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by Entis Halimi

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NATURE OF ALUMINUM TOLERANCE IN CORN (*Zea Mays* L.)

E.S. Halimi

Department of Agroecotechnology Faculty of Agriculture Sriwijaya University
Kampus Unsri Indralaya, Ogan Ilir 30662, South Sumatera

Abstrak

Kajian tentang karakter tolerasi tanaman jagung terhadap alumunium (Al) merupakan topik penting dalam pemecahan masalah peningkatan produktivitas, mengingat domain penanaman jagung adalah lahan-lahan masam dengan permasalahan alumunium yang komplek. Tujuan penelitian ini adalah untuk mengidentifikasi respon tanaman terdahap permasalah alumunium tersebut. Penelitian yang dilakukan meliputi tiga seri percobaan untuk membentuk germplasma melalui introduksi dan persilangan, memilahkan kelompok tanaman yang toleran dan sensitif, dan mengevaluasi respon tanaman dengan menggunakan larutan nutrisi yang diberikan secara kontinyu. Penelitian secara jelas menunjukkan bahwa karakter sensitivitas diperlihatkan melalui penebalan, pemendekan, dan penurunan pembentukan bulu. Penelitian ini tidak berhasil menunjukkan adanya perbedaan dalam berat kering, dan kadar N,P,K, Al di dalam tajuk dan akar, namun ada petunjuk bahwa tanaman yang sensitif secara berangsur menjadi semakin toleran, ketika larutan nutrisi diberikan secara kontinyu. Penelitian ini sepertinya memperlihatkan bahwa karakter toleransi tersebut merupakan mekanisme inklusi, karena tanaman tidak menolak Al untuk masuk ke dalam jaringan tanaman.

Kata kunci: Nature, aluminum, tolerance, corn

INTRODUCTION

Aluminum (Al) is an essential element in the plant including in corn. In low concentration the element may be beneficial, but in higher concentration the element will inhibit growth and development of the plants (Foy and Fleming (1978). In the field, condition of higher concentration of alumnium usually occurs in acid soils, such as podzolic, latosol, organosol, alluvial, hidromorph, and peat soils (Sanches, 1976). Such soils cover more than 200 million ha of farmland in Indonesia (Setiyono and Soepardi. 1985), and therefore, nature of aluminum tolerance in plant is considered as an imprortant subject to explore in order to solve the problem of promoting plant growth and development in Indonesia.

Rhue and Grogan (1977) and Marschner (1986) described that high Al concentration might inhibit development of root cells of less tolerant corn plant and therefore, the root became shorter and thicker as compared to more tolerant corn plants. The similar research result was reported by Suthipradit et al. (1990) in soybean (*Glycine max)*, cowpea (*Vigna anguiculata*) , green bean (*Vigna radiata*), and in sorghum (Furiani and Clark, 1981).

Furthermore, Wilcox (1987) stated that, the root condition as described above, would result in the sensitivity of the plant to water stress since the root lost its ability to absorp water. Wagatsuma et al. (1987) explained that the permiability of cell membrane was destroyed due to formation of alumunimun complex in the root cap. In addition, many researches reported the change in nutrient transport which was related to aluminum tolerance in sorghum (Baligar et al., 1993; and Galvez and Clarck 1991), and in wheat as reported by Delhaize et al., (1993). Rangel (1992) stated that higher aluminum concentration inhibited cell division (mytosis), while, Delhaize et al. (1993) reported the relation of aluminum tolerance with the excretion of malic acid from root apices of wheat. As consequence of root dectruction, the less tolerant plants generally showed very bad growth and development when they were planted in the soil with high concentration in aluminum. Kasim and Isman (1992) and Bahar et al. (1994) stated that aluminum stress decreased vigor, delay maturity, and significantly decreased yield. Bahar et al. (1994) reported that the yield of corn decreased from 5.88 ton/ha to 1.89 ton/ha along with the increase of saturated aluminum concentration in the soil from 35% to 65%, while Halimi (1999) reported the tolerant plant produced significantly higher yield of 5.6 ton/ha as compared less tolerant plant of 2.8 ton/ha, when they were planted at Podzolic soil without liming. Furthermore some researches reported differentiation of nutrient content of less and more tolerant plant to aluminum, which was indicated the change in absorption and transportation of the nutrient in the plants. Sallisburry and Ross (1995) reported the nutrient content of corn plant grown in normal condition was about 1.5% N, 0.20% K, 0.92%, and 0.89 % Al.

Taylor (1991) described aluminum tolerance in plants in two types of mechanisms of "exlussion" and "inclussion" mechanisms. In exclusison mechanism, the plants show cability of rejecting aluminium to enter the plants. Foy et al. (1978) stated that such capability derived from the ability of plants to change pH arround the root surface, and some other reserchers stated that this capability derived from formation of alumimum complex through secretion of citric and maleic acid (Delhaize et al., 1993), oxalic acid, sulphyc acid, and phenolic acid (Suthipradit et al., 1990) to bind aluminum before entering the plants. Furthermore, in the inclussion mechanism, the aluminum enter the plants, but the plant was able to revive, since the aluminum was enclaved into inactive form. Marschner (1986) called this mechanism as "inactivation mechanism", since the aluminum, somehow, was inactivated by the plants. The objective of this reasearch is, therefore, to identify nature of more and less tolerant corn plant to aluminum.

RESEARCH METHODS

Research incorporated three series of experiments (Halimi, 2000; Amran, 2001; and Rosa, 2004) as follows:

Experiment I was done to provide elite germplasm of aluminum tolerant accession of corn. For this purpose population of SA 3 as aluminum tolerant germplasm (Granados et al., 1995) was introduced to Indonesia in April 1994, through letter of authorization from Departmen of Agricuture of the Republic Indonesia No.UP.220.226. This introduced germplasm was top-crossed to dry-tolerant corn germplasm of Tey DT supplied by BPTP Bogor. The random seed sample of resulting crossed progeny (F1 seeds) of Tey DTxSA 3 was planted in the field of yellow-red podsolic soil and polycrossed to produced Syn-1 seeds, which was then used in the experiment II.

Experiment II incorporated three populations of newly corn accession derived from the crossed of Tey.DT x SA3, hybdrid variety of C7, and local variety of "Genjah mas" . The consideration to use Tey DTxSA3 accession was its genetic recombination of dry and acid tolerance as explained in the experiment I. The consideration to use C7 was its sensitivity to aluminum, while the "Genjah mas" was used as a local control. Population C7 is a commercial Indonesian-hybrid variety, and "Genjah mas" is a local variety of Karang Agung South Sumatera. This experiment, basically, was done to differentiate group of plant in each population to be group of more and less tolerance to aluminum. The experiment utilized nutrient culture technique as outlined by Rhue and Grogan (1977) and proven as an effective method to defferentiate more dan less tolerant corn plant to aluminum by Halimi (2000). A Random sample of 300 seeds of each population were germinated on the petridish for 3 days, and then transplanted into nutrient culture. The nutrient composition in the culture was indicated on Table 1. The observation was done 7 days later to differentiate groups of plants which were more and less tolerant to Alumunimum as indicated on Figure 2. These groups of plants, then, were transplanted into experiment III.

Experiment III was continuation of the experiment II. Groups of more and less tolerant plants resulted from the experiment II, 20 plants per group, were prepared for experiment III. These plants were planted on sand by using 10 kg polybag. The sand was pretreated (floaded, washed with tap water, and sun dried) to ensure a minimum content of natural nutrient. The experiment was set up according to Randomized Complete Block Design (RCBD) as outlined by Montgomery (1976). A week after planting, the plants were individually treated by using aluminium nutrient solution as shown in Table 1. The application of nutrient solution was done by using a continuous droplet method, 500 ml per day per plant.. No other standard practices were impossed to the plants. Observation was done to measure plant growth and development of the plants including plant height at 15 and 30 days after transplanting. At the end of the research period (30 days after planting), measurements were taken on dry weights of root and shoot, and nutrient content of N, P, K, and Al of the shoot and root. Nuntrient content was analysis by using standard method on the composite sample. Appropriate statistical data analysis at α=0.05 was carried out by the use of Analysis of Variance (ANOVA) followed Contrast Analysis to differentiate response of more and less sensitive group of plants (Montgomery, 1976) by using computer program of Statistical Analysis System (SAS-Institute, 1988).

RESULTS AND DISCUSSION

As an introduced germplasm for aluminum tolerant accession, SA 3 performed well as a male source for crossing with Tey.DT. The cross of these accession resulted more seeds (±400 seed/plant) as compared to average (±300 seed/plant), indicated no-serious sterility problem occured on the crossed progeny, which was important for plant breeding prespective (Fehr, 1987). The yield potential of this crossed progeny (Syn-1 progeny) was 66.5 g dry seeds per plant (about 3.5 ton dry seeds/ha) and weight of 100 seeds was about 25 g (Halimi, 2000).

Nature of aluminum tolerance in corn can be differentiated qualitively as more and less tolerant plants (Figure 1), although its quantitative differences can not be significantly shown through statistical analysis (Table 2). As indicated on Figure 1, the root growth of less tolerant plants was shorter, thicker, less formation of root hair, and seemed to be halted at certain point, as compared to root growth of more tolerant plants. Similar response was reported by Rhue and Grogan (1976) and Marschner (1986). Futhermore, Wilcox (1987) stated that in such root development, the plants would be more sensitive to water stress and lost their ability to absorb mineral and nutrients from the soil. Marchner (1986) explained that the first response of sensitive plant to aluminum was indicated by slow development on mitosis and cell elongation due to formation of aluminum complex with nucleat acid in the apical cells of the root, and therefore, in the field the root tip often look brownish in color. Wagatsuma (1984) indicated in his research that, the permiability of cell membrane was also destroyed because of higher content of aluminum in cortex and endodermis of the roots.

Despite clear qualitative differentiation in response of less and more tolerant plants, this research did not observe quantitative differentiation of tolerant corn plant to aluminum

(Table 2). Statistical analysis on te data including plant height (15 and 30 days after transplanting), dry weight , and N, P,K, Al content in the shoot and root showed no significant differences (Table 2). There is indication, however, that in the observation at 15 days after planting, the plants of more tolerant plants tend to grow taller than less tolerant plant. Later on, in the observation at 30 days after planting the plant heights were about the same (Figure 2). This is an interesting for this research. In observation at 15 days after planting, the less tolerant plants had shorter plant height than more tolerant plants indicated that the less tolerant plant suffered from aluminum treatment which was applied in continuous droplet method. Later on, in the observation at 30 days after planting, the plant heights were about the same. This indicated that, when the aluminum treatment is given as a contiuous dorplet (i.e. 0.125 mM $Al_2(SO_4)_3$ in 500 ml solution/day), the less tolerant plants gain the ability to reappearence tolerance to aluminum. This is insteresting, since such phenomenon never been reported by any researchers. At 15 days after planting the plants height of less and more tolerant plant was 40-50 cm and 50-70 cm respectively. At 30 days after planting, the plant height of less and more tolerant plants was about the same of 90-110 cm, respectively (Figure 4). The dry weight of shoot and root of less and more tolerant plants at 30 days after planting was about the same and not significantly different by Contrast Analysis at α=0.05 (Table 2).

Furthermore, this research indicated no significant differences of nutrient content (N,P,K, aand Al) in the shoot and root of less and more tolerant plants measured at 30 days after planting (Table 2). The N, P, K, and Al content of shoot of less tolerant plants were 1.58-1.72 % , 0.19-0.32%, 1.94-2.28%, and 0.01-0.02%, respectively; while The N, P, K content of root less tolerant plants were 0.62-0.78 % ,0.13-0.14%, 0.90-1.06 .%, and 0.18-0.19%, respectively. On the orher hand, The N, P, K, and Al content of shoot of more tolerant plants were 1.57-1.67% , 0.26-0.50%, 2.09-2.51%, and 0.02-0.03%, respectively; while The N, P, K content of root more tolerant plants were 0.64-072% , 0.12-0.13%, 0.95-1.11%, and 0.17-0.19%, respectively. No significant differencers of nutrient content in the shoot and root indicated no rejection of corn plants againts nutrients to enter the plant through root surface. As described by Taylor (1992) such type of tolerant mechanism was called as “Inclussion mechanism“ in which the resistant plant was not rejecting of aluminum to enter the plants.

CONCLUSSION

This research conclude that nature of less tolerant corn to aluminum can be differentiated qualitatively as a shorter and thicker root, and less formation of root hair as compared to more tolerant plants. Despite clear qualitative differentiation, this research do not observed significant differences in most variables measured at 30 days after planting, including dry weight, and N,P,K, Al content of shoot and root. However, there is indication that, when the application of aluminum solution is given in a continuous droplet method , the less tolerant plant is sufferred more as compared to more tolerant plants, but later on, they gain ability to reappearence as more tolerant plant. This research, finally, concludes that nature of aluminum tolerance in corn considered as "as "Inclussion mechanism" in which the plant was not rejecting aluminum to enter the plants.

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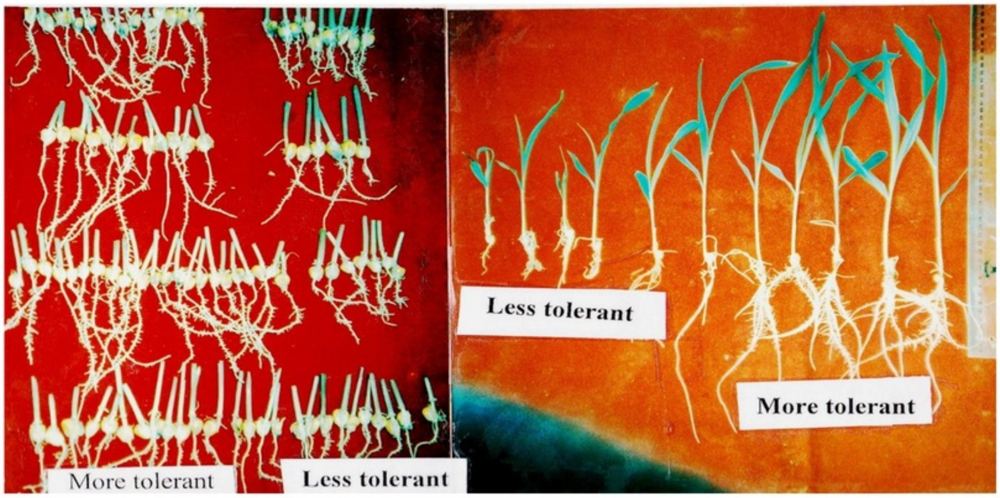
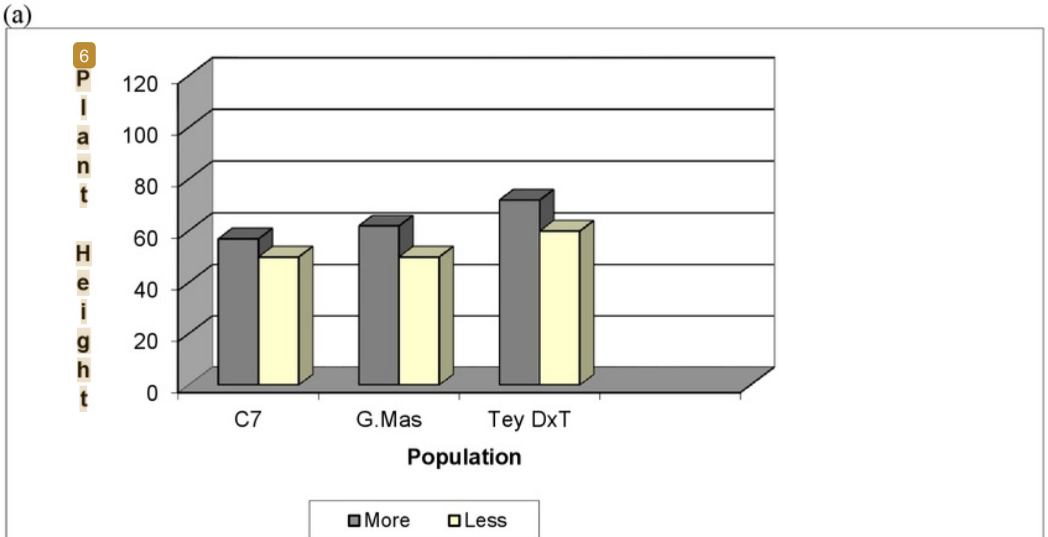


Figure 1. Differentiation of groups or more and less tolerant plants to Alumimun by using nutrient culture technique.

(a)



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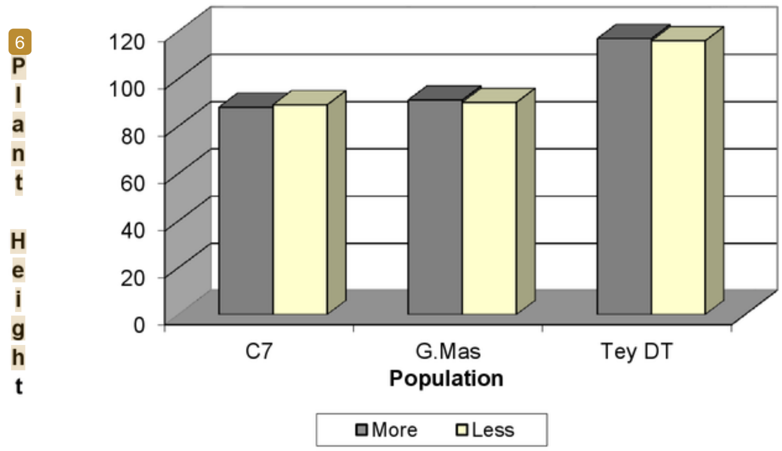

Figure 2. Plant height (cm) of more and less tolerant plants to aluminum measured at 15 (a) and 30 (b) days after planting on corn variety of C7, "Genjah Mas", and Tey DT

Table 1. Nutrient composition solution to test Aluminum tolerance in corn (Rhue and Grogan, 1977).

Nutrient sources	Concentration
$Ca(NO_3)_2$	1.00 mM
$MgSO_4$	0.50 mM
KNO_3	0.50 mM
$(NH_4)_2SO_4$	0.05 mM
KH_2PO_4	0.10 mM
$MnSO_4$	2.00 µM
$CuSO_4$	0.30 µM
$ZnSO_4$	0.80 µM
NaCl	30.0 µM
$FeCl_3$	10.0 µM
Na_2MoO_4	0.30 µM
H_3BO_3	10.0 µM
$Al_2(SO_4)_3$	0.125 mM

Table 2. Avarage value of variable measured on the research at 30 days after planting and the F-value of contrast analysis of more and less tolerant plant in variety of C-7, "Genjah Mas", and Tey DT x SA3 Acession.

No	Variables	variety of C-7		F value	Varietyy of "Genjah Mas"		F value	Tey DT x SA3 accession		F value
		More	Less		More	Less		More	Less	
1.	Dry weight of root (g)	5.90	5.63	0.16	3.84	4.77	2.16	4.79	4.68	0.35
2.	Dry weight of shoot (g)	25.6	24.21	0.46	19.0	18.0	0.04	24.80	25.08	0.11
3.	N content on shoot (%)	1.63	1.68	0.44	1.67	1.72	0.30	1.57	1.58	0.05
4.	P content on shoot (%)	0.50	0.19	1.08	0.33	0.31	2.16	0.26	0.32	2.14
5.	K content on shoot (%)	2.51	2.28	1.24	2.10	2.27	2.12	2.09	1.94	2.16
6.	Al content on shoot (%)	0.02	0.02	1.61	0.02	0.01	2.19	0.03	0.02	1.67
7.	N content on root (%)	0.68	0.71	1.22	0.72	0.78	2.15	0.64	0.62	0.16
8.	P content on root (%)	0.13	0.13	0.05	0.13	0.14	1.16	0.12	0.13	1.02
9.	K content on root (%)	0.95	0.90	2.08	1.00	1.01	0.01	1.11	1.06	2.15
10.	Al content on root (%)	0.17	0.18	2.19	0.18	0.18	0.33	0.19	0.19	0.05

Note: No significant differences of the F-values at α=0.05

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