International Journal on Advanced Science Engineering Information Technology

Vol.6 (2016) No. 1
ISSN: 2088-5334

Sorghum (*Sorghum bicolor* L. Moench) Early Growth in Response to Al Stress: In Search for Al-tolerant Sorghum Genotypes

Irawati Chaniago[#1], Sutoyo[#], Aries Kusumawaty[#], Irfan Suliansyah[#], Rizki A. Siregar[#]

[#] *Department of Agroecotechnology, Andalas University, Padang 25163 – Indonesia*
E-mail: [1] ichaniago@faperta.unand.ac.id; irawatichaniago@yahoo.com

***Abstract*— An experiment to study the effect of aluminium stress on the growth of 10 genotypes of sorghum (*Sorghum bicolor* L. Moench) in nutrient solution was carried out at Plant Physiology Laboratory and greenhouse of Andalas University, Padang, Indonesia from July to September 2014. The study aimed at determining sorghum genotypes potentially tolerant to aluminium stress. The sorghum genotypes were Super1, Super2, No.2, No. 4, No.10, No.12, No.33, No.40, and No.50. Sorghum seeds were germinated in sterile sand and were kept for six days prior to transplanting into Hoagland's nutrient solution for two weeks. The genotypes were subjected to 0 ppm and 8 ppm aluminium concentrations in the nutrient solution. Results demonstrated that sorghum early growth responded differently to the treatments. Reduction in root growth, root length, root weight and shoot weight were observed in all genotypes grown in 8 ppm aluminium treated nutrient solution. Genotypes of No. 10, No. 34, Super 1, and No. 45 were found to be potentially tolerant to aluminium stress at 8 ppm.**

***Keywords*— sorghum; tolerant; early growth; aluminium stress**

I. INTRODUCTION

Sorghum has been important and promising crop in Indonesia for the last decade and has high potential to be grown and developed. This crop can be used to produce bio-ethanol as well as for alternative food sources [1]. Compare to other cereal crops, sorghum is more tolerant to drought and water log, better growth potential in marginal land, and relatively resistant to pest and diseases [2].

Acid mineral soil constitutes as much as 67% of the total area of Indonesia and spread from Sumatra Island at the west to the Island of Papua in the east. Dry land has low nutrient due to alkaline depletion in response to intensive rainfall. The intensive rainfall, especially in the tropical region like Indonesia, may cause soil and organic matter decomposition which will in turn leave adsorbed Al^{3-} ions toxic to the plants [3]. Aluminium stress and toxicity in agricultural crops, including sorghum, may severely affect growth and yield of the crops. This limits farmers' access to the land in cultivating sorghum. In addition, little is known about the effect of Al stress in sorghum genotypes in Indonesia. Therefore, attempts should be made to obtain Al tolerant sorghum genotypes that may be used to create high yield but Al-tolerant sorghum variety through breeding program.

Under developed ("stubby", thickened) root specially main root is the first sign of Al toxicity in plants due to suppression in cell division and elongation [4],[5]. Other effects are limitation of nutrient intake, decrease cell wall maturity, and suppression in cell division [6] which makes plants susceptible to drought [7]. Research to determine the effects of Al stress on plant have focused on the plant early growth. This is in line with Hasanah *et al*., (2010) who stated that the early growth condition will directly affect the plants' ability to yield high [8]. Research reported here was aimed at determining sorghum (*Sorgum bicolor* L. Moench) genotype(s) tolerant to 8 ppm Al stress.

II. RESEARCH METHODS

The experiment has been carried out at the Plant Physiology laboratory and Glass house of Andalas University, Padang from October 2014 to January 2015. A split plot design in A Completely Randomised Block Design with three replicates was used for the experiment. The main plot was two levels of Al i.e 0 and 8 ppm and the sub plot was 10 sorghum genotypes. The genotypes were Super 1, Super 2, No. 2, No. 4, No. 10, No. 12, No. 33, No. 34, No. 40, and No.45. Sorghum genotypes were obtained from Research Center for Cereal Crops, Maros, South Sulawesi, and from the Directorate of Cereal Crops, the Ministry of Agriculture.

Sorghum seed were germinated and kept in sterile sand in seed beds (Figure 1) for six days prior to transfer into

Hoagland solution [9]. The pH of the solution was maintained at 4 for the 8 ppm Al treatment group. Cotton wool was wrapped around the coleoptiles before insertion into the holes made on the Styrofoam bed to hold the seedlings in place (Figure 2). The solution was aerated with a continuous flow of air bubbles using fish-tank pumps. The plants were then kept in a glass house for 3 weeks.

Fig. 1 Seed beds with sterile sand for germinating sorghum seeds

Fig. 2 Young sorghum plants on the Styrofoam bed grown in Hoagland's nutrient solution

Observation included initial root length (IRL) prior to transfer into Hoagland's nutrient solution, root length of sorghum after grown in Al-treated solution was measured and recorded as RL Al_0 and RL Al_8 for the treatment groups of 0 ppm and 8 ppm Al, respectively. Root Dry Weight (RDW) and Shoot Dry Weight (SDW) were recorded from the treatment groups of 0 and 8 ppm. Relative root length (RRL), relative root length growth (RRLG), relative root dry weight (RRDW), and relative shoot dry weight (RSDW) were calculated [10]. They are:

RRL = RL Al_8 / RL Al_0 x 100%
RRLG = (RL Al_8 – IRL) / (RL Al_0 – IRL) x 100%
RRDW = RW Al_8 / RW Al_0 x 100%
RSDW = SW Al_8 / SW Al_0 x 100%

Data were analysed with analysis of variance and multiple comparisons of Duncan's New Multiple Range Test at 5% level. Each sorghum genotypes were grouped into three categories following Baligar *et al.*, 1989 in Syafruddin *et al.* (2006). The groups are (1) tolerant with $\bar{X}i \geq \bar{x}$ + SE t(table), (2) moderate-tolerant with $\bar{X}$ - SE t(table) and $\bar{X}$ +SE t(table), and (3) susceptible with $\bar{X}i \leq \bar{x}$- SE t(table).

III. Results and Discussion

A. Shoot Growth

Sorghum genotypes and Al content in the nutrient solution interacted and affected the shoot weight and relative shoot weight at 4 weeks after planting. Shoot weight and relative shoot weight are presented in Table 1 and Table 2.

TABLE I
SHOOT DRY WEIGHT (MG) AND TOLERANCE LEVELS (%) BASED ON RELATIVE SHOOT DRY WEIGHT (RSDW) OF SORGHUM PLANTS AT FOUR WEEKS AFTER GERMINATED WITH 0 AND 8 PPM AL IN HOAGLANDS' SOLUTION.

Genotype	Shoot dry weight (mg) Aluminium (ppm)		Level of tolerance (%) as for RSDW	
	Al_0	Al_8	Al (8 ppm)	Remarks
Super 1	28.8 A bcd	35.1 B ab	124.28	Tolerant
Super 2	23.5 A de	23.3 A d	99.79	Moderate - Tolerant
No. 2	25.8 A cd	22.3 A d	86.80	Moderate - Tolerant
No. 4	33.5 A ab	30.6 A bc	91.94	Moderate - Tolerant
No. 10	26.4 A cd	20.4 B de	77.56	Susceptible
No. 12	32.9 A ab	24.8 B cd	75.28	Susceptible
No. 33	31.1 A ab	35.0 A ab	112.27	Moderate - Tolerant
No. 34	35.3 A a	37.1 A a	106.15	Moderate - Tolerant
No. 40	29.4 A bc	31.4 A ab	107.79	Moderate - Tolerant
No. 45	10.7 A f	12.1 A f	119.88	Tolerant

Mean values within column 2 and 3 for shoot weight followed by small letters and rows between those columns followed by capital letters are not significantly different by DNMRT at 5% level. Notes for level of tolerance (%): (Tolerant $\geq$ 116.72%), (Moderate-Tolerant 83.63% – 116.72%), (Susceptible $\leq$ 83.63%)

Sorghum early growth responded differently to Aluminium. It was expected that Al 8 ppm reduced the shoot weight. However some genotypes such as Super 1, No. 33, No. 34, No. 40 dan No. 45 demonstrated increased shoot weight although they were grown in Al-added nutrient solution. This is possible and is assumed that those genotypes were more responsive to Phosphorous even under Al stress condition. Syafruddin (2004) stated that Al-stress plants but efficient in P uptake would resulted in higher biomass accumulation than that of inefficient plants [10].

Two genotypes, Super 1 and No.45 were found to be tolerant to 8 ppm Al stress. On the other hand, genotypes No. 10 and No. 11 were susceptible. It is interesting to note that the genotypes grown in 8 ppm Al with higher ry shoot weight fell into tolerant and moderate-tolerant categories. The higher shoot weight reflected their tolerance to Al stress.

B. *Root Growth*

The observed different phenomena in root growth. Al content of 8 ppm in the nutrient solution reduced sorghum root length.

TABLE II
ROOT LENGTH (CM) AND TOLERANCE LEVELS (%) BASED ON RELATIVE ROOT LENGTH (RRL) OF SORGHUM PLANTS AT FOUR WEEKS AFTER GERMINATED WITH 0 AND 8 PPM AL IN HOAGLANDS' SOLUTION.

Genotype	Root length (cm) Aluminium (ppm)		Level of tolerance (%) as for RRL	
	Al_0	Al_8	Al (8 ppm)	Remarks
Super 1	40.73 A a	29.81 B ab	73.78	Moderate - Tolerant
Super 2	39.37 A a	30.13 B ab	77.05	Moderate - Tolerant
No. 2	37.14 A ab	19.42 B c	53.22	Susceptible
No. 4	41.76 A a	26.36 B b	67.21	Moderate - Tolerant
No. 10	32.90 A bc	27.63 A b	83.96	Moderate - Tolerant
No. 12	37.18 A ab	19.46 B c	52.38	Susceptible
No. 33	37.91 A ab	19.52 B c	51.51	Susceptible
No. 34	40.54 A a	35.32 A a	87.60	Tolerant
No. 40	32.86 A bc	24.30 B b	07.11	Moderate - Tolerant
No. 45	29.59 A c	24.18 A bc	82.60	Moderate - Tolerant

Mean values within column 2 and 3 for root length followed by small letters and rows between those columns followed by capital letters are not significantly different by DNMRT at 5% level. Notes for level of tolerance (%): Tolerant ≥ 87.50%), (Moderate - Tolerant 53.50% – 87.50%), and (Susceptible ≤ 53.50%).

Root growth of sorghum genotypes responded differently to the Al 8 ppm treatment. Different to their shoot growth response where Al 8 ppm treatment either increased or decreased shoot weight, inclusion of Al 8 ppm to the nutrient solution significantly reduced root length in all genotypes tested except for No. 10, N0. 34, and No. 45. Genotype No. 33, No. 12, and No. 2 were affected most with a reduction in root length for as much as 48.5% compare to similar genotypes of control treatment group. These three genotypes were categorized as susceptible with level of Al tolerance of ≤ 53,50% and are not suitable to be cultivated in acid soil due to lacking of resistant mechanism towards Al ions. In contrast, plants with mechanism of stress tolerance may prevent themselves from toxic ions Fitter and Hay [11].

On the other hand, sorghum genotype No. 34 was least affected with 12.9% reduction in root length and was the only tolerant genotype according to its relative root length. Variation in root length reduction among genotypes tested demonstrates wide genetic diversity in sorghum [12]. As a consequence, each genotype would respond differently to growth conditions as directed by their genetic traits. This is in line with research reported by Proklamasiningsih *et al*., (2012) that Al stress resulted in shorter but bigger roots in soybean and confirmed that Al stress and toxicity affected plant growth and more severe in roots [13].

Sorghum root dry weight varied among genotypes in response to 8 ppm Al stress treatment. Decreased in root length in all genotypes from the Al treatment group is not always followed by decreased in root dry weight. Apparently, some genotypes responded in an opposite way with increased root dry weight (Table 3).

TABLE III
ROOT DRY WEIGHT (MG) AND TOLERANCE LEVELS (%) BASED ON RELATIVE ROOT DRY WEIGHT (RRDW) OF SORGHUM PLANTS AT FOUR WEEKS AFTER GERMINATED WITH 0 AND 8 PPM AL IN HOAGLANDS' SOLUTION.

Genotype	Root dry weight (mg) Aluminium (ppm)		Level of tolerance (%) as for RRDW	
	Al_0	Al_8	Al (8 ppm)	Remarks
Super 1	28.1 A ab	32.9 Aab	116.97	Tolerant
Super 2	28.8 A ab	24.5 A cd	85.25	Moderate - Tolerant
No. 2	28.7 A ab	24.3 A cde	85 04	Moderate - Tolerant
No. 4	31.9 A ab	28.8 A bc	91.55	Moderate - Tolerant
No. 10	30.6 A ab	25.9 A cd	84.36	Susceptible
No. 12	26.9 A ab	19.1 B ef	71.27	Susceptible
No. 33	26.0 A bc	26.2 A cd	101.24	Moderate - Tolerant
No. 34	32.5 A a	35.2 A a	110.65	Tolerant
No. 40	20.6 A de	21.3 A def	104.74	Moderate - Tolerant
No. 45	14.0 A f	15.9 A f	113.84	Tolerant

Mean values within column 2 and 3 for root weight followed by small letters and rows between those columns followed by capital letters are not significantly different by DNMRT at 5% level. Notes for level of tolerance (%): (Tolerant ≥ 108.15%), (Moderate – Tolerant 84.84% – 108.15%), and (Susceptible ≤ 84.84%)

Slight increase (1-17%) in root dry weight was observed in genotypes Super 1, No. 33, No. 34, No. 40, and No. 45 and genotype Super 1 increased most for as much as 17%. Genotypes Super 1, No. 34, and No. 45 fell into a group of tolerant and potential to be explored more for the breeding of Al tolerant genotype. It is interesting to note that 8 ppm Al inclusion in the nutrient solution did not necessarily reduce root weight. The largest reduction (29%) in root dry weight was observed in genotype No. 12 and coincide with the shortest root from the Al treated group. Increase in root dry weight may be resulted from shorter roots and relatively grew more intensively. Root length was measured from the main root only whereas root weight was obtained through weighing all parts of the roots including tertiary roots and root hairs.

Genotypes No. 10 and No. 12 were found to be susceptible to Al stress according to their relative root dry weight. Consistent with this character on root length, genotype No. 12 also fell into the group of susceptible for the root growth point of view. Aluminium content in the nutrient solution was high enough for this genotype that affected the root growth and biomass. The toxicity resulted from this Al treatment may significantly reduce growth and development of the sorghum.

IV. CONCLUSIONS

Our research concluded that early growth of sorghum was affected by Al stress at 8 ppm in nutrient solution. Reduction in root growth, root length, root weight and shoot weight were observed in all genotypes grown in 8 ppm aluminium-treated nutrient solution. Genotypes of No. 10, No. 34, Super 1, and No. 45 were found to be potentially tolerant to 8 ppm aluminium stress and may be further explored through breeding program.

ACKNOWLEDGMENT

This work is part of our research project through the Fundamental Research Scheme. We are very grateful for the opportunity to carry out the research funded by Dana DIPA (Daftar Isian Pelaksanaan Anggaran) Universitas Andalas, BOPTN Fund Grant Number: 05/UN.16/PL/D-FD/2014 dated 10 March 2014.

REFERENCES

[1] Soenartiningsih. 2009. Evaluasi ketahanan beberapa varietas/galur sorgum dan efektivitas fungisida terhadap penyakit anthraknosa. *Dalam*: Prosiding Seminar Nasional Serealia 2009. Balai Penelitian Tanaman Serealia.

[2] Sirappa, M.P. 2003. Prospek pengembangan sorgum di Indonesia sebagai komoditas alAlternatif untuk pangan, pakan, dan industri, *Jurnal Litbang Pertanian*, 22(4):133-140.

[3] Firmansyah, M.A. 2010. Respon tanaman terhadap Aluminium, *Agripura*, 6 (2):807-818.

[4] Ryan, P. R., T. B. Kinraide, and L. V. Kochian, 1994. Al^{+3}-Ca^{+2} interaction in aluminium rhizotoxicity. I. Inhibition of root growth is not caused by reduction of calcium uptake, *Planta* 192:98-103.

[5] Sasaki, M., M. Kasai, Y. Yamamoto, and H. Matsumoto, 1994. Comparation of the early response to aluminium stress between tolerant and sensitive wheat cultivars: Root growth, aluminium content, and efflux of K^{+}, *J. Plant Nutr* 17(7):1275-1288.

[6] Hanum, C., W.Q. Mugnisjah, S.Yahya., D. Sopandy., K. Idris., dan A. Sahar. 2007. Pertumbuhan akar kedelai pada cekaman Aluminium, kekeringan dan cekaman ganda Aluminium kekeringan, *Agritrop*, 26 (1):13-18.

[7] Yamamoto, Y., K. Ono, K. Mametsuka, M. Kasai, and H. Matsumoto, 1992. Growth inhibition by aluminium is alleviated by phosphate starvation in cultured tobacco cells. Plant Cell Walls as Biopolymer with Physiological Functions, p404-406.

[8] Hasanah, U.,Ardiyansyah dan A. Rosidi. 2010. Pertumbuhan awal dan evapotranspirasi aktual tanaman tomat (*Lycopersicum esculentum* Mill) pada berbagai ukuran agregat Inceptisols, *Jurnal Agroland*, 17 (1):11-17.

[9] Schweitzer, L.E. and J.E. Harper. 1980. Effect of light, dark, and temperature on root nodule activity (Acetylene Reduction) of soybean, *Plant Physiology*, 65: 51-56

[10] Syafruddin. 2004. Genotipe jagung efisien hara P, *Buletin Plasma Nutfah*, 10(1):17-22

[11] Fitter, A.H., and R.K.M. Hay. 1991. Fisiologi Lingkungan Tanaman. Gadjah Mada University Press. 421 hal.

[12] Santoso, S.B., M.S. Pabbage, dan M.B. Pabendon. 2013. Plasma nutfah sorgum. *Dalam*: Sumarno., D.S. Damardjati, M. Syam, dan Hermanto, (editor). Sorgum: Inovasi Teknologi dan Pengembangan. Jakarta: IAARD *press*.

[13] Proklamasiningsih, E., I.D. Prijambada., D. Rachmawati dan R.P. Sancayaningsih. 2012. Pengaruh pemberian garam Aluminium (Al) terhadap serapan Al dan pertumbuhan akar kedelai pada media tanam masam.