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Variability of Soybean [*Glycine max* (L) Merr] Growth in Relation to Chemical Properties of Ultisol from East Lampung

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ABSTRACT

Acidic dry land in Lampung is potential for soybean development area. Low soybean yield in farmer level is one of factor causing its' low competitiveness. Soil fertility is the main constrain related to low yield of soybean. Objective of the research was to diagnose a cause of poor soybean growth on dry land Ultisol at Sukadana sub District, East Lampung District. Soil and soybean plant samples were collected from farmers' field at Sukadana ilir village during planting season April – July year 2010. Plant and soil samples were taken when soybean at R1 stage (starting to bloom) using stratified random sampling method. The result showed that variability of soybean growth on Ultisol at Sukadana, East Lampung related to variability of soil pH, exchangeable Al, exchangeable K, Ca, and Mg. The poor soybean growth was due to low soil pH, high exchangeable Al, low exchangeable K, Ca, and Mg.

Keywords: Chemical properties, *Glycine max*, Ultisol

INTRODUCTION

Lampung Province is one of potential soybean development areas in Indonesia. Dry land areas in Lampung that suitable for agriculture development cover 639,518 ha of 3,195,000 ha, and it is dominated by Ultisol and Oxisol (Sudaryanto *et al*. 2002). Average soybean productivity in Lampung in 2008 and 2009 was around 1.2 Mg ha^{-1} (BPS 2010). Soybean yield reached 1.5-2.5 Mg ha^{-1} by appropriate soil fertility management (Taufiq and Mansyuri 2005; Taufiq *et al*. 2007).

Ultisol in Indonesia have a wide range characteristic depending on parent material (Prasetyo and Suriadikarta 2006), and therefore this will rise a various problem. Variability of soil condition and cultural practices can exhibit variability of soybean growth. Genetically, soybean growth interact with environmental condition. Naeve *et al*. (2008) reported that high-yielding environments produced soybean plants with greater canopy N reserves and total dry matter. Sawchik and Mallarino (2008) and Cox *et al*. (2003) found intercorrelation between variability of soil properties and soybean yield.

Observation in farmers' field at Lampung in year 2003-2006 and 2010 showed that there was huge variation in soybean growth performance even in the same land and management. This can be due to the difference in soil fertility condition. The soil where soybean grows well might have fertility status better than the poor one. Soil analysis is one of the proper tools to identify what is the soil fertility factor that might cause the difference of soybean growth performance.

Soil is a medium for root growth, and the root absorbs water and nutrient from the soil. Therefore, soil fertility condition will affect nutrient absorption by plant root, and as the result will affect plant growth. By comparing soil analysis data taken from good and poor plant growth performance, it can be diagnosed what is a possible fertility factor that cause the problem.

Objective of the research was to diagnose a cause of poor soybean growth on dry land Ultisol at Sukadana sub District, East Lampung District.

MATERIALS AND METHODS

Study Site

Soil and soybean plant samples were collected from farmers' field at Sukadana ilir village, Sukadana sub district, East Lampung district during planting season at April-July year 2010.

Soybean Cultural Practices

Farmer planted soybean of Anjasmoro variety with planting distance of 40 cm between row and 15 cm within row, two plants per hole. Fertilization using Urea at rate of 45 $kgha^{-1}$ N was applied at 15 days after planting (DAP).

Plant Sampling

Plant samples were taken at R1 phase (starting to bloom, about 35 DAP) using stratified random sampling method. Stratification was based on plant growth performance. Soybean sampled was Anjasmoro variety, and no insect or disease attack. Soybean plant in the farmers' field was grouped into three categories based on the plant growth performance in the field: (1) poor plant growth: dwarfed or stunted, lack vigor of stem and leaf, small leaf size and there was interveinal chlorosis started on the leaf margin, and necrotic spot on the older leaves, (2) medium plant growth: little bit dwarfed, little bit vigorous stem and leaf, normal green leaves and no nutritional disorder symptom, and (3) good plant growth: plant grows normally, vigorous stem and leaf, normal green leaves and no nutritional disorder symptom.

The total of fourteen plant samples was taken. They consisted of five samples of poor plant growth, four samples for medium plant growth, and five samples of good plant growth. Each sample consisted of composite of 9 to 21, 7 to 12, and 2 to 6 plants, respectively. The collected samples were washed with fresh water to clean soil and dust, air-dried and oven-dried.

Soil Sampling

Soil sample was taken from root zone at place where plant samples were pulled out. The soil sample was taken at the same time of plant sampling. The collected samples were air-dried, crushed and sieve and preserved for analysis. Soil analysis conducted at Soil and Plant Laboratory of Indonesian Legumes and Tuber Crops Research Institute at Malang.

Parameter Observation

Plant parameter observation was consisted of plant growth performance visually, plant height, and weight of oven-dried shoot (SDW). Soil analysis consisted of pH (1:2.5), total C-organic (Curmis method), total N (micro Kjedahl), available P (Bray method), exchangeable K, Ca, and Mg (extracted with 1 *N* ammonium acetate, pH 7), exchangeable Al (extracted with 1 *N* KCl), available Fe and Mn (extracted with DTPA).

Statistical Analysis

The data was analyzed using descriptive statistic. Correlation and regression methods were applied to detect interrelationship between soil and plant parameter.

RESULTS AND DISCUSSION

Plant Height and Shoot Dry Weight

Plant height and shoot dry weight (SDW) of good plant growth showed higher than poor and medium plant growth. At R1 stage, plant height of poor and medium plant growth was 12.0-32.5 cm, while plant height for good plant growth was 33.5-51.3 cm. The SDW of poor and medium plant growth was 0.17-2.23 g $plant^{-1}$, while SDW for good plant growth was 4.80-12.35 g $plant^{-1}$ (Table 1). Shoot dry weight (Y) correlated exponentially with plant height (X) with equation of $Y = 0.0931{*}e^{0,101X}$ (Figure 1). It means that accumulation of shoot biomass did not increase linearly as plant height increase. Reducing light intensity due to shading can cause plant grow higher, longer internode, but lower number of the leaf (Susanto and Sundari 2010), and this phenomenon more or less same with effect of photoperiods as reported by Arifin (2008). Arifin (2008) showed that shorter photoperiods cause soybean plant grow shorter. Plant height has a high correlation and a significant direct effect on soybean yield (Sumarno and Zuraida 2006).

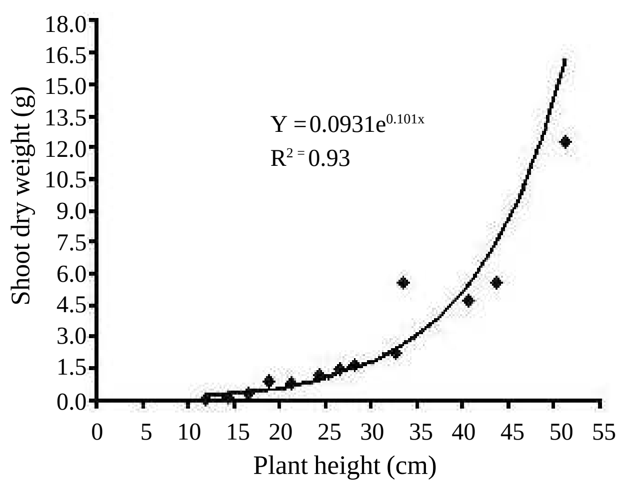

Figure 1. Relationship between soybean shoot dry weight and plant height at R1 stage growth on Ultisol Sukadana, East Lampung during the second rainy season of year 2010.

Table 1. The performance of soybean plant height and shoot dry weight at R1 stage, and characteristic of Ultisol Sukadana, East Lampung, year 2010.

Growth performance	Plant height (cm)	Shoot dry weight (g plant^{-1})	pH	Exch-Al (me 100 g^{-1})	Total N (%)	Organic C (%)	P-Bray I (ppm P_2O_5)	Exch-K (me 100 g^{-1})	Exch-Ca (me 100 g^{-1})	Exch-Mg (me 100 g^{-1})	DTPA-Fe (ppm)	DTPA-Mn (ppm)
Poor	14.3	0.33	4.0	1.11	0.08	1.60	60.40	0.13	0.63	0.33	214	2.90
Poor	12.0	0.17	4.2	0.89	0.14	1.42	20.80	0.06	0.80	0.38	259	2.71
Poor	21.3	0.84	4.4	1.33	0.11	2.05	17.20	0.05	0.99	0.46	316	2.32
Poor	24.4	1.21	4.3	1.34	0.12	2.51	31.80	0.06	1.31	0.57	300	2.09
Poor	24.4	1.33	4.3	0.89	0.10	1.40	26.50	0.07	1.01	0.50	153	2.29
Poor	19.0	0.91	5.5	0.25	0.17	2.23	21.50	0.07	0.78	0.58	274	1.89
Poor	21.1	0.83	6.0	0.00	0.17	1.81	13.60	0.06	1.25	0.52	263	1.96
Medium	26.2	1.64	4.3	0.45	0.08	2.23	43.30	0.10	0.91	0.47	155	3.01
Medium	28.1	1.72	4.7	0.22	0.11	2.50	14.30	0.07	2.48	0.58	242	2.31
Medium	32.5	2.23	4.8	0.67	0.12	2.36	17.20	0.07	2.12	0.71	268	2.53
Good (normal)	33.5	5.73	4.4	0.45	0.09	2.02	99.30	0.17	1.22	0.50	171	3.02
Good (normal)	43.5	5.55	5.0	0.00	0.13	2.22	53.60	0.21	2.58	0.60	170	2.33
Good (normal)	40.3	4.80	5.6	0.00	0.08		24.00	0.11	3.85	0.72	133	2.76
Good (normal)	51.0	12.35	5.3	0.45	0.15	2.28	28.30	0.11	1.88	0.70	242	2.55

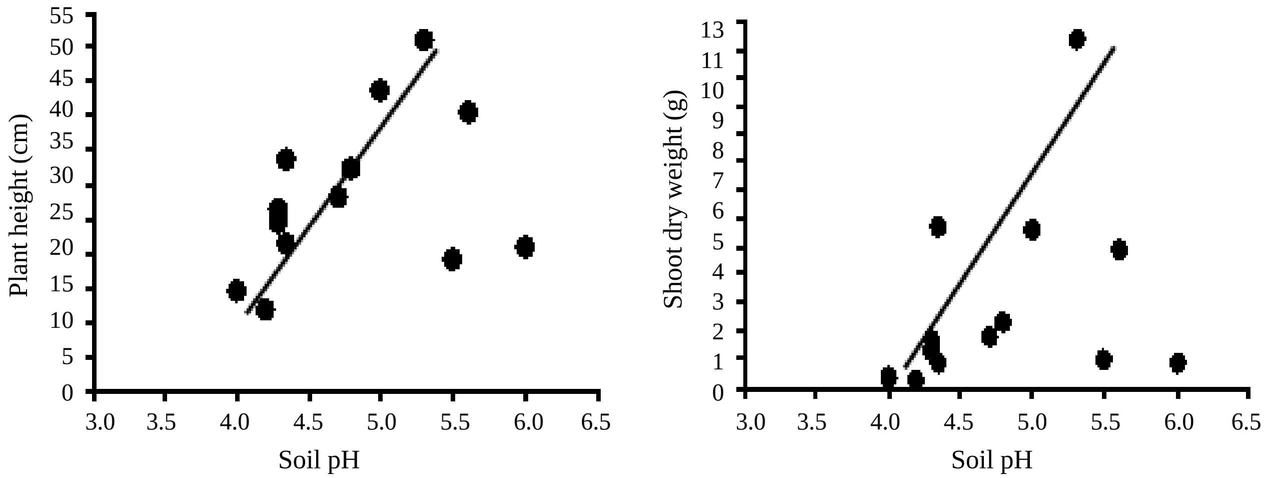

Figure 2. Relationship between pH with soybean shoot dry weight and plant height at R1 stage growth on Ultisol Sukadana, East Lampung during the second rainy season of year 2010.

Soil Properties and Plant Performance

Poor, medium, and good soybean growth performances grow on soil pH 4.0-6.0, 4.3-4.8, and 4.4-5.6, respectively (Table 1). Critical soil pH for soybean is 5.5 (Follet *et al*. 1981). Even thought the majority of soil pH at the study site was below the critical pH value (Table 1), but there were soybean plants that performed good growth. Purwantoro *et al*. (2007) reported that soybean of Tanggamus, Sibayak, Seulawah, and Wilis variety can produce 1.6-1.9 Mg ha^{-1} dry seed on soil pH 4.4 and exch-Al 1.2 me 100 g^{-1} soil which were fertilised by 35 kg N ha^{-1} + 36 kg ha^{-1} P_2O_5 + 60 kg ha^{-1} K_2O. This indicated there was another factor contributed to the variability of soybean growth.

On soil pH between 4.2 to 5.3, plant height and SDW at R1 stage positively correlated with pH with r = 0.92 and r = 0.79, respectively. The relationship between plant height and SDW with pH was linear with regression equation of Y= –93.3 + 26.97 X, R^2= 0.83 and Y=–30.5 + 7.44 X, R^2=0.64 respectively (Figure 2). The coefficient determination value (R^2) of these equation indicated that 83% of plant height and 64% of SDW variability might be due to soil pH variation. Plant height and SDW at R1 stage increased as pH increased from 4.2 up to 5.3. However, plant height and SDW decreased on soil pH > 5.3. Poor soybean growth on soil pH 5.5-6.0 might be due to low exch-K (0.09-0.07 me 100 g^{-1}. This data indicated that there was another factor rather than pH affected soybean growth on Ultisol Lampung at the study site.

Exchangeable Al (exch-Al) varied from 0.0 to 1.34 me 100 g^{-1} (Table 1). Poor, medium, and good soybean growth were shown on soil having exch-Al 0.0-1.34, 0.22-0.67, and 0.0-0.45, respectively.

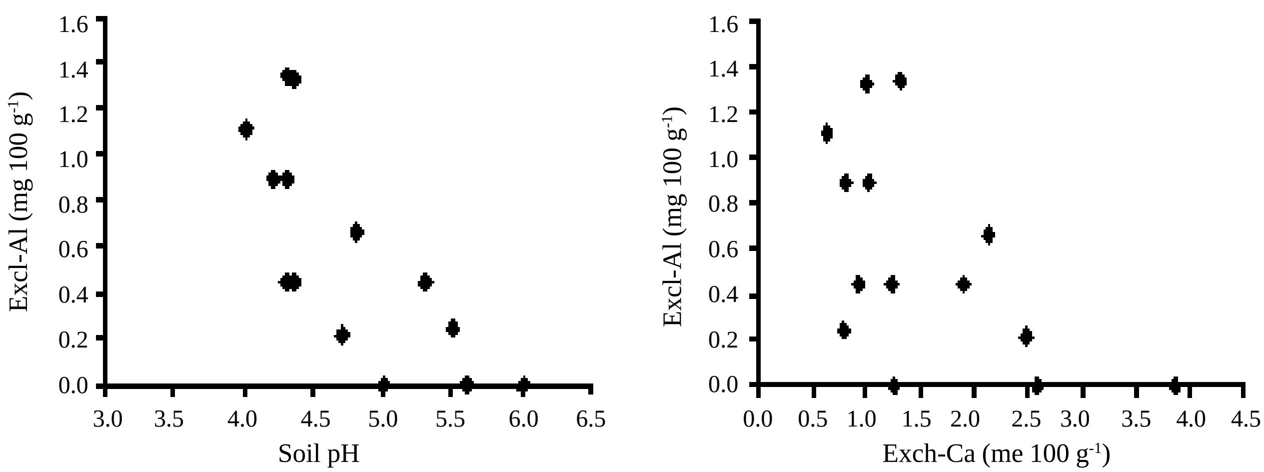

Figure 3. Relationship between pH and exchangeable Ca (exch-Ca) with exchangeable Al (exch-Al) on Ultisol Sukadana, East Lampung.

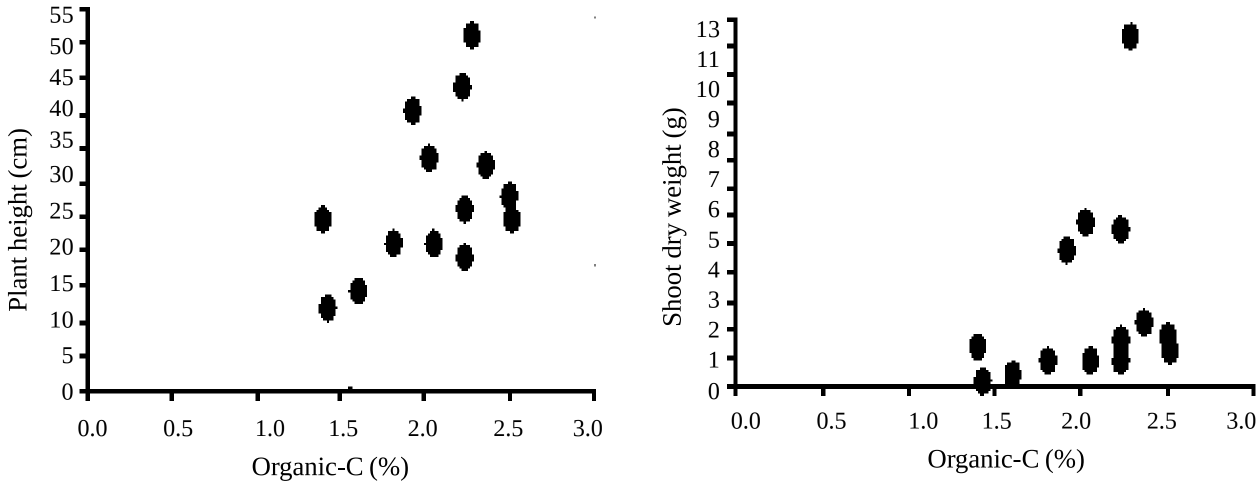

Figure 4. Relationship between soil organic C with plant height and shoot dry weight on Ultisol Sukadana, East Lampung.

Plant height and SDW negatively correlated with exch-Al (Table 2). Exchangeable Al (exch-Al) negatively correlated with pH (r = –0.75) and exch-Ca (r = –0.55). It means that increasing pH and exch-Ca could reduce exch-Al (Figure 3). Aluminum is in insoluble state on soil pH $\geq$ 5.5 (Lindsay 1979). Hairiah *et al*. (1998) found that on soil pH 5-5.5, 1% of Al on Ultisol Lampung in the form of monomeric-Al. Increasing pH and/ or Ca supply could reduce Al saturation and better soybean growth (Sartain and Kamprath 1977).

Exchangeable Ca (exch-Ca) and Mg (exch-Mg) where soybean plant performed medium and good growth was commonly higher than in the poor one (Table 1). The exch-Ca where soybean plant performed poor, medium, and good growth were in the range of 0.63-1.31, 0.91-2.48, 1.22-3.85 me 100 g^{-1}, respectively. The exch-Mg where soybean plant performed poor, medium, and good growth were in the range of 0.33-0.58, 0.47-0.71, and 0.50-0.72 me 100 g^{-1}, respectively. Fegeria (2009) reviewed from many researches and showed that optimum exch-Ca and Mg for soybean is 2.8 and 1.4 me 100 g^{-1}, respectively. Plant height was positively correlated with exch-Ca (r = 0.69) and exch-Mg (0.74) (Table 2). Poor soybean growth on soil pH < 5.3, therefore, was not only due to low pH as such, but also due to low exch-Ca and exch-Mg. Soybean stunted and necrotic spot on older leaf were a common symptom appears in the field. This symptom could be due to Ca and Mg deficiency. Calcium is immobile nutrient in the plant, but at very slow growing plants with a deficient supply of calcium may re-translocate sufficient calcium from older leaves to maintain growth with only a marginal chlorosis of the leaves (Fegeria 2009).

Organic C content varied from 1.42 to 2.51% (Table 1). Poor, medium, and good soybean growth were shown on soil having organic C 1.42-2.51, 2.23-2.50, and 1.92-2.28 respectively. Even thought organic C status was low, but total N was around 0.1% (high). There was week correlation between organic C and total N with plant height and SDW (Table 2). However, the soil where soybean grows medium-good having higher organic C (Figure 4). Figure 4 showed that good soybean growth was shown on soil having organic C 2.0-2.5%.

Table 2. Correlation between Ultisol characteristic from root zone with plant height and shoot dry weight of soybean at R1 stage on Ultisols Sukadana, East Lampung, year 2010.

Variable	Soil characteristics								
	Exch-Al	Organic C	Exch-Ca	Exch-Mg	Total N	P-Bray 1	Exch-K	DTPA-Fe	DTPA-Mn
Shoot dry weight	-0.33	0.21	0.41	0.55	0.12	0.24	0.49	-0.25	0.28
Plant height	-0.45	0.32	0.69	0.74	0.03	0.11	0.50	-0.35	0.24

Exchangeable K (exch-K) varied from 0.07 to 0.21 me 100 g^{-1} (Table 1). Good plant performance was shown on soil having higher exch-K. Poor, medium, and good soybean growth were shown on soil having exch-K 0.05-0.13, 0.07-0.10, and 0.11-0.21 respectively. Critical level of K for soybean is 0.2-0.3 me 100 g^{-1} soil (Franzen 2003). Exch-K was positively correlated with plant height (r= 0.50) and SDW (r=0.49). Soybean stunted, interveinal chlorosis started on the leaf margin were a common symptom appear in the field. This symptom could be due to potassium deficiency. Nursyamsi (2006) found that soil organic-C and cation exchange capacity were the main soil factors that effect on soil K availability in Ultisols. Therefore, building up soil organic matter might be encounter potassium deficiency. High soil K improves soybean leaf K concentration (Yin and Vyn 2005).

Available P content was high in all samples (Table 1). Critical level of available P for soybean is 13.7-22.9 ppm P_2O_5 (Tandon and Kimno 1993; Franzen 2003). Available P (Bray 1) on Ultisol Lampung categorized as low for soybean if < 12.8 ppm P_2O_5 (Wijanarko and Sudaryono 2007), < 12 ppm P_2O_5 (Nursyamsi *et al*. 2004). There was no P deficiency symptom on soybean leaf of poor plant except stunted growth. Ultisol in the study site had low soil pH and high exch-Al and therefore had high P retention that lead to reduce P absorption by plant. Ige *et al*. (2007) reported that phosphorus retention becomes higher on low soil pH and high exch-Al.

Fe and Mn content in the soil did not show clear different among various soybean growth performances. DTPA extractable Fe and Mn content was 133-300 ppm Fe and 1.9-3.0 ppm Mn (Table 1). Field observation did not find Fe or Mn deficiency or toxicity symptom. No high correlation between Fe and Mn with plant height and SDW (Table 2), means that Fe and Mn were not responsible to poor soybean growth. The critical DTPA extractable Mn level for soybean in Ustochrepts is 3.3 mg kg-1 soil or 3.3 ppm (Bansal and Nayyar 1990).

Nutrient availability and organic matter content are important fertility factor. Soybean could grow well with SDW 5.73 g $plant^{-1}$ on soil pH 4.4 but having available P 99.3 ppm P_2O_5, exch-K 0.17 me 100 g^{-1}, and exch-Ca 1.22 me 100 g^{-1} (Table 1). It's indicated that negative effect of low pH can be encounter by high soil P, K, and Ca content. Based on growth performance at R1 stage indicated that soybean could grow well on Ultisol Lampung which pH e $\geq$ 5, exch-Al <0.5 me 100 g^{-1}, organic C $\geq$ 2%, available P (Bray 1) $\geq$ 24 ppm P_2O_5, exch-K $\geq$ 0.11 me 100 g^{-1}, exch-Ca $\geq$ 2 me 100 g^{-1}, and exch-Mg $\geq$ 0.5 me 100 g^{-1} (Table 1).

Field observation showed that poor plant growth showed dwarfed, interveinal chlorosis started on the leaf margin, and necrotic spot on older leaf. The medium plant growth showed little bit dwarfed, but having normal green leaf. From the data above and the visual symptom point of view indicated that there was potassium, magnesium, and calcium deficiency. Taufiq and Mansyuri (2005) found that low pH, low available P and K cause low soybean yield on Ultisol Lampung. By using DRIS index, Wijanarko *et al*. (2007) found that deficiencies of K, Ca, and P on Ultisol Lampung become limiting factors for soybean to produce high yield.

CONCLUSIONS

That variability of soybean growth on Ultisol at Sukadana, East Lampung was related to variability of soil pH, exchangeable Al, exchangeable K, Ca, and Mg. The poor soybean growth was due to low soil pH, high exchangeable Al, low exchangeable K, Ca, and Mg.

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