Evaluation of Soil Characteristics on Coffee Land in Sinjai Regency, South Sulawesi

A. Assa*, Jamilah Jamilah, A. Pratama, R. Wahyudi, Mamang, A.N. Amalia, and D. Indriana

Balai Besar Industri Hasil Perkebunan, Kementerian Perindustrian, Jl. Prof. Dr. Abdurahman Basalamah No. 28
Makassar, South Sulawesi, Indonesia, 90231

*Corresponding author. E-mail: asmaassa209bbihp@gmail.com

ABSTRACT
The soil chemical properties were important factors influencing growth, productivity, quality, and coffee flavour. The research aimed to evaluate the soil characteristics of coffee land at different growing altitudes in Sinjai Regency, South Sulawesi. The soil samples were collected in June 2019, within the canopies of the coffee tree to the depth of 15 and 30 cm at each of 1200 m a.s.l. (Botolempangan village) and 1400 m a.s.l. (Balakia village) for Arabica coffee, while Robusta coffee at an altitude of 700 m a.s.l. (Arabika village). Preparation and analysis of the soil samples were conducted at the Laboratory of Chemical and Microbiological Testing, Center for Plantation Based Industry, in Makassar. The result showed that soil properties such as pH, C-organic, N-total, C/N ratio, Cation Exchange Capacity, texture and particle size of soil different for each altitude of the coffee land.

Keywords: Sensory, Chemical, Arabica Coffee, Sinjai Regency, Altitude

1. INTRODUCTION

Coffee is a plantation commodity that has an important contribution to the national economy. Indonesia is the third-largest producer and exporter of coffee, after Brazil (32.54%) and Vietnam (14.98%), which is 7.86% of the total world coffee production [1]. Coffee types are known to have economic value and are commercially traded, namely Arabica coffee and Robusta coffee.

Geographical conditions greatly affect the place to grow both types of coffee. Arabica coffee (Coffee arabica) grows maximally at an altitude of 1000-2000 m a.s.l. with rainfall ranging from 1200-2000 mm/year. The most suitable environmental temperature for this plant ranges from 15-24°C. Robusta coffee (Coffee canephora) comes from the word 'robust' which means strong, strong levels of thickness. Robusta coffee can grow in the lowlands, but the best location for cultivating this plant is at an altitude of 400-800 m a.s.l. The optimal temperature for growth of Robusta coffee ranges from 24-30°C with rainfall from 2000 to 3000 mm/year [2].

In South Sulawesi, one of the coffee-producing centres is located in the southern highlands region of the Sinjai Regency. Manipi is the capital of the West Sinjai sub-district, located at an altitude of around 900-1500 m a.s.l. Sinjai Regency has rainfall ranging from 2000-4000 mm/year, with rainy days varying between 100-160 rainy days/year. The average air humidity ranges from 64-87% with an average air temperature ranging from 21.1°C - 32.4°C [3].

In addition to environmental factors, among others, differences in altitude of the growing place, the characteristics of climatic elements such as temperature, humidity, and light intensity, the condition of the plantation soil are very important for the growth of coffee plants. The interaction between climatic elements with soil conditions and other cultivation factors will cause differences in the growth and yield of coffee to be obtained. According to [4], the chemical properties of soil can affect coffee productivity. If coffee plants...
experience a deficiency of one of the nutrients they need can result in nutrient deficiency and inhibition of the growth and production of coffee so that the productivity of coffee plants is not optimal. The research aimed to evaluate the soil characteristics of coffee land at different growing altitudes in Sinjai Regency, South Sulawesi.

2. MATERIALS AND METHODS

2.1. Soil sampling

Soil samples were randomly collected from each the selected location in June 2019. The soil samples were collected within the canopies of the coffee tree to the depth of 15 and 30 cm at each of 1200 m a.s.l. (Botolempangan village) and 1400 m a.s.l. (Balakia village) for Arabica coffee, while Robusta coffee at an altitude of 700 m a.s.l (Arabika village).

2.2. Soil preparation for analysis

The composite soil samples were crushed, air dried, and then ground and sieved through 2 mm. The 2 mm sieved soil samples were used for the determination of total nitrogen by the micro Kjeldahl method, organic carbon determined by the wet digestion (oxidation) method of Walkley-Black, Cation exchange capacity (CEC) was determined by the ammonium acetate (CH3COONH4) saturation method, while the determination of exchangeable Ca, Mg, K, and Na were by atomic absorption spectrophotometer [5], soil pH was measured electrometrically in 1:2.5 (weight/volume) soil: water suspensions, particle size analysis using gravimetry methods.

Preparation and analysis of the soil samples were conducted at Laboratory of Chemical and Microbiological Testing, Center for Plantation Based Industry, in Makassar, South Sulawesi.

3. RESULT AND DISCUSSION

Physical chemistry characteristics of the soil on coffee land differ for each altitude. The results of soil analysis in the land of Arabica coffee are presented in Table 1.

The results of the analysis showed that the pH values on the land of Arabica coffee varied between 5.84-6.24. The pH value at an altitude of 1200 m a.s.l is 5.84 (15 cm) and 5.84 (30 cm), while the altitude of 1400 m a.s.l. is 6.24 (15 cm) and 6.18 (30 cm). The pH value tends to increase with increasing altitude. One of the contributing factors is higher soil organic matter content at an altitude of 1400 m a.s.l. compared to 1200 m a.s.l. (Table 1). Organic matter can increase soil pH, whose value depends on the quality of organic matter [6]. In addition, the increase in pH is due to the decomposition process of various types of organic matter to produce alkaline cations. The maximum soil acidity (pH) for growth and production and quality of Arabica coffee is 5.8 - 6.2 [7]. In general, the plantation in the research location is suitable for the development of Arabica coffee.

Soil acidity is linearly related to base saturation, if base saturation is low then base cations will decrease and be replaced by H+ ions so that the soil pH will decrease. The acidity will decrease and fertility will increase with increasing base saturation. The rate of release of absorbed cations for plants depends on the level of base saturation.

Organic matter (organic-C) is higher with increasing altitude. The highest organic C is obtained at an altitude of 1400 m asl. This is because decomposition runs slowly due to low temperatures so that organic C accumulates in the soil [8]. The percentage of organic C and organic matter indicating the mineralization of nutrients and the ability of the soil to hold nutrients cations, structural stability and water holding capacity [9].

Organic matter is an energy source for microorganisms to form their bodies. According to Marvelia et al., 2006, due to the binding of N by microorganisms (immobilization of N), the plant will lack N elements. The higher the value of the C/N ratio, the greater the lack of element N. In line with the results obtained that at an altitude of 1400 m a.s.l. the highest C/N ratio is 18.78% with the lowest N value of 0.18%.

Organic C is very important for the ability of the soil to maintain soil fertility and productivity through the activity of soil microorganisms. Soil organic matter is a central element in soil fertility, land productivity and quality [10] because it plays an important role in creating fertile soil conditions. Organic matter is also a major source of humus colloidal formation [4].

In a natural system, topsoil is commonly the upper 12-18 cm of the soil profile. They contain high amounts of organics matter, nutrients, water and microbes relative to subsoils. This is indicated at an altitude of 1400 m a.s.l. with a depth of 15 cm obtained by the highest organic matter. Topsoil properties such as high levels of organic and stable aggregates will help increase nutrient retention [11] and improve drainage [12]. Topsoil is also the main zone of root distribution [11].

The cation exchange capacity (CEC) value of the soil is positively correlated with the altitude of coffee land. The highest CEC value was obtained at an altitude of 1400 m a.s.l. i.e. 4.80 me/100g (15 cm) and 5.78 me/100g (30 cm). The higher altitude of coffee land will cause a higher CEC value. This is because the vegetation density is also getting bigger so that it contributes more organic matter [9]. Organic colloids
also have a greater cation capacity than clay colloids so that the addition of organic matter to the soil can increase the CEC value of soil [6]. According to [13], the fine-textured soils usually have greater exchange capacity than course-textured soils due to a higher proportion of colloids.

The CEC values at an altitude of 1400 m a.s.l. are higher than the altitude of 1200 m a.s.l. and supported by a neutral pH will be able to absorb and provide nutrients better than soils with low CEC [14].

The basic contents of cations (K, Ca, and Mg) on the coffee land area of the Sinjai district are suitable for Arabica coffee plants. The critical limits of nutrients K, Ca, and Mg in the soil for coffee plants are 0.4; 0.89; 0.8 cmol/kg [15].

Calcium (Ca) is one of the nutrients in the form of cations that are included in the macronutrients of plants and it’s very important for plants because they can function as a constituent of cell walls and maintain cell elasticity [16]. Calcium availability is related to soil CEC and concentrations of other cations as they compete with Ca$^{2+}$ for exchange sites, reducing the overall availability of Ca. This competition usually occurs when an excessive amount of Ca$^{2+}$ is present [17].

The highest Ca content is obtained at an altitude of 1200 m a.s.l. with a depth of 15 cm (77.39 mg/kg).

The basic contents of cations (K, Ca, and Mg) on the coffee land area of the Sinjai district are suitable for Arabica coffee plants. The critical limits of nutrients K, Ca, and Mg in the soil for coffee plants are 0.4; 0.89; 0.8 cmol/kg [15].

Calcium (Ca) is one of the nutrients in the form of cations that are included in the macronutrients of plants and it’s very important for plants because they can function as a constituent of cell walls and maintain cell elasticity [16]. Calcium availability is related to soil CEC and concentrations of other cations as they compete with Ca$^{2+}$ for exchange sites, reducing the overall availability of Ca. This competition usually occurs when an excessive amount of Ca$^{2+}$ is present [17].

The highest Ca content is obtained at an altitude of 1200 m a.s.l. with a depth of 15 cm (77.39 mg/kg).

Calcium (Ca) is one of the nutrients in the form of cations that are included in the macronutrients of plants and it’s very important for plants because they can function as a constituent of cell walls and maintain cell elasticity [16]. Calcium availability is related to soil CEC and concentrations of other cations as they compete with Ca$^{2+}$ for exchange sites, reducing the overall availability of Ca. This competition usually occurs when an excessive amount of Ca$^{2+}$ is present [17].

The highest Ca content is obtained at an altitude of 1200 m a.s.l. with a depth of 15 cm (77.39 mg/kg).

Calcium (Ca) is one of the nutrients in the form of cations that are included in the macronutrients of plants and it’s very important for plants because they can function as a constituent of cell walls and maintain cell elasticity [16]. Calcium availability is related to soil CEC and concentrations of other cations as they compete with Ca$^{2+}$ for exchange sites, reducing the overall availability of Ca. This competition usually occurs when an excessive amount of Ca$^{2+}$ is present [17].

The highest Ca content is obtained at an altitude of 1200 m a.s.l. with a depth of 15 cm (77.39 mg/kg). Calcium affects the productivity and flavour of the coffee. According to [18], the higher Ca content will affect productivity and the better flavour of the coffee.

As a secondary macronutrient, Mg is also very important in soil and plants. Magnesium functions as a constituent of chlorophyll which is involved in various plant enzyme systems [16]. The highest Mg content is obtained at an altitude of 1200 m a.s.l. with a depth of

---

### Table 1. Characteristics of the composite soil sample inland of Arabica coffee

| Soil Characteristics | Land of Arabica coffee | Land of Arabica coffee |
|----------------------|------------------------|------------------------|
|                      | Altitude of 1200 m a.s.l. | Altitude of 1400 m a.s.l. |
|                      | Depth 15 cm      | Depth 30 cm      | Depth 15 cm | Depth 30 cm |
| pH (H2O)             | 5.96             | 5.84             | 6.24         | 6.18         |
| Organic-C (%)        | 0.89             | 1.16             | 3.38         | 1.36         |
| Total-N (%)          | 0.42             | 0.25             | 0.18         | 0.18         |
| C/N                  | 2.12             | 4.64             | 18.78        | 7.56         |
| Kalium (K2O) (mg/kg) | 13.60            | 58.44            | 8.47         | 3.74         |
| Base saturation (%)  | 3.37             | 1.44             | 0.87         | 0.63         |
| Exchangeable bases (mg/kg) |             |                  |              |
| Ca                   | 77.39            | 42.13            | 52.60        | 8.80         |
| Mg                   | 1200             | 400              | 300          | 300          |
| K                    | 11.28            | 48.49            | 7.03         | 3.11         |
| Na                   | 101.11           | 49.81            | 58.12        | 48.94        |
| Total                | 1389.78          | 540.44           | 417.7        | 360.85       |
| Cation Exchange Capacity (me/100g) | 4.12 | 3.76 | 4.80 | 5.78 |
| Soil Characteristics | Land of Arabica coffee | Land of Arabica coffee |
|                      | Altitude of 1200 m a.s.l. | Altitude of 1400 m a.s.l. |
|                      | Depth 15 cm      | Depth 30 cm      | Depth 15 cm | Depth 30 cm |
| Texture              |                   |                  |              |
| Sand (%)             | 13.14            | 12.46            | 14.13        | 2.99 9.46 |
| Silt (%)             | 5.77             | 23.78            | 50.14        | 26.16        |
| Clay (%)             | 22.67            |                  |              |
| Particle size 2-5 mm (%) | 27.24 | 21.70 | 53.32 | 32.81 |

m a.s.l. is meters above sea level
In the 2+ photosynthesis process, Mg acts as a building block of chlorophyll, which makes leaves appear green. Magnesium ion also facilitates energy transfers in photosynthesis [19].

Table 2. Characteristics of the composite soil sample in the land of Robusta coffee

| Soil Characteristics | Land of Robusta coffee | Altitude of 700 m a.s.l. | Depth 15 cm | Depth 30 cm |
|----------------------|------------------------|-------------------------|------------|------------|
| pH (H2O)             |                        |                         | 5.84       | 5.98       |
| Organic-C (%)        |                        |                         | 1.03       | 0.53       |
| Total-N (%)          |                        |                         | 0.09       | 0.14       |
| Kalium (K2O) (mg/kg) |                        |                         | 119.32     | 118.32     |
| C/N                  |                        |                         | 11.44      | 3.79       |
| Base saturation (%)  |                        |                         | 0.94       | 1.74       |
| Exchangeable bases   |                        |                         | 0.94       | 1.74       |
| Ca                   |                        |                         | 400        | 400        |
| Mg                   |                        |                         | 48.57      | 62.82      |
| K                    |                        |                         | 630.71     | 611.87     |
| Na                   |                        |                         | 630.71     | 611.87     |
| Cation Exchange Capacity (me/100g) | 6.50 | 3.51 |
| Texture              |                        |                         | 8.51       | 7.15       |
| Sand (%)             |                        |                         | 23.15      | 24.86      |
| Silt (%)             |                        |                         | 41.96      | 43.86      |
| Clay (%)             |                        |                         | 35.90      | 29.83      |
| Particle size 2-5 mm (% |                        |                         |            |            |

Lack of Mg elements will encourage leaf fall so that it has a direct effect on chlorophyll synthesis, phytochemical reactions, and stomatal functions, consequently, the growth of coffee plants is hampered [20].

The highest K content is obtained at an altitude of 1200 m a.s.l. with a depth of 30 cm (49.81 mg/kg). Potassium element plays an important role in the synthesis of protein, carbohydrates, and adenosine triphosphate (ATP), regulation of osmotic pressure, and tolerance to pests and diseases through the effects of resistance and permeability of plasma membranes [21]. In addition, the K element also plays a role in the reproduction of coffee plants, especially in yield and seed size [22], determines the quality of flavour by activating the polyphenol oxidase enzyme and determining the caffeine and phenol content in coffee beans [22], [23].

Sodium ions (Na+) are not essential nutrients, but the presence of these ions in the soil needs attention. Good soil is a soil containing low Na or <1.0 cool/kg) because if the concentrations of Na ion is high, it will adversely affect the soil and plants [24].

The highest Na content is obtained at an altitude of 1200 m a.s.l. with a depth of 15 cm (101.11 mg/kg).

In this study, the highest macronutrient content on average was obtained at an altitude of 1200 m a.s.l. compared to 1400 m a.s.l. It is suspected that the Arabica coffee landa at an altitude of 1200 m a.s.l. is include in the category of Plantation that get good cultivation treatment.

The results of soil analysis in the land of Robusta coffee are presented in Table 2. Robusta coffee can grow in the lowlands, but the best location for cultivating this plant is at an altitude of 400-800 m a.s.l. In this study, the pH values on the land of Robusta coffee at an altitude of 700 m a.s.l. varied between 5.84 (15 cm) and 5.98 (30 cm), there are similarities in the pH value of Arabica coffee with an altitude of 1200 m a.s.l.

4. CONCLUSION

In general, the soil properties on Robusta coffee plantations has a lower value compared to Arabica coffee, except for the Mg and K elements. The highest Mg on Robusta coffee land is 400 mg/kg, equal to the depths of 15 and 30 cm. For the K element is found the highest value at a depth of 30 cm is 68.08 mg/kg. The highest macronutrient content on average was obtained at an altitude of 1200 m a.s.l. compared to 1400 m a.s.l. It is suspected that the Arabica coffee land at an altitude of 1200 m a.s.l. is categorized of plantations a good cultivation.

REFERENCES

[1] Pusat Data dan Informasi Pertanian. Outlook Kopi 2015 epublikasi.setjen.go.id.
[2] F. Agus, M.V. Noordwijk, G. Garrity. 2001 Technical and Institutional Innovations for
Environmentally Sustainable Agriculture. International Center for Research in Agroforestry, Bogor.

[3] Buku Putih Sanitasi (BPS) Kabupaten Sinjai 2012 www.ppsp.nawasis.info

[4] H.E. Supriadi, Randriani, J. Towaha 2017 Correlation between altitude, soil chemical properties, and physical quality of arabica coffee beans in highland areas of Garut.

[5] AOAC, Official Methods of Analysis 999.10. 2012.

[6] Y. Nazari, A. Soemarno, L. Agustina. 2012 Pengelolaan kesuburan tanah pada pertanaman kentang dengan aplikasi pupuk organik dan anorganik. *Indonesian Green Techn. J.*, 1 (1): 712.

[7] G. Maro, B. Msanya, J. Mrema. 2014 Soil fertility evaluation for coffee (*Coffea arabica*) in Hai and Lushoto Districts, Northern Tanzania. *Intl. J. Plant Soil Sci.*, 3 8, 934-947.

[8] DL. Rowell. Soil Science Methods and Applications, UK, London 1994 1: 153,176,256,259,278.

[9] N.P. Sari, T.L. Santoso, S. Mawardi, S 2013 Sebaran tingkat kesuburan tanah pada perkebunan rakyat kopi Arabika di dataran tinggi Ijen-Raung menurut ketinggian tempat dan tanaman penaung. *Petita Perkebunan* 29 (2): 93 – 107. [in Bahasa].

[10] J.C. Katyal, N.H. Rao, M.N. Reddy. 2001. Critical aspects of organic matter management in the Tropics: the example of India. Nutrient Cycling in Agroecosystems.

[11] N.C. Brady. 1990 The nature and properties of soils. 10th ed. Macmillan Publishing Company, New York City.

[12] W.K. Clatterbuck, D.C. Fare 2016 Identification of and corrective action for poorly drained soils in the landscape. 2009. In Texas A&M Agrilife Extension: Tree Care Kit.

[13] A. McCauley, C. Jones, J. Jacobsen 2005 Soil and water management module 1: basic soil properties. Montana State University Extension Service, Bozeman.

[14] H. Soewandita. 2008 Studi kesuburan tanah dan analisis kesesuaian lahan untuk komoditas tanaman perkebunan di kabupaten Bengkalis. *J. Sains Teknol. Indonesia*, 10 (2) 128 - 133 [in Bahasa].

[15] C.I. Iloyanomon, M. A. Daniel, P.E Aikpokpodion. 2011 Soil fertility evaluation of coffee (*Coffea canephora*) plantations of different ages in Ibadan, Nigeria. *J. Soil Nature*, 5(1): 17 21.

[16] K. Mengel, E.A. Kirkby. 2007 Principles of Plant Nutrition. Inter. Potash Inst. WorblaufenBern, Switzerland.

[17] D. Rosen, 1992 The chemistry of tea. In TEA: Cultivation to Consumption. K.C. Willson and M.N. Clifford (ed). Springer Science+Business Media, Dordrecht, Netherlands.

[18] S.A. Silva, J.S.S. Lima, E.L. Bottega, 2013. Yield mapping of Arabic coffee and their relationship with plant nutritional status. *J. Soil Sci. Plant Nutrition*, 13 (3): 556 – 564.

[19] K. Brown, J. Lemon 2016 Fact Sheets Cations and Cation Exchange Capacity. Retrieved Oct. 10th, 2016. http://www.soilquality.org.au/factsheets/cation-exchange-capacity.

[20] D.M. Da Silva, L.R. Brandão, J.D. Alves, M.O. de Santos, K.R.D. de Souza, H.R.O. de Silveira. 2014 Physiological and biochemical impacts of magnesium-deficiency in two cultivars of coffee. *Plant and Soil*, 382 (1): 133 -150.

[21] W.M. Moura, Y.J.B. Soares, A.T.A. Júnior, P.C. de Lima., H.E.P Martinez., G.A. Amaral, Gravina 2015 Genetic diversity in arabica coffee grown in the potassium-constrained environment. *Ciênc. Agrotec.*, Lavras, 39 (1): 23 - 31.

[22] J.M. Clemente, H.E.P. Martinez, L.C. Alves, M.C.R. Lara, 2013 Effect of N and K doses in nutritive solution on growth, production and coffee bean size. *Rev. Ceres, Viçosa*, 60 (2), 279 - 285.

[23] J.M. Clemente, H.E.P. Martinez, L.C. Alves, F.L. Finger, P.R. Cecon. 2015 Effects of nitrogen and potassium on the chemical composition of coffee beans and beverage quality. *Maringá*, 37 (3): 297 - 305.

[24] D. Foth. 2010 Fundamentals of Soil Science. John Wiley and Sons, New York.

[25] D.C. Ferreira, J.A.R. de Souza, R.O. Batista, C.M.M. Campos, M.T.A. Matangue, D.A. Moreira. 2011 Nutrient inputs in soil cultivated with coffee crop fertigated with domestic sewage, Revista Ambiente and Água - An Interdisciplinary. *J. Applied Sci.*, 6 (3): 77 - 85.

[26] Z. Jouyban. 2012 The effects of salt stress on plant growth. *Tech. J. Engin. App. Sci.*, 2(1): 7 -10.