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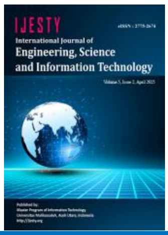

# Analysis of Glyphosate Herbicide Residues in Coffee Plantations in Bener Meriah Regency

**Dedi Suheri*, Nasruddin, Ismadi, Jamidi, Baidhawi**

*Department of Master of Agroecotechnology, Faculty of Agriculture, Universitas Malikussaleh, Aceh, Indonesia*

**Corresponding author Email: dedi.215411101008@mhs.unimal.ac.id*

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## Abstract

Coffee is a leading plantation commodity as it serves as a source of income for farmers, provides raw materials for industries, creates job opportunities, and promotes regional development in Bener Meriah Regency. To achieve optimal production results, farmers must adequately manage and maintain their coffee plantations, one way being the reduction of chemical usage that may affect the coffee beans. The negative impact of excessive chemical use includes rejecting exports to several European countries due to residue levels exceeding the limits set by European Union regulations. Therefore, analyzing herbicide residues and studying the factors affecting their persistence is necessary. Sampling was conducted in five sub-districts: Gajah Putih, Bandar, Permata, Timang Gajah, and Bukit, by collecting soil and bean samples from five points in each sub-district for analysis using gas chromatography. The research showed glyphosate residue levels of 0.002 mg/kg in each soil and bean sample. These levels are considered low compared to the maximum residue limit (MRL) for coffee, which is 0.1 mg/kg. This indicates that glyphosate residue contamination in the sampled plots is considered safe for consumption. Observations and interviews with farmers concluded that the low residue levels in the soil samples were influenced by several factors, including climate (temperature, humidity, rainfall), soil characteristics, topography, herbicide characteristics, and weed types.

***Keywords***: *Glyphosate Herbicide Residues, Coffee, Plantations, Raw Materials, Industries*.

## 1. Introduction

Coffee plants are a plantation commodity with significant domestic and international market opportunities and an export crop that can increase regional and state income sources [1]. Bener Meriah Regency is one of the areas that produces superior coffee, better known as Gayo coffee. To be able to increase good production results, farmers must carry out reasonable maintenance. One way is to reduce the use of chemicals affecting coffee beans.

The negative impact of using chemicals is the rejection of exports abroad due to the maximum residue limit (MRL) set exceeding the threshold. According to the Head of the Bener Meriah Regency Agriculture and Food Service, the European Union regulations that have been set for glyphosate content in consumption ingredients are 0.1 mg/kg. Therefore, farmers must limit and reduce the use of chemicals to maintain coffee plants so that export activities are no longer disrupted and coffee prices remain stable [2].

Glyphosate has systemic properties that can enter plant tissue through absorption by plant roots and penetrate stomata. Herbicides that fall to the ground will be adsorbed by soil particles, absorbed by plant roots, degraded or carried into the groundwater. Continuous use of herbicides can negatively affect the environment and non-target organisms [3] [4]. Therefore, herbicide residues in soil and coffee beans need to be analyzed as an essential reference for herbicide residue levels in coffee plantations and their persistence in the soil.

This study aimed to determine the levels of glyphosate herbicide residues in soil and beans in Bener Meriah Regency Coffee Plantations.

## 2. Research Methods

This research was conducted from September to October 2024 in Bener Meriah Regency in five sub-districts, namely Gajah Putih, Bandar, Permata, Timang Gajah and Bukit, by taking soil and seed samples from coffee plantations owned by farmers at 5 points per sub-district to be tested in the Organic Chemistry Laboratory of the Faculty of Mathematics and Natural Sciences (MIPA) Syiah Kuala University.

The tools for taking soil samples include hoes, bayonet knives, meters, markers, scales, stationery, cameras, and GPS. Meanwhile, the materials to be used in the study include soil samples, plastic bags, aluminium foil, plastic wrap, 29 x 39 cm envelopes, cotton, tissue, and labels.

The research data was obtained by surveying five plots of soil and seed sample locations in each sub-district. Samples obtained from the soil and seeds from the field were then taken to the laboratory and analyzed using gas chromatography (GC). The sample was extracted, and then the mixture of components that had been extracted was carried by the carrier gas into the column, so separation occurred. The results of the residue will later be compared with the Maximum Residue Limit (MRL) of herbicides that can still be tolerated.

Determination of the concentration of herbicide residues is calculated using the formula according to the formula from the Pesticide Commission (2006):

$$Residu\ (R) = Ac \times Ks \times FP/As \times Bc \quad \text{.......}(1)$$

Description:
R: Residue concentration (ppm) Ac: Sample area
As: Standard area
Ks: Standard concentration (ppm) FP: Dilution factor (ml)
Bc: Sample weight (g)

## 3. Result and Discussion

### 3.1. Glyphosate residues in soil samples

The results of herbicide residue testing, namely Glyphosate, in soil and coffee plantation beans taken in five sub-districts were carried out using gas chromatography. The chromatography used in this study is a chemical analysis for the separation and analysis of herbicide residues found in soil and coffee bean samples. Typical uses of GC include testing certain compounds' purity or separating different components in a mixture. The results of herbicide residue levels in the soil are shown in Table 1.

Based on Table 1 above, gas chromatography analysis of five samples of coffee plantation soil in Bener Meriah Regency showed very low levels of glyphosate residue, namely 0.002 mg/kg for each sample.

**Table 1.** Results of Soil Chromatography Analysis

| No. | Residue Glyphosate (subdistrict) | Concentration (mg/kg) | Method |
|---|---|---|---|
| 1. | Bandar | 0,002 | Gas Chromatography |
| 2. | Bukit | 0,002 | Gas Chromatography |
| 3. | Permata | 0,002 | Gas Chromatography |
| 4. | Gajah Putih | 0,002 | Gas Chromatography |
| 5. | Timang Gajah | 0,002 | Gas Chromatography |

These results are far below the maximum residue limit (MRL) of the European Union (EU) regulation, set at 0.1 mg/kg. In comparison, the United States Department of Agriculture (USDA) regulation is 0.2 mg/kg, indicating that glyphosate contamination in the soil at the sampling location is relatively safe. According to interviews with coffee farmers, glyphosate herbicides are administered once a year, accompanied by weeding, so no weeds remain buried in the soil. Furthermore, weed control is carried out by providing organic materials such as compost or manure, which stimulate the growth of soil microorganisms. This causes the low glyphosate content in the soil; soil microorganisms have degraded the residue over time. The above statement is in line with [4] [5], which states that providing balanced and measured organic materials will suppress the persistence of herbicides in the soil.

### 3.2. Glyphosate residues in seed samples

The results of the chromatography analysis of coffee beans on coffee plantations in Bener Meriah Regency are shown in Table 2. These results are well below the maximum residue limit set for coffee products, indicating that glyphosate contamination of coffee beans at the sampling location is relatively safe for consumption.

**Table 2.** Results of Seed Chromatography Analysis

| No. | Residue Glyphosate (subdistrict) | Concentration (mg/kg) | Method |
|---|---|---|---|
| 1. | Bandar | 0,002 | Gas Chromatography |
| 2. | Bukit | 0,002 | Gas Chromatography |
| 3. | Permata | 0,002 | Gas Chromatography |
| 4. | Gajah Putih | 0,002 | Gas Chromatography |
| 5. | Timang Gajah | 0,002 | Gas Chromatography |

Several factors cause the low residue level in coffee beans; in addition to the factors mentioned in soil residue, other factors include: 1). The harvest time is quite long after the last application of Glyphosate and 2). Coffee varieties that are less sensitive to herbicides. Coffee plant management, especially the effects of herbicide applications, will undoubtedly impact the quality of the coffee beans produced [6] [7] [8].

### 3.3. Factors of low persistence of glyphosate herbicide

The results of observations and interviews, the low level of residue in soil samples was caused by several factors, namely climate (temperature, humidity, rainfall), soil characteristics, topography, herbicide characteristics, weed types, and good agricultural practices, in this case, the practices carried out were more dominant in organic control than in the administration of herbicides.

1. Climate factors

   According to 2022 temperature data, the coldest air temperature in Bener Meriah Regency is in October, with a temperature of 19°C, and the highest in March, with an average of 22.5°C. Air humidity ranges from 90.5% to 91.5%. March, June and September are the months with the highest average air humidity reaching 91.50%[9].

   Such climate conditions will significantly affect the rise and fall of temperature differences between the dry and rainy seasons, so some areas have a wet climate.

   According to rainfall input data from the Bener Meriah Regency Agriculture and Food Service from 2012 to 2022, rainfall in the Bener Meriah Regency area is classified as medium and high (±100-300 mm) [9] [10].

   Temperature, humidity, and rainfall are the most critical climate factors determining herbicide degradation (Curran, 1998). The rate of herbicide degradation generally increases when soil temperature and humidity increase. This is because the rate of microbial decomposition increases when temperature and humidity are high. The type and number of microbes greatly determine the speed of the decomposition process. Microbes require optimal environmental conditions for herbicide growth and use (decomposition) [11].

   In addition, high rainfall will cause herbicides to dilute, dissolve, or wash away. The solubility of herbicides in water helps determine their leaching potential. Herbicides can quickly be disbanded due to heavy rainfall and washed away from the weed germination zone, reducing their efficacy and herbicide persistence.

2. Soil characteristics

   Soil factors affecting herbicide persistence are included in three categories: soil physics, soil chemistry, and soil biology. Soil composition is a physical factor providing soil texture and organic matter content. The soil chemistry that most influences herbicide persistence is pH, while microbial aspects include the type and abundance of soil microbes. The low glyphosate residue in coffee plantations in several villages in Bener Meriah is due to the provision of regular and good organic matter. Several studies have stated that adding appropriate organic matter can improve the properties of soil exposed to glyphosate residue. Organic matter is closely related to soil aggregate stability because it is one of the binding materials for soil fractions to form soil aggregates. This is because ions can bind soil particles on the surface of organic matter to form soil aggregates [12] [13].

   The decomposition process of organic matter in the soil will release acids that help destroy soil minerals so that nutrients become available and can be absorbed by plants. Therefore, it is essential to note the dosage of glyphosate-based herbicides so that they are not too high because they can cause reduced soil fertility and degradation of soil biota. Additionally, the provision of organic matter also needs to be considered because excessive provision can affect the effectiveness of herbicides in controlling weeds [14].

3. Topography

   Topography plays a role in determining the speed and volume of surface runoff and herbicide residues. Two topographic elements that influence erosion are slope length and slope gradient. According to [15], the longer the slope, the greater the volume of excess water accumulates on it, and then all will fall with increasing volume and speed. This causes the persistence of herbicides in the soil to be easily carried away and not settle for long. Bener Meriah's slope classification is divided into slope classes: 0 - 8%, 8-15%, 15-25%, 25-40% and >40%. Based on the description of the slope classification, it can be seen in Table 3.

**Table 3.** Regional Slope (ha) According to the District in Bener Meriah Regency

| No | Subdistrict | Slope | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | $0 – 8^o$ | $8 – 15^o$ | $15 – 25^o$ | $25 – 40^o$ | $> 40^o$ | |
| 1 | Bandar | 16,01 | 2.624,29 | 1.408,20 | 1.233,71 | 5.018,34 | 10.300,55 |
| 2 | Bukit | 261,15 | 3.033,35 | 873,89 | 566,16 | 4.787,67 | 9.522,22 |
| 3 | Permata | - | 3.855,55 | 3.683,96 | 4.639,96 | 7.231,62 | 19.414,04 |
| 4 | Gajah Putih | - | 6.811,19 | 6.020,73 | 3.909,27 | 7.307,65 | 24.048,84 |
| 5 | Timang Gajah | - | 1.439,25 | 2.385,53 | 2.716,84 | 3.498,58 | 10.040,20 |
| | Total | 277,2 | 17.763,6 | 14.372,3 | 13.065,9 | 27.843,9 | 73.325,85 |

The data above shows the area with the highest slope, located on a hill of >40, with an area of 27,843.9 ha. The vast area indicates the amount of nutrients, organic materials and chemicals (fertilizers and herbicides) that accumulate and are carried down to canals, rivers and lakes. In addition, this process is assisted by rainfall factors and weed control. The reasonably high rainfall in the area makes it easy for rainwater to enter and be stored in the soil as infiltration water and soil aggregates are easily carried away by erosion. Meanwhile, weed control by administering herbicides results in rainwater that falls to the surface, no longer being obstructed by the presence of weeds that function as vegetation, so herbicide residues are more easily transported and carried away by water [16].

The high rainfall in Bener Meriah Regency is partly caused by altitude. The higher the altitude of an area, the lower the temperature and air pressure. This causes the air to become thinner and more easily condensed, thus triggering rain [17].

4. Herbicide characteristics

Herbicide characteristics significantly affect herbicide persistence, including water solubility, vapour pressure and sensitivity of herbicide molecules to chemical or microbial degradation. The solubility of herbicides in water can determine the potential for leaching. Leaching occurs when the herbicide is dissolved in water and moves through the soil profile. Herbicides easily leached will quickly go to the sensitive plant root zone.

Various other factors, including the characteristics of herbicide-soil binding, soil physical characteristics, frequency and intensity of rainfall, herbicide concentration, and time of herbicide application, greatly determine herbicide leaching. Generally, herbicides with low solubility will be strongly adsorbed by soil colloids and are less leached to have a longer persistence potential [11].

The vapour pressure of the herbicide determines volatility. Volatilization is the process of changing herbicides from liquid to solid or gas. Volatile herbicides (with high vapour pressure) generally disappear more quickly than those with low vapour pressure. Volatilization increases as temperature and humidity increase. According to Hager and Sprague (2003), chemical degradation depends on the herbicide's chemical properties and soil and climate factors. Chemical degradation of herbicides includes hydrolysis, oxidation, and reduction reactions [18].

5. Types of weeds

The most widely used type of systemic herbicide is herbicide containing Glyphosate because it is quite effective in suppressing weed growth and has a broad spectrum in controlling weeds. In addition to a single application, herbicide application in weed control is usually used in a mixture to increase the effectiveness of herbicides in controlling annual and perennial weeds, traditionally used for grass and sedge weeds because they have deep roots.

According to the study's results, the five sub-districts, namely Permata, Bukit, Bandar, Timang Gajah, and Pintu Rime Gayo are dominated by broadleaf weeds and annual life cycles. Broadleaf weeds have the characteristics of fibrous roots or can have primary taproots with smaller lateral roots so that they are easier to remove. Generally controlled by manual weeding to the origins and conventional soil cultivation such as ploughing, combing, and levelling the soil [19] [20].

This also makes coffee farmers reduce the dose of glyphosate herbicide and not apply excessive herbicides that impact minimal herbicide persistence. In line with research [21], using herbicides and Glyphosate significantly affected the dry weight of weeds. He added that paraquat herbicide suits light broadleaf weeds such as Ageratum conyzoides, Galinsoga parviflora, Asystasia gangetica, and Borreria alata. The types of weeds that have vegetative development in the soil, such as weeds or sedges, can be controlled by systemic herbicides, such as Glyphosate.

## 4. Conclusion

The results of glyphosate residue testing using gas chromatography on soil and coffee plantation beans taken in 5 districts were 0.002 mg/kg, which is relatively low compared to the coffee BMR set by European regulations, which is 0.1 mg/kg. This indicates that glyphosate residue contamination in the sample plots is relatively safe for consumption. According to the results of farmer interviews, the low glyphosate residue was caused by several factors, namely climate (temperature, humidity, rainfall), soil characteristics, herbicide characteristics and weed types. The role of organic matter is to increase soil fertility, improve the physical and chemical properties of the soil, increase the soil's ability to hold water, increase soil pores, and improve soil development media.

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