity leading to less runoff, and more interception. Increased abundance of vegetation also leads to higher levels of evapotranspiration which can decrease the amount of infiltration rate. Debris from vegetation such as leaf cover can also increase infiltration rate by protecting the soils from intense precipitation events.

Geomorphology of agricultural land and its surroundings is in the form of alluvial lands. Alluvial material in this area is a soil type that resulted from the silt deposition usually carried by rivers. This soil is most often found in the downstream or low areas. The soil colour ranges from brown to grey. his land is fertile and suitable for agriculture, either for horticutural , rice, crops, or tobacco. This soil is soft and easy to work on. This soil type is widely distributed in the Kendal plains area.

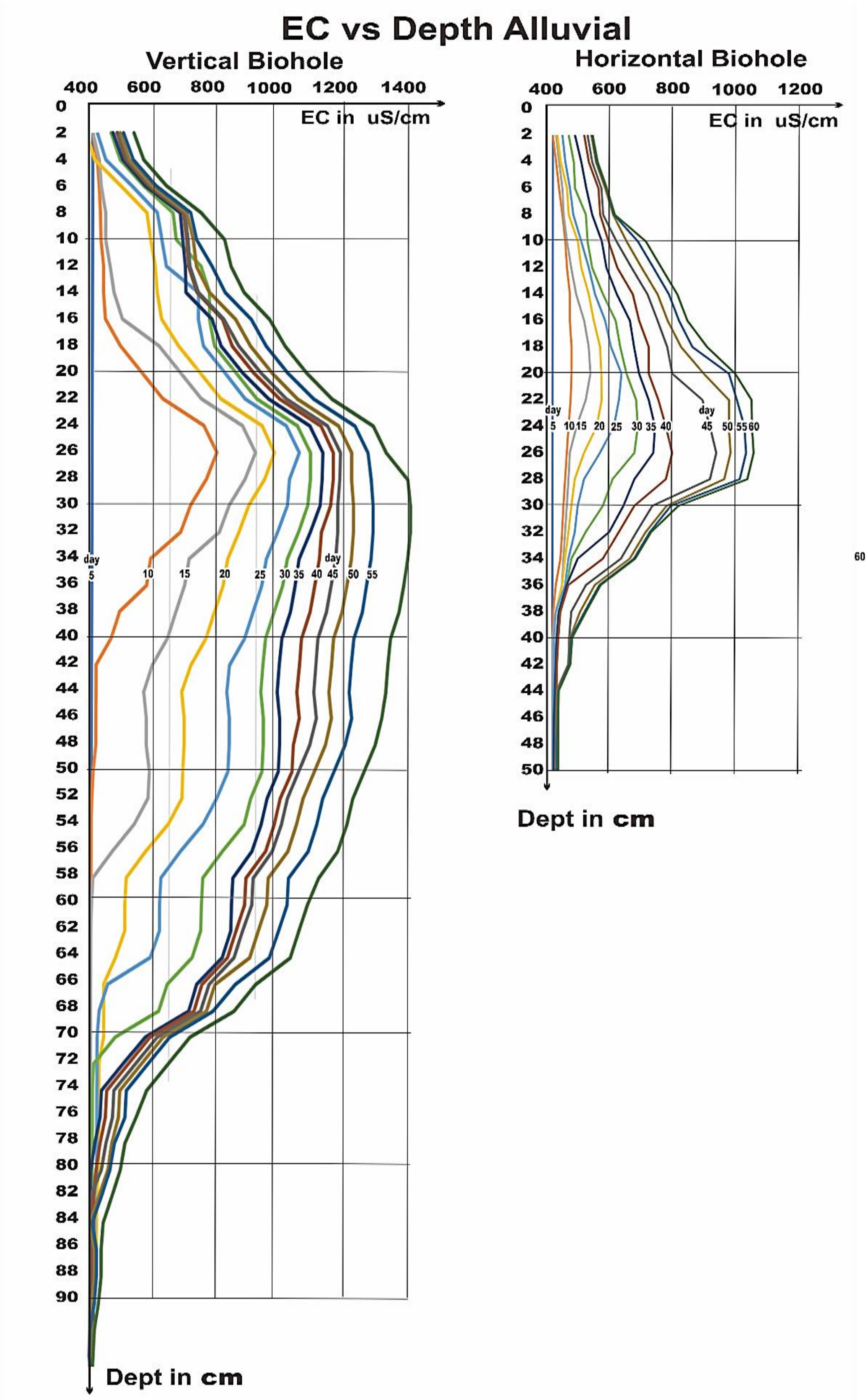


Figure 5. Graph of EC vs Depth

Alluvial soil fertility simulation based on biohole type with

- **Varibale 1** = using vertical type Biohole diameter 30 cm depth 80 cm with microbial population 10 ^{8} / cfu, recording soil parameters is done every 5 days for 60 days at every 10 cm depth.
- **Varibale 2** = using horizontal type Biohole diameter 25 cm depth 40 cm with Microbial Population 10 ^{8} / cfu, recording soil parameters is done every 5 days for 60 days at every 10 cm depth.

The initial nutrient condition before simulating the soil fertility value with the Electrolyte Conductivity (EC) parameter is 420 uS / cm, a distance of 3 meters from the center of the Biohole. From one point for every 10 cm depth, the EC value was measured to a depth of 90 cm, which was observed in real time every 5 days.

A. The results of observations & recording on the **Vertical Biohole** variable are:
   1. Increased Electrolyte value the conductivity is less than optimal between the ground surface to a depth of 20 cm, which is below 1000 uS / cm Electrolyte Conductivity values only moved from 400 to 1000 uS / cm and were reached from day 5 to day 40.
   2. The increase in the value of electrolyte conductivity is quite significant at a depth of 20 to 60 cm, namely moving from 1000 uS / cm to 1400 uS / cm achieved from day 30 to day 60.
   3. While the depth of 60 cm to the bottom again the increase in the value of electrolytes. The less optimal conductivity only moves from 400 to 800 uS / cm and is reached from day 20 to day 50.
   4. In general, the rate of EC increase at each depth varies considerably, while the most effective root growth zone is at a depth of 20 to 60 cm which contains significant electrolyte conductivity values to support growth from the vegetative to generative phase of a plant.

B. The results of observation & recording on the **Horizontal Biohole** variable are:
   1. Increasing the value of electrolytes conductivity is less than optimal between the ground surface to a depth of 15 cm, which is below 800 uS / cm. Electrolyte Conductivity values only moved from 400 to 800 uS / cm which was achieved from day 5 to day 40.
   2. Increased value of Electrolyte Conductivity is quite significant at a depth of 15 to 30 cm, namely moving from 800 uS / cm to 1100 uS / cm achieved from day 40 to day 60.
   3. While the depth of 30 cm to the bottom again the increase in the value of electrolytes. The less optimal conductivity only moves from 400 to 800 uS / cm and is reached from day 10 to day 40.
   4. In general, the rate of increase in EC at each depth varies considerably while the most effective root growth zone is at a depth of 15 to 30 cm which contains a significant electrolyte conductivity value to support growth from the vegetative to generative phase of a plant.

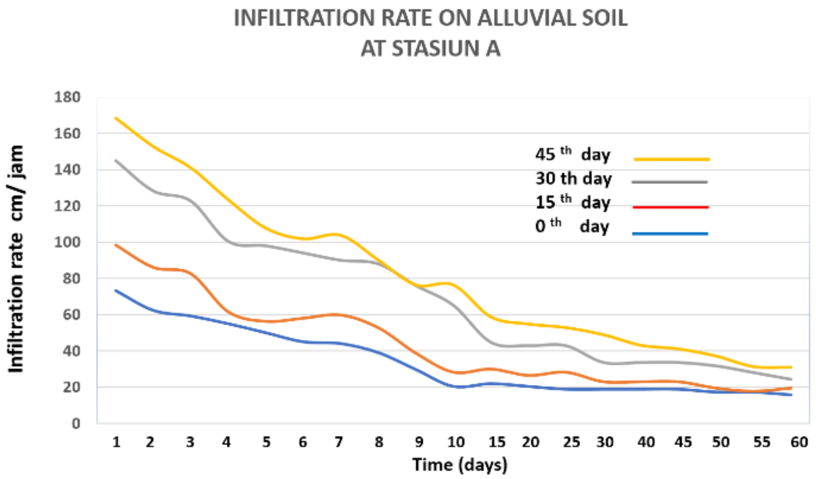


Figure 6. Graph of Infilration Rate

C. The above-mentioned soil parameters can be controlled towards the infiltration rate, where the infiltration rate graph shows a constant value at the level of 20 to 40 cm/h reached after 30 days with the value ranging from 600 to 700 uS/cm. The biological agent activities in alluvial soils with infiltration levels will be optimal on the 30th day.

4. Conclusion

a) Vertical Type Biohole on alluvial soils has an effective zone for root growth at a depth of between 20 to 40 cm making it suitable for seasonal crops such as chilies, tomatoes, papikra, asparagus, rosella, alfalfa etc.
b) Type Horizontal Biohole on alluvial soils has an effective zone for root growth at a depth between 15 to 30 cm making it suitable for vegetable crops such as lettuce, broccoli, shallots, garlic etc.
c) From the results of observations and recording of nutrient enhancement, if the distance between the center points of the two types of biohole is 6 meters, the EC value will be achieved between 1000 to 1400 uS / cm, namely on the 60th day, so if you want to increase the EC value, you must increase the number of microbial populations or increase microbial dispersal time.
d) In general, the rate of EC increase in each biohole depth varies considerably from the results of this study "effective root growth zone" covers 37 % of the internal size (H) of horizontal biohole and covers 50 % of the size in (H) of the vertical biohole.
e) Technically, the “effective root growth zone” can be enlarged and expanded based on the size of the biohole and the type of biohole used. For fiber-rooted plants and tubers, horizontal biohole is quite effective to use. On the other hand, for plants that have taproots, vertical biohole is quite effective to use.

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