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Land Characteristics Impact Productivity and Quality of Ginger (*Zingiber officinale* Rosc) in Java, Indonesia

Nur Azizah *), Sri Lestari Purnamaningsih and Sisca Fajriani

Department of Agronomy, Faculty of Agriculture, Universitas Brawijaya, East Java, Indonesia

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*) Corresponding author:
E-mail: nurazizah@ub.ac.id

ABSTRACT

Environmental condition plays an important on ginger production and its quality especially gingerol. Ginger exploration from various environmental conditions was carried out to obtain collection of ginger accessions that potentially developed as superior quality planting material. The study was aimed to assess the productivity and quality of gingers from different topography. The explorations of ginger accession was conducted in low-mid land and upland area within Java island, Indonesia from June to August 2018. A total of 24 ginger accessions were collected, consisting of 11 big white ginger, 8 small white ginger, and 5 red ginger. Differences in environment condition (i.e topography) affected ginger productivity and gingerol content. The highest productivity of ginger for big white ginger, red and small white ginger were 32, 15 and 23 t/ha, respectively. The gingerol content was higher in red ginger (4-5%) than big white (3-4%) and small white (1%) gingers. However, there were two accessions of small white ginger contained gingerol above the average accessions of small white ginger, as well as higher than big white (4%) and red gingers (6%). Overall, land characteristics controlled yield and diameter of ginger rhizome through soil properties both chemical (e.g CEC) and physical (e.g soil texture).

INTRODUCTION

Ginger (*Zingiber officinale Rosc.*) is one type of rhizome plant from the family Zingiberaceae which is known as a medicinal plant. Ginger rhizome contains essential oils, resins, starches, proteins, minerals and variety bioactive compounds. Gingerol and shogaol are the main bioactive components in the ginger rhizome (Ravindran & Babu, 2004). The pungent taste indicates the presence of gingerol compound in fresh ginger rhizome. Gingerol is the major bioactive component that responsible to the spicy taste of ginger rhizome, but it is very unstable in hot conditions and at high temperatures, the substances will change to shogaol. The shogaol tastes are more spicy than gingerol, and is a major component of dry ginger (Semwal, Semwal, Combrinck, & Viljoen, 2015; Syafitri, Levita, Mutakin, & Diantini, 2018).

In the world, ginger cultivation covers an area of 387,300 ha with a production of 1,476.9 tons (Kizhakkayil & Sasikumar, 2011). Indonesia is one of important ginger producing countries in Southeast Asia, having cultivation area more than 10,000 ha with average production of 84,878 tons (Ravindran & Babu, 2004). There are three types of ginger cultivated in Indonesia, namely big white ginger (*Z. officinale* var. Officinale), small white ginger (*Z. officinale* var. Amarum), and red ginger (*Z. officinale* var. Rubrum). These three-ginger types have different morphological characters, starch content, fiber content and essential oils (Bermawie & Purwiyanti, 2011). The big white ginger is commonly said as “elephant” ginger, “kebo” ginger or rhino ginger in local name due to the larger rhizome than others. Small white ginger known as “emprit” ginger or “sunti” ginger has smaller size, but is more spicy than white ginger. The red ginger has a red rhizome skin when harvested, but turns into brownish after certain period of storage. In addition, those three types also have differences in terms of productivity and active compound content (Rostiana, Efendi, &

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Bermawie, 2007). The differences in productivity and the content of the active compounds in the ginger rhizome depends on cultivation systems (monoculture/intercropping/agroforestry), the type of ginger and environmental condition, such as altitude, climate, and soil.

Ginger is generally cultivated as intercropping or planted under the tree in agroforestry systems, ranging from lowland to upland. The study in South Eastern Nigeria by Nwaogu (2014) reported that planting ginger in-between pigeon pea hedgerow alleys improved soil fertility (i.e exchangeable Ca, Mg, K, base saturation, soil organic C, and available P). While planting ginger under the shade trees in agroforestry system ginger can grow well and tolerate up to 45 to 55% shading (Pandey, Shukla, Saxena, Khan, & Kumar, 2018).

In Indonesia, central ginger cultivation is located in the Java Island in diverse growing environmental conditions. During 2011 to 2017, ginger production in Indonesia had double increase from 94,743 to 216,587 tons (BPS, 2017; Riptanti, Qonita, & Fajarningsih, 2018). East Java is one of the main centers of ginger production in Indonesia, supplying about one third of national ginger production (Nugroho & Ningsih, 2017). Ilyas, Palupi, & Susila (2016) reported that rhizome production of ginger is strongly affected by seed rhizome age, while rhizome quality (e.g. water content) is influenced by the water content of growing media. Then, another factor controlling the production and quality of ginger rhizomes are the climate. Sukarman & Melati (2011) explained that ginger can grow optimally on the areas with climate types A, B, and C (Schmidt and Ferguson), at the altitude of 300 - 900 meters above sea level (m asl) with 7-9 wet months per year, rainfall of 2,500 - 4,000 mm per year and light intensity of 70-100% or slightly shaded to open. In addition, Murni, Pujiastuti, & Octoria (2017) stated that optimum temperature for ginger is ranged from 25 to 30^{0}C.

Soil properties is also a factor controlling ginger production and its quality. The growth of ginger rhizome is optimum in fertile, loose soil and contains a lot of organic matter with a soil pH ranged from 6.8-7.4 (Rostiana, Efendi, & Bermawie, 2007; Sukarman & Melati, 2011). In terms of soil fertility, ginger requires macro and micro nutrient for its growth and production. Without nutrient input and soil tillage, ginger production from 2014 to 2016 in Southwest Nigeria tends to decrease from 20.5 t/ha to 18.3 t/ha (Agbede & Adekiya, 2018). Djazuli & Sukarman (2007) reported that rhizome production was higher in an area with altitude of 500 m asl and contain high macro nutrient (i.e. N, P, K) as compared to those production in an area with altitudes of 800 m asl and contain lower levels of soil nutrient. While Mao, Ran, & Li (2016) reported that ginger absorbed higher N and K element as compared to P, shown by the higher content of N and K than P in various part of ginger (i.e. tuberous root, leaf, stem).

Beside affecting ginger growth and production, variation in environment condition results differences in content of active compounds. Environmental stress will affect the expression of genes in plants resulting in an adaptation mechanism. Pressure from certain environmental factors can induce the synthesis of secondary metabolites that are used to defend themselves against unfavorable environmental conditions. To our knowledge, the study about productivity and quality of ginger from various land characteristics is limited. Therefore, exploration of ginger from various land characteristics with different environments is carried out to obtain genetic diversity of ginger accessions that have the potential to be developed into superior quality planting materials, in terms of production potential and high active compounds and adaptive properties in various environmental conditions. The purpose of this study was to assess the effect of land characteristics on the productivity and quality (i.e. gingerol content) of ginger.

MATERIALS AND METHODS

Exploration of ginger accession was carried out during the ginger harvest season, starting from June to July 2018, while laboratory analysis was done from August to December 2018. The research method was survey and exploration of ginger accession. The exploration of ginger accession was carried out at 10 regencies in East Java province, including Banyuwangi, Malang, Mojokerto, Nganjuk, Ngawi, Pasuruan, Pacitan, Pamekasan, Sumenep, Trenggalek and one district, Wonogiri (Central Java). The ginger and soil samples were gathered from 15 locations, covered three locations in Malang, two locations in Sumenep and Trenggalek and one location for the rest targeted area. The sampling area is divided in two group, including low-mid (0-600 m asl) area (i.e. Pamekasan, Wonogiri, Nganjuk, Sumenep, Mojokerto, Pasuruan) and upland (> 600 m asl) area (i.e. Malang, Ngawi, Pacitan, Trenggalek). The study mixed the lowland and mid land into one group due to the area of ginger cultivation in low and mid land is limited. Based on preliminary survey, most of ginger cultivation in agroforestry system within East Java province was found in upland area. Most of ginger in sampling area (> 80%) was cultivated as understorey in agroforestry systems. The sampling locations were determined using serial sampling (multilevel) following snowball sampling method. From these activity, 24 ginger accession collections were obtained, consisting of 5 red ginger, 8 small white ginger and 11 big white ginger (Table 1).

The altitude of each collecting was recorded and the rhizome and soil samples were collected. Ginger rhizomes and soil samples were collected randomly from three subplots with size 1 x 1 m each. The ginger rhizome morphology (i.e. the number of rhizomes per plant, rhizome length and rhizome diameter), production potential (i.e. rhizome weight per plant and production per ha), and quality (gingerol content) were observed. The gingerol content was analyzed by using *Thin-Layer Chromatography* (TLC) analysis method in the laboratory of Indonesian Spice and Medicinal Crops Research Institute (BALITRO), Bogor. Analysis of soil fertility was also carried out by measuring the soil organic C, soil nutrient (i.e total N, available P, exchangeable K, Na, Ca, Mg), soil pH and soil particle size distribution (soil texture) from soil sample which is collected from 0-20 cm depth of soil. All soil analysis was conducted in Department of Soil Science, Faculty of Agriculture, Universitas Brawijaya, Malang. Descriptive analysis was used to obtain an initial description of ginger accession type from various land characters. In addition, statistical analysis was used to compared differences in ginger productivity and quality between low-mid land and upland for each ginger type (big white ginger, small white ginger, and red ginger) by using paired T-test at 5%. Then, Spearman's correlation test was used to analysed the relationship between land characterics and ginger productivity as well as quality).

Table 1. Location for ginger exploration and type of ginger accession gathered form sample collections

No.	Village	Districts	Regency	Elevation (m asl)	Type of ginger*
1	Sepanjang	Glenmore	Banyuwangi	450	BW
2	Tulungrejo	Ngantang	Malang	718	SW
3	Toyomarto	Singosari	Malang	631	SW
4	Argosari	Jabung	Malang	664	BW
5	Kebon agung	Sawahan	Nganjuk	447	SW
6	Hargomulyo	Ngrambe	Ngawi	760	BW, SW, RG
7	Lebbek	Pakong	Pamekasan	303	SW
8	Lenteng Barat	Lenteng	Sumenep	102	RG
9	Miri	Kismantoro	Wonogiri	351	BW, SW, RG
10	Kledung	Bandar	Pacitan	880	BW, SW, RG
11	Lenteng Barat	Lenteng	Sumenep	79	BW
12	Sukereno	Prigen	Pasuruan	450	BW
13	Nggenting	Ngoro	Mojokerto	150	BW
14	Sidomulyo	Pule	Trenggalek	995	BW, SW
15	Puyung	Pule	Trenggalek	1,036	BW, RG

Note: * BW = big white, SW = small white, RG= red ginger

RESULTS AND DISCUSSION

The Production and Quality of Ginger from Different Land Topography

The statistical analysis showed that the rhizome morphology (i.e. number, length and diameter) of big white, small white and red gingers was not significantly different between low-mid land and upland areas, except rhizome length of big white ginger which were higher in upland area than those in low-mid land area (Table 2). The difference in character is more indicated by the different types of ginger. In terms of size, big white ginger has a greater length and diameter of rhizome as compared to small white ginger and red ginger, as well as higher number of rhizome than red ginger. In contrast, the amount of rhizome was lower in big white ginger than small white ginger (Fig. 1). Furthermore, the gingerol content of small white ginger (1-3%) was lower than big white and red gingers which could reach more than 4%. However, the gingerol content among ginger types (e.g. big white, small white, and red gingers) was not significantly different between low-mid land and upland area (Table 2).

The impact of site characteristics is evident in the potential yield of ginger rhizomes, both production per plant and per ha for big white and small white gingers, whereas the rhizome production per ha of red ginger was not significantly different between low-mid land and upland (Table 2, Fig. 1). Among the types of ginger, big white ginger has the highest production potential, followed by small white ginger, and red ginger is the lowest. Agbede (2019) reported that differences in site characteristics (i.e soil pH, soil nutrient content) with similar soil tillage gave a different impact on fresh ginger yield in Nigeria.

Based on the altitude of cultivation area, the production of rhizomes per plant and yield per ha for small white ginger was higher in the low-mid land area than those in the upland. The average yield of ginger rhizome in the low-mid land can reach 164 g per plant with a production potential of 23 t/ha, while in the uplands the production potential only reaches an average of 17 t/ha. This tendency is different from the potential of big white ginger and red ginger which show the opposite results, where the production of rhizomes in the uplands was higher than in the low-mid lands. In big white ginger, differences in yield of rhizomes both per plant and production per hectare up to more than 40%. Differences in rhizome yield between low-mid and upland areas indicated that topography affect ginger production probably through variation in precipitation, temperature, and soil. Islam, Rahman, & Hasan (2011) noted that some spices plant (e.g ginger, garlic, chilli) were sensitive to climate, temperature, and topography.

Table 2. Average potential and levels of gingerol from three types of ginger in low-mid land (< 600 m asl) and upland (> 600 m asl) areas

Location	Yield (g per rhizome)	Total yield (Mg/ha)	Length of rhizome (cm)	Number of rhizome	Rhizome diameter (cm)	Gingerol (%)
Small white ginger						
Low-mid land	*163.9 ± 72.3 b	22.7 ± 4.1 b	17.3 ± 2.5	14.2 ± 3.2	2.3 ± 0.2	3.1 ± 1.8
Upland	77.1 ± 7.2 a	16.6 ± 0.9 a	15.1 ± 0.9	12.0 ± 0.6	2.3 ± 0.2	1.9 ± 0.7
mean	120.5 ± 39.8	19.7 ± 2.5	16.2 ± 1.7	13.1 ± 1.9	2.3 ± 0.2	2.5 ± 2.3
Big white ginger						
Low-mid land	161.2 ± 47.4 a	18.3 ± 5.4 a	16.2 ± 1.2 a	12.5 ± 3.1	2.7 ± 0.3	4.4 ± 0.4
Upland	293.4 ± 57.7 b	31.9 ± 4.8 b	21.5 ± 1.8 b	11.7 ± 1.4	3.6 ± 0.2	4.0 ± 0.4
mean	227.3 ± 52.6	25.1 ± 5.1	18.9 ± 1.5	12.1 ± 2.3	3.2 ± 0.3	4.2 ± 0.4
Red ginger						
Low-mid land	46.6 ± 8.4 a	11.0 ± 7.3	13.7 ± 1.2	8.9 ± 1.9	2.1 ± 0.4	4.9 ± 0.2
Upland	91.8 ± 22.5 b	15.2 ± 2.0	14.7 ± 0.6	10.8 ± 0.9	2.3 ± 0.3	4.8 ± 0.2
mean	69.2 ± 15.5	13.1 ± 4.7	14.2 ± 0.9	9.9 ± 1.4	2.2 ± 0.4	4.9 ± 0.2

Remarks: * Means ± S.E.D followed by different lower case letters indicate significant differences between lowland and upland (paired t test at $p \leq 0.05$ and $p \leq 0.09$)

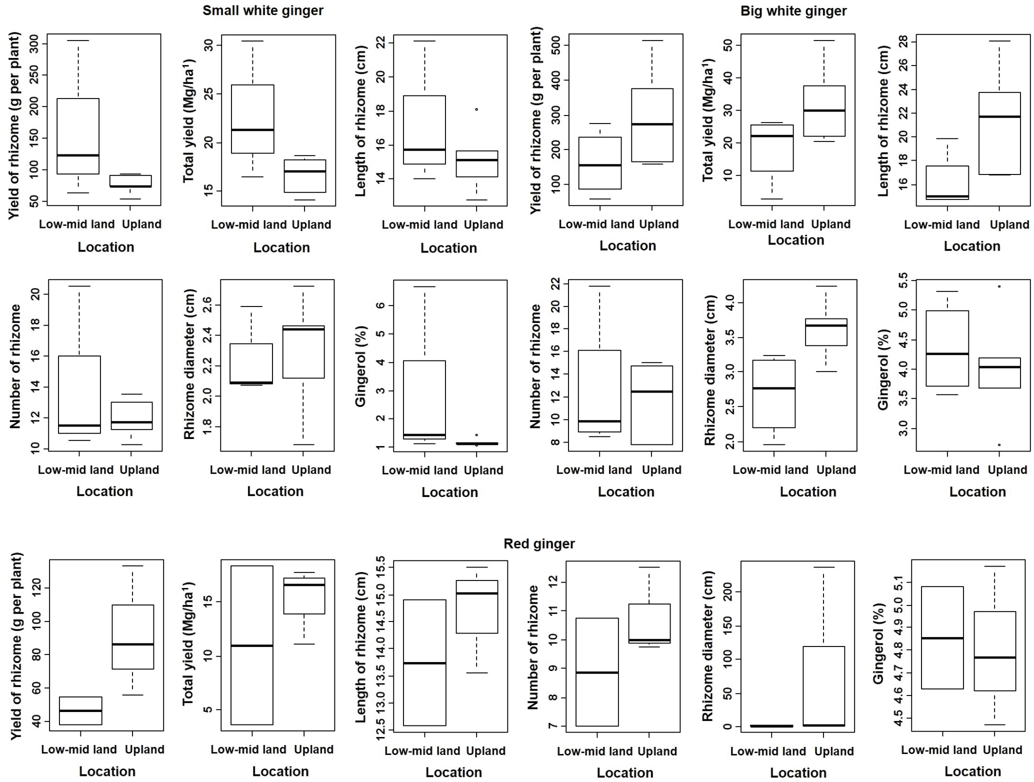

Fig. 1. The productivity and quality of ginger rhizomes that is cultivated in the low-mid land and

The average production potential of big white ginger rhizomes in the uplands and low-mid lands are 32 t/ha and 18 t/ha, respectively, with potential yields of rhizomes per plant reached 293 g in the upland and 161 g in the low-mid land. The similar result is also found in red ginger, the potential yield of rhizomes per plant in red ginger which is cultivated in the low-mid lands is lower than the uplands, but the potential yields per hectare was not different. The rhizome weight of red ginger per plant in the uplands is twice higher than those in the low-mid lands, which reaches an average of 92 g per plant, while its production potential only reaches 11-15 t/ha.

The Diversity of Land Characteristics for Ginger Cultivation

Based on observations on land characteristics, the particle size distribution in sampling site of ginger was dominated by silt loam (40% of sampling area) and clay loam (33% of sampling area) (Fig. 2). Ginger can be grown in a wide range of soil texture class, ranging from heavy loams to clayey. Soil texture highly influences the yield and quality of ginger. Loam soil has a good porosity and aeration to hold water and nutrition. This is important to seedling growth and development of root and rhizomes. According to Xizhen, Jinfeng, & Xia (2005), quality of rhizome and yield of ginger were observed higher when planted under loamy soils.

Clayey soils are generally located in the low-mid land which have greater ability to bind water and nutrients than the sandy texture. This result similar to the result of Gupta, Kumar, & Gupta (2019) who was reported that upland soil had lower clay content than lowland soil. Silty soil texture was found in the upland region where the parent material is derived from volcanic ash (Table 3). The higher clay content has the potential to inhibit the growth and size of rhizome due due to the rigid characterictic. These characteristic also may inhibit root growth especially when the soil tillage is minimal. In contrast to clay, silty-textured soils are easily penetrated by roots so that the growth and production of rhizome will be less inhibited. This can be seen in the production of big white and red ginger in the upland areas, which are higher than those from the low-mid land areas (Fig. 1).

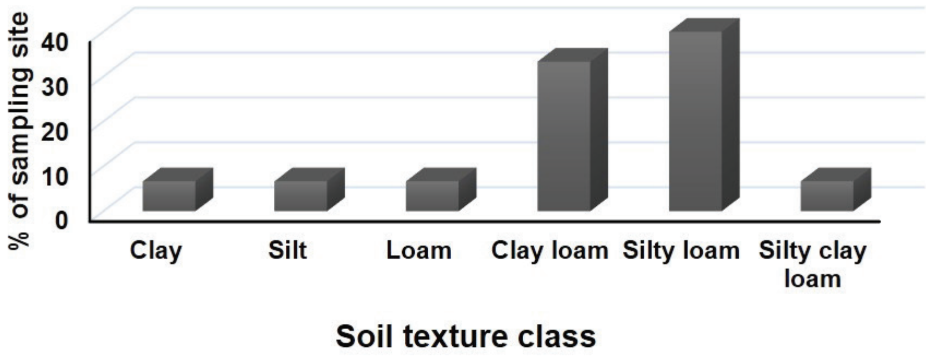

Fig. 2. Soil texture class from all sampling location of ginger

Table 3. Soil particle distribution from each sample location

No.	Village	Districts	Regency	Topography	Soil particle			Soil texture class
					Sand (%)	Silt (%)	Clay (%)	
1	Sepanjang	Glenmore	Banyuwangi	Low-mid land	9	61	30	Silty clay loam
2	Tulungrejo	Ngantang	Malang	Upland	23	44	33	Clay loam
3	Toyomarto	Singosari	Malang	Upland	40	28	32	Clay loam
4	Argosari	Jabung	Malang	Upland	35	33	32	Clay loam
5	Kebon agung	Sawahan	Nganjuk	Low-mid land	12	47	41	Clay loam
6	Hargomulyo	Ngrambe	Ngawi	Upland	5	84	11	Silt
7	Lebbek	Pakong	Pamekasan	Low-mid land	14	37	49	Clay
8	Lenteng Barat	Lenteng	Sumenep	Low-mid land	40	36	24	Loam
9	Miri	Kismantoro	Wonogiri	Low-mid land	23	54	23	Silty loam
10	Kledung	Bandar	Pacitan	Upland	9	41	50	Silty clay
11	Lenteng Barat	Lenteng	Sumenep	Low-mid land	9	61	30	Silty loam
12	Sukereno	Prigen	Pasuruan	Low-mid land	10	47	43	Silty clay
13	Nggenting	Ngoro	Mojokerto	Low-mid land	13	68	19	Silty loam
14	Sidomulyo	Pule	Trenggalek	Upland	35	37	28	Silty clay
15	Puyung	Pule	Trenggalek	Upland	35	37	28	Silty clay

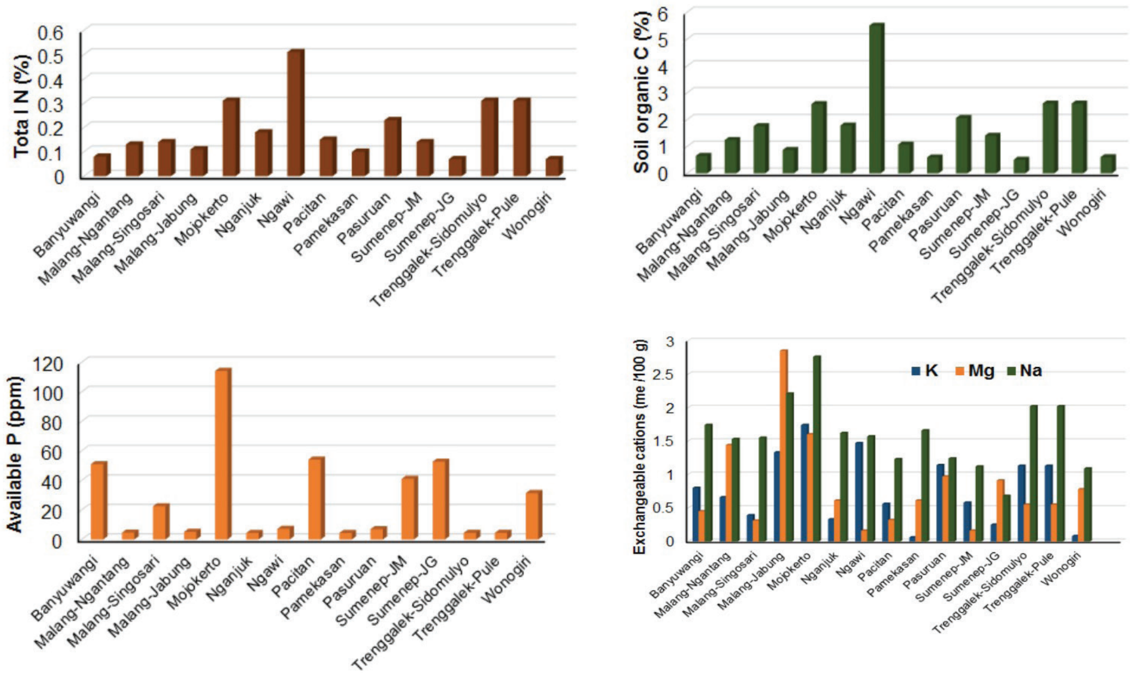

Fig. 3. The soil nutrient at 20 cm depth of soil from all sampling sites

The studied soils have low to very high soil organic C (based on the criteria from the Bogor soil research center 3 – 5 % is categorized as high). Fig. 3 showed that the highest soil organic C was found in Ngawi (Ngrambe) area, while the lowest is in Sumenep. The high soil organic C in the Ngrambe area was due to the fact that the soil in Ngrambe might have volcanic ash from the eruption of Mount Lawu and high input of organic matter from litter (coffee complex agroforestry system). The low soil organic C in Sumenep might be resulted from low input organic matter, since it was located near the coast and also intensive agriculture practices. Higher soil organic matter induces better soil properties for ginger rhizome growth, thus increases size and productivity. Other research which is conducted by Srinivasan et al. (2019) reported that rhizome yield and soil organic matter was greater with addition of organic nutrient management as compared to chemical nutrient management. This was indicated by the results of the correlation test between the soil organic C and the rhizome length (for red ginger), where the increase in rhizome length shows a tendency to be positively related to soil organic C (pearson correlation test $r = 0.77$, $p = 0.12$). This study showed that soil in the upland areas is more fertile than soil in the low-mid land area, supported by the higher CEC. As consequency, the research found positive correlation between topography and cation exchangeable capacity or CEC ($r = 0.73$, $p < 0.05$, $n = 11$).

In contrast to the soil organic C, the total N in the top soil (0-20 cm, Fig. 3) from all sampling site in East Java and Central Java was included in the criteria of very low (< 0.2% N; criteria for the Soil Research Institute, Bogor), except the total N in Mojokerto, Ngawi, Pasuruan, and Trenggalek which are included in the criteria of medium (0.21 – 0.5 % N; criteria for the Soil Research Institute, Bogor). The increasing total N content of the soil has the potential to increase the growth of ginger rhizomes. This was indicated by the Spearman's rank correlation test, where the total N content of the soil is positively correlated with the length of the red ginger rhizome (Spearman's rank correlation test $r = 0.9$, $p = 0.08$).

In general, the soil available P (Fig. 3) of all sampling areas is categorized in the very low and low, except soil available P in the Banyuwangi, Singosari, Pacitan, Mojokerto, Pacitan, Sumenep, and Wonogiri regions which is categorized in very high (> 20 ppm; criteria based on the Soil Research Center - Bogor). The P element is needed by plants for root development, so that the increases of soil available P is potentially to increase the development of roots and ginger rhizomes (Srinivasan et al., 2019). However, the study was unable to detected significant correlation between the soil available P with the production and size of ginger due to the high variation of soil P among sampling site and rhizome yield was closely related to soil organic matter as compared to soil available P.

Overall, the soil exchangeable K from all site is classified as moderate to very high (Fig. 3), except in Nganjuk, Pamekasan, Sumenep, and Wonogiri areas which are classified as low to very low criteria (< 0.3 me/100 g). The similar condition is also found in soil exchangeable sodium (Na) which is indicates that the majority of sampling locations for ginger have high to very high of soil exchangeable Na (except Sumenep). Although the land at the sampling location of ginger has a high soil exchangeable Na, but due to Na is not included in the essential nutrients it does not significantly affect the production of ginger. On the contrary, the majority of locations for collection ginger samples have a low to very low soil exchangeable magnesium (Mg; < 1.1 me/100 g), except in the areas of Ngantang, Jabung, and Mojokerto which have soil exchangeable Mg moderate to very high (Fig. 3). The correlation test showed a significant correlation between soil exchangeable K and ginger rhizome length (especially in red ginger) ($r = 0.876$, $p < 0.05$). This showed that the available K in the soil is very necessary in the formation and growth of rhizomes (Srinivasan et al., 2019).

The Role of Land Characteristics on Productivity and Quality of Ginger

The effect of land characteristics on ginger rhizome productivity (i.e. number, length, diameter, yield) and quality (gingerol content) was analysed by using correlation test. Based on correlation test, the relationship between land characteristics and ginger rhiozome performance and yield was found in big white ginger and red ginger. The increase of land topography resulted an increase of rhizome diameter and yield (e.g. big white ginger), supported by the positive correlation between topography and rhizome diameter and yield ($r = 0.65 – 0.81$, $p = < 0.05$, $n = 11$). Since there were no correlation between climate (i.e. temperature, humidity, light intensity) and rhizome yield and characteristics then probably land topography affected rhizome yield and diameter through both chemical and physical soil properties.

The role of chemical soil properties on ginger rhizome performance and yield was supported by CEC and soil nutrient content (e.g. K, Na). CEC plays an important role on cation availability in soil solution for supporting ginger performance. The higher value of CEC showed the more cations will be interchanged between soil solution and soil particle, resulted an increase of cation concentration in soil solution (e.g K, Na, Ca, Mg; Uddin, 2008) and ginger productivity (Srinivasan et al., 2019). The positive correlation between CEC and rhizome diameter of big white ginger ($r = 0.76$, $p < 0.01$, $n = 11$) and rhizome yield of red ginger ($r = 0.87$, $p < 0.05$, $n = 5$) correspond with the result from Djazuli & Sukarman (2007) and Mao, Ran, & Li (2016) that ginger production is higher in the fertile than unfertile soils due to ginger absorbed nutrient (e.g. N, P, K) for growth and production. While the role of soil nutrient content on performance and yield of ginger shown by positive correlation between cation exchangeable (e.g. K and Na) with rhizome yield and its performance (number and diameter) in big white ginger ($r = 0.62 – 0.84$, $p < 0.05$, $n = 11$), as well as positive correlation between rhizome length and soil exchangeable K in red ginger ($r = 0.89$, $p < 0.05$, $n = 5$). Since Potasssium (K) have function in improving root growth and plant vigor, as well as preventing lodging and enhancing crop resistance to pests and diseases (Tavakol et al., 2018; Ghao et al., 2018), the positive correlation between exchangeable K and Na with ginger yield and performance indicated that K affected rhizome growth.

Beside soil chemical properties, ginger rhizome performance and yield is also affected by soil physical properties. In this study, the effect of soil physical properties on ginger rhizome performance and yield was shown from the size of ginger rhizome. The rhizome size was larger in the silty loam and clay loam soils as compared to clay, silt, loam, and silty clay loam soils (Fig. 2). In the soil, differences in soil texture give rise to different pore size and affect to soil bulk density, soil moisture content, and root growth (Chaudhari, Ahire, Ahire, Chkravarty, & Maity, 2013; Vishkaee, Mohammadi, & Vanclooster, 2014; Lazarovitch, Vanderborght, Jin, & van Genuchten, 2018). Clay has a normal range of bulk densities from 1.0 to 1.6 mg/m^3 with potential root restriction occur at > 1.4 mg/m^3. While a normal range for sand is 1.2 to 1.8 mg/m^3 for clay with potential root restriction occur at > 1.6 mg/m^3 (Chaudhari, Ahire, Ahire, Chkravarty, & Maity, 2013).

Clayey soil generally has lower soil bulk density as compared to sandy soils. Agbede & Adekiya (2018) reported that ginger yield in Southwest Nigeria during three years cultivation increased in soil with low bulk density and high soil moisture content.

CONCLUSION

Differences in the character of ginger rhizomes (i.e. length, diameter and number of rhizomes) depend on the type of ginger, whereas topography affected the length of ginger rhizome (e.g big white ginger). In addition, the potential production of small white ginger is large in the low-mid lands (23 t/ha), whereas big white and red gingers production was higher in the upland rather than the lowlands (reaching 32 and 18 t/ha, respectively). The gingerol concentration in the ginger rhizome was not influenced by the altitude, but is more influenced by the type of ginger. The gingerol content of the small white ginger rhizomes is 1-3% on average, whereas in big white and red gingers on average of more than 4%. Based on land characteristics, the size of the ginger rhizome is greater in silty-textured soils and correlates with the soil chemical properties (e.g. CEC, soil nutrients of N and K). Thus, proper soil management (e.g. fertilization) is needed to maintain the sustainability of ginger production in agricultural land.

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REFERENCES

Agbede, T. M., & Adekiya, A. O. (2018). The effect of tillage on soil physical and chemical properties and yield of ginger. *Agriculturae Conspectus Scientificus*, *83*(4), 315–320. Retrieved from https://hrcak.srce.hr/207931

Agbede, T. M. (2019). Influence of Five Years of Tillage and Poultry Manure Application on Soil Properties and Ginger (Ziginber officinale Roscoe) Productivity. *Journal of Crop Science and Biotechnology*, *22*(2), 91–99. https://doi.org/10.1007/s12892-018-0155-0

Bermawie, N., & Purwiyanti, S. (2011). Botani, sistematika dan keragaman kultivar jahe. In *Status teknologi hasil penelitian jahe* (pp. 1-19). Bogor, ID: Balai Penelitian Tanaman Obat dan Aromatik. Retrieved from https://www.scribd.com/document/335760055/botani-sistematika-dan-keragaman-kultivar-jahe-pdf

BPS. (2017). *Statistik tanaman obat Indonesia*. Badan Pusat Statistik. Retrieved from https://www.bps.go.id/subject/55/hortikultura.html#subjekViewTab6

Chaudhari, P. R., Ahire, D. V, Ahire, V. D., Chkravarty, M., & Maity, S. (2013). Soil bulk density as related to soil texture, organic matter content and available total nutrients of coimbatore soil. *International Journal of Scientific and Research Publications*, *3*(2), 1–8. Retrieved from http://www.ijsrp.org/research-paper-0213/ijsrp-p1439.pdf

Djazuli, M., & Sukarman. (2007). *The effect of growth environment on growth and productivity of ginger*. Paper presented at Prosiding Seminar Nasional XIII PERSADA: Pembangunan Nasional Berbasis IPTEK untuk Kemandirian Bangsa, Bogor (pp. 96-99). Bogor, ID: Institut Pertanian Bogor.

Gao, X., Zhang, S., Zhao, X., & Wu, Q. (2018). Potassium-induced plant resistance against soybean cyst nematode via root exudation of phenolic acids and plant pathogen-related genes. PLOS ONE, 13 (7): e0200903. https://doi.org/10.1371/journal.pone.0200903.

Gupta, C. K., & Kumar, R. (2019). *Physical and Chemical Properties of Soil in Upland and Lowland Agro-Ecosystem of Garhwa District , Jharkhand*. *37*(March), 393–397.

Ilyas, S., Palupi, E. R., & Susila, A. D. (2016). Growth, yield and quality of ginger from produced through early senescence. *International Journal of Applied Science and Technology*, *6*(1), 21–28. Retrieved from http://www.ijastnet.com/journals/Vol_6_No_1_February_2016/4.pdf

Islam, M.S., Rahman, K.M.M., & Hasan, M.K. (2011). Profitability and resource use efficiency of producing major spices in Bangladesh. The Bangladesh journal of agricultural economics, XXXIV (1&2), 1-13. https://doi.org/10.22004/ag.econ.199330

Kizhakkayil, J., & Sasikumar, B. (2011). Diversity, characterization and utilization of ginger: A review. *Plant Genetic Resources*, *9*(3), 464–477. https://doi.org/10.1017/S1479262111000670

Lazarovitch, N., Vanderborght, J., Jin, Y., & van Genuchten, M.T. (2018). The root zone: soil physics and beyond. Vadose Zone J, 17, 1-6. https://doi.org/10.2136/vzj2018.01.0002.

Mao, H., Ran, L., & Li, H. (2016). Study on soil nutrient contents and nutrient characteristics of ginger (*Zingiber officinale* Rosc.). *Agricultural Science & Technology*, *17*(1), 92–95. Retrieved from https://search.proquest.com/openview/a00aefbe4eeebc5bc2df6034afa174b0/1?cbl=1596357&pq-origsite=gscholar

Murni, S., Pujiastuti, I. S. S., & Octoria, D. (2017). Improving the production quality of atsiri oil industry through the introduction of equipment and diversification of raw materials. *Review of Integrative Business and Economics Research*, *6*(Supplementary Issue 1), 32–41. Retrieved from http://buscompress.com/uploads/3/4/9/8/34980536/riber_6-s1_sp_a17-061_32-41.pdf

Nugroho, R. A., & Ningsih, E. A. (2017). Produksi tanaman obat. In Z. Salim & E. Munadi (Eds.), *Badan Pengkajian dan Pengembangan Perdagangan* (pp. 9–20). Jakarta, ID: Badan Pengkajian dan Pengembangan Perdagangan Kementerian Perdagangan Republik Indonesia. Retrieved from http://bppp.kemendag.go.id/media_content/2017/12/Isi_BRIK_Tanaman_Obat.pdf

Nwaogu, E. N. (2014). Soil fertility changes and their effects on ginger (*Zingiber officinale* Rosc.) yield response in an ultisol under different pigeon pea hedgerow alley management in South Eastern Nigeria. *African Journal of Agricultural Research*, *9*(28), 2158–2166. https://doi.org/10.5897/ajar2013.7291

Pandey, V., Shukla, S., Saxena, J., Khan, S., & Kumar, R. (2018). Ginger (*Zingiber officinale* Rosc.) productivity in tree based agro forestry system. *JOJ Horticulture & Arboriculture*, *1*(4), 555568. Retrieved from https://www.researchgate.net/publication/327221775_Ginger_Zingiber_Officinale_Rosc_Productivity_in_Tree_Based_Agro_Forestry_System

Ravindran, P. N., & Babu, K. N. (2004). *Ginger: The genus zingiber* (1st ed.). Boca Raton, FL: CRC Press. Retrieved from https://www.crcpress.com/Ginger-The-Genus-Zingiber/Ravindran-Babu/p/book/9780415324687

Riptanti, E. W., Qonita, A., & Fajarningsih, R. U. (2018). Potentials of sustainable development of medicinal plants in Wonogiri regency of Central Java province of Indonesia. *Bulgarian Journal of Agricultural Science*, *24*(5), 742–749. Retrieved from https://www.agrojournal.org/24/05-03.pdf

Rostiana, O., Efendi, D. S., & Bermawie, N. (2007). *Teknologi unggulan jahe*. *Booklet Puslitbangbun* (Vol. 16). Bogor, ID: Pusat Penelitian dan Pengembangan Perkebunan. Retrieved from https://scholar.google.com/scholar?cluster=4580333649652769608&hl=en&oi=scholarr

Semwal, R. B., Semwal, D. K., Combrinck, S., & Viljoen, A. M. (2015). Gingerols and shogaols: Important nutraceutical principles from ginger. *Phytochemistry*, *117*, 554–568. https://doi.org/10.1016/j.phytochem.2015.07.012

Srinivasan, V., Thankamani, C. K., Dinesh, R., Kandiannan, K., Hamza, S., Leela, N. K., & John Zachariah, T. (2019). Variations in soil properties, rhizome yield and quality as influenced by different nutrient management schedules in rainfed ginger. *Agricultural Research*, *8*(2), 218–230. https://doi.org/10.1007/s40003-018-0382-y

Sukarman, & Melati. (2011). Produksi benih jahe (*Zingiber officinale* Rosc.) sehat. In *Status teknologi hasil penelitian jahe* (pp. 20-30). Bogor, ID: Balai Penelitian Tanaman Obat dan Aromatik. Retrieved from https://www.scribd.com/doc/214406360/produksi-benih-jahe

Syafitri, D. M., Levita, J., Mutakin, M., & Diantini, A. (2018). A review: Is ginger (*Zingiber officinale* var. Roscoe) potential for future phytomedicine? *Indonesian Journal of Applied Sciences*, *8*(1), 8–13. https://doi.org/10.24198/ijas.v8i1.16466

Tavakol, E., Jakli, B., Cakmak, I., Dittert, K., Karlovsky, P., Pfohl, K., & Senbayram, M. (2018). Optimized potassium nutrition improves plant-water-relations of barley under PEG-induces osmotic stress. Plant soil, 430, 23-35. https://doi.org/10.1007/s11104-018-3704-8.

Uddin, F. (2008). Clays, nano clays, and montmorillonite minerals. Metall Mater Trans, 39, 2804–2814. https://doi.org/10.1007/s11661-008-9603-5

Vishkaee, F.M., Mohammadi, M.H., & Vanclooster, M. (2014). Predicting the soil moisture retention curve, from soil particle size distribution and bulk density data using a packing density scaling factor. Hydrology and Earth System Sciences, 18, 4053-4063. https://doi.org/10.5194/hess-18-4053-2014.

Xizhen, A., Jinfeng, S., & Xia, X. (2005). Ginger production in Southeast Asia. In P. N. Ravindran, & K. Nirmal Babu (Eds.), *Ginger: The genus zingiber* (pp. 241-278). Boca Raton: CRC Press. Retrieved from https://www.taylorfrancis.com/books/e/9780429120770/chapters/10.1201/9781420023367-10