Response of Oil Palm Varieties to Aluminium Stress

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ABSTRACT

Aluminum (Al) will be toxic to plants when soil is very acid. Soil reaction on acid condition tends to turn Al into trivalent cation (Al^{3+}) disturbing the function of the root end cells in doing the division and elongating the function. Today, the study of Al stress on crop trees as oil palm is very little. This research was aimed to study the growth of oil palm varieties in growing media treated Al stress. The experiment was conducted in the screen house using a randomized block design with two treatments, oil palm varieties and concentrations of Al. Varieties consisted of five oil palm progenies (OPP) i.e. PPKS239, PPKS540, PPKS718, Simalungun, and Dumpy. They were planted into the sterile sand medium in the form of sprouts and Al was treated with five different concentrations, 0, 75, 150, 225, and 300 ppm. Al was applied at the same time in the plant from 4 to 12 weeks after planting. Observations were conducted on several morphological and physiological variables at shoots and roots. The results showed a significant interaction between varieties and Al on the length of primary roots and reducing sugar content. The average of reducing sugar content was 24% less from control than it was when treated by Al 300 ppm. Simalungun varieties had more tolerant to Al than others. The length of Simalungun primary roots was more stable when the concentration of Al was 300 ppm whereas PPKS718 and PPKS540 varieties were decreased 24.3 and 12.4% respectively. The tolerance of Simalungun was also marked from reducing sugar content which was lower than other varieties. According to Koch (2004) [1], the low content of reducing sugar when given Al was an indication of plant resistance mechanisms against Al toxicity where the number of sugar was transported from roots to the shoots for immobilizing Al. Consequently, it decreased sugar content in the shoot.

Keywords: *Oil palm, Al stress, length of root primary, reducing sugar content, stress tolerance index (STI)*

INTRODUCTION

Currently palm oil is still a quite advantageous commodity. Oil palm products such as crude palm oil (CPO) and palm kernel oil (PKO) are widely used for daily necessities as cooking oil, margarine, soaps, cosmetics, pharmaceuticals and even potentially be used as an alternative fuel replacing fuel derived from fossils. Besides directed at high-productivity, activities of the genetic material improvement also have a secondary character that can specifically be adapted to marginal lands such as tidal wetlands - , lowland, salinity, or land with a real dry season [2].

One of the problems occurred at marginal land is soil acidity. Some characteristics of acid soil are low pH soil, low cation exchange capacity (CEC), low base saturation, and high content of heavy metals such as aluminum and iron (Supardi, 2001). The form of Al that can disrupt plant roots is trivalent cation (Al^{3+}) causing inhibition of cell division and elongation and will reduce the ability to uptake water and nutrients [3] resulting in reduced crop production.

Several studies indicating a disruptive influence to plant physiologically were the decrease in photosynthetic product which reduced photosynthetic citrus by increasing Al content led to decrease water use efficiency. This decrease was caused by reduction in net photosynthesis and thus transpiration rate

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increased. The photosynthetic reduction was probably caused by structural damage in the thylakoid [4]. Another influential mechanism due to Al stress was impaired cellulose synthesis in roots of barley and wheat crop [5], disruption of lipid metabolism in Arabica coffee's plant cell membranes [6] and the signal was transduced and led to the death of Al-exposed cells [7]. Based on observations by Teraoka et al., (2002) [5], inhibition of incorporation of 14C-glucose along with cellulose fraction occurs very rapidly with exposure treatment of Al for 15 minutes. Decrease in glucose synthesis was more severe in the Al sensitive wheat cultivars than those in Al-tolerant wheat. It is alleged by Teraoka et al. (2002) [5] that the loss or inhibition of root elongation is due to reduced synthesis of glucose.

Mechanisms of plant stress in the face of Al were different from each other. The mechanism was to show the various responses, such as by setting up the system tolerance. According to Scott and Fisher (1989) [8], there are two mechanisms of plant tolerance to Al stress i.e. external and internal mechanisms. External mechanism was how Al can be prevented from entering the simplast system by way of immobilizing Al in the cell wall, selective permeability of the plasma membrane, pH barrier in the rhizosphere, exudation of Al chelation ligands, and efflux of Al-phosphate. External mechanism is described by Zheng et al. (2005) [9] in the buckwheat plant, where Al-tolerant plants have the ability to immobilize Al through the release of inorganic phosphate roots and in rice plants [10] where Al in the cell wall of indica species (sensitive cultivars) is more than that in the species japonica (cultivar tolerant). Whereas, internal mechanism occurs in the form of Al chelation by organic acids, protein or other organic ligands in cytoplasm, Al compartmentation in vacuole, induction of Al-binding protein synthesis, development of resistant enzyme, synthesis of a specific protein bound Al in the plasma membrane that will reduce uptake of Al or increased expenditure Al. Meanwhile the study of the mechanisms of tolerance to stress Al on oil palm had not been obtained.

One of the existing research on oil palm plantation showed a significant interaction between the progeny of Al concentration on the character of the number of leaves, root volume, lateral root length, the content of Mg and K in

root tissue and shoots, as well as the content of Ca and N in shoot tissue [11]. This article was to study how morphology and physiology of oil palm variety responded to Al stress and observed variables were the length of root primary, content of reducing sugar, and nutrients content in the shoot.

MATERIALS AND METHODS

This study was conducted in November 2012 to April 2013 at the screen house of Agriculture Faculty, University of Brawijiaya, Indonesia.

Materials needed were: (1) planting materials of oil palm seedlings consisting of 5 varieties from crosses dura and Pisifera (DXP) derived from Indonesian Oil Palm Research Institute (IOPRI), (2) sterilized sand, (3) nutrient solution according to Hoagland and Arnon (1950) as shown in Table 1, (4) aluminum chloride ($AlCl_3.6H_2O$), (5) NaOH and H_2SO_4 to stabilize the pH at the desired level.

Table 1. Composition of the nutrient solution and the required volume (per 1 L solution)

No	Mineral salts	Molarity	Volume
1	$Ca(NO_3)_2.4H_2O$	1	5 ml
2	KNO_3	1	5 ml
3	KH_2PO_4	1	1 ml
4	$MgSO_4.7H_2O$	1	2 ml
5	H_3BO_3	-	2.86 g
6	$MnCl_2.4H_2O$	-	1.81 g
7	$ZnSO_4.7H_2O$	-	0.22 g
8	$CuSO_45H_2O$	-	0.08 g
9	$H_2MoO_4.H_2O$	-	0.02 g
10	Fe EDTA	-	1 ml

The tools needed were calipers, digital scales, mixing a solution of (electrical magnet), pH meter, digital camera, SPAD, areameter scanner, spectrophotometer, glass measure, containers for nutrient solution.

This research experiment used the randomized block design with two treatment factors. The first factor was the treatment of Al stress by using $AlCl_3.6H_2O$ and the second factor was the treatment of oil palm varieties. Al stress treatment consisted of five (5) levels of concentration i.e. 0, 75, 150, 225, and 300 ppm. These levels were referred to Cristancho et al.,

(2011) [11] with slight modification. The treatment consisted of five genotypes (5). The level of palm crosses (DXP) had been released as varieties of palm PPKS. Five varieties used were PPKS239 DXP, DXP PPKS540, PPKS718 DXP, DXP and DXP Simalungun Dumpy. Each of these varieties had the same opportunity to receive five levels of Al stress treatments so that there were 25 units of treatment with the combination of two treatments. Each unit consisted of 15 seeds and 3 replications. The stage of research was described as follows:

Preparation of growth media

The planting medium was sand which had been homogenized and sieved steril sand. The first step was filtering sand with 3 mm of sieve. Next, sand was cleaned with running water and soaked with disinfectant water containing (NaClO 5.25%) for 15 minutes and then rinsed again with running water. After the sand was steamed with boiling water, it was dried for 24 hours and then put into polybag size 15 x 15 cm.

Preparation of nutrient solution

To create a formula of nutrient solution as explained Hoagland and Arnon (1950) [12], firstly, stock should be made by preparing materials for chemical solution such as $Ca(NO_3)_2.4H_2O$, KNO_3, KH_2PO_4 and $MgSO_4. 7H_2O$ in which each was weighed 236.1, 101.1, 246.5 and 136.1 g. Then, each ingredient was dissolved into a measuring cup that had been filled with water to 1 L solution of aquadest and with a dissolved substance and it would each have concentration of 1 M. To facilitate the dissolving chemicals, stirrer was used. Furthermore, every solution was put into a bottle and prepared as stock solution. To prepare micro nutrients, salt H_3BO_3, $MnCl_2.4H_2O$, $ZnSO_4.7H_2O$ were weighed $H_2MoO_4.H_2O$ respectively 2.86, 1.81, 0:08, and 0:22 g. The salts were dissolved into water of 1 l distilled water for the solution.

One liter of Hoagland solution consisted of 5 ml of stock solution of $Ca (NO_3)_2.4H_2O$, KNO_3 5 ml, 2 ml $MgSO_4.7H_2O$, 1 ml KH_2PO_4, 1 ml of micronutrient stock solution of distilled water and the remaining water. For additional, well prepared stock solution was added with 1 ml FeEDTA solution into the nutrient solution.

Oil Palm Planting

Oil palm seeds of five varieties namely DXP PPKS239, DxPPPPKS540, PPKS718, Simalungun DXP and DXP Dumpy were planted into polybag size 15 cm x 15 cm which already contained media that had been prepared. In every media in polybag, there were planting holes of 3 cm depth and 1.5 cm in diameter. Planting was done by inserting a shell sprout into the planting hole where the radicle tip facing down and plumula to the top and then covered again with sand. After planting, media was watered with deionized water in advance as much as 100 ml/ polybag.

Treatment of Al stress and Varieties

Treatment of Al with five levels of different concentration range awarded jointly five varieties in 4 weeks after planting or when leaves of the plant began to form. Al was given along by doing this because of the nutrient. Watering solution acted as a source of stress $AlCl_3.6H_2O$ where Al had been mixed evenly into Hoagland nutrient solution with the concentration corresponding to a predetermined level. Before mixing Al into the nutrient solution, first made 1 L of stock solutions $AlCl_36H_2O$. Concentration of stock solution was made up to 0.1 M, meaning that 21,443 g of $AlCl3.6H_2O$ was dissolved in distilled water until the water volume of the solution reached 1L. The first level was the concentration of Al 0 ppm or the nutrient solution. It was not given aluminum which was useful as a control. The second stage, at 75 ppm, 7.5 mL of stock solution $AlCl_3.6H_2O$ was dissolved into the nutrient solution up to a volume of 10 L solution and so on for the concentration of 150, 225 and 300 ppm, respectively, meaning that 15.0, 22.5 and 30.0 ml stock solution was diluted to a volume of 10 L liter of solution. Setting the pH of the solution used the solution of H_2SO_4 0.1 N. At 0 ppm level pH range 5.5 while on stage 75, 150, 225 and 300 ppm solution pH was adjusted to be ± 3.5. Treatment of aluminum stress was done where the application was in conjunction with watering every two days in the morning or afternoon. Solution volume when watering was about 100 ml per polybag. The application was stopped until the plant was completed. It was

when the plants were observed ranged from three months.

Observation variables

Observations were made on variables, i.e. parts of plant's shoot (leaves and stems) and roots of plants when the plants were 2-3 months. Primary root length (cm), measured from the base of the roots to limit bottom of root end. Measurements were performed using GiaRoot Software. Samples were taken to separate the roots of the plant shoot and then the roots were cleaned from particles in growing media. The next one, the root of the sample was captured by using the camera and then the results were transferred to a computer for further analysis using GiaRoot Software [13]. Total root length (cm) was gained by measuring the entire length of the existing roots from the primary root, secondary roots and the ends with GiaRoot Software. Root surface area was calculated with GiaRoot Software. Root volume was calculated with GiaRoot Software. Nutrient content (N, P, and K) in the plant shoot was calculated by using the Kjeldahl method. Reducing sugar content was observed by following the Nelson-Somogyi method as explained [14].

Data Analysis

The data obtained was analyzed by using the analysis of variance. When there were significant differences in the interaction of varieties and Al. they were followed by analysis DMRT at 5% significance level ($\alpha = 0.05$ level). Relationships between variables were calculated based on the value of the correlation observed Pearson. Next, to determine which varieties had resistance level Al the best, it was calculated based on the value of the selection criterion variables which were significantly influenced by the interaction of varieties and Al. Value selection criteria used was Unmatched tolerance index (STI) as described by Fernandez (1992) [15] with the following formula which denotes the average value of varieties without Al stress. Ys is the average value of varieties when given stress Al, and yp is the average of all varieties when given stress level of resistance varieties Al. The determination was based on the comparison of the mean value of STI varieties and standard deviation. This resistance level was adopted from Purwani and Marjani (2009) [16] as the following:

$$STI = \frac{Yp + Ys}{\bar{Y}p^2}$$

Very strong tolerant (**VT**)
: if STI varieties > the mean + standard deviation across varieties

Strong tolerant (**ST**)
: if the varieties STI > + average value of all varieties ½ standard deviation

Moderate tolerant (**M**)
: if STI varieties > average value of all varieties - ½ standard deviation

Weak tolerant (**WT**)
: if STI varietie s> average value of all varieties - ½ standard deviation

Sensitive (**S**)
: if STI varieties < mean value of all varieties - standard deviation

RESULTS AND DISCUSSION

General observations showed interaction of Al treatment and varieties providing a noticeable effect on primary root length variables (at $\alpha = 0.05$ level), nutrient content of potassium ($\alpha = 0.01$), in reducing sugars shoot ($\alpha = 0.01$), and reducing sugar root ($\alpha = 0.01$). The only variables influenced by Al were stem diameter, total root length, root surface area, root volume, and N nutrients. Meanwhile, the only variables influenced were varieties of dry shoot weight, root fresh weight, root dry weight, and chlorophyll content.

Al effect on root morphological growth

Based on Table 2, the interaction of Al and varieties significantly affected primary root length (PAP) at $\alpha = 0.05$. DMRT result showed PAP five varieties at 0 ppm. Al was not significantly different from the PAP at the time of Al 75 and 150 ppm (Table 3). PPKS239 varieties and Simalungun PAP did not even show a real difference to Al given at 225 ppm. At the time of Al 225 ppm PAP PPKS718 varieties and PPKS540 increased respectively by 16.1 and 13.7% and were significantly different from the current state of Al 0 ppm. Decrease in PAP occurred when Al was given 300 ppm. The decline was found in varieties PPKS718, PPKS540 and Dumpy. PAP PPKS718 varieties and PPKS540 on Al 300 ppm was each measured 24.3% and 12.4% shorter than the PAP at the time of Al 225 ppm. Meanwhile, in the varieties

Simalungun, shortening PAP had occurred when Al 225 ppm was equal to 11.5%. It was shorter than the current PAP Al 150 ppm. At the time of Al 300 ppm, PAP Dumpy varieties were not significantly different from PAP when Al was at 225 ppm. Unlike the varieties PPKS718, PPKS 540 and Dumpy, PAP and Simalungun PPKS239 varieties showed no significant differen ces when Al was at 225 ppm. PAP PPKS239 was even longer when Al was given 300 ppm which was equal to 18.4% and longer than the PAP when Al 0 ppm was based on DMRT. PPKS239 PAP was significantly different at $\alpha = 0.05$ level in the two conditions. For Simalungun varieties, although PAP at 300 ppm appear longer than when Al 0 ppm based on DMRT, PAP values were not significantly different in the two conditions (Table 3).

Decrease in root length was allegedly caused by a decrease in cell growth activity. As stated by [17] Delhaize and Ryan (2012), symptoms of root growth inhibition are the most easily recognized toxicity of Al and was the most accepted measure to Al stress in plants generally. The study was in line with [11] Cristancho et al. (2011) in young plant oil palm. According to [18] Fitter and Hay (1994), decreasing root growth is caused by the disruption process of cell division at the ends of roots because cell walls in the root tip has very small resistance on the movement of Al^{3+}, where the ions Al rapidly penetrate into cells meristem cells and inhibit DNA synthesis.Besides slowing root growth, it was also the result of bond formation among Al and the root plasma membrane [19] (Matsumoto et al., 1992) in the cell walls of the roots [20] (Ma et al., 1999) where it would result in inhibition of cell and root function.

Tabel 2. F values and the significance on shoot and root variables

No	Observation variables	Al xVar		Aluminum		Varieties	
		F value	Sig.	F value	Sig.	F value	Sig.
1	Length of root primer	2.2687	*	1.7037	tn	1.4578	ns
2	total length of root	0.8528	ns	2.6519	*	0.4183	ns
3	root surface	0.7703	ns	5.1580	**	0.3203	ns
4	root volume	0.8328	ns	7.3680	**	0.5187	ns
5	Nitrogen (N)	1.7103	ns	9.8092	**	1.7012	ns
6	Fosfor (P)	0.7500	ns	2.0000	ns	0.7500	ns
7	Kalium (K)	5.9069	**	37.1710	**	4.2429	**
8	shoot reducing sugar	47.0152	**	323.9519	**	33.1792	**
9	root reducing sugar	333.9860	**	7314.7900	**	292.1050	**

Note. * = Significant at $\alpha=0.05$; ** = Significant at $\alpha=0.01$; ns= not significant.
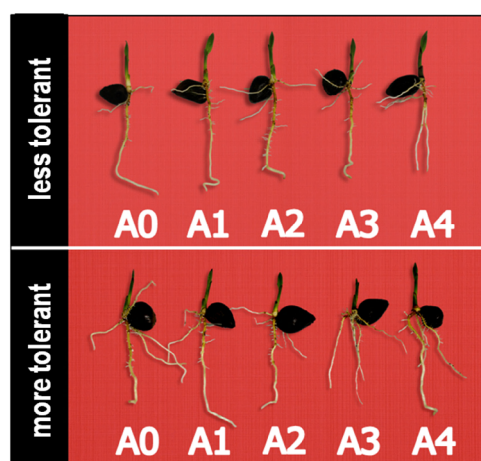

Figure 1. Roots of varieties which were more tolerant (bottom) and less tolerant (above) to Al.

Al effect in nutrient content of N and K

Furthermore, the results of [21] Basset et al. (2010) add that Al can prevent the process of cell division and elongation through inhibition of Al in the absorption of water and sucrose in the process of cell division and elongation.

Table 3 showed the content of K was the highest at 150 ppm and Al concentration was 0.56%, while the lowest K occurred when the maximum Al (300 ppm) was 0.19%. Based on the results of DMRT, the lowest K value was not significantly different from the value of K as normal (control) and the level of 225 ppm Al. Whole variety had the highest K value when Al concentration was 150 ppm except PPKS540. K content in the highest Dumpy varieties was followed by 0.73% and PPKS239, PPKS718

respectively 0.72 and 0.61%. Varieties PPKS540 was at the lowest value among other varieties of 0.33% value. PPKS540 variety was only able to raise the content of K at the concentration of Al 75 ppm after K content decreased. Next, at the Al maximum (300 ppm), the value of K of each variety was at the lowest value, PPKS718 was at highest score by 0.26% and was significantly different to other varieties. At the maximum concentration of Al, PPKS239 and PPKS540 varieties were the lowest in which each valued 0.14%.

Average nutrient content of all varieties of K increased as Al was 75 ppm. Increasing nutrient K occurred until Al was given 150 ppm but then decreased when given Al 225 ppm, although the decrease was not a significant value to the nutrient content of K when the Al was 0 ppm. Decline in nutrient content of an average K continued until Al was given the maximum (300 ppm) at the time the nutrient content was significantly different with the lowest and K nutrient content when Al was 0 ppm. Along with the decrease in K content at the time of maximum stress Al (300 ppm), N content was also low in most circumstances amounting 2.37%. N content value decreases slowly with increasing concentrations of Al. Highest N content was at 0 ppm Al and at 2.83%. When Al was given 75 ppm, N nutrient content showed no significant difference compared to that when Al 0 ppm. Significant differences began to occur when Al was given 150 ppm, wherein the content of N decreased by 12.5%. N nutrient values continued to decline until Al was given 225 and 300 ppm, respectively decreased by 13.4% and 16.2%. Observation was consistent with the results in which Al can alter the ability of the plasma membrane in taking some of the nutrients in cation form of which was K^+ and NH^{4+}. These changes were related to the direct interaction with the Al^{3+}ion channels in the plasma membrane and changes in potential membrane.

Nutrient imbalance caused by exposure to Al had been reported in several plant species. Eleven families pteridophita indicated an imbalance of nutrients (mostly in Ca, Mg, P, K) Differences were caused by the accumulation of Al (Olivares et al., 2009) [22] In Sirait's study (2004) [23], it reports that the nutrient content of maize decreases significantly with N increasing Al. In addition to affecting N nutrient, Al also

influences the determining nutrients of Ca and Mg and Mn as macro nutrients and micro nutrients Zn in maize [24]. However, the Al-tolerant genotype plants are capable to accumulate concentrations of Ca, Mg [24] and K of the wheat crop genotypes sensitive. Both tolerant and sensitive genotypes show a decrease in K content and Mg in roots while Ca, Al and Si were in opposite [26]. Yet, sensitive wheat genotypes show an imbalance of nutrients and accumulation of Al (in crowns and roots) in which both are higher than the tolerant genotype [26].

The content of reducing sugar

Table 14 described Al, varieties and interaction amongst each of them giving a very real effect on reducing sugar contained in the header and in the roots (at $\alpha = 0.01$). The difference in the value of the reduced sugar content can be seen in attached Chart 1 and Table. The table showed that the average content of reducing sugar in the shoot decreased with the increasing concentration of Al given. The average of sugar content in five varieties was not significantly different at level 0 , 75 and 150 ppm of Al, but subsequently decreased significantly at the time Al increased to 225 ppm. The average of the lowest sugar content occured when Al (300 ppm) was 2,137% and it was significantly different from the sugar content at the time of Al was 225 ppm.

According to the attached table, it showed varieties with an average reduction of sugar. They were found in varieties of the highest editorial Dumpy at 2.79% while the content of the least was the varieties of Simalungun (2.54%). Based on the table it also showed that the interaction of Al-variety had a significant influence ($\alpha = 0.01$) in the observed value of the sugar content. The highest sugar content was found in varieties Dumpy while Al concentration of 150 ppm was equal to 3.31% followed by varieties Simalungun at 75 ppm concentration and PPKS239 at 0 ppm, respectively with an average sugar content of 3.26 and 3.05%. Meanwhile, the lowest ones were in varieties of sugar Simalungun, Dumpy, and PPKS 540 at the concentration of 300 ppm respectively 1.98, 2.04 and 2.06%.

According to Koch et al. (2004) [1], the low sugar content when given Al shows the resistance mechanisms of plants to Al toxicity. He also

explaines that during the process of cell division and enlargement, sucrose was taken and hydrolyzed into glucose and fructose by inverting enzyme and then secreting it to extracellular cell wall acid atmosphere. At the moment, it was probable that the changing process of fructose, and sucrose into glucose by the enzyme invertase induced Al^{3+} to be part of the mechanism of cell wall resistance to aluminum toxicity.

Based on the explanation of Koch (2004) [1], it gives the sense that Al-tolerant plants can be indicated by the decrease in sugar or carbohy-drate content when given Al stresses. Based on these explanations, when reducing sugar content was revisited, as Table 3, it would seem that DXP Simalungun were varieties that had resistance mechanisms best followed by Dumpy DXP and

DXP PPKS540. This was certainly because when Al was given 300 ppm varieties, it had sugar content of at least shoot reduction among other varieties. Mechanisms of plant resistance to Al which has such negative relationship patterns have also been reported previously by Lima and Copeland (1990) [27] who explain that Al induces a decrease in reducing sugar content in plant with tolerant cultivars of wheat. Several other studies including Scott et al. (1991) [28] report that added concentration in starch and fructans in wheat cultivar tolerant and sensitive increases with Al content of fructans sensitive cultivar but it was higher than that in the tolerance. He also describes the accumulation of fructans as an indication that sensitive cultivars are not able to export sugar to the plant roots in response to Al.

Table 3. Values of observation variables (length of root primer, K content, and reducing sugar) in each varieties

Observation variables	Levels of Al (ppm)	PPKS239	PPKS718	PPKS540	Simalungun	Dumpy	Mean (%)
length of root primer	0	13.74 ab	14.32 abc	14.66 abc	15.50 bcd	15.51 bcd	14.75
	7	14.83 abc	14.33 abc	14.68 abc	15.51 bcd	14.36 abc	14.75
	150	16.01 bcd	14.47 abc	13.82 abc	14.23 abc	16.40 d	14.99
	225	15.38 bcd	16.62 d	16.67 d	15.63 bcd	14.52 abc	15.77
	300	16.27 cd	12.58 a	14.61 abc	16.57 d	14.84 abc	14.98
K	0	0.38 i	0.50 k	0.35 h	0.15 a	0.21 bc	0.31bc
	75	0.32 g	0.22 cd	0.39 ij	0.52 l	0.32 g	0.35 c
	150	0.41 j	0.72 n	0.33 gh	0.61 m	0.73 n	0.56 d
	225	0.19 b	0.25 ef	0.23 de	0.21 bc	0.39 ij	0.25ab
	300	0.14 a	0.26 f	0.14 a	0.19 b	0.23 de	0.19 a
shoot reducing sugar	0	3.055 j	2.82gh	2.910 hi	2.230 b	3.030ij	2.809 c
	75	2.510 c	2.95ij	2.910 hi	3.260 k	2.800fgh	2.887 c
	150	2.680 def	2.76 defg	2.640 d	2.760defg	3.305 k	2.828 c
	225	2.670 de	2.32 b	2.230 b	2.470 c	2.780efg	2.493 b
	300	2.265 b	2.35 b	2.055 a	1.975 a	2.040 a	2.137 a
root reducing sugar	0	0.357 j	0.388 m	0.309 g	0.337i	0.329 h	0.344 d
	75	0.389 m	0.365 k	0.288 f	0.368 k	0.378 l	0.357 d
	150	0.173 b	0.149 a	0.148 a	0.192 c	0.194 c	0.171 a
	225	0.148 a	0.212 d	0.216 d	0.196 c	0.314 g	0.217 b
	300	0.247e	0.247 e	0.286 f	0.217 d	0.249 e	0.249 c

Note : the same laters was not different from at α=0.05 based on duncan multiples range test (DMRT)

Furthermore, Chen et al. (2005) [29] show Al inhibits that the ability of citrus roots take sugar and water in the process of cell elongation but at the crown, Al stimulate the improved performance enzymes involved in the cycle of Kelvin as ribulose-1, 5-bisphosphate carboxylase /oxygenase (Rubisco), NADP-glyceraldehyde-3-phosphate dehydrogenase (GAPDH), phospho-rribulokinase (PRK), fructose-1, 6-bisphospha-tase (FBPase), and an important enzyme used in starch synthesis, ADP-glucose pyrophospho-rylase (AGPase). In tobacco plants, Basset et al. (2010) [21] explain Al can inhibit root in making sugar from a solution containing sucrose which can potentially inhibit cell elongation, although it will not be toxic to plants

Level of varieties tolerance to Al stress

The level of tolerance to Al stress values was obtained by stress tolerance index (STI) and its standard deviation. STI calculation was performed on primary root length. The level of tolerance to Al stress on the variables is presented in Table 4. The table showed that the sequence of varieties having the best resistance to the lowest level was Simalungun, Dumpy, PPKS540, PPKS239 and PPKS718. Simalungun varieties resistance seen from the primary root length were relatively unaffected Al, apparently it was caused by the resistance mechanism to Al toxicity which sugar content decreased significantly in the shoot and were the lowest among other varieties. As explained by Koch (2004) [1], the low content of reducing sugar when given Al was an indication of plant resistance mechanisms against Al toxicity where the number of sugar was transported from roots to the shoots for immobilizing Al. Consequently, it decreased sugar content on the shoot. In contrast to most varieties approaching sensitive varieties (PPKS718), which it was had a lowest of STI caused by decrease of root primer length at 300 ppm of Al. this condition was not followed by reduction of the reducing sugar content on shoot as seen on Table 3.

Determining the level of plant resistance to environmental stress using STI values was described by Fernandez (1992) [15]. In addition to STI, there are other criteria that can be used as stress intensity (SI), sucsebility stress index (SSI), the value of tolerance (TOL), and mean productivity (MP). However STI is pretty much

used to identify genotypes which are tolerant to environmental stress [15].

Table 4.   Tolerance status of each oil palm varieties

Oil palm varieties	STI	Status of Tolerance
PPKS239	0.94	M
PPKS718	0.91	M
PPKS540	0.96	WT
Simalungun	1.05	ST
Dumpy	1.02	M
Average of STI	0.98	
Standard Deviation	0.06	

Note :   ST=strong tolerant; WT=weak tolerant; M=moderately tolerant

CONCLUSIONS

In variables of shoot and root growth, five varieties only gave different responses at variable primary root length whereas in the physiological variables, it gave different responses at nutrient of K, reducing sugar content on shoots and roots when treated by aluminum. Simalungun had the best tolerance to Al toxicity among other varieties. The mechanism of Simalungun's Al tolerance was indicated by decreasing the content of reducing sugar on shoot when given Al treatment so that length of primary root relatively unaffected al. The next varieties based on the tolerance index to Al was Dumpy, PPKS540, PPKS239, and PPKS718.

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