Secondary metabolites of turmeric and ginger on various altitudes and soil characteristics

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Abstract. Turmeric (Curcuma longa) and ginger (Zingiber officinale) are included in important spice commodities in Indonesia. The altitude and the environmental condition have an impact on the secondary metabolite content in the medicinal plants. Moreover, the current situation of climate change also affecting on the local environmental condition which is impacting on the secondary metabolite production. This research aims for determining the effects of altitude and soil characteristics on secondary metabolites. The research method was surveyed, then purposive sampling on farmlands with different altitude and soil characteristics at Karanganyar District, Indonesia. The variables observed were altitude, climate, soil characteristics (soil pH, Cation Exchange Capacity, Organic Matter, texture, Nitrogen, Phosphorus and Potassium), and secondary metabolites of turmeric and ginger (curcuminoid, gingerol, shogaol). The results indicated that the secondary metabolite of turmeric affected by altitude, soil pH, soil texture sand and soil available phosphorus. On the other hand, the secondary metabolites of ginger are affected by altitude, soil pH, soil organic matter, soil texture (silt and sand), and soil phosphorus. Turmeric and ginger in the highlands were produced more secondary metabolites compared with in lowlands.

1. Introduction
The altitude and the environmental condition have an impact on the secondary metabolite content in the medicinal plants. Moreover, the current situation of climate change also affecting on the local environmental condition which is impacting on the secondary metabolite production. The secondary metabolite content of turmeric and ginger are widely used for the people health as a traditional medicine. Numerous studies have been carried out to characterize and isolate their main bioactive compounds that effective against several diseases. Turmeric contains a secondary metabolite compound that called curcumin which has several properties such as an anti-inflammatory and neuroprotective [1]. Ginger possessing anticancer and antiradical properties which it could be employed in ethmo-medicine for the management of cancerous diseases [2].
As the source of medicinal plant, the amount of secondary metabolite content is quite to be concert because it would be affected to the quality of a medicinal plant. The secondary metabolites are produced by plants in certain quantities under stressful conditions, both of biotic and abiotic [3]. The environment factors have a role in the affected of secondary metabolite content especially in the medicinal plant. Such as the minimum relative humidity, altitude, soil nitrogen and soil pH are greatly affected in the curcumin content in turmeric [1]. Vanhaelen et al. [4] stated that secondary metabolites content in the plant can be influenced by the environment such as altitude, rainfall, temperature, soil (physical, chemical, and microbiological properties), and nutrition conditions, including minerals.

Kliebenstein [5] suggests that environmental factors critically influence the content of secondary metabolites in the plant. Soil type will affect the amount and availability of nutrients and affects the uptake of nutrients in the plant and affects the secondary metabolites [6]. The availability of soil nutrients are reported that it could affect the content of artemisinin in Artemisia plant [7], and phosphorus or potassium fertilization can increase curcuminoid content in the turmeric [8]. Nihayati and Murdiono [9] reported that the rhizome yield and curcumin content on Javanese ginger increased by the addition of nitrogen (N) and potassium (K) fertilizer.

Moreover, the study of the identification of altitude and soil characteristics influences on secondary metabolites content in turmeric and ginger are not widely discussed yet. The purpose of this study is to determine the effect of altitude and soil characteristics on secondary metabolites contents in turmeric and ginger.

2. Materials and methods
The research conducted from July 2015 to March 2016 at Karanganyar District, Central Java, Republic of Indonesia. The research site is the center of medicinal plant production, which use local seeds of Turmeric and ginger. Organic fertilizer from composting animal manure and leaf litter was applied twice during of land preparation and three months after planting. This study used the rhizome of turmeric and ginger of plant local varieties which is planted on dry land under rainfed agroforestry system.

This research is a descriptive exploratory with survey method and purposive sampling. Sampling points were determined according to soil type and altitude, the detail information of sampling points is displayed in Table 1.

Table 1. Characteristics of sampling points

| Sampling point | Soil type               | Altitude (m asl) | Classification of altitude | Annual rainfall (mm/y) |
|----------------|-------------------------|------------------|----------------------------|------------------------|
| 1              | Andisol and Inceptisol  | 858 – 918        | High land (> 700 m asl)    | 3.117 (very high)      |
| 2              | Inceptisol              | 439 – 464        | Medium land (400 – 700 m asl) | 2.370 (medium)         |
| 3              | Alfisol                 | 277 – 303        | Low land (<400 m asl)      | 2.478 (medium)         |
| 4              | Alfisol                 | 197 – 214        | Low land (<400 m asl)      | 2.440 (medium)         |

Generally, soil type in research site is divided into three types, namely Andisols, Inceptisols, and Alfisols. The altitude ranged from low to high land. Andisol soils colours were dark or dark brown, crumb structure, medium texture, porous and with high organic matter, and pH ranged by 4.5 to 6.0. Andisols spreaded on 0 - 3000 m asl altitude. Inceptisols colour were black, gray and dark brown, dusty to clay soil texture, crumbed structure, pH 5.0 - 7.0, organic materials content about 10% to 30%, with medium to high nutrients availability. The characteristics of Alfisols are brown to red colour, clay to clay texture, clump structure, pH 6.0 – 7.5, low organic matter and high nutrient availability.
2.1. Preparation for soil analysis
The soil samples (approximate 500 g) were collected from selected four locations and air dried for a day. Solid particles like litter and roots were removed. Then, about half of each sample were grounded. After grinding, each sample was passed through 0.5 mm and 2.0 mm nylon mesh sieve. Finally, soil samples were repacked, labelled and preserved for further analysis. The soil was analyzed for pH by electrometric method, soil Cation Exchange Capacity (CEC) by ammonium acetate method, soil organic matter with Walkley-black method, soil texture by pipette method, total Nitrogen by Kjeldahl method, available phosphorus by Bray I method, and available potassium by ammonium acetate method. [10].

2.2. Preparation of sample for HPLC (High Performance Liquid Chromatography) analysis
The sample preparation technique for plants involved steps such as, washing, drying, grinding, packing, labelling, and storage. Fresh rhizomes were cleaned, washed with water, sliced and air dried for a day and then dried at 50°C oven for six hours. Dried rhizomes were cut in small pieces then powdered by electronic mill. Finally, the powder was passed through 0.5 mm nylon mesh sieve and packed to prevent an absorption of water from the humid environment [11].

2.3. Preparation of secondary metabolites extraction by HPLC method
The HPLC analysis for secondary metabolites of turmeric (curcumin, demethoxy-curcumin, bisdemethoxy-curcumin) was analyzed according to the methods of Adzkiya [12], and for secondary metabolites of ginger (6,8,10-gingerol and 6-shogaol) was analyzed according to the methods of Lee et al. [13]. Analytical standards of curcuminoids were obtained from Chromadex Inc. (Santa Ana, CA, USA), while gingerol and shogaol were obtained from Sigma-Aldrich (Germany).

First, the samples of turmeric powder 0.05 g extracted with methanol and ultrasonication device (Branson: 1510E-MT, USA) to be obtained the filtrate. Secondly, the filtrate was filtered with membrane filters of Ekicrodisc 25CR (0.45-µm pore size; PTFE; P/N E252) obtained from Gelman Science Japan Co. (Tokyo, Japan) were used for the filtration of the mobile phase and the real samples solution. The filtrate of samples was injected to HP-LC device with syringe. The HP-LC instrument to be analyzed is Hitachi U-2800 (Hitachi, Tokyo, Japan) with UV/Vis detector fitted with a C-18 column (VP-ODS, 150L x 4.6) as the stationary phases. The chromatography conditions for turmeric were as follows: column temperature, flow rate, and injection volume were adjusted at 30°C, 1 mL / min, and 20 µL. The gradient mobile phase was using acetonitrile and acetic acid 2% which has been sonicated and the detection wavelength was set at 425 nm.

Samples of ginger powder 1 g was extracted same with turmeric methods. The chromatography conditions for Ginger were as follows: column temperature, flow rate, and injection volume were adjusted at 40°C, 1 mL / min, and 20 µL. The gradient mobile phase was using aquadest and acetonitrile which has been sonicated and 280 nm wavelength.

Curcumin and gingerol level analyze secondary metabolite level

\[
\text{sample area wide} \times \text{standart area wide} \times \text{vol. of measuring flasks} \times \text{dilution factor} \\
\text{sample weight (g)} \times 1000
\]

2.4. Data analysis
Data were analyzed with correlation, the level of 5% t test and regression test.

3. Result and discussion
The survey site was possessing a variety of soil type, altitude and rainwater quantity, which affected to the amount of nutrients and plant growth. The result of soil analysis was showing in table 2.
Table 2. The selected soil analysis in the research site

| Soil characteristic          | Quantity | Unit   | Criteria       |
|------------------------------|----------|--------|----------------|
| pH                           | 4 - 6    | -      | Acid - neutral |
| Cation Exchange Capacity     | 8 - 15   | Cmol(+) / kg | Low            |
| Organic matter               | 2 - 4    | %      | Low            |
| Clay fraction                | 4.800 – 58.145 | % | -              |
| Silt fraction                | 19.305 - 74.370 | % | -              |
| Sand fraction                | 14.990 – 57.365 | % | -              |
| Total N                      | 0.008 – 0.081 | % | Very low      |
| Available P                  | 0.3 – 2.5 | Ppm   | Very low      |
| Available K                  | 0.006 – 0.025 | Cmol(+) / kg | Very low      |

Table 2 shows that the soil criteria at the survey location have acid soil pH (4-6), low cation exchange capacity (8-15 Cmol (+) / kg), soil organic matter (2-4 %), N total soil, P and K available were 0.008-0.081 %, 0.3-2.5 ppm, 0.006-0.025 Cmol (+) / kg, respectively. The available P content of andisol, inceptisol, and alfisol soils were because the three types of soil contain quite high Al and Fe minerals, this mineral can bind P soil to form Al-P and Fe-P so that it is not available to plants. The soil texture at the survey location were varies, ranging from sandy clay loam, clay, sandy loam, clay loam.

The results of the analysis of the content of secondary metabolites are presented in table 3. The secondary metabolites in turmeric analyzed were bisdemethoxi-curcumin (BDMC) (5.20-7.58 µg/g), demethoxi-curcumin (DMC) (6.59-9.28 µg/g), and curcumin (C) (15.14-23.16 µg/g), curcuminoid (CNOID) which is the total amount of BDMC, DMC, and C. In general, the highest secondary metabolite content of turmeric is the location 2 and lowest in the location 1. Meanwhile, the analyze of secondary metabolite content of ginger were 6-8, 10-gingerol (6-, 8-, 10-gin) (9.55-12.74 µg/g, 1.66-2.32 µg/g, 2.66-4.44 µg/g), and 6-shogaol (6-sho) (1.43-2.36 µg/g), the total gingerol (Tot-Gin) is a total of 6-, 8-, and 10-Gin. In general, the highest secondary metabolite content of ginger was site on location 3 and the lowest in location 2. There was no ginger plant in location 4 so sampling could not be carried out for analysis.

Table 3. The Average of secondary metabolite content at research site

| Sampling position | Turmeric (µg/g) | Ginger (µg/g) |
|-------------------|---------------|---------------|
|                   | BDMC | DMC | C | CNOID | 6 - GIN | 8 - GIN | 10 - GIN | TOT - GIN | 6 - SHO |
| 1                  | 6.56 | 8.40 | 15.14 | 30.10 | 9.55 | 2.32 | 4.44 | 16.30 | 1.43 |
| 2                  | 7.58 | 9.28 | 23.16 | 40.02 | 10.64 | 1.66 | 2.66 | 15.00 | 2.36 |
| 3                  | 5.68 | 7.63 | 22.83 | 36.14 | 12.74 | 2.12 | 3.20 | 18.05 | 2.06 |
| 4                  | 5.20 | 6.59 | 19.88 | 31.67 | - | - | - | - | - |

Pearson correlation results from secondary metabolites of turmeric and soil character are presented in Tables 4 and 5. Secondary turmeric metabolites correlate with altitude (+), soil pH (+), soil texture.
While the secondary metabolites of ginger were correlate with altitude (+), soil pH (++), organic material (+), soil texture clay (+) and sand (+), and P available soil (+).

### Table 4. Pearson’s correlation of secondary metabolites of turmeric vs soils characteristics at all sites

| Secondary metabolism | Altitude | Soils characteristic |
|----------------------|----------|----------------------|
|                      |          | pH | CEC | OM | Clay | Silt | Sand | N  | P  |
| BDMC                 | +        |    |    |    |      |      |      |    |    |
| DMC                  | -        | +  |    |    |      |      |      |    |    |
| C                    | -        | -  | -  |    |      |      |      |    |    |
| CNOID                | -        | -  | -  |    |      |      |      |    |    |

Note: “+” means the correlation is significant at 5% C: Curcumin
“++” means the correlation is significant at 1% CNOID: Curcuminoid
“-” means the correlation is not significant
BDMC: Bisdemetoxy-curcumin TOT-GIN: Total Gingerol
DMC: Demetoxy-curcumin 6-SHO: 6-Shogaol

### Table 5. Pearson’s correlation of secondary metabolites of ginger vs soils characteristics at all sites

| Secondary metabolism | Altitude | Soils characteristic |
|----------------------|----------|----------------------|
|                      |          | pH | CEC | OM | Clay | Silt | Sand | N  | P  |
| 6-GIN                | -        |    |    |    |      |      |      |    |    |
| 8-GIN                | -        |    |    |    |      |      |      |    |    |
| 10-GIN               | +        | ++ | -  |    |      |      |      |    |    |
| TOT-GIN              |          |    |    |    |      |      |      |    |    |
| 6-SHO                | -        | ++ | -  |    |      |      |      |    |    |

Note: “+” means the correlation is significant at the 0.05 level
“++” means the correlation is significant at the 0.01 level
“-” means the correlation is not significant

The relationship between secondary metabolites of turmeric and ginger with soil characteristics was analyzed using regression.

3.1. Altitude

Altitude were affecting the secondary metabolites content of turmeric and ginger (Figures 1 and 2). The higher secondary metabolite of turmeric (BDMC, $R^2 = 0.2236$) and ginger (10-gingerol, $R^2 0.6979$) were found in the highland. Secondary metabolites of turmeric and ginger tend to increase in the highlands, and the content will decrease with decreasing altitude.

The results showed that the highest content of secondary metabolites in turmeric was found in location 1 with altitude 858-918 masl (6.56 µg / g) and the lowest was found at location 4 with altitude 197-214 masl (5.20 µg / g), while the highest content of secondary metabolites in ginger was found in location 1 with altitude 858-918 masl (4.44 µg / g) and the lowest was found in location 2 with altitude 439-464 masl (2.66 µg / g). As the results of Arya et al [14] study, high secondary metabolites of turmeric were found in turmeric which grew at a higher altitude. The highest curcumin level was found in turmeric at an altitude of 1.755 masl (3.26 ± 0.126 mg / g) and the lowest was found at an altitude of 198 masl (7.6 ± 0.51 mg / g). Although stating that it is not significant, it can be concluded that the content of secondary metabolites is influenced by the height place that plant grows. The results of the Estu and Irwanto [15] study showed the same results that the highest secondary metabolite levels of ...
Narcissus bulbs (galantamine) were found in tubers that grew at an altitude of 1,250 masl (63.59 µg / g) and the lowest was found in tubers growing at 350 meters above sea level (8.163 µg / g).

3.2. Hydrogen potential (pH)
Hydrogen potential (pH) affects the secondary metabolite content of BDMC turmeric (R² = 0.3631), DMC (R² = 0.3909) and 10-gingerol ginger (R² = 0.6615), 6-shogaol (R² = 0.6079). Regression results indicate that pH can decrease (Figures 3, 4, 5) and increase (Figure 6) the content of secondary metabolites in turmeric and ginger.

The results showed that secondary metabolites of turmeric and ginger tended to decrease with increasing soil pH (pH 4-6). Turmeric and ginger are more suitable to be cultivated on slightly acidic soils. The highest yield of curcumin content (0.20 %) in turmeric is cultivated in dark red soil (pH 5.2) and lowest (0.06 %) in red soil (pH 4.4) Hossain and Ishimine [16] proved that soil pH can affect plant secondary metabolism, possibly due to optimal soil pH levels. Soil pH can affect the absorption of minerals in the soil by plants that can affect the production of secondary metabolism in plants. Acidic soil (pH 4-6) will increase the absorption of minerals by plants, a higher pH will inhibit its absorption. In this study, in general the increase in pH will reduce the secondary metabolite content of turmeric and ginger, in the secondary metabolite 6-shogaol, the increase in pH increases the content of secondary metabolites (Figure 6), possible because the shogaol compound is reduced to a gingerol compound.
Shogaol is a derivative of gingerol which loses one atomic bond to its OH group, the cause is heat from the environment which causes it to decompose into shogaol. Gingerol is a heat-labile compound both during storage and during processing. In other words, if the gingerol content of ginger is low, it is possible that it has turned into shogaol. According to Huang et al [17], higher temperatures in drying will increase the change in compounds from 6-gingerol to 6-shogaol. The amount of compound 6-gingerol in fresh ginger 5.91 mg/g, after drying 6-gingerol decreased significantly to 2.12 mg/g. So that it can be concluded that the high temperature and duration of drying will increase the decomposition of 6-gingerol to 6-shogaol. The results of the study by Puengphian [18] also state that the molecular structure of gingerols in ginger has a labile nature. After drying, the content of 6-gingerol in ginger decreased from 21.15 ± 0.13 mg/g to 18.81 ± 0.15 mg/g based on its dry weight. High temperatures and length of drying time will reduce and change 6-gingerol levels in ginger.

3.3. Soil organic matter
Soil organic matter only affects the content of secondary metabolites of ginger (10-gingerol, $R^2 = 0.4728$). Regression results indicate that soil organic matter can increase the secondary metabolite content of ginger (Figure 5).
The results showed that the secondary metabolite content of ginger tended to increase (2.088-6.221 µg / g) along with an increase in the content of organic matter in the soil (2.4%). Organic matter plays an important role in the availability of soil micro nutrients and growth and yields [19]. The relationship of soil organic matter with curcumin production is very strong, this shows that rhizome production is very sensitive to the increase of organic matter in soils with low organic matter content [21]. According to the research of Sharath Pal [21], states that the addition of organic ingredients can increase growth, yield, and quality of ginger plants. Estu and Irwanto [15] also states that there is a positive correlation ($R^2 = 0.862$) between the content of soil organic matter and galantamine secondary metabolites. Higher soil organic matter can increase the secondary metabolite content of plants.

3.4. Soil texture
Soil texture affects the secondary metabolite content of turmeric and ginger. Sand texture affects the secondary metabolite content of turmeric, Curcumin ($R^2 = 0.5019$) and 6-shogaol ginger ($R^2 = 0.5226$). While clay texture affects the metabolite content of secondary ginger 6-gingerol ($R^2 = 0.4520$). The regression results indicate that the texture of sand can reduce the content of secondary metabolites (Figures 6 and 7), while the texture of clay can increase it (Figure 8).

**Figure 5.** Regression of 10-gingerol with soil organic matter

$$y = 0.5459x + 1.871 \quad R^2 = 0.4728$$

**Figure 6.** Regression of curcumin with soil texture (sand)

$$y = -0.165x + 26.558 \quad R^2 = 0.5019$$
The results showed that the secondary metabolite content of turmeric and ginger will increase in soils with high clay texture (Figures 6 and 7) while decreasing on soils with high sand texture (Figure 8). This is consistent with the study of Nurcholis et al [22], the higher content of secondary metabolites produced by plants in locations with a higher clay texture. Soils with high clay content cause pressure on rhizome growth. Lower rainfall and higher clay are thought to cause stress in increasing the production of secondary metabolites at the study site. Sutandi and Barus [21] also stated that the higher the content of clay in the soil, the curcumin production will increase. The sand fraction of soil texture causes loose soil aggregation. High sand fractions make the soil loose and less able to store water. When water is not available for plants, its growth is disrupted, so secondary metabolites will decrease. This shows that the synthesis of secondary metabolites is strongly influenced by environmental conditions. Under conditions of environmental stress, plants synthesize more secondary metabolites [23].
Soil texture can affect the penetration of plant roots into the soil. Rhizomes such as ginger and turmeric need loose soil for growth. Loose soil makes the growth and development of rhizomes better. According to the research of Nihayati and Murdiono [9], the physical structure of soil that is loose and has a higher nutrient content provides a better root growth organ effect. The soil structure associated with porosity greatly influences the activity of the enzyme PAL (Phenyl Alanine Ammonialase) which catalyzes the formation of secondary metabolites. PAL activity increases in extreme environmental conditions, including low nutrient levels and low soil water content.

3.5. Available soil phosphorus
Available soil phosphorus affects the secondary metabolite content of turmeric, Curcumin ($R^2 = 0.5492$), Cnoid ($R^2 = 0.6075$) and ginger, 6-shogaol ($R^2 = 0.5114$). Regression results indicate that available P soil can increase the content of secondary metabolites (Figures 9, 10 and 11).

![Figure 9](image1.png)

**Figure 9.** Regression of curcumin with soil Phosphorus.

![Figure 10](image2.png)

**Figure 10.** Regression of curcuminoid with soil Phosphorus.
The results showed that the secondary metabolite content of turmeric and ginger will increase with increasing soil P content (Figures 9, 10, and 11). In accordance with the results reported by Akamine et al [8], that P fertilizer can significantly increase curcumin levels in turmeric (0.17 ± 0.01 %). Suharti et al [24] in their study showed the relationship between P elements in soil and secondary metabolites in ginger (6-shogaol). Arbuscular mycorrhizal fungi (AMF) in ginger plants can increase yield and composition of secondary metabolites compared to plants without AMF (control). Ginger introducing AMF has a higher shogaol level with a larger peak area which has a high peak area (139 and 0.15 %) compared to ginger without AMF (111 and 0.08%). Mycorrhizae can increase P uptake by plants. Dwivedi et al. [25] that mycorrhizae help plants absorb less available nutrients such as P, Zn, Mo, and Cu. In addition, mycorrhiza is also able to change P in soil that can be absorbed by plants.

4. Discussion

The Pearson’s correlation of secondary metabolite contents of turmeric and ginger with altitude and soil characteristics is shown in Table 4 and 5. It can be seen that secondary metabolites of turmeric correlated with altitude, soil pH, soil texture (sand) and soil phosphorus. Meanwhile, the secondary metabolites of ginger correlated with altitude, soil pH, soil organic matter, soil texture (clay and sand), and phosphorus.

The relations of secondary metabolites of turmeric and ginger with altitude are presented in Figures 1 and 2. Altitude affected the secondary metabolites content of turmeric and ginger (Figure 1 and 2). Secondary Metabolites turmeric and ginger tend to be higher in the highlands, and the levels will decrease with decreasing altitude. This is consistent with the results reported by Arya et al [14], that the higher secondary metabolites of turmeric found in turmeric grewed at higher altitude. The highest levels of curcumin found in turmeric at altitude 1.755 meters above sea level (32.6 ± 0.126 mg/g) and the lowest was found at altitude 198 meters above sea level (7.6 ± 0.51 mg/g). The journal states that it is not significant, but it can be concluded that the secondary metabolite content is affected by the height of the place where it growth.

Potential of hydrogen (pH) affected the secondary metabolites content of turmeric (BDMC and DMC) and ginger (10-gingerol and 6-shogaol). Regressions result show that pH can decreased and increased the secondary metabolite content on turmeric and ginger (figure 3, 4, 5 and 6).

The result of curcumin content was the highest (0.20%) in the turmeric cultivated on dark- red soil (pH 5.2) followed by gray soil (0.10%) (pH 7.4), and lowest (0.06%) on red soil (pH 4.4) [16]. This proved that soil pH can affected the secondary metabolism of plant, perhaps due to optimum pH soil levels. Soil pH can affect the mineral absorption on soil that it can influenced the production of secondary metabolism on plants.
The soil organic matter can affect the secondary metabolite content on ginger (Figure 5). Organic materials play an important role in the availability of micro nutrients the soil and the growth and yield [19]. The relationship of soil organic matter with curcumin production is very strong, this shows that rhizome production is very sensitive to the increase of organic matter in low organic matter soils [20].

The secondary metabolism of turmeric and ginger are affected by soil texture sand (Figure 6 and 7) and clay (Figure 8). This result is consistent with Nurcholis et al [22], reported that the higher secondary metabolism content is produced by the plant in site location with higher soil clay texture. The soil with high clay content caused pressure or stress on the growth of rhizome. Lower rainfall and higher clay soil estimated that it induction of stress in increasing production of secondary metabolite content in the study site [22]. Sutandi and Barus [20] also states that the higher the clay content in the soil, curcumin production will increase. Sand fraction of soil texture induces more loose soil aggregation. High sand fraction makes soil loose and cannot store water. When the water is not available for plants, the growth is distracted, and so the active compounds will decrease. This indicated that syntheses of secondary metabolite were strongly affected by the environmental conditions. It seems that under environmental stress conditions plant synthesizes more constituents [23].

The soil texture can influence plant root penetration into the soil. Rhizomes plants such as ginger and turmeric requires loose soil for growth. Loose soil makes the growth and development of rhizomes better. According to research Nihayati and Murdiono [9], soil physical structure and chemical more crumbs have a higher nutrient available, giving the effect of better root growth organ. Soil structure relating to the porosity greatly affect the activity of PAL enzyme that catalyzes the formation of secondary metabolites. PAL activity increased in extreme environmental conditions, including low nutrient levels and soil moisture content is low.

The secondary metabolism of turmeric and ginger are affected by soil available P (figure 9, 10 and 11). This is consistent with the results reported by Akamine et al [8], that P fertilizer can increased the levels of curcumin content significantly on turmeric (0.17 ± 0.01 %). Suharti et al [24] in his research indicates linkages between elements of P in soil with secondary metabolite on ginger (6 shogaol). Introductions Arbuscular Mycorrhizal Fungi (AMF) on ginger plant can increase the yield and composition of secondary metabolite compared with plants without AMF (control). Ginger that introduced AMF, have a higher level of shogaol with greater peak area which has a high peak area (139 and 0.15%) compared with the ginger without AMF (111 and 0.08%). Mycorrhizae can improve P uptake by plants. Dwivedi et al. [25] that mycorrhizae help plants absorb nutrients less available as P, Zn, Mo, and Cu. In addition, mycorrhizae also able to change P in the soil can be absorbed by plants.

5. Conclusion
Secondary metabolites in plants are a complex physiological process. Secondary metabolites in plants are influenced by genotype and harvest age, soil nutrient status and other environmental factors. The effects of soil and environmental factors on the secondary metabolite content of turmeric and ginger are varied and more complex. This research resulted that the levels of secondary metabolites of turmeric and ginger are influenced by environmental factors such as altitude and soil factors such as soil characteristics, pH and other soil nutrients. So that further research is needed to obtain a more accurate prediction of soil and environmental factors that affect the secondary metabolite content of plants, especially turmeric and ginger.

Acknowledgement
The gratefully acknowledges the United Graduate School of Agricultural Science, Gifu University, Japan (UGSAS-GU) for this research and support.

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