

ANALYSIS OF THE RELATIONSHIP BETWEEN MICROBIAL ACTIVITIES IN INSEPTISOL SOIL TOWARDS INFILTRATION RATE FOR FERTILITY IMPROVEMENT WITH BIOSOILDAM TECHNOLOGY FOR PEPPER PLANTATION

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Abstract

This research was conducted on Inseptisol soils, especially for pepper plantation, aimed at restoring soil health and fertility due to the use of chemical fertilizers and pesticides. Through controlled microbial activity through biohole. This study observes periodically changes in soil acidity, infiltration rate and electrolyte conductivity levels around the center of the biohole as the center of microbial distribution. As a comparison, observations were made using biohole which was only filled with water without microbes. Furthermore, these two conditions, namely biohole with microbes and biohole without microbes, were compared to changes in parameters: soil acidity, infiltration rate and electrolyte conductivity levels. So that it can be seen a real difference in the speed of improvement of the two soil conditions and the ability of the soil to provide nutrients during vegetative and generative growth. Soil carrying capacity research using microbial activity variables as a measurable control is called Biosoildam Technology. This research was conducted on agricultural land with commodities as above. The tools used are the Double Ring Infiltrometer to measure the infiltration rate at three radial distances from the center of the microbial hole (Biohole), the measurement of electrolyte salt content as an indication of soil fertility using Electrolyte Conductivity, and the use of a PH meter as a measure of soil acidity. Infiltration calculations were carried out every 5 minutes and observed every 15 days for 45 days. This research is expected to: reduce production costs, increase crop yields, make agriculture sustainable, produce multiplier economies of effect, strengthen crops to face global climate change. The result of research show that the highest of infiltration rate, infiltration capacity, fertility & acidity was happened on soil with involve Biofertilizer MA-11, ie 83-99 cm/hour, 325 – 970 uS/cm, PH = 6- 6,5. While the lowest of infiltration rate, infiltration capacity, fertility & acidity was happened on soil without involve Alfaafa Microba MA-11, ie 31- 52 cm/hour, 325 – 540 uS/cm, PH 5 – 6.

Keywords: inseptisol; biohole; infiltration; biosoildam; land use; Alfaafa Microba; fertility; acidity

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Introduction

The current decline in carrying land capacity continues to expand. 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) (Widiasmadi, 2019). To restore the land's capacity quickly and measurably and to restore soil productivity as well, infiltration is not enough. Biological agents 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, 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 (Eng & Dr, 2004).

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 (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 (Dr, 2020) due to excessive use of chemical fertilizers and pesticides which hardens the soil as well.

Bioisoldam is a Biodam technology that involves microbial activity in increasing the measured and controlled infiltration 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.

Increased soil friability by involving microbial activities (Bioinfiltration) can be used as the development of the science of Civil Hydro Engineering as Eco-Civil Engineering. So that engineering is able to provide value to the carrying capacity of land productivity through soil and water conservation (Widiasmadi, 2019).

Method

The study was conducted on Humus land which for decades has been the source of livelihood for the community of Banteng Village Pangakalan Baru District Bangka Tengah 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 January – April 2019, intends to restore the carrying capacity of the land.

Tools and materials used in research are: Biohole as Bioisoldam Injector, microbial decomposer Alfafaa MA-11, red onion straw as microbial nest, Abney level, measuring tape, Double Ring Infiltrometer, stirring rod, Erlemeyer, ruler, Stop watch / watch, bucket plastic, tally sheet, measuring cup, scales, hydrometers and water (Douglas, 1988).

A. Determining plot and sensor points

To determine plots and sensors, this study uses purposive sampling at various distances: 0.5; 1,0; 1,5 meter from the centre of Biohole with a diameter of 1 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 measurement sensors with parameters: EC/salt ion (macronutrients), pH, the infiltration rate with a Double Ring Infiltrometer on the variable distance from the centre 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, 1988).

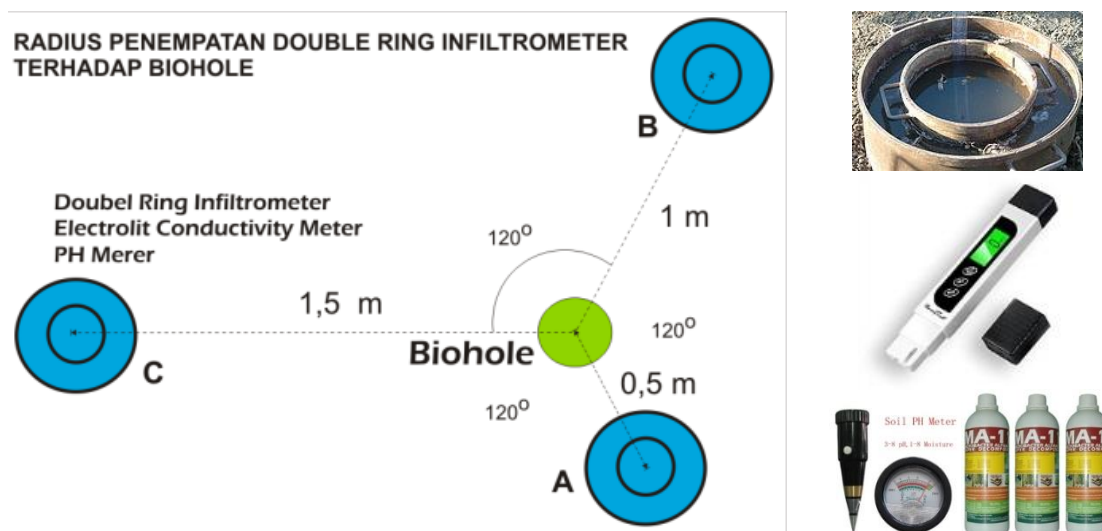


Figure 1
Double Ring Infiltrometer setting

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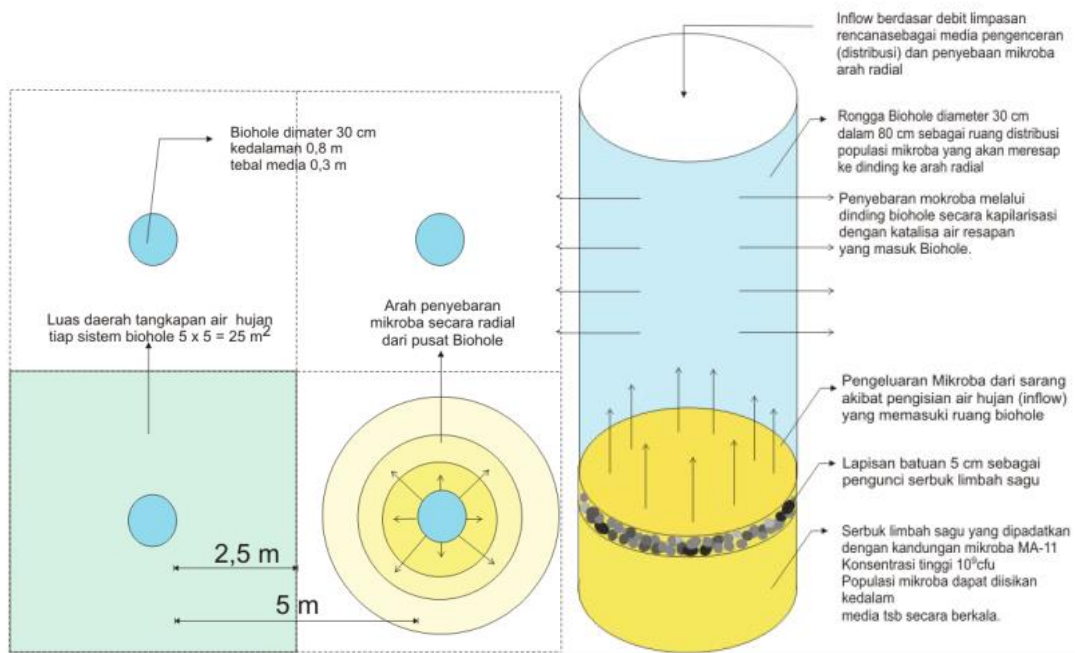


Figure 2
Distribution biohole -Biohole Structure & Humus Land

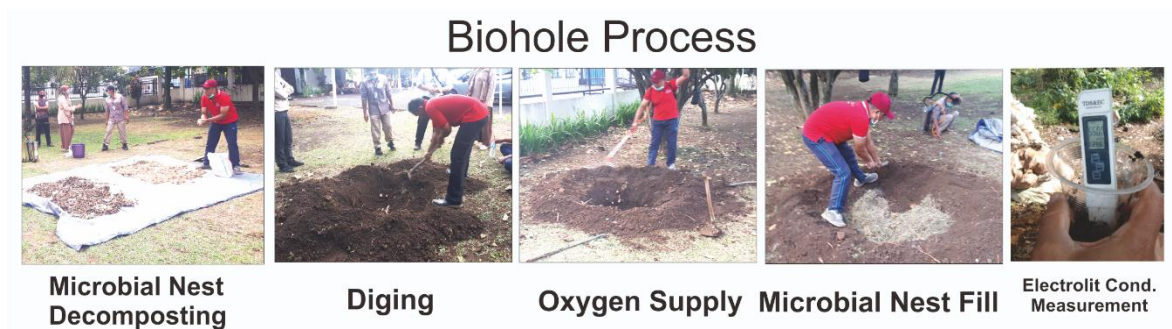


Figure 3
Biohole Process

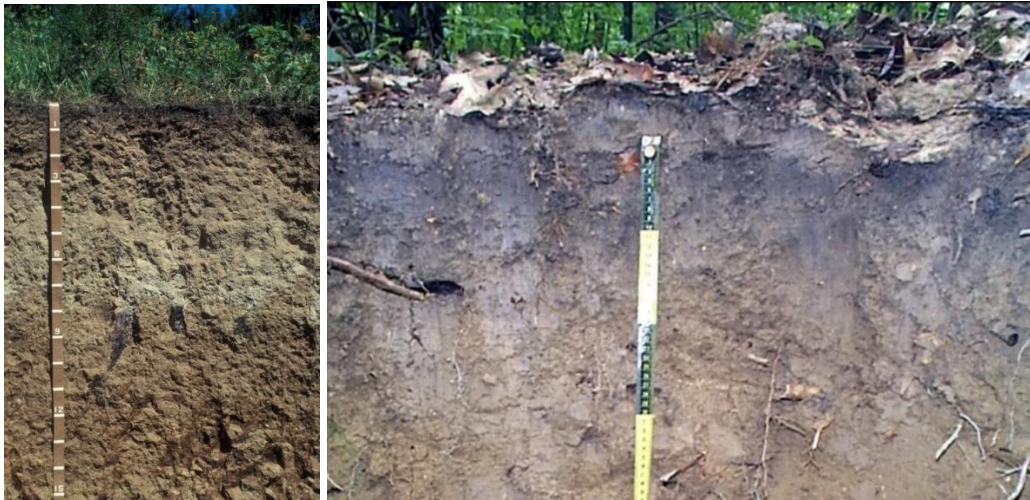


Figure 4
Inseptisol Soil Layers





Figure 5
Pepper Plantation

B. Data Processing

1. Catalytic Discharge

Bioisoldam 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 Bioisoldam formula requires the following stages:

- a) conducting a rainfall analysis,
- b) calculating the catchment area, and
- c) analyzing the soil/rock layers.

Bioisoldam 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:

$$Q = 0,278 CIA \quad (1)$$

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

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. Infiltrimeters, 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 decomposing agent can be controlled through the calculation of the infiltration rate at several point radii from Biohole as the centre of the spread of microbes. by using the Horton method. Horton observed that infiltration starts from a standard value f_0 and exponentially decreases to a constant condition f_c . One of the earliest infiltration equations developed by Horton is:

$$f(t) = f_c + (f_0 - f_c)e^{-kt} \quad (2)$$

where :

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

f_0 is an infiltration rate capacity at the beginning of the measurement.

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

The f_0 and f_c parameters are obtained from the field measurement using a double-ring infiltrimeter. The f_0 and f_c 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 (Sutanto, 2012).

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 each distance from the centre of Biohole are converted in units of cm/hour with the following formula:

$$\text{Infiltration rate} = (\Delta H/t \times 60) \quad (3)$$

where:

ΔH = height decrease (cm) within a certain time interval,

T = the time interval required by water in ΔH to enter the ground (minutes) (Zhanbin et al., 1997). This observation takes place every 3 days for one month.

C. 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. Similarly to vegetation, animals that burrow in the soil also create cracks in the soil structure.

D. Microbial Population

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

Table 1
Microbes Analysis

No	Population Analysis	Result	No	Population Analysis	Result
1	Total of Micobes	18,48 x 10 ⁸ cfu	8	Ure-Amonium-Nitrat Decomposer	Positive
2	Selulolitik Micobes	1,39 x 10 ⁸ cfu	9	Patogenity for plants	Negative
3	Proteolitik Micobes	1,32 x 10 ⁸ cfu	10	Contaminant E-Coly & Salmonella	Negative
4	Amilolitik Micobes	7,72 x 10 ⁸ cfu	11	Hg	2,71 ppb
5	N Fixtation Micobes	2,2 x 10 ⁸ cfu	12	Cd	<0,01 mg/l
6	Phosfat Micobes	1,44 x 10 ⁸ cfu	13	Pb	<0,01 mg/l
7	Acidity	3,89	14	As	<0,01 ppm

Resource: (Widiasmadi, 2019)

Its application in Bioisoldam is concentrating the microbes into "population media", as a source of soil conditioner for increasing infiltration rates and restoring natural fertility (Widiasmadi, 2020).

E. Soil Fertilizer & Soil Acidity

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) (Widiasmadi, 2020).

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 (Widiasmadi, 2020).

Result and Discussions

1. Design Rainfall and Frequency Duration Intensity (FDI)

The design rainfall intensity was determined using rainfall data from Ngawi Station in 2009-2017. 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.

2. Design Discharge

The design discharge 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 design discharge has various catchment areas, between 9 m² to 110 m² 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. Biohole Design

Biohole walls use natural walls with a 0,3-diameter and a 0.8-depth or the storage area of 36 m². Organic material (solid pressed corn 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.

The Biohole volume capacity for that dimension is 0.0565 m³, with a catchment of 36 m² and the 25 year-discharge = 0.0000841 m³/sec and will be fully filled in about 10 to 15 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.

4. 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 inceptisol lands. Soil consists of horizons that lie above the source rock formed from the interaction of various soil-forming factors such as climate, organisms, parent material and relief that occurs all the time. Different processes in soil formation will produce different soils that can be observed from soil morphological properties.

Inceptisols are young soil and begin to develop. Its profile has a horizon formation is rather slow as a result of alteration of the parent material. The horizons are not shows the results of intensive weathering. The horizons of accumulation of clays and iron oxides & aluminum is clearly not present in this soil.

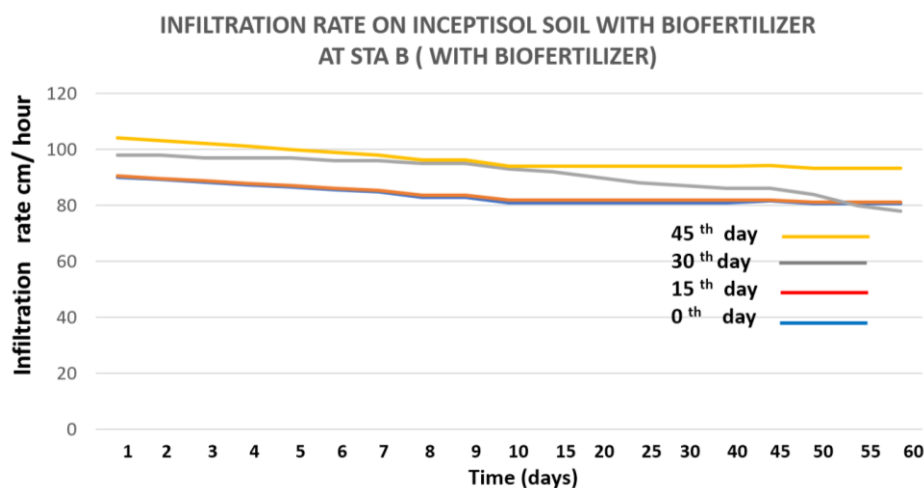
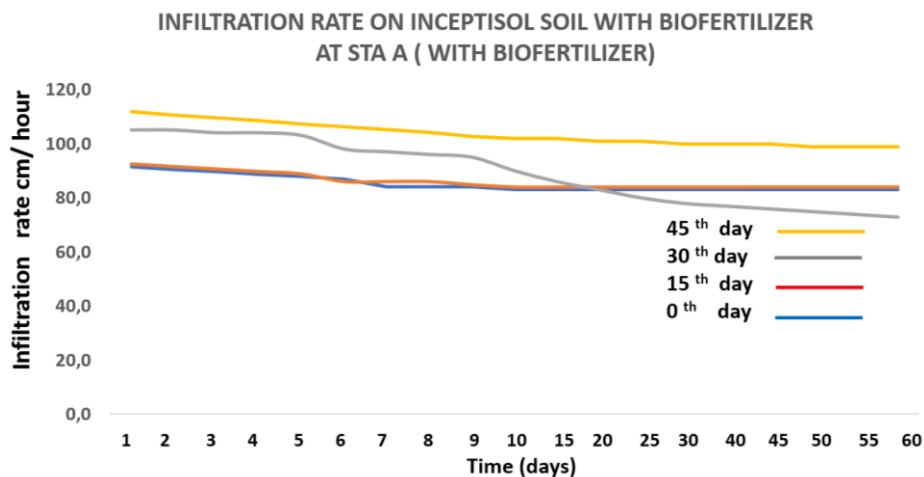
Its profile is more developed than that of entisol. The lands that were once classified as brown forest, andosols and brown soil can be incorporated into Inceptisols. Most Inceptisols have cambic. Inceptisol soil characteristics are:

- a) Has a rather thick soil solum, which is 1-2 meters
- b) The color is black or gray to dark brown
- c) The textures are dust, dusty loam, loam
- d) The soil structure is crumb, loose consistency, pH 5.0 - 0.7
- e) Organic material content is quite high, 10% -30%
- f) Nutrient content: medium to high
- g) Soil productivity: moderate to high.

Inceptisols may be also found on alluvial deposits where temporary flooding alters the soil profile due to the deposition of soil particles on the soil surface and the soil profile becomes saturated. For example, Inceptisols in the southern Mississippi River Valley are developed on alluvial deposits. Virtually many pedogenic processes are active to some extent in Inceptisol profiles but none predominates. The genesis of Inceptisols includes multiple pathways depending on the processes occurring on a given landscape and geographic area. Environmental factors can slow down weathering (e.g. low temperatures, low precipitation, or

resistant parent material) and soil development to form other soil orders is retarded or even inhibited.

Biological properties are still have parent material so there are still many microorganisms decomposition plant residue Soil There are still many parent materials including plant litter. There are still main ingredients so there are still many microorganisms decompose the rest of the plant. Chemical properties are pH close to neutral or higher (pH <4 soil problems) Base saturation less than 50% at a depth of 1.8 m COLE between 0.07 and 0.09 BO high (1.64% -7.78%) (. P content low potential to high and very low potential K to moderate. Potential P content is generally higher than the potential K, both the upper and lower layers. Cation Exchange Capacity (CEC) is medium to high in all layer. Low to high alkaline saturation (KB). In It is generally concluded that the natural fertility of Inceptisol varies from low to high. Physical properties are Most of the inceptisols exhibit texture class clay with a fairly high clay content (35-78%) however some include fine clay with a clay content lower (18 - 35%). This soil type is widely distributed in the Bangka Island.



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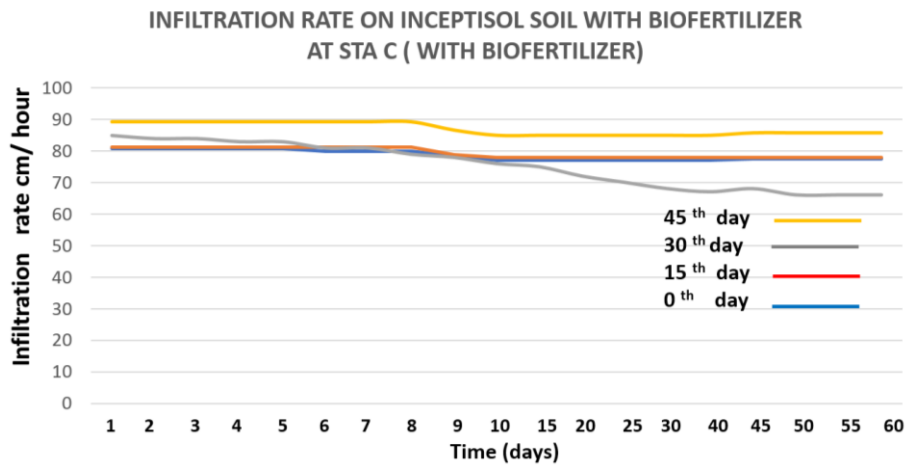
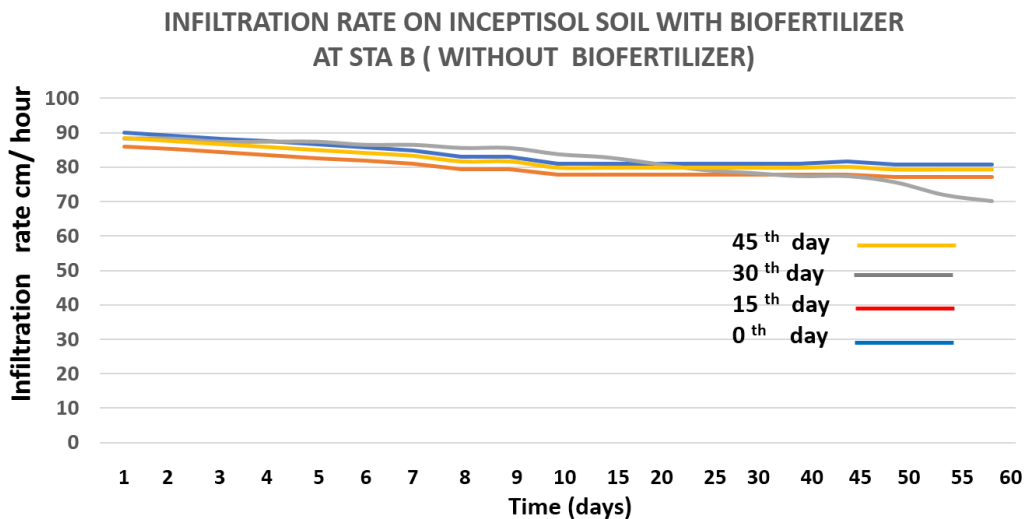
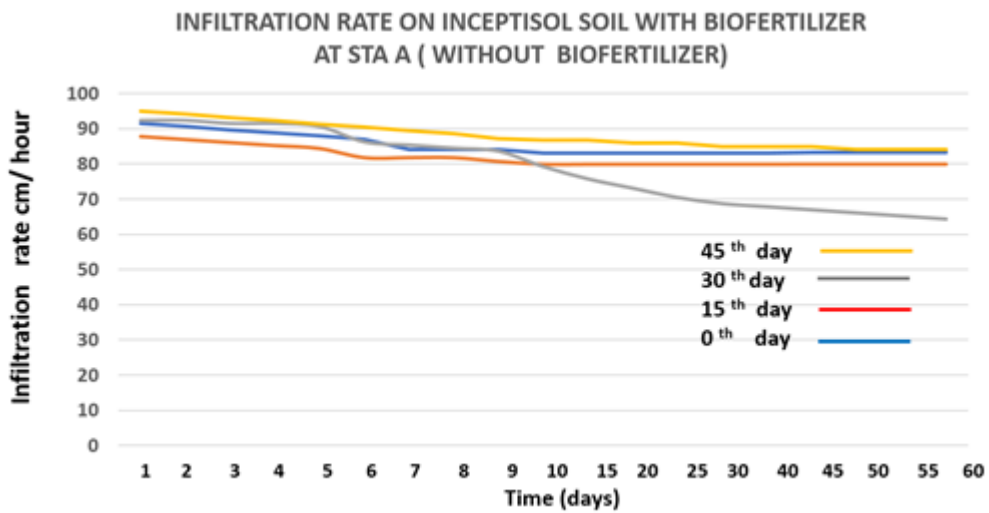


Figure 5
Graph Infiltration Rate With Biofertilizer



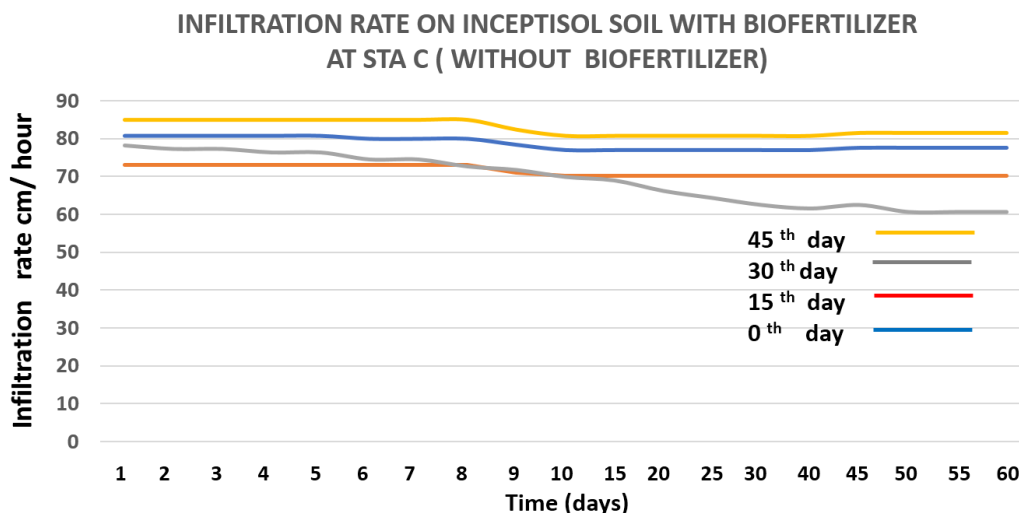


Figure 6
Graph Infiltration rate with Biofertilizer

Technically at the beginning of the spread the infiltration rate is still relatively small because it only relies on capillary power, but in the following period the microbial activity that has spread can increase the cavity (poruosity), so that the infiltration rate in this advanced period is also greater in Alluvial soils. In addition, the ability of microbes to break down (decomposing) organic material biomass is able to increase nutrient content in the soil and neutralize soil acidity, along with the increasing infiltration rate. 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 humus soils with infiltration levels will be optimal on the 30th day.

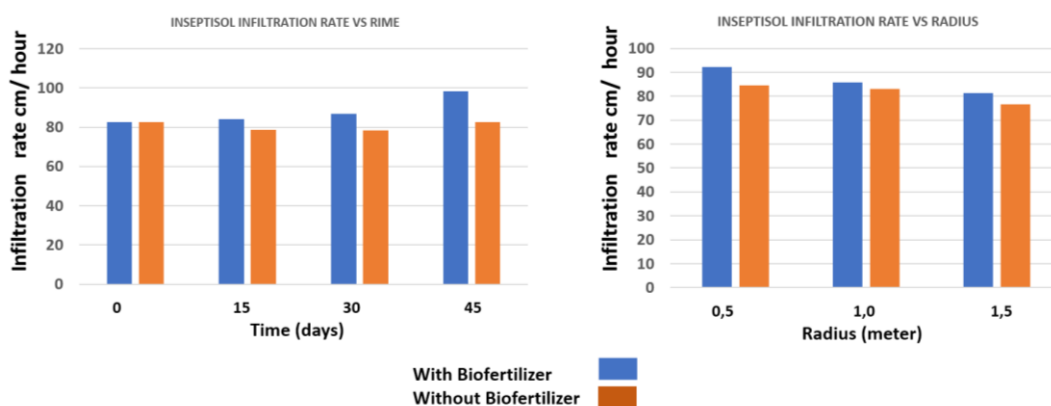


Figure 7
Infiltration Rate vs Time

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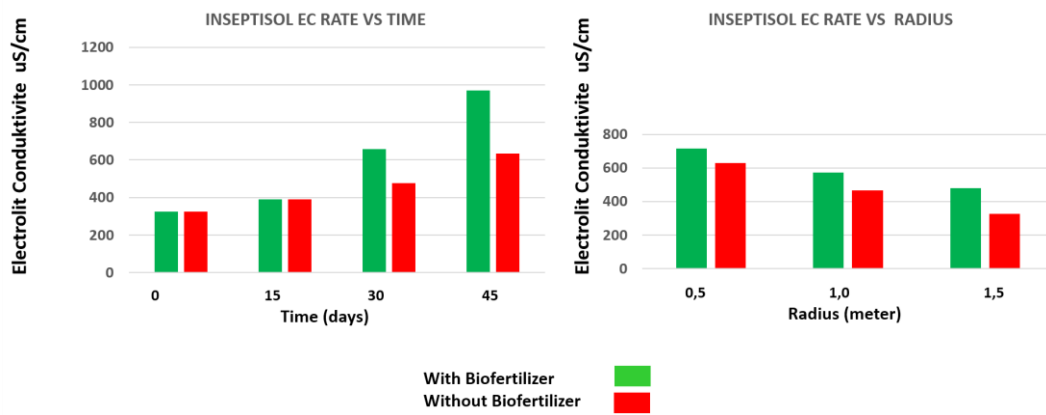


Figure 8
EC Rate vs Time & EC Rate vs Radius

Conclusions

1. Microbial distribution in this case that is the Humus soil layer is quite effective at a maximum radius of 2 meters with a distance between Bioholes of 5 meters and even the spread of the microbes can be even further.
2. The use of microbes in the infiltration well system or the bioisoldam method as a biological agent is very effective, especially to increase the productivity of barren land into fertile land in a measurable manner, so that it does not merely include water.
3. Bioisoldam method still needs to be tested for various lands with various rock soil formations so that the relationship between the soil permeability level and the concentration value of microbial population involved for a fertility target of an area to be a productive land is acquired.
4. Bioisoldam can be called "Active Infiltration System" since it involves microbial activities that can be useful for:
 - a) Expanding soil porosity that increases oxygen content as a source of soil health.
 - b) Increasing macro and micro soil nutrient content of the biomass elements that the microbes break down in the distribution zones from the biohole centre.
 - c) Repairing saturated soils that have long been contaminated with chemical fertilizers and pesticides by the microbial degradation.

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