

Soil chemical characteristics and phosphatase activity in soil of two mangosteen cultivation patterns in the mangosteen thematic village, District of pauh, Padang

Agustian^{a*}, Indra Dwipa^b, Roza Yunita^b, Firsta Ninda Rosadi^b, Kesi Dwi Putri^a

^aDepartment of Soil Science and Land Resources, Faculty of Agriculture, Andalas University

^bDepartment of Agronomy, Faculty of Agriculture, Andalas University

*Corresponding Author: agustian@agr.unand.ac.id

Abstract

This research discusses the critical role of phosphatase enzymes in soil, particularly in the phosphorus cycle and soil fertility. Acid and alkaline phosphatases are identified as crucial components, with their activities serving as indicators of soil fertility. This study evaluates the soil chemical and biological characteristics in mangosteen orchards in the Mangosteen Thematic Village, specifically in monoculture and polyculture cultivation patterns on slopes ranging from 8-15%. Soil pH, organic C, available P, total P, soil respiration, microbial C-biomass, and phosphatase enzyme activities were assessed at 0-20 cm and 20-40 cm depths. Total P did not show significant changes based on cultivation patterns. The results show that the soil pH values tend to be acidic to slightly acidic (5.21-5.45) with no significant differences based on depth. Organic C, available P, soil respiration, microbial C-biomass, and acid phosphatase enzyme activity were higher in polyculture cultivation patterns but alkaline phosphatase enzyme activity was higher in monoculture. The cultivation pattern influences the dynamics of agricultural ecosystems and should be considered in land management to enhance productivity and soil ecosystem balance.

Keywords: Acid and alkaline phosphatases; mangosteen; cultivation pattern.

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INTRODUCTION

Enzymes are biocatalysts produced by living tissues that function as biocatalysts in cells. Enzymes are specific because they work on specific substrates with specific reaction forms (Burns, 1982). Various classes of enzymes, including oxidoreductases, transferases, hydrolases, lyases, isomerases, and ligases, can be found in soil. Most enzymes in the soil come from the excretion of bacteria and fungi living in the soil. Hydrolase is the dominant enzyme group found in the soil, playing a role in the decomposition of organic matter in the soil, involved in nutrient cycles, and often used as an indicator of changes in the soil ecosystem (Dick et al., 2000). Phosphatase is an enzyme in the

hydrolase class that plays a crucial role in the rhizosphere zone for the availability of P nutrients. The mineralization of organic phosphorus also involves the role of soil microbes through phosphatase enzyme products, such as acid and alkaline phosphatases. Several phosphatase enzymes are generally found in the soil, including phosphomonoesterase, phosphodiesterase, trifosphomonoesterase, and phosphoamidase. These enzymes are responsible for the hydrolysis of organic P bonds into inorganic phosphates (H_2PO_4^- , HPO_4^{2-}), available to plants (Alkorta et al, 2003). Soil phosphatase enzymes are obtained as extracellular enzymes. The phosphatase produced by microbes is active under both acidic and alkaline conditions, leading to the naming of acid and alkaline

phosphatases. The sensitivity of phosphatase activity to environmental changes makes it a representative indicator of soil fertility. In the observation of phosphatase activity, Carreira et al (2000) suggested that since most soil organic P is esterified, the activities of phosphomonoesterase and phosphodiesterase could represent parameters for observing phosphatase enzyme activity in soil.

According to Tabatabai and Bremmer (1969), phosphomonoesterase consists of acid and alkaline phosphatases. Both act as orthophosphoric monoester phosphohydrolases and are extensively studied. The classification into acid and alkaline phosphatases is based on their optimal pH, with some enzymes functioning optimally in acidic pH and others in alkaline pH. On the other hand, Makoi and Ndakidemi (2008) suggest that phosphomonoesterase comprises enzymes that work optimally at pH 4–6 (acidic), pH 6.5–7 (neutral), and pH 9–10 (alkaline) with an optimal temperature of 40–60°C.

Acid and alkaline phosphatases primarily hydrolyze ester bonds that bind P and C (C-O-P ester bonds) in organic matter. Inorganic P is released from organically bound P in materials such as leaf litter, rhizosphere, and other organic sources. Phosphatases serve as good indicators in assessing soil fertility; deficiency of P in the soil is marked by an increase in acid phosphatase secretion to dissolve and remobilize phosphate, thereby affecting the plant's ability to cope with P stress (Murni et al., 2020). Due to the crucial role of phosphomonoesterase enzymes in the mineralization of organic soil P and plant nutrition, some literature combines acid and alkaline phosphomonoesterases as soil phosphomonoesterases. However, the majority of literature refers to them as acid phosphatases. In acidic soils, the concentration of acid phosphatase enzymes is higher, while in alkaline soils, alkaline phosphatases predominate (Kunito et al, 2018).

Phosphorus is one of the essential elements for plant growth. Soil contains various organic components containing phosphorus, and about 50 to 70% of organic P has been identified

(Stevenson, 1999). Organic P is recognized in the form of carbon-phosphorus structures (C-P chains) known as phosphonates, phosphorus-oxygen-phosphorus structures (P-O-P chains) called polyphosphates, and carbon-oxygen-phosphorus structures (C-O-P chains) as phosphate esters. Most organic P in the soil belongs to the phosphate ester group. Huang et al. (2011) found that phosphorus fractions could be bound in various organic materials from animal and plant residues to microbes, either in the form of polymer bonds. These phosphorus bonds range from easily extractable to strongly bound, requiring an alkaline environment for their breakdown.

The organic carbon content on the soil surface correlates with the activities of both acid and alkaline phosphatases, as well as other enzymes such as phosphodiesterase, arylsulfatase, amidase, urease, and invertase (Mina and Chaudry, 2011). Phosphate mineralization under the forest canopy occurs due to soil acidification and a decrease in labile inorganic phosphate. The decrease in alkaline phosphatase activity is caused by this acidic condition (Carreira et al., 2000). Acid phosphatase activity is high in forest soils dominated by a particular vegetation type (*Quercus pyrenaica* Wild.) with low soil acidity and rich organic matter. Plant phosphorus uptake is influenced by root density and hydrolysable organic matter (Huang et al., 2011). Root exudates affect soil microbial activity and also impact phosphatase activity and phosphate mineralization dynamics. Observations were made on forest soils vegetated with *Pinus radiata* compared to soils vegetated with *Lolium perenne*, resulting in significant differences (Hai-Ming et al, 2014).

MATERIALS AND METHODS

This research was conducted from July 2023 to November 2023. Soil sampling was carried out in the community mangosteen orchard of the Mangosteen Thematic Village in Limau Manis Subdistrict, Pauh District, Padang City. Soil sample analysis was conducted at the Soil Biology and Chemistry Laboratory, Department of Soil Science and Land Resources, Faculty of Agriculture, Andalas University.

The research method employed a survey approach with the determination of sampling points using purposive sampling based on cropping patterns (monoculture and polyculture) and slope classes (8-15%). Composite soil samples with three replications were taken and disturbed soil samples were collected using a soil

auger at depths of 0-20 cm and 20-40 cm. Thus, there were a total of 24 composite soil samples and 24 disturbed soil samples. The survey activities followed the guidelines outlined in the Technical Observation Field Guide by the Soil Research Institute in 2004.

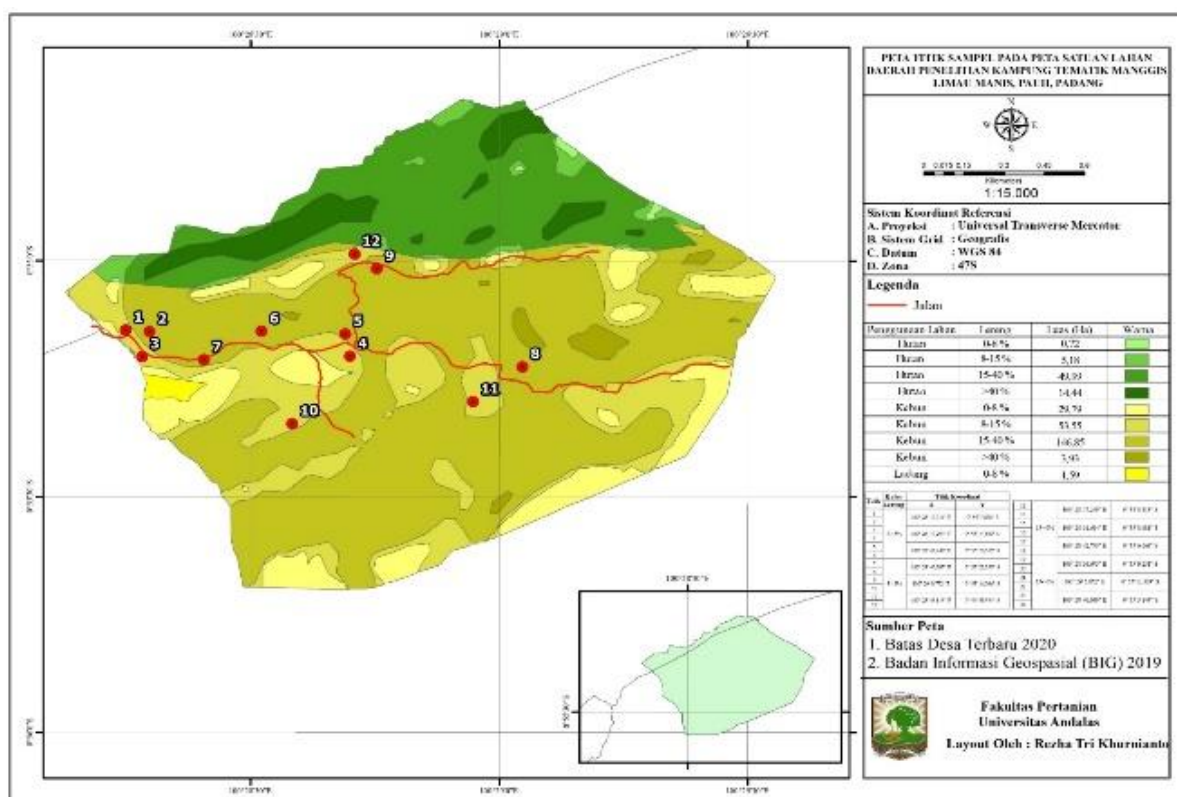


Figure 1. Map of sampling points on land units in Manggis Thematic Village in Pauh Padang District

Chemical and Biological Soil Characteristics Observed

The chemical soil characteristics observed include pH, Total P (extracted with HCl 25%), available P (Bray I), and organic C (Walkley and Black). Meanwhile, the biological soil characteristics include C-biomass (CFI-CFE), soil respiration (KOH absorption), acid and alkaline phosphatase activity (p-nitrophenolphosphate).

Data Processing

Data processing involved assessing the significance of the influence of mangosteen

planting patterns on the observed parameters through statistical analysis using the t-test at a significance level of 5%. Data obtained from laboratory analysis were then processed using Microsoft Excel.

RESULTS AND DISCUSSION

The pH values in the research area of the Mangosteen Thematic Village ranged from 5.21 to 5.45 (monoculture planting pattern) with criteria indicating acidity to slightly acidic soil. Soil pH is a crucial determinant of reactions occurring within the soil. Based on the T-test, the average soil pH did not show a significant depth-

related effect in the Mangosteen Thematic Village research location. No significant difference was found in pH values between the depths of 0-20 cm and 20-40 cm. However, the average soil pH at a depth of 20-40 cm tended to be higher than that at a depth of 0-20 cm. Nevertheless, other observed elements were lower in the 20-40 cm layer.

Table 1. Soil Chemical Characteristics in Monoculture and Polyculture Planting Patterns with a Slope of 8-15% in the Mangosteen Thematic Village

Depth	Monoculture	Polyculture
pH		
0-20 cm	5.29 a	5.23 a
20-40 cm	5.45 a	5.52 a
C-organic (%)		
0-20 cm	1.58 ab	1.59 b
20-40 cm	1.51 a	0.96 a
P-available (ppm)		
0-20 cm	8.47 a	11.41 a
20-40 cm	8.28 a	14.14 a
P-total (ppm)		
0-20 cm	31.34 a	34.93 a
20-40 cm	17.03 a	28.68 a

Note: Numbers in the table on the same row followed by the same lowercase letter are not significantly different according to the t-test, $p > 0.05$.

The t-test results indicate a significant influence of planting patterns (polyculture and monoculture) on soil organic C in the Mangosteen Thematic Village, as well as at different depths (Table 1). The findings suggest a notable change in soil organic C due to variations in planting patterns, impacting the soil organic C values in the research location. On average, soil organic C values at a depth of 0-20 cm are higher than at a depth of 20-40 cm for slope classes in the research area. This is attributed to the influence of vegetation litter in the upper soil layer, serving as a source of organic matter. Additionally, there is an accumulation of organic matter in the upper layer, specifically at a depth

of 0-20 cm. The presence of other plant roots, such as grasses and vegetation around the mangosteen plants, contributes root exudates containing organic acids, thereby affecting the organic C content. According to Li et al (2018), the organic matter content and soil microbial activity in soil generally decreases with increasing soil depth. The soil organic C values obtained in the Polyculture planting pattern are higher than those in the Monoculture pattern in the research area. This is influenced by the high organic matter contributed by diverse vegetation in the Polyculture planting pattern. The more varied vegetation in Polyculture cultivation produces more roots and litter, contributing more organic C to the soil. In line with Makoi et al. (2008), who stated that organic C increases with the increasing organic matter produced by vegetation. This phenomenon aligns with Burns (1978) statement that phosphatase activity is influenced by the organic C content, meaning an increase in organic C content will enhance phosphatase activity.

Based on the t-test, the average values of available P in the soil did not show a significant influence of planting patterns on available P values in the Mangosteen Thematic Village. The same result was found for soil depth, where there was no significant difference at depths of 0-20 cm and 20-40 cm for both planting patterns. Nevertheless, it is evident that the average available P values in the Polyculture planting pattern are higher than those in the Monoculture pattern. This demonstrates that vegetation influences the content of available P in the soil. The availability of P in the soil is strongly influenced by organic matter, which indirectly releases P from Fe and Al bonds in the soil (Stevenson and Cole, 1999). High available P is influenced by the activity of acid phosphatase enzymes. High phosphatase enzyme activity will result in high inorganic P in the soil, making more P available in the soil. Phosphatase plays a role in the mineralization of organic P into inorganic P, which is then absorbed and metabolized by plant root cells and soil microbes. The available P values in the Monoculture planting pattern are lower than those in the Polyculture pattern because of its lower

phosphatase enzyme activity.

The low available P values are due to several factors in the research area, including the low pH values ranging from 5.14 to 5.52 (acidic). As stated by Schreider et al (2001), available P in the soil is most affected by its availability due to soil pH. Low soil pH causes phosphate to react with iron and aluminum, forming iron phosphate and aluminum phosphate, which are poorly soluble in water and therefore unavailable to plants. Another factor contributing to low available P is the low organic matter content. In this study, the organic matter was found to be in the low category. According to Hai Ming et al., (2014), the low decomposition of organic materials in the soil can lead to a decrease in the availability of humus to supply available P.

Available P in the top 0-20 cm is lower than that in the depth of 20-40 cm. This is influenced by the soil pH value. Lower soil pH in the top 0-20 cm causes a decrease in P availability in the soil because phosphate reacts with iron and aluminum, which are poorly soluble in water and therefore cannot be used by plants. Phosphate in the form of orthophosphate acid with a negative charge will be fixed to form Al-P and Fe-P bonds (Sanchez, 1976).

Based on the t-test, the average values of total P in the soil did not show a significant influence of planting patterns on Total P values, both on slopes of 8-15% and 15-40% in the Mangosteen Thematic Village. The same result was found for soil depth, where there was no significant difference at depths of 0-20 cm and 20-40 cm for both planting patterns. This indicates that there is no significant change in total P in the soil with differences in planting patterns. This is in line with Helal (1990), who state that P in the soil can be classified into organic and inorganic P. Organic P comes from humus or other organic matter undergoing decomposition and releasing P into the soil solution. Inorganic compounds are found in various bonds with Al, Fe, Ca, and Mn, and these compounds are only slightly soluble in water. In general, inorganic P is always higher than organic P.

Based on the content of Total P and Available

P, it is known that in the polyculture planting pattern, the P content is lower compared to monoculture land use. This is because the polyculture planting pattern has diverse vegetation, so the source of available P nutrients through the decomposition of various plant residues is more varied compared to the monoculture planting pattern, which only has one type of plant, namely mangosteen in that land. The source of available P nutrients can come from minerals in the soil containing P and organic matter through the decomposition of plant residues, which is one of the nutrient sources in the soil. P nutrients will become available if they undergo mineralization through the activity of soil phosphatase enzymes (Schneider, et al., 2001).

Soil respiration values were found to be higher in the polyculture planting pattern compared to the monoculture pattern. The same result pattern was found at depths of 0-20 cm and 20-40 cm for both planting patterns. Nevertheless, it is evident that the average soil respiration values with the polyculture planting pattern are higher than those with the monoculture pattern. This is because the polyculture planting pattern has diverse vegetation such as mangosteen, durian, rambutan, cloves, and others, while the monoculture pattern only has mangosteen vegetation. The organic matter content in mangosteen plantation land varies, indicating that the percentage of organic matter is not the same in each soil layer, even when taken from the same location and soil type (Murni et al, 2020).

High soil respiration values in the polyculture planting pattern. This is due to the high organic matter content in the polyculture planting pattern compared to the monoculture pattern. Lakshmi et al (2015) explains that organic matter plays a role in providing substrates for decomposition processes involving soil fauna and microflora. Organic carbon compounds can be assimilated within microorganism cells or released in the form of metabolic products or CO₂ that will return to the atmosphere, so the higher the organic matter content in the soil, the higher the microorganism respiration tends to be. Decomposition in the soil occurs with the activity

of microorganisms, which are the drivers of soil respiration. The results of decomposition are partially used as an energy source by soil microbes. Based on the t-test in Table 2, the average soil microbial biomass C values in both polyculture and monoculture planting patterns in the Mangosteen Thematic Village showed a significant effect on soil depth, where there was a higher biomass C values at depths of 0-20 cm than to 20-40 cm. This indicates a significant influence of planting patterns on microbial biomass C values.

Biomass-C is a sensitive parameter to soil management activities. Measuring microbial biomass describes soil quality through the ongoing activities of soil microorganisms.

Based on the t-test in Table 2, the average activity values of soil acid phosphatase enzymes in both polyculture and monoculture planting patterns in Mangosteen Thematic Village showed a significant effect on soil depth, where there was a significant difference at depths of 0-20 cm compared to 20-40 cm for both planting pattern. This is in line with the statement by Helal (1990) that plants can survive in low P conditions by secreting phosphohydrolase (phosphatase) into the rhizosphere, which can convert organic phosphate into soluble inorganic phosphate, such as acid phosphate, in response to P deficiency.

Table 2. Soil Biological Characteristics in Monoculture and Polyculture Planting Patterns with a Slope of 8-15% in the Mangosteen Thematic Village

Depth	Monoculture	Polyculture
Soil respiration (mgCO ₂ /g soil/7 days)		
0-20 cm	8.28 a	9.95 b
20-40 cm	5.23 a	8.38 b
C-biomassa (µg C/g soil)		
0-20 cm	14.26 a	13.59 a
20-40 cm	11.69 a	14.88 a
Acid phosphatase (µmol pNP/g soil/hour)		

0-20 cm	1.88 a	3.98 b
20-40 cm	2.22 a	2.38 a
Alkaline phosphatase (µmol pNP/g soil/hour)		
0-20 cm	1.94 a	1.56 a
20-40 cm	2.53 a	1.56 b

Note: Numbers in the table on the same row followed by the same lowercase letter are not significantly different according to the t-test, $p > 0.05$.

In this study, it was found that the value of acid phosphatase enzyme activity is higher than alkaline phosphatase enzyme activity. Acid phosphatase in this study ranged from 1.9 to 4 µmol pNP/g soil/hour, while alkaline phosphatase ranged from 1.5 to 2.5 µmol pNP/g soil/hour. It is also known that acid phosphatase enzyme activity is more stable than alkaline phosphatase enzyme activity. Thus, in acidic soil conditions, acid phosphatase activity will dominate over alkaline phosphatase activity (Bandick and Dick, 1999). Stevenson and Cole (1999) stated that acid phosphatase works optimally at pH 4-6, while alkaline phosphatase works optimally at pH 9-11.

The soil acid phosphatase activity at a depth of 0-20 cm is higher than at a depth of 20-40 cm. It is because enzyme activity is maximum in the root zone. Root exudates released by the roots are needed by microbes as energy to produce enzymes. The analysis of the average alkaline phosphatase enzyme activity in various cultivation patterns and slopes of mangosteen plants in the Mangosteen Thematic Village shows that in polyculture patterns, is lower than the range in monoculture patterns. Upon examining the data based on soil depth we found at a depth of 0-20 cm, is lower than that at a depth of 20-40 cm for each cultivation pattern. This phenomenon is influenced by the absence of inputs provided by mangosteen farmers, resulting in lower enzyme activity in the upper layer of the soil. Moreover, the soil at a depth of 20-40 cm has a higher pH value (5.52), contributing to elevate alkaline phosphatase enzyme activity (Murni, 2021).

CONCLUSION AND RECOMMENDATIONS

The activity of acid phosphatase enzyme is higher, ranging from 1.9-4 $\mu\text{mol pNP/g soil/hour}$, than alkaline phosphatase, which ranges from 1.5-2.5 $\mu\text{mol pNP/g soil/hour}$ for both of planting pattern. The planting pattern has a noticeable impact on the dynamics of agricultural ecosystems and should be considered in land management practices to enhance productivity and soil ecosystem balance.

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