

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

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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 (*Coffea 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 (*Coffea 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 ($\text{CH}_3\text{COONH}_4$) 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

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

Soil Characteristics	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 (H ₂ O)	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 (K ₂ O) (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			
	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	2.56 9.11
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

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 coarse-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 Ca²⁺ for exchange sites, reducing the overall availability of Ca. This competition usually occurs when an excessive amount of Ca²⁺ 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

15 cm (1200 mg/kg). 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 (H ₂ O)	5.84	5.98
Organic-C (%)	1.03	0.53
Total-N (%)	0.09	0.14
Soil Characteristics	Land of Robusta coffee	
	Altitude of 700 m a.s.l.	
	Depth 15 cm	Depth 30 cm
C/N	11.44	3.79
Kalium (K ₂ O) (mg/kg)	58.53	82.04
Base saturation (%)	0.94	1.74
Exchangeable bases (mg/kg)	119.32	85.37
Ca	400	400
Mg	48.57 62.82	68.08 58.42
K	630.71	611.87
Na		
Total		
Cation Exchange Capacity (me/100g)	6.50	3.51
Texture		
Sand (%)	8.51	7.15 24,30
Silt (%)	23.15	43.86
Clay (%)	41.96	
Particle size 2-5 mm (%)	35.90	29.83

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). Although high Na content can increase soil salinization so that it can result in reduced coffee production [25], if there is sufficient Ca, plants will be protected from stress due to Na elements. This condition is suitable for coffee plants [26].

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 ciltivation 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.

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