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A model of relationship between climate and soil factors related to oxalate content in porang (*Amorphophallus muelleri* Blume) corm

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ABSTRACT

*Indriyani S, Arisoesilaningsih E, Wardiyati T, Purnobasuki H (2011) A model of relationship between climate and soil factors related to oxalate content in porang (*Amorphophallus muelleri *Blume) corm. Biodiversitas 12: 45-51.* The abiotic environment as well as the biotic environment, involved climate and soil affect directly or indirectly to plant growth as well as plant substance. The objective of the research was to obtain a model of relationship between climate and soil factors related to oxalate content in porang corm. Porang corms were collected from five locations of porang agroforestry in East Java. The locations were (i) Klangon Village, Saradan Subdistrict, Madiun District; (ii) Klino Villlage, Sekar Subdistrict, Bojonegoro District; (iii) Bendoasri Village, Rejoso Subdistrict, Nganjuk District; (iv) Sugihwaras Village, Nggluyu Subdistrict, Nganjuk District and (v) Kalirejo Village, Kalipare Subdistrict, Malang District. Geography variable consist of altitude. Climate variables consist of percentage of radiation, temperature and rainfall. Soil variables consist of electrical conductivity, pH, soil specific gravity, soil organic matter, available of calcium, and cation exchange capacity (CEC). Vegetation variables consist of species of plant tree and percentage of coverage. Porang vegetative growth variables consist of plant height, number of bulbil, canopy diameter, and petiole diameter. Corm variables consist of corm diameter, corm weight, and corm specific gravity. Oxalate variables consist of total oxalate, soluble oxalate, insoluble oxalate, and density of calcium oxalate crystal. Oxalate contents were measured based on AOAC method. All of variables were collected from first to fourth growth period of porang. Data were analyzed by smartPLS (Partial Least Square) software. The results showed that there were significantly direct effect between altitude and temperature, altitude and CEC of soil, temperature and CEC of soil, altitude and percentage of coverage, temperature and percentage of coverage, CEC of soil and percentage of coverage, CEC of soil and petiole diameter, petiole diameter and corm diameter, and petiole diameter and corm oxalate content. There were no significantly direct effect among altitude, temperature, percentage of coverage and petiole diameter; and among corm total oxalate, soluble oxalate, insoluble oxalate, and density of calcium oxalate crystal and corm diameter. The value of Goodness of Fit of the developing model was R^2=0.99.

Key words: corm, climate, model, oxalate, smartPLS, porang, soil.

INTRODUCTION

Porang is a seasonal herb and perennial plant that produces corm, grouped in Araceae. Porang stem is erect, smooth, green color with pale spots. Actually, stem of porang is a petiole that known as false stem. Petiole is divided to three and then divided again to support leaves blade. At the junction between false stem and petiole is produced bulbil with dark brown color and it used as vegetative reproduction (Yuzammi 2000). The height of porang can reach 1.5 m depend on the fertile soil. Porang tolerant to shading, it need 40-60% light intensity. Appropriate shading plants for porang planting are *Tectona grandis*, *Swietenia mahagoni*, and *Pterocarpus* sp. Porang can grow until 700 m above sea level. Planting of porang need pH of soil 6-7. Porang corms consist of high fiber without cholesterol, and 20-65% glucomannan as a healthy food for diet (Jansen et al. 1996; Sulaeman 2004; Lase 2007).

Processing of porang corm produces noodle, tofu, *rangginang*, some Japanese food such as konyaku and shirataki, industrial material, etc. Porang corm produces glucomannan that can used as a waterproof material if it is mixed with sodium hydroxide; beside that it can utilized to purify water and floating colloid in beer, sugar, and oil industry. Pharmacy industries utilize glucomannan in porang corm for tablet glue and capsule coat. The product of porang corms are exported to Japan, Taiwan, Korea, and some countries in Europe. The economic value of porang corm is very high especially in Japan (Sulaeman 2004; Lase 2007).

The cultivation of porang is conducted in some agroforestry in East Java. The plantation area consist of six KPH (*Kesatuan Pemangkuan Hutan*), there are (i) the area in KPH Jember is 121.3 ha, (ii) the area in KPH Nganjuk is 759.8 ha, (iii) the area in KPH Padangan is 3.9 ha, (iv) the area in KPH Saradan is 615.0 ha, (v) the area in KPH Bojonegoro is 35.3 ha, and (vi) the area in KPH Madiun is

70.0 ha. In the early of porang plantation, it was developed in 1975 in KPH Blitar with 100 ha for cultivation, and in KPH Saradan in 1990 with 20 ha. Porang cultivation in KPH Nganjuk was done since 2003 by farmers in Sugihwaras Village (Lase 2007).

Porang production in Bogor (rainfall > 3000 $mm.year^{-1}$) higher than in Blitar or Blora, whereas the climate of each location based on Schmidth-Ferguson involved B and C (Afriyol 1993). The rainfall and climate type correlate with porang corm production. Production of porang corm depends on life cycle phase during 38-43 months. Sumarwoto (2005) explained scheduling of life cycle: time of seedling was 1.5-2 months, time of growth of seedling was 1.5-2 months, time of each of vegetative phase in year one to three was 5-6 months, time of each of dormancy in year one to three was 4 months, time of flowering to fruit maturing was 8-9 months. Flowering occurs in corm weight more than 500 g and minimally two times of life cycle or growth period. Then the plant growth predicted alternately between vegetative and generative phase.

Monoculture cultivation in Bogor resulted the information that planting distance for first growth period was 37.5x37.5 cm^2; second growth period was 57.5x57.5 cm^2; and third growth period was 100x100 cm^2 (Sumarwoto 2005). Whereas, Jansen et al. (1996) reported that planting distance for *Amorphophallus* vary with the plant material used, e.g. seeds at 10 cm, bulbils at 35-70 cm, and tubers at 35-90 cm. Normally, tubers become larger at wider spacing, but tuber growth is also influenced by the size of planting material, water availability and soil fertility. Harvesting was done when corm age minimally reach second growth period with glucomannan 41.8%. Wider canopy diameter accompanied with higher corm glucomannan (Sumarwoto 2005).

Although porang corm has multifunction for human being, as an Araceae plants, there are very high calcium oxalate in all plant organs. Oxalate in food causes unavailability of calcium in human body, and toxic to animal (Nakata 2003). In high content, oxalic acid affects mechanical aberration in digestive tract and smooth tubules in kidney. Chemically, oxalic acid absorbs calcium that important for nerve and muscle fiber function. In an extreme condition, absorption of calcium affects hypocalcaemia and paralysis (Brown 2000). Although many factors affect kidney problems, it is recommended to limit consumption of food that consists of high oxalate, especially for kidney stone risk people (Noonan and Savage 1999).

Plants produce oxalate 3-80% from dry weight, 90% of total calcium found in oxalate salt involved calcium oxalate. Calcium oxalate crystals found in many kind of plant tissue, but the highest content of calcium oxalate found in specialized vacuoles named crystal idioblast. Oxalate in plant found as soluble (oxalic acid) such as potassium oxalate, sodium oxalate, and ammonium oxalate and insoluble as calcium oxalate (Holloway et al. 1989). Plants produce calcium oxalate crystal in various shape and size. Based on the shape, there are five categories of crystal, e.g. sand, raphide (needle), druse, stiloid, and prismatic (Nakata 2003). The types of calcium oxalate crystal in Araceae are raphide and druse (Prychid and Rudall 1999; Prychid et al. 2008). Hagler and Herman (1973) reported that the formation of calcium oxalate via cleavage of respiratory carbohydrate or from protein metabolism. While, Franceschi and Nakata (2005) reported that the formation of calcium oxalate via glycolate, but others stated via L-ascorbic acid precursor.

Actually, climate and soil influence plant growth and development, as well as plant substance. Research in this field, usually was conducted partially or univariately. In fact, in the environment, climate and soil influence directly or indirectly to plant growth as well as plant substance. The information of climate and soil factors related to oxalate content in porang corm that are analyzed simultaneously and multivariately in a model has not been intensively studied yet. Based on this argument, research was conducted using model simulation with smartPLS software to obtain a model of relationship between climate and soil factors related to corm oxalate content in porang.

MATERIALS AND METHODS

Porang exploration was conducted on March to May 2009 in five agroforestries in East Java, Indonesia involved (i) Klangon Village, Saradan Subdistrict, Madiun District; (ii) Klino Village, Sekar Subdistrict, Bojonegoro District; (iii) Bendoasri Village, Rejoso Subdistrict, Nganjuk District; (iv) Sugihwaras Village, Ngluyu Subdistrict, Nganjuk District and (v) Kalirejo Village, Kalipare Subdistrict, Malang District. The number of total samples was 107 plants as many as soil samples. Geography variable consists of altitude (g1) was measured by Global Positioning System (GPS). Climate variables consist of percentage of radiation (i1) was measured by solarimeter, temperature (i2) was measured by thermometer, and rainfall (i3) was obtained from Meteorology, Climatology, and Geophysics Agency at Karangploso Malang. Soil variables consist of electrical conductivity (s1), pH (s2), soil specific gravity (s3), soil organic matter (s4), available of calcium (s5), and cation exchange capacity / CEC (s6). Soil electrical conductivity was measured by conductivitymeter, soil pH (H_2O) was measured by pHmeter, soil specific gravity was measured by cylindrical method, soil organic matter was measured by volumetry, available of calcium was measured by EDTA titration, and CEC was measured by flame photometry. Soil variables were measured at Soil Department, Faculty of Agriculture, Brawijaya University. Vegetation variables consist of species of plant tree (v1) and percentage of coverage (v2). Porang vegetative growth variables consist of plant height (t1), number of bulbil (t2), canopy diameter (t3), and petiole diameter (t4). Corm variables consist of corm diameter (u1), corm weight (u2), and corm specific gravity (u3). Oxalate variables consist of total oxalate (o1), soluble oxalate (o2), insoluble oxalate (o3), and density of calcium oxalate crystal (o4). Oxalate contents were measured based on AOAC (1990) and calcium oxalate crystal density were counted based on Cao (2003). All of variables were collected from first to fourth growth period of porang. The determination of growth period of porang was referred to Sumarwoto (2005). Oxalate measurement was done at Biology and Chemistry Department, Faculty of Mathematics and Natural Sciences, Brawijaya University, Malang, East Java, Indonesia.

The relationship between climate and soil factors that influence oxalate content of porang corm was simulated by smartPLS software (Ghozali 2008; Solimun and Fernandes 2008; Sarmanu et al. 2009). Pairing data were obtained from all variables that compelled in MS Excel table. Data were analyzed multivariately to examine a designed structural equation model with smartPLS software. Sequentially stage were: (i) Designing Structural Model (inner model), (ii) Designing Measuring Model (outer model), (iii) Constructing Path Diagram, (iv) Converting Path Diagram to Equation System, (v) Estimation: Path Coefficient, Loading, and Weight, (vi) Evaluation of Goodness of Fit, and (vii) Hypothesis Examination (Resampling Bootstrapping). Statistically examination with t-test α=5%. If *p-value* ≤ 0.05 means a real model. Real outer model shows that indicator is valid, real inner model shows the real effect of measurable variable. The examination of Goodness of Fit of structural model in inner model was measured by predictive-relevance (Q^2) value as the follow formula:

$$Q^2 = 1-(1-R_1^2) (1-R_2^2) ... (1- R_p^2)$$

$R1^2$, R_2^2, … R_p^2 were R-square value of endogen variable in model. The interpretation of Q^2 was equal with the total determination coefficient in path analysis (resemble with R^2 in regression).

RESULTS AND DISCUSSION

Proposed model was very useful to explain the phenomenon of the relationship between abiotic and biotic factors that influence plant growth and plant substance. Figure 1 revealed a model (structural model) of relationship between climate and soil factors related to oxalate content in porang corm based on empirical study.

The result of examination of Measurement Model

Measurement model (outer weight) will be examined whether the weight of each formative indicator significantly composes the latent variables. Outer weight value reveals the weight of each indicator as measurement of each latent variable. The examination of signification of outer weight can revealed in p-value, if p-value < 5% or 0.05 the indicator significantly composes latent variables. The highest value of outer weight of indicator indicates that this indicator as a strong measurement of variable (dominant).

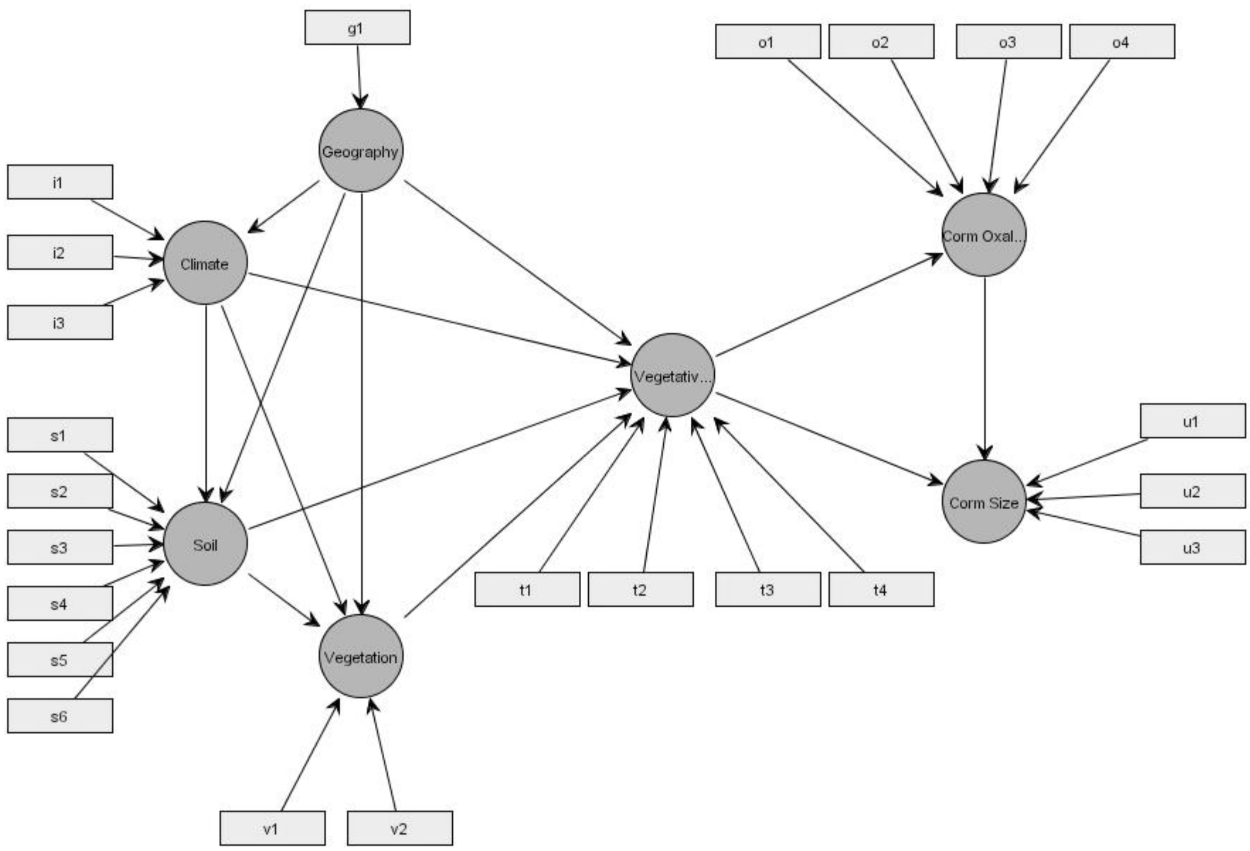

Figure 1. A model of relationship between climate and soil factors related to oxalate content in porang corm. Note: g1: altitude, i1: percentage of radiation, i2: temperature, i3: rainfall, s1: electrical conductivity, s2: pH, s3: soil specific gravity, s4: soil organic matter, s5: available of calcium, s6: cation exchange capacity (CEC), v1: species of plant tree, v2: percentage of coverage, t1: plant height, t2: number of bulbil, t3: canopy diameter, t4: petiole diameter, u1: corm diameter, u2: corm weight, u3: corm specific gravity, o1: total oxalate, o2: soluble oxalate, o3: insoluble oxalate, and o4: density of calcium oxalate crystal.

Table 1. The result of the examination of indicators that compose latent variables

Indicator	Outer weight	Standard deviation	T-Statistic	p-value
Geography				
▪ Altitude (g1)	1			
Climate				
▪ Percentage of radiation (i1)	0.076	0.329	0.231	0.817
▪ Temperature (i2)	0.803	0.237	3.39	0.001*
▪ Rainfall (i3)	0.338	0.304	1.113	0.266
Soil				
▪ Electrical conductivity (s1)	-0.092	0.147	0.624	0.533
▪ pH (s2)	-0.049	0.214	0.227	0.820
▪ Soil specific gravity (s3)	0.226	0.273	0.828	0.408
▪ Soil organic matter (s4)	0.143	0.179	0.8	0.424
▪ Available of calcium (s5)	-0.506	0.348	1.455	0.146
▪ Cation exchange capacity (s6)	1.392	0.313	4.45	0.000*
Vegetation				
▪ Species of plant tree (v1)	0.48	0.346	1.388	0.165
▪ Percentage of coverage (v2)	0.774	0.416	1.86	0.063*
Vegetative growth				
▪ Plant height (t1)	0.019	0.549	0.035	0.972
▪ Number of bulbil (t2)	-0.091	0.5	0.183	0.855
▪ Canopy diameter (t3)	-0.22	0.474	0.464	0.643
▪ Petiole diameter (t4)	1.229	0.431	2.849	0.004*
Corm size				
▪ Corm diameter (u1)	1.018	0.215	4.73	0.000*
▪ Corm weight (u2)	0.033	0.233	0.14	0.889
▪ Corm specific gravity (u3)	0.094	0.112	0.842	0.400
Corm oxalate content				
▪ Total oxalate (o1)	-6.342	2.035	3.116	0.002*
▪ Soluble oxalate (o2)	6.504	2.074	3.136	0.002*
▪ Insoluble oxalate (o3)	2.126	0.801	2.654	0.008*
▪ Density of calcium oxalate crystal (o4)	0.742	0.2	3.703	0.000*

Note: * = significant (p-value < 0.05)

Table 2. The result of repeat examination of indicators that compose latent variables

Indicator	Outer weight	Standard deviation	T-Statistic	p-value
Geography				
▪ Altitude (g1)	1			
Climate				
▪ Temperature (i2)	1	0		
Soil				
▪ Cation exchange capacity (s6)	1	0		
Vegetation				
▪ Percentage of coverage (v2)	1	0		
Vegetative growth				
▪ Petiole diameter (t4)	1	0		
Corm size				
▪ Corm diameter (u1)	1	0		
Corm oxalate content				
▪ Total oxalate (o1)	-6.125	2.218	2.761	0.006*
▪ Soluble oxalate (o2)	6.274	2.352	2.668	0.008*
▪ Insoluble oxalate (o3)	2.09	0.535	3.904	0.000*
▪ Density of calcium oxalate crystal (o4)	0.771	0.099	7.825	0.000*

Note: * = significant (p-value < 0.05)

Based on Table 1, it was recognized that there were two climate indicators, five soil indicators, one vegetation indicator, three vegetative growth indicators, and two corm size indicators were not significantly to compose each latent variables, so it was necessary to evaluate the early PLS model. Next, Table 2 revealed the result of measurement model without no significant indicators that compose latent variables. Based on Table 2, it was revealed that all of indicators significantly to compose latent variables.

The examination of Goodness of Fit Model

The examination of Goodness of Fit of structural model in inner model utilizes predictive-relevance value (Q^2). R^2 value of each endogen variables in this research as follow:

The meaning of table 3 was explained as follow: first column showed latent variables that used in this model; second column showed R^2 value of each variable, third column showed the value of one minus R^2, and the fourth column showed the multiplication of each row in the third column with the value of sequence previous row in fourth column. Counting of the values were: geography = 1 because only one indicator (altitude) that used in the model; climate = 0.157x1 = 0.1570; soil = 470x0.157 = 0.07379; vegetation = 0.572x0.07379 = 0.042208; vegetative growth = 0.572x0.042208 = 0.039296; corm size = 0.141x0.039296 = 0.005541; and corm oxalate content = 0.771x0.005541 = 0.004272.

Beside that, the explanation of Table 3 is as follow: (i) R^2 = 0.843 for climate variable. The meaning of the value, 84.3% climate was influenced by geography; (ii) R^2 = 0.530 for soil variable. The meaning of the value, 53.0% soil was influenced by climate and geography; (iii) R^2 = 0.428 for vegetation variable. The meaning of the value, 42.8% vegetation was influenced by geography, climate, and soil; (iv) R^2 = 0.069 for vegetative growth variable. The meaning of the value, 6.90% porang vegetative growth was influenced by geography, climate, soil, and vegetation; (v) R^2 = 0.859 for corm size variable. The meaning of the value, 85.9% corm size was influenced by vegetative growth; and (vi) R^2 = 0.229 for corm oxalate content variable. The meaning of the value, 22.9% corm oxalate content was influenced by vegetative growth. The predictive-relevance value was obtained with the equation as follow:

$$Q^2 = 1-(1-R_1^2) (1-R_2^2) ... (1- R_p^2)$$

$$Q^2 = 1-(1-0{,}843) (1-0{,}530) (1-0{,}428) (1-0{,}069) (1-0{,}859)(1-0{,}229)$$

$$Q^2 = 99{,}45\% \text{ or } 0{,}99$$

The result revealed that the predictive-relevance value Q^2 was 99% or 0.99 and above 80%, so the model reasonable to possess a relevant predictive value. The predictive relevance value 99% indicated that the information in the data 99% could be explained by this PLS model. The residue 1% was explained by other variables that not involved in the model yet.

Table 3. The relationship between R² and Q² value for the examination of Goodness of Fit

	R-square	1-(R-square)	Multiplication of 1-(R-square) with the value of sequence previous row
Geography			1
Climate	0.843	0.157	0.157
Soil	0.530	0.470	0.07379
Vegetation	0.428	0.572	0.042208
Vegetative growth	0.069	0.931	0.039296
Corm size	0.859	0.141	0.005541
Corm oxalate content	0.229	0.771	0.004272

Table 4. The result of direct effect examination

Independent variables	Dependent variables	Inner weight	T-statistics	p-value	Note
Geography	Climate	-0.918	63.864	0.000	Significant
Geography	Soil	0.363	2.299	0.022	Significant
Climate	Soil	1.047	7.807	0.000	Significant
Geography	Vegetation	1.466	9.1	0.000	Significant
Climate	Vegetation	1.033	4.625	0.000	Significant
Soil	Vegetation	0.249	2.206	0.027	Significant
Geography	Vegetative growth	0.357	1.241	0.215	No significant
Climate	Vegetative growth	0.417	1.331	0.183	No significant
Soil	Vegetative growth	-0.306	2.304	0.021	Significant
Vegetation	Vegetative growth	-0.063	0.543	0.587	No significant
Growth	Corm Size	0.892	31.979	0.000	Significant
Corm oxalate content	Corm Size	0.069	1.555	0.120	No significant
Growth	Corm oxalate content	0.478	7.089	0.000	Significant

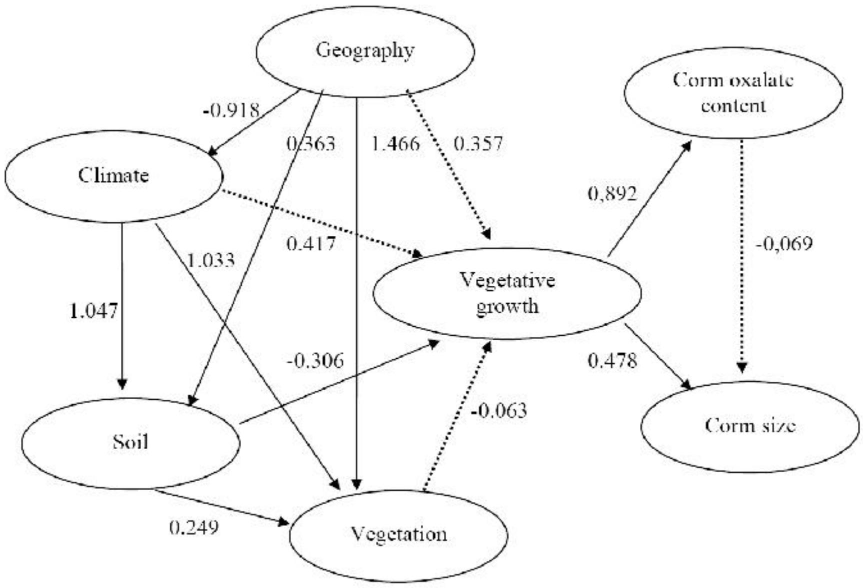

Figure 2. Path diagram of the result of the examination of direct effect hypothesis. Note: Dot line indicates indirect effect, straight line indicates direct effect

The result of examination of Inner Model

Basically, the examination of inner model (structural model) is to examine the research hypothesis. The hypothesis examination was done through t-test of each path that influence directly and partially. The result of analysis completely involved in PLS analysis. Table 4 revealed the result of the examination of direct effect hypothesis. The paths of hypothesis examination were revealed as follow (Figure 2).

Beside that, it was obtained the examination result of indirect effect. The coefficient of indirect effect was obtained from the multiplication result of two or more direct effect. If there were two or more direct effect that composes indirect effect significantly, so indirect effect also significant. The result of direct effect examination (Table 4) was explained as follow: (i) There was significantly direct effect (p-value 0.00 < 0.05) and negative (inner weight-0.918) between altitude and temperature. The meaning was higher altitude condition affects lower temperature condition; (ii) There was significantly direct effect (p-value 0.022 < 0.05) and positive (inner weight 0.363) between altitude and CEC of soil. The meaning was higher altitude condition affects higher CEC of soil condition; (iii) There was significantly direct effect (p-value 0.000 < 0.05) and positive (inner weight 1.047) between temperature and CEC of soil. The meaning was higher temperature condition affects higher CEC of soil condition; (iv) There was significantly direct effect (p-value 0.000 < 0.05) and positive (inner weight 1.466) between altitude and percentage of coverage. The meaning was higher altitude condition affects higher percentage of coverage condition; (v) There was significantly direct effect (p-value 0.000 < 0.05) and positive (inner weight 1.033) between temperature and percentage of coverage. The meaning was higher temperature condition affects higher percentage of coverage condition; (vi) There was significantly direct effect (p-value 0.027 < 0.05) and positive (inner weight 0.249) between CEC of soil and percentage of coverage. The meaning was higher CEC of soil condition affects higher percentage of coverage condition; (vii) There was not significantly direct effect (p-value 0.215 > 0.05) or there was indirect effect between altitude and petiole diameter condition; (viii) There was not significantly direct effect (p-value 0.183 > 0.05) or there was indirect effect between temperature and petiole diameter condition; (ix) There was significantly indirect effect between temperature and petiole diameter. The coefficient of indirect effect was 1.047x-0.306 =-0.320. The meaning was higher temperature condition affects lower petiole diameter condition if the condition of CEC of soil was lower too; (x) There was significantly direct effect (p-value 0.021 < 0.05) and negative (inner weight-0.306) between CEC of soil and petiole diameter. The meaning was higher CEC of soil condition affects lower petiole diameter condition; (xi) There was not significantly direct effect (p-value 0.587 > 0.05) or there was indirect effect between percentage of coverage and petiole diameter condition; (xii) There was significantly direct effect (p-value 0.000 < 0.05) and positive (inner weight 0.892) between petiole diameter and corm diameter. The meaning was higher petiole diameter condition affects higher corm diameter condition; (xiii) There was not significantly direct effect (p-value 0.120 > 0.05) or there was indirect effect among corm total oxalate, soluble oxalate, insoluble oxalate, and density of calcium oxalate crystal and corm diameter condition; (xiv) There was significantly direct effect (p-value 0.000 < 0.05) and positive (inner weight 0.478) among petiole diameter and corm total oxalate, soluble oxalate, insoluble oxalate, and density of calcium oxalate crystal condition. The meaning was higher petiole diameter condition affects higher corm total oxalate, soluble oxalate, insoluble oxalate, and density of calcium oxalate crystal condition.

Many scientific information explain the correlation between environmental factors and plant growth. The interaction between environmental factors and genetic factors will influence plant production (Sugito 1999). Environmental factors also affect plant growth as well as plant substance in this case plant oxalate content. Although oxalate is not a secondary metabolite compound, plant oxalate content is affected by environmental factors. Rahman et al. (2006) reported that oxalate content in napiergrass (*Pennisetum purpureum* Schumach) was significantly affected by the season with the highest value (3.77%) being associated with early summer samples and the lowest value (1.76%) with late autumn samples. Cao (2003) reported that environmental factors such as rhizospheric nutrition concentrations and light intensity were affected calcium oxalate crystals in an ornamental plant *Dieffenbachia*. Both of these previous research results support the results. The altitude, temperature, and percentage of coverage were indirectly affected to petiole diameter. The CEC of soil was directly affected to petiole diameter. The petiole diameter was directly affected to corm oxalate content and corm size, while corm oxalate content was not directly affected to corm size.

Based on plant physiology experts, oxalate synthesis in plant presumed via some precursors for example oxidation and dismutation of glyoxylate, cleavage of oxaloacetate, and cleavage of ascorbate (Libert and Franceschi 1987; Franceschi and Nakata 2005), while Hagler and Herman (1973) reported that the formation of calcium oxalate via cleavage of respiratory carbohydrate or from protein metabolism. Based on the results, oxalate synthesis in plant was not directly influenced by temperature and CEC of soil, but it was 89.2% directly influenced by petiole diameter. Whereas, petiole diameter was 30.6% directly influenced by CEC of soil, but negative value. The meaning was higher CEC of soil affects lower petiole diameter of porang. The petiole diameter was 47.8% directly affected to corm diameter; and 89.2% directly affected to corm total oxalate, soluble oxalate, insoluble oxalate, and density of calcium oxalate crystal. The corm total oxalate, soluble oxalate, insoluble oxalate, and density of calcium oxalate crystal were not directly affected to corm diameter.

The information of the correlation between the environment and plant oxalate content also obtained from Singh (1974) who explained that vegetable plant *Chenopodium album* L. and *C. amaranticolor* L. which treated with light (climate), fertilizers and salinity (soil mineral) revealed that oxalic acid synthesized in leaves as a metabolite from both photosynthesis and non-photosynthesis pathway. The meaning was light directly influenced to photosynthesis and indirectly influenced to oxalate synthesis. However, in this research revealed that light was not influenced to corm oxalate content but temperature indirectly influenced to petiole diameter. Therefore, temperature also indirectly influenced to porang corm oxalate content. The difference of this results presumed due to the former design and data analysis were analyzed partially or univariately.

Some researchers reported that oxalate content different for any kind of plant species depend on age, physiology, environment, and genetic (Libert and Franceschi 1987). Palaniswamy et al. (2002, 2004) explained that oxalic acid was influenced by nitrogen (soil mineral) and the age of leaves in hydroponic vegetable plant *Portulaca oleraceae* L. Sumarwoto (2008) explained that P and K fertilizer (soil mineral) influenced corm size (diameter, thickness, and weight of corm) of *Amorphophallus muelleri*, but no information about corm oxalate content.

Ambarwati and Murti (2001) reported that corm diameter and weight of *Amorphophallus variabilis* positively and significantly correlated with glucomannan and starch, and negatively correlated with corm oxalate content. However, the increasing of corm size was not always followed by the decreasing of corm oxalate content and vice versa. This fact was appropriate with the report of Indriyani et al. (2010a,b) that mentioned there was difference of oxalate content based on corm size, but its correlation was not linear. Soil factors were seemly more dominantly affected corm oxalate content than climate factors.

CONCLUSION

The result revealed that predictive-relevance Q^2 value or the Goodness of Fit model R^2 was 99.45%, so the model reasonable to possess a relevant predictive value. The developing model to determine the relationship between climate and soil factors related to oxalate content in porang corm revealed that temperature and CEC of soil possessed indirect effect to corm total oxalate, soluble oxalate, insoluble oxalate, and density of calcium oxalate crystal. In this developing model only porang petiole diameter was influenced indirectly by altitude, temperature, percentage of coverage, and it was influenced directly by CEC of soil. Porang petiole diameter was influenced positively, directly and significantly to corm total oxalate, soluble oxalate, insoluble oxalate, and density of calcium oxalate crystal and corm diameter. The correlation among corm total oxalate, soluble oxalate, insoluble oxalate, and density of calcium oxalate crystal and corm diameter oxalate content was negative, but the increasing of corm diameter was not always followed by the decreasing of corm total oxalate, soluble oxalate, insoluble oxalate, and density of calcium oxalate crystal and vice versa. There was indirect effect between corm total oxalate, soluble oxalate, insoluble oxalate, and density of calcium oxalate crysta and corm diameter.

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