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Root Morphology of Eight Hybrid Oil Palms Under Iron (Fe) Toxicity

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ABSTRACT

The research aims to study the change of morphology root characters of eight hybrid oil palms under iron toxicity (Fe). Field experiment done in arranged in a Randomized Complete Block Design (RCBD) two factors and three blocks as replications. The first factor was Fe concentration. It consists of two levels which are concentration 0µ.g^{-1} and concentration 600 µg.g^{-1} Fe. The second factor is the hybrid of oil palms which consists of eight hybrid oil palms as Yangambi, Avros, Langkat, PPKS 239, Simalungun, PPKS 718, PPKS 540 and Dumpy. Fe was applied by pouring $FeSO_4$ solvent for 600 µg.g^{-1} 500 ml.$^{-1}$plant.$^{-1}$day^{-1} on two months of plants after transplanting in the main nursery. Data were collected on root morphology and plant dry weight The data were analysis of variance (ANOVA) at 5% significanly, followed by Duncan's multiple range test (DMRT). The relationships by among variables were determined by correlation analysis. The results showed that Fe concentration 600 µg.g^{-1} inhibits relatively root growth rate, narrows surface area, reduces the diameter, and shrinks root volume of all hybrid oil palms tested. The slowing relatively root growth rate, narrowing of root surface area and root diameter also root volume shrinkage due to Fe stress. It was also shown that the dry weight of plants was inhibit by existing of Fe toxicity.

Keywords: Fe Toxicity, Morphology Root, Plant Dry Weight

INTRODUCTION

Oil palms is currently the main commodity which supports national economic of Indonesia. Oil palms has highest commodity if it is compared to other vegetable oil productivity as it is economically profitable for the planters. The commodity prices of oil palm are also quite stable and they tend to increase from year to year seen on the productivity development in Indonesia which has shown many progresses. There are many commodity derivative products of oil palm which are foodstuffs, cosmetics, pharmaceuticals, and energy. Therefore, the oil palm has a huge market opportunity as its production needs to be increased (Dradjat, 2008; Syahbana, 2007).

Several strategies adopted to increase the national production of oil palm, namely extensification, cultivation, and intensification. Extending oil palm aerage is mostly done on marginal land, especially on acidic mineral soils found in many agro-climate areas and they are suitable for oil palm. Acidic mineral soil has distinctive feature which consists of layers of sulfidic materials (clay sulfur) which contains pyrite (FeS_2). When the soil is under or oxidized, the compounds will form ferrihydroxide pyrite ($Fe(OH)_3$), sulfate (SO_4^{2-}) and hydrogen ions (H^+) and the soil turned. Consequently, the solubility of ions Fe^{2+}, Al^{3+} and Mn^{2+} increases in the soil of grown exposed crops with toxicity. The availability of phosphate is reduced the treatment of iron or aluminum in form of iron phosphate or aluminum phosphate (Hasibuan, 2008).

Sufficient amount in plants, metal elements and essential functions facilitate the metabolic activity, N fixation, photosynthesis, oxidation, hydrogenases and trans-location N (Kabata-Pendias and Pendias, 2001).Enough amount of availability of metal will improve nutrient uptake. However, the excess amount of metal supresses absorption of macro nutrients since its inhibition of plant growth due to the effects of Fe toxicity. Each metallic element has a different critical threshold of toxicity, particularly in palm oil, giving the effect of varying the macro nutrient uptake (Audebert, 2006).

Fe toxicity is able to change characters of morphology, anatomy, and physiology of the plant, where the response of each genotype varies depending on the nature of tolerance to this metal. Fe toxicity caused by Fe^{2+} uptake by roots excessively, and then it is translocated to leaf through the flow transpiration (Majerus *et al*., 2007). The mechanism of Fe toxicity exposure starts from the increasing of permeability of root cells caused by the increase of the Fe^{2+} ions it also causes reducing microbial activity in the root zone of plants, so that the Fe^{2+} ion absorption increased rapidly. Reduction of Fe^{2+} that occurred in the root zone is continuously causing damage so that the iron oxide Fe^{2+} uncontrolled influx into the roots of oil palm (Lindsay, 1992). Root is the first plant organ that is exposed to Fe toxicity. Fe toxicity causes the inhibition of root growth and root damage. This research aims to study the changes in the morphology root characters of eight variety oil palms affected by Fe toxicity.

MATERIALS AND METHODS

The research was conducted from June 2014 - June 2015 in Bendosari Madurejo village, Prambanan subdistrict, Sleman, Yogyakarta and Laboratory of Plant Science, Faculty of Agriculture, Gadjah Mada University, Yogyakarta. Materials used are oil palm seed obtained from Palm Research Center consisting Yangambi, DP Avros, DP langkat, PPKS 239, Simalungun, PPKS 718, PPKS 540 and Dumpy, sandy soils, polybag with size 20 cm x 15 cm and 40 cm x 40 cm, NPK (15:15:15), urea, Ferrous Sulfate ($FeSO_4$. H_2O), plastic sizes 5 Kg, alcohol, striped plastics and pesticides. The tools used in the study include: Bucket, cethok, Leaf Area Meter, Microscope, Optic Laboratorium, Termohygrometer, Luxmeter, grinder, scaler, digital callipers, meter, flask, measuring glass, beaker glass, glass objects, ruler, markers, flacon, digital cameras, pinboard, and pH meters.

Field experiments were using a Randomized Complete Block Design (RCBD) factorial with three blocks as replications. The first factor was Fe toxicity which consists of two levels as without and with Fe toxicity. The second factor was the hybrid oil palms which consists of eight hybrids which are Yangambi, Avros, Langkat, PPKS 239, Simalungun, PPKS 718, PPKS 540, and Dumpy. Application Fe toxicity is done by spraying a solution of $FeSO_4.H_2O$ with concentration of 600 $\mu g.g^{-1}$ in the planting media of 500 ml/day, along with watering activity. Application of Fe toxicity begins in the fourth week after transplanting seedlings of oil palm pre nursery to the main nursery. The variable observed root surface area (Richard *et al*., 1979; Collins *et al*., 1987 *cit* Indradewa, 2001), root diameter, root volume, Relatively root growth rate and plant dry weight. Data were then analyzed with variance (ANOVA) at 5% significanly. When the F test showed a significant difference it would be continued with DMRT (Duncan's Multiple Range Test) at test level 5%. Relationships by among variables were determined by observation of correlation and regression analysis. Grouping resistance level of oil palms hybrids on Fe stress based on morphology root character would be analyzed with cluster analysis.

RESULT AND DISCUSSION

Results

Table 2 gives information that there is no interaction between the factors of Fe toxicity with hybrid oil palms on a variable root surface area. Fe toxicity significantly effects on the variable root surface areas. Fe toxicity causes oil palm roots narrower. However, hybrid oil palms have no significant effects on the variable of root surface area. Eight hybrid oil palms are used in the research have the same root surface areas.

Hybrid oil palms factors also significantly affect the Relative root growth rate (Table 1). Fe toxicity exposed oil palms can be observed by looking at some of the symptoms that appear in root organ. Common symptoms are indicated in plant roots exposed by Fe toxicity as the root system does not develop as well (Yamanouchi and Yoshida, 1981). Table 1 provides the information that PPKS

Table 1. Relatively root growth rate of eight hybrid oil palms without and with Fe toxicity treatments

Factors	Relative Root Growth Rate ($g^{-1}\ g^{-1}.week^{-1}$)
Fe toxicity	
0 $\mu g.g^{-1}$	2.98 a
600 $\mu g.g^{-1}$	2.65 b
Hybrid	
Yangambi	2.75 abc
Avros	2.78 abc
Langkat	2.88 ab
PPKS 239	3.10 a
Simalungun	2.99 ab
PPKS 718	2.72 bc
PPKS 540	2.47 c
Dumpy	2.82 ab
Average	2.81
Interaction	(-)
CV (%)	9.51

Remarks: The average in a column with the same letter is not significantly different according DMRT test level of 5%.
(-) : There is no interaction between factors.

Table 2. The root surface area of eight hybrid oil palms without and with Fe toxicity treatments

Factors	Root Surface Area (cm²)	
	18 WAT	25 WAT
Fe toxicity		
0 µg.g-1	826.73 a	2678.8 a
600 µg.g-1	406.11 b	1653.4 b
Hybrid		
Yangambi	607.2 a	2277.6 a
Avros	596.2 a	2288.9 a
Langkat	877.7 a	2303.2 a
PPKS 239	571.2 a	2333.5 a
Simalungun	549.5 a	2205.1 a
PPKS 718	730.3 a	2283.6 a
PPKS 540	557.0 a	1997.1 a
Dumpy	442.2 a	1640.1 a
Average	616.417	2166.131
Interaction	(-)	(-)
CV (%)	*8.94	*5.60

Remarks: The average in a column with the same letter is not significantly different according DMRT test level of 5%.
WAT : Week After Transplanting
(-) : There is no interaction between factors.
(*) : For the analysis this data was transformed with log x

Table 3. Root diameter of eight hybrid oil palms without and with Fe toxicity treatments

Factors	Root Diameter (mm)	
	18 WAT	25 WAT
Fe toxicity		
0 µg.g-1	14.24 a	25.80 a
600 µg.g-1	6.50 b	15.06 b
Hybrid		
Yangambi	9.54 ab	21.61 a
Avros	9.43 ab	22.83 a
Langkat	13.68 ab	21.34 a
PPKS 239	8.96 b	20.58 a
Simalungun	8.59 b	19.61 a
PPKS 718	15.88 a	19.57 a
PPKS 540	9.81 ab	17.50 a
Dumpy	7.06 b	20.39 a
Average	10.36	20.43
Interaction	(-)	(-)
CV (%)	*24.59	26.34

Remarks: The average in a column with the same letter is not significantly different according DMRT test level of 5%.
WAT : Week After Transplanting
(-) : There is no interaction between factors.
(*) : For the analysis this data was transformed with log x

239 has a relatively root growth rate faster than PPKS 718 and PPKS 540.

Table 2 gives information that there is no interaction between the factors of Fe toxicity with hybrid oil palm on a variable root surface area. Fe toxicity significantly effects on the variable surface area of roots. Fe toxicity causes oil palm roots narrower. However, hybrid oil palms have no significant effects on the variable of root surface area. Eight hybrid oil palms are used in the research have the same root surface areas.

Table 3 provides information that there is no interaction between the factors of Fe toxicity and root diameter of hybrid oil palms. Fe toxicity significantly reduces root diameter of oil palms. Table 3 which provides information that Fe toxicity causes oil palm plant root diameter becomes smaller. The root diameter is one of the key indicators of the activity of root growth. Hybrid oil palms factors, significantly affect to root diameter oil palms at 18 weeks after transplanting. At the age of 25 weeks after transplanting, all the hybrids were tested in this research and they have the same root diameter size. At 18 weeks after transplanting, PPKS 718 has a root diameter larger than the PPKS 239, Simalungun, and Dumpy, but they are not significantly different from Yangambi, Avros, Langkat, and PPKS 540.

Root volume indicates uptake capacity of plant nutrient which is accommodated by root after through the root outer wall. Table 4 gives information that Fe toxicity factor does not interact with oil palms hybrid factor in the root volume variable. Fe toxicity significantly affects the volume of oil palms roots. The oil palms exposed by Fe toxicity has smaller root volume compared with root plants that grow in a normal environment. Fe toxicity significantly reduces the volume oil palm root. When, be observed hybrids factors, hybrids do not significantly affect the volume of oil palms plant roots. All hybrids were tested in this research as their root volumes have equal size.

Based on the results of analysis of variance in Table 5, it is found that the total plant dry weight of oil palm is not affected by the interaction between the factors of Fe toxicity and hybrid oil palms. Clearly, Fe toxicity significantly affects to total plant dry weight of oil palm. Oil palms exposed by Fe toxicity shows lighter dry weight than the oil palms plants which grow in normal environment. The same case is also found in hybrid oil palms factors. Hybrid factor oil palms significantly influences plant dry weight variable. At 18 weeks after plant transplanting, the dry weight of the hybrid PPKS 239 is heavier than the Avros, PPKS 540, and Dumpy, but it is not significantly different from Yangambi, Langkat, Simalungun, and PPKS 718. At the age of 25 weeks after transplanting, the dry weight of the hybrid PPKS 239 also is heavier than the PPKS 540 and

Table 4. Root volume of eight hybrid oil palms without and with Fe toxicity treatments

Factors	Root Volume (ml)	
	18 WAT	25 WAT
Fe toxicity		
0 µg.g^{-1}	60.97 a	104.07 a
600 µg.g^{-1}	57.50 b	47.75 b
Hybrid		
Yangambi	55.17 a	78.70 a
Avros	61.75 a	80.90 a
Langkat	73.33 a	78.58 a
PPKS 239	60.42 a	75.92 a
Simalungun	53.92 a	66.53 a
PPKS 718	59.67 a	75.04 a
PPKS 540	53.33 a	72.92 a
Dumpy	56.29 a	78.71 a
Average	59.23	75.91
Interaction	(-)	(-)
CV(%)	51.79	31.62

Remarks: The average in a column with the same letter is not significantly different according DMRT test level of 5%.
WAT : Week After Transplanting
(-) : There is no interaction between factors.

Table 5. Plant dry weight of eight hybrid oil palms without and with Fe toxicity treatments

Factors	Plant Dry Weight (g.plant^{-1})	
	18 WAT	25 WAT
Fe toxicity		
0 µg.g^{-1}	74.46 a	131.11 a
600 µg.g^{-1}	40.72 b	117.29 b
Hybrid		
Yangambi	58.03 ab	112.93 bc
Avros	53.17 b	105.84 c
Langkat	60.75 ab	126.37 abc
PPKS 239	69.57 a	153.23 a
Simalungun	60.78 ab	142.42 ab
PPKS 718	57.37 ab	121.56 abc
PPKS 540	48.68 b	110.21 bc
Dumpy	52.41 b	121.07 abc
Average	57.59	124.20
Interaction	(-)	(-)
CV(%)	21.08	20.01

Remarks: The average in a column with the same letter is not significantly different according DMRT test level of 5%.
WAT : Week After Transplanting
(-) : There is no interaction between factors.

Avros, but it is not significantly different from langkat, Simalungun, PPKS 718, and Dumpy.

Discussions

The high solubility of Fe^{2+} high acid sulphate soils occur when flooded the tide or rain water. The concentration of Fe^{2+} can reach 5000 ppm within a few weeks after the flooded, especially on newly reclaimed land and pyrite content> 2%. Fe^{2+} ions that causes Fe toxicity. Fe is involved in the metabolism of many plants such an important role in basic biological processes such as photosynthesis, chlorophyll synthesis, respiration, fixation and pengmbilan N. Fe toxicity can affect the growth of plants such as changes in morphology and anatomy.

The roots play a role in the extraction and transportation of water and minerals from the soil (Hock and Wolf, 2005). Therefore, the root is the proper organ to be used as the object of study related to the response of plant oil palms on Fe toxicity. Parameters that can describe the respond roots of Fe toxicity include Relatively root growth rate, root diameter, root surface area, root volume and dry weight of plants. Relatively root growth rate is the root ability to produce dry material result of assimilation per unit of dry weight and each unit time ($g^{-1}.g^{-1}$. week^{-1}).

Fe toxicity significantly depresses and inhibits the Relatively root growth rate which makes oil palms plant roots do not well develop. Inhibition of Relatively root growth rate caused by Fe toxicity seen on (Table 1) is indicated by the root surface area becomes seen on (Table 2). There is a positive correlation between Relatively root growth rate and root surface area oil palms (r = 0.34). The deceleration of the Relatively root growth rate results on narrowing the root surface area of oil palms.

The smaller root diameter of oil palm plant exposed to Fe toxicity is associated with root relative growth rate (Table 1) which also indicates a slower root relative growth rate when exposed to Fe toxicity. There is a positive correlation between root relative growth rate and root diameter with correlation coefficient (r) of 0.38. The deceleration of root relative growth rate of the oil palms plant exposed to Fe toxicity is followed by reduction of root diameter.

The contents of the data in Table 4 are in line with the contents Table 1, 2 and 3. The correlation analysis is the analysis of the correlation between variables observation and indicated by coefficient correlation. A was possitively correlated root volume with Relatively root growth rate, surface area root, and root diameter (r= 0.35, 0.72 and 0.88, $P < 0.05$ and $P < 0.01$) respectively. Fe toxicity on oil palms causes inhibition Relatively root growth rate. Inhibition Relatively root growth rate causes the narrowing of the surface area. The reduction of the root diameter of oil palm plants which is exposed by Fe toxicity oil palms plants causes roots narrowing the root surface area. Small root diameter results the crop root volume also becomes smaller (Table 4). The reduction of the root volume (Table 4) is a direct

Figure 1. (a) Oil palms root without Fe. (b) Oil palms root with Fe toxicity treatment. (c) Morphology of Oil palms without Fe. (d) Morphology of Oil palms with Fe toxicity treatments.

effect of narrowing root surface area (Table 2) and the reduction of the root diameter (Table 3) as well as an indirect effect of the decelation Relatively root growth rate (Table 1) exposed by Fe toxicity.

Relatively root growth rate is positively correlated with plant dry weight ($r = 0.79$). The decreasing of plant dry weight (Table 5) on the hybrid oil palm plants exposed Fe toxicity is a result of a slowing Relatively root growth rate. The slowing Relatively root growth rate of oil palms plant root causes the roots cannot develop well and the roots tend to be narrower seen on (Table 2), diameter and small volume seen on (Tables 3 and 4). The roots of the plants which do not develop well weaken the plant growth as it also weakens the ability of the roots to absorb water and nutrients in sufficient quantities. Insufficient supply of water and nutrients of the roots can inhibit the metabolism of plants. The slowing Relatively root growth rate the plant is indicated by a light plant dry weight (Table 5). Lighted plant dry weight lighter is the indication of less developed plant which means the assimilate accumulation capacity is small. Less developed plant organ and low assimilate capacity of the plant have resulted on lighter dry weight.

Fe toxicity resulted in root morphology changes oil palms. When the oil palms exposed Fe resulted in root oil palms become damaged and can not well developed. Oil palms plant exposed Fe has rarely roots, the roots become black, and rude, in contrast with the oil palms without Fe has stronger root, more branched and the color is brighter. The appearance differences in rooting without Fe and with Fe toxicity treatmeants can be seen in Figure 1 (a) until 1.(d)

CONCLUSION

Fe toxicity inhibits relative rate of growth of root, narrows root surface area, reduces root diameter, shrinks root volume of tested hybrid oil palms. The slowing relative growth rate of root, narrowing root surface area and root diameter, also root volume shrinkage caused by Fe toxicity in roots can inhibit the dry material accumulation and make plant dry weight becomes lighter.

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REFERENCES

Audebert, A 2006. Iron partitioning as a mechanism for iron toxicity tolerance in lowland rice. Africa Rice Center (WARDA). pp : 34-46.

Carver BF, Ownby JD (1995). Acid Soil Tolerance in Wheat. Adv. Agron 54:117–173.

Delhaize E, Ryan PR (1995). Iron toxicity and tolerance in plants. Plant Physiol 107:315–321.

Dradjat, B 2008. Prospek Kebun Sawit Masih Cerah. Lembaga Riset Perkebunan Indonesia. Jakarta.

Foy CD 1984, Physiological effects of hydrogen, iron,and manganese toxicities in acid soil. In: Adams F (ed) Soil acidity and liming, 2nd edn. American Society of Agronomy,Inc, Madison, pp : 57–97.

Hasibuan, BE 2008. Pengelolahan Tanah dan Air Lahan Marjinal. Univerisitas Sumatera Utara, Medan.

Hock B, Wolf NM 2005. Characteristic of plant life: hazard from pollutant. Di dalam: Hock B, Elstner EF, editor. Plant Toxicology (fourth edition). New York : Marcel Dekker.

Horst WJ, Wagner A, Marschner H (1982). Mucilage protects root meristems from aluminium injury. Z Pflanzen physiol 105:435–444.

Indradewa D 2002. Gatra agronomist and Physiological Effect of inundation in the trenches on soybean plants. (Dissertation). University of Gadjah Mada, Yogyakarta, Indonesia. pp: 265.

Kabata Pendias, A. and H. Pendias. 2001. Trace Element in Soil and Plants. Third Edition. CRC Press. LLC. Boca Raton, Florida pp: 331.

Lindsay, WL. 1992. Chemical Equilibria in Soils. Wiley Interscience. New York.

Majerus, VP. Bertin, S. Lutts. 2007. Effects of iron toxicity on osmotic potential, osmolytes and polyamines concentrations in the African rice (Oryza glaberrima Steud.). Plant Science. 173: 96–105. Marcel Dekker, Inc.

Marschner, H. 1995. Mineral Nutrition of Higher Plants. 3rd ed. San Diego: Academic Press. pp: 321.

Syahbana, S. 2007. Palm Oil and Rubber Plantation Business Prospects. Pidato Ilmiah pada Peringatan Dies Natalis ke 23 Politeknik Negeri Lampung. Bandar Lampung.

Yamanouchi, M and S. Yoshida.1981. Physiological mechanisms of rice's tolerance for iron toxicity. Paper presented at the IRRI Saturday Seminar, June 6, 1981. Int. Rice Res.Inst. Los Banos, The Philippines.