P status of Andisol and Its correlation with P content of Arabica coffee leaves in Bener Meriah District

Hifnalisa1*, A Karim1, Manfarizah1, Syakur1, A Sahar2 and T Sabrina2

1Soil Sciences Department, Universitas Syiah Kuala, Darussalam, Indonesia.
2Faculty of Agriculture, Universitas Sumatera Utara, Padang Bulan, Indonesia.

*Corresponding author’s email: hifnalisa@unsyiah.ac.id

Abstract. Bener Meriah district is one of the arabica coffee producing regions in Indonesia with an average production of 700-800 kg ha\(^{-1}\) year\(^{-1}\). Most of arabica coffee in this area are grown in Andisol. This study aims to determine the P status of Andisol, namely P-available, P-total, P-retention, P content of arabica coffee leaves and the correlation between soil P-available and P content of arabica coffee leaves in Bener Meriah district. This research was conducted using survey methods. The observed parameters were made on Andisol planted with arabica coffee which is located at an altitude of 1,200-1,400 m above mean sea level (AMSL) at slopes 0-3, 3-8, 8-15, 15-30, and >30% respectively. The results showed that Andisol Bener Meriah has a P-available ranging from 0.3 to 12.81 ppm (very low-high). Most of the Andisol observed (73.33%) had P-available at very low and low levels. Andisol Bener Meriah has a P-total ranging from 159.4 to 1,246.7 ppm (low-very-high). Most of the Andisol observed (73.33%) have P-total at moderate, high and very high levels. Andisol Bener Meriah has a P-retention ranging from 85.2 to 87.4%. Arabica coffee leaves have P content levels ranging from 0.10% to 0.23%. Most of the arabica coffee leaves (78.57%) were observed have P content at a minimum level.; there is a close relationship between soil P-available with P content of arabica coffee leaves with a value of \( r = 0.97 \).

1. Introduction

Aceh is the largest producer of arabica coffee in Indonesia. Bener Meriah Regency is one of the arabica coffee producing areas in Aceh with an average production of 700-800 kg ha\(^{-1}\) year\(^{-1}\) and with a planting area of around 39,533 ha [1]. The average production of arabica coffee in Bener Meriah is still low when compared to the potential production of arabica coffee which ranges from 3 tons ha\(^{-1}\) year\(^{-1}\) [2].

Most of arabica coffee in Bener Meriah Regency is grown in Andisol. Andisols are soil that have Andik soil properties \( \geq 60\% \) of soil thickness, low bulk density (< 0.90 g/cm\(^3\)), high water content, water availability for plants form medium to low, high water holding capacity and high total porosity [3]. Andisol are soil that developed from volcanic materials whose colloidal fraction is dominated by short-range order minerals (allophane, imogolite, halloysite, ferritic) or Al-humus complex [4, 5, 6]. This mineralogical association gives unique properties to such soils, including a high phosphate-fixing capacity, low cation retention, and a high water-holding capacity [5,6].

Andisol has many free Al-OH groups on the surface of all ophane which causes high P-retention
 (> 85%) and low P-available [6]. The high P-retention and low P-available in Andisol cause the soil is unable to supply the P nutrient for arabica coffee. Phosphorus (P) is a macronutrient that is very important for plant growth and production [7]. P element deficiency in plants will cause various obstacles in the process of metabolism [8].

P is a macronutrient that is needed for plant growth and production. P element deficiency in plants will cause various obstacles in the metabolic process, which results in stunted growth in the decline in plant production.

Coffee production in Bener Meriah can be increased by proper land management and coffee cultivation. Appropriate land management can be done by first knowing the resources contained in the land in order to empower these resources to be more optimal. The condition of Arabica coffee plantation land resources can be known by conducting research on soil nutrient status and nutrient content in arabica coffee leaves.

This study aims to determine the P status of Andisol namely P-available, P-total, P-retention and P content of arabica coffee leaves and the correlation between P-available soil and P nutrient content of arabica coffee leaves in Bener Meriah district. The results of this study are expected to be used as a reference in the recommendation of fertilizing arabica coffee in Bener Meriah for improving yield and quality of arabica coffee.

2. Methods
The study was carried out in an arabica coffee plantation in Bener Meriah Regency. This research was conducted using survey methods. Observations were made on Andisol planted with arabica coffee which is located at an altitude of 1200-1400 m AMSL respectively at slopes 0-3, 3-8, 8-15, 15-30, and >30%. Soil samples and coffee leaf samples were taken on each of these slopes from three different observation points.

Soil samples at each of these sample points were taken in a compositely using a ground drill. Soil samples were taken at the coffee root area at a depth of 0-30 cm at the four wind points [9]. Coffee leaf samples taken were taken just before the flowering season. Leaves picked are the third and fourth leaves on four branches representing the four winds [9].

The sample tree for soil sampling is the same as the sample tree for leaf sampling. The sample tree at each sample point is a 10-year-old healthy coffee tree. The location of the sample points is presented in Table 1.

Observations made were: 1) soil pH by electrode method [10], 2) P-available by Bray II method [10], 3) P-total by HCl extraction method [10], 4) P-retention by the Blakemore method [11], 5) P content of coffee leaves with H$_2$SO$_4$ wet extraction method [10]. The data obtained were analyzed descriptively.

3. Results and discussion
3.1. P status of Andisol in Arabica Coffee Plantations
Results of pH, P-available, P-total, P-retention analysis of Andisol can be seen in Table 2. Andisol at the study site has a pH ranging from 5.7 to 6.6 (slightly acidic-neutral). Most of Andisol (93%) has a slightly acidic pH, only one sample point (sample point 7) has a neutral pH. The pH situation at Andisol shows that there has been a leaching process of base cations on the soil due to high rainfall in the district of Bener Meriah. This is in accordance with the opinion of [12], which states that Andisol has an acidic to slightly acidic pH due to the presence of high alkaline leaching. The research location has high rainfall of 1,806.3 mm$^{-1}$year$^{-1}$ with the B type of climate (wet).

The P-available content ranges from 0.3 to 12.81 mg kg$^{-1}$ (very low to high). Most of the Andisol observed (73.33%) has very low and low P-available. Two sample points (13.33%) namely sample points 8 and 15 that have moderate P-available and two observation points (13.33%) namely observation points 1 and 7 have high P-available.
Andisol has a P-total ranging from 159.4 to 1,246.7 mg kg\(^{-1}\) (low-very high). Most of the Andisol observed (73.33\%) had P-total at moderate, high and very high levels. Only one observation point (6.67\%), namely observation point 7 which shows low P-total content.

Andisol in Bener Meriah has P-retention ranging from 85.2-87.4\%. The high P-retention (\(\geq 85\%\)) is one of the soil criteria classified into the Andisol order [3]. The high P-retention and low P-available in Andisol are due to the fact that Andisol is dominated by allophane. Andisol contain > 50\% allophane. Allophane with a Si / Al ratio of about 0.5 is highly reactive to phosphate [13, 14, 15]. The allophane surface has many free Al-OH groups [5,6]. The free Al-OH group can dissociate or undergo protonation so that it can be either acidic or basic. In the form of acid (\(\text{Al-OH}^+\)) on the surface of clay minerals, it has a high activity to bind anions, especially F\(^-\) and PO4\(^{3-}\) [16, 17].

**Table 1.** Location description of Andisol sample points and arabica coffee leaves in Bener Meriah Regency

| No. | Location | Geographical location | Slope (%) | Altitude (m AMSL) | Arabic coffee variety |
|-----|----------|-----------------------|-----------|-------------------|----------------------|
| 1.  | Kute Kering, Bukit | N 04°42'45.58" E 096°51'33.0" | 0-3 | 1,392 | Ateng Super |
| 2.  | Kute Kering, Bukit | N 04°42'42.8" E 096°51'33.6" | 0-3 | 1,387 | Tim-tim |
| 3.  | Kute Kering, Bukit | N 04°42'40.1 E 096°51'34.0" | 0-3 | 1,386 | Tim-tim |
| 4.  | Kute Lintang, Bukit | N 04°41'52.7" E 096°51'33.3" | 3-8 | 1,339 | Tim-tim |
| 5.  | Kute Lintang, Bukit | N 04°41'54.3" E 096°51'33.1" | 3-8 | 1,340 | Tim-tim |
| 6.  | Kute Lintang, Bukit | N 04°41'54.1" E 096°51'32.0" | 3-8 | 1,342 | Tim-tim |
| 7.  | Blang Sunteng, Bukit | N 04°42'24.6" E 096°53'00.8" | 8-15 | 1,351 | Tim-tim |
| 8.  | Blang Sunteng Bukit | N 04°42'23.7" E 096°52'59.9" | 8-15 | 1,353 | Tim-tim |
| 9.  | Blang Sunteng, Bukit | N 04°42'24.1" E 096°53'02.1" | 8-15 | 1,351 | Tim-tim |
| 10. | Bukit Mulie, Timang Gajah | N 04°46'12.1" E 096°46'33.9" | 15-30 | 1,253 | Tim-tim |
| 11. | Bukit Mulie, Timang Gajah | N 04°46'14.4" E 096°46'35.0" | 15-30 | 1,265 | Ateng Super |
| 12. | Bukit Mulie, Timang Gajah | N 04°46'13.3" E 096°46'36.6" | 15-30 | 1,275 | Tim-tim |
| 13. | Bukit Mulie Ds.III, Timang Gajah | N 04°46'27.0" E 096°46'44.8" | >30 | 1,333 | Tim-tim |
| 14. | Bukit Mulie Ds.III, Timang Gajah | N 04°46'25.5" E 096°46'43.2" | >30 | 1,331 | Ateng Super |
| 15. | Bukit Mulie Ds.III, Timang Gajah | N 04°46'24.8" E 096°46'42.4" | >30 | 1,324 | Ateng Super |

3.2. P Content of Arabica Coffee Leaves

The results of the analysis of nutrient levels of arabica coffee leaves can be seen in Table 2. The arabica coffee leaves have P levels ranging from 0.10% -0.23%. According to [18], the optimum levels of P content in coffee leaves ranges of 0.15-0.20%. Most of the coffee leaves (78.57\%) have P content at a minimum level. The low P content in coffee leaves is due to the low P-available in the soil. Only coffee leaves which were at observation locations 2 and 15 have P content at optimum levels, while coffee leaves that were at observation locations 1 and 7 have P content at maximum levels. The high level of P content in coffee leaves at these four locations is due to the high P-available in the soil.

Table 2 shows that the higher P-available in the soil, the higher P content levels in arabica coffee leaves. The high P-available in the soil causes the high ability of the soil to supply P nutrient for
arabica coffee which in turn causes high P content in arabica coffee leaves. The result of the correlation analysis showed there is a close relationship between P-available of soil with P content in arabica coffee leaves with a value of \( r = 0.97 \).

**Table 2.** P status of Andisol and P content of arabica coffee leaves

| No. | Location            | Soil pH | P-available (ppm) | P-total (ppm) | P-retention (%) | P content (%) |
|-----|---------------------|---------|-------------------|---------------|-----------------|---------------|
| 1   | Kute Kering, Bukit  | 5.8 SA  | 12.81 H           | 501.8 H       | 85.2            | 0.23          |
| 2   | Kute Kering, Bukit  | 6.4 SA  | 8.12 M            | 228.4 M       | 87.4            | 0.18          |
| 3   | Kute Kering, Bukit  | 6.1 SA  | 4.34 VL           | 491.8 H       | 85.3            | 0.10          |
| 4   | Kute Lintang, Bukit | 6.2 SA  | 0.30 VL           | 331.2 M       | 85.4            | 0.08          |
| 5   | Kute Lintang, Bukit | 6.5 SA  | 4.86 L            | 1,246.7 VH    | 86.2            | 0.13          |
| 6   | Kute Lintang, Bukit | 6.2 SA  | 4.63 L            | 1,240.8 VH    | 87.0            | 0.12          |
| 7   | Blang Sunteng, Bukit| 6.6 N   | 10.99 H           | 159.4 L       | 87.0            | 0.21          |
| 8   | Blang Sunteng, Bukit| 6.1 SA  | 2.04 VL           | 261.8 M       | 86.1            | 0.10          |
| 9   | Blang Sunteng, Bukit| 5.7 SA  | 4.49 L            | 287.1 M       | 86.4            | 0.13          |
| 10  | Bukit Mulie, Timang Gajah | 5.9 SA  | 4.20 VL           | 557.3 H       | 85.6            | 0.11          |
| 11  | Bukit Mulie, Timang Gajah | 6.1 SA  | 4.66 L            | 512.0 H       | 85.3            | 0.12          |
| 12  | Bukit Mulie, Timang Gajah | 5.8 SA  | 4.38 VL           | 690.9 H       | 86.4            | 0.10          |
| 13  | Bukit Mulie Ds.III, Timang Gajah | 5.9 SA  | 3.41 VL           | 221.2 M       | 87.0            | 0.10          |
| 14  | Bukit Mulie Ds.III, Timang Gajah | 6.0 SA  | 4.21 VL           | 551.8 H       | 86.4            | 0.12          |
| 15  | Bukit Mulie Ds.III, Timang Gajah | 6.2 SA  | 7.66 M            | 223.1 M       | 86.5            | 0.16          |

Keterangan: SA : slightly acidic  
L : low  
N : neutral  
VL : very low  
H : high  
M : moderate  
VH : very high

**4. Conclusions**

Andisol Bener Meriah has a P-available ranging from 0.3 to 12.81 mg kg\(^{-1}\) (very low-high). Most of the Andisol observed (73.33%) had P-available at very low and low levels. Andisol Bener Meriah has a P-total ranging from 159.4 to 1,246.7 mg kg\(^{-1}\) (low-very-high), most of the Andisol observed (73.33%) have P-total at moderate, high and very high levels. Andisol Bener Meriah has a P-retention ranging from 85.2 to 87.4%. Arabica coffee leaves have P content levels ranging from 0.10% to 0.23%. Most of the arabica coffee leaves (78.57%) were observed have P content at a minimum level. There is a close relationship between P-available soil and P content of arabica coffee leaves (\( r = 0.97 \)).

**References**

[1] Dinas Pertanian dan Pangan Bener Meriah 2018 Laporan Tahunan Dinas Pertanian dan Pangan Bener Meriah
[2] Pusat Penelitian dan Pengembangan Perkebunan 2014 Varietas Unggul Kopi Arabika
[3] Soil Survey Staff 2014 Keys To Soil Taxonomy 12th Edition United States Departement of Agriculture-Natural Resources Conservation Service Washington DC.
[4] Kapur S 2010 Andosols University of Çukurova Departments of Soil Science and Archaeometry, Adana, Turkey
[5] Eswaran and Reich P F 2005 World Soil Map Encyclopedia of Soils in the Environment Reference Module in Earth Systems and Environmental Sciences Elsevier
[6] Georges S, Sedov S, Shoba S 2018 Regoliths and Soils on Volcanic Ash Interpretation of Micromorphological Features of Soils and Regoliths 2nd Edition Elsevier
[7] Richardson A E and Simpson R I 2011 *Plant Physol.* **156** 989-996
[8] Mengel K and Kirkby E A 2001 Principles of plant nutrition 5th Edition (Dordrecht: Kluwer Academic Publishers)
[9] Mawardi S, Hulupi R, Wibawa A, Wiryadiputra S dan Yusianto 2008 Panduan Budidaya dan Pengolahan Kopi Arabika Gayo Pusat Penelitian Kopi dan Indonesia.

[10] [DAR] Department of Agricultural Research 1983 Analytical Methods of Service Laboratory for Soil, Plant and Water Analysis Royal Tropical Institute (Amsterdam: Maurritskade)

[11] Blakemore L C, Searle P L, and Daly B K 1987 Methods for Chemical Analysis on Soils 2nd Edition (New Zealand: NZ Soil Bureau Scientific Report)

[12] Tan K H 1984 Andosols A Hutchinson Ross Benchmark Book Van Nostrand Reinhold Company

[13] Fiantis D, Hakim N, and Van Ranst E 2005 J. Integrated Field Sci. 2 29-37.

[14] Pizarro C, Fabris J D, Stucki J W, Garg V K, Galindo G  2008 J. Chil. Chem. Soc. 53 1581-1584

[15] Elsheikh M A, Matsue N, and Henmi, T 2009 Int. J. Soil Sci. 4 1-13

[16] Parfitt R L 1978 Advances Agronomi 30 1-5

[17] Parfitt R L and Saigusa M 1985 Soil Sci. J. 139 149-155

[18] Winston E, de Laak J O, Marsh T, Lempke H, and Chapman K 2005 Arabika Coffee Manual for Lao PDR FAO Regional Office for Asia and Pacific Bangkok, Thailand.