AGRIVITA VOLUME 37 No. 3 OCTOBER - 2015 ISSN : 0126 - 0537

THE APPLICATION OF PEATY MINERAL SOIL WATER IN IMPROVING THE ADAPTABILITY OF BLACK SOYBEAN TOWARD ALUMINIUM STRESS ON TIDAL MINERAL SOIL WITH SATURATED WATER CULTURE

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Received: March 24, 2015/ Accepted: August 18, 2015

ABSTRACT

Soybean development in mineral soils of tidal land is hindered by aluminum toxicity. Modification of growing environment and the use of tolerant variety are feasible alternatives. The experiment was conducted with several objectives (1) to identify growth and yield of black soybean at depths of water table, (2) to identify growth and yield of black soybean as effected by application of ameliorants, (3) to identify growth and yield of black soybean, (4) to identify interaction between depth of water table, type of ameliorant, and black soybean variety. It also used mineral soils with watershed B type of tidal land in South Sumatera on May to August 2014. Factors investigated were depth of water table (10 and 20 cm), (Tanggamus – as control, Cikuray, Ceneng) and ameliorant type (river water, peaty mineral soil water, and high-tide water). These factors were arranged in a Split-plot Design. The results demonstrated that, for growing black soybean, soils with water table depth of 20 cm was better than those of 10 cm, peaty mineral soil water ameliorant was better than river water or high-tide water ameliorant, Ceneng produced higher yield, but not to those of Cikuray. There was no interaction between surface water depth, ameliorant and variety.

Keywords: aluminium tolerant; ameliorant; mineral soil

INTRODUCTION

Agricultural extension program in Indonesia might be applied in marginal area including the tidal soil. Tidal soil was one of the alternatives to solve the shortage of fertile lands in Java island by doing land conservation. Total tidal area in Indonesia was approximately 20.1 million ha and around 9.53 million ha was having potential that could be converted into agricultural land (Alihamsyah, 2004).

Al was one of the limiting factors in mineral soil in tidal area. Al toxicity in plants was the main limiting factor of plant growth in acid land (Basu *et al*., 1994; Jones and Kochian, 1995). Plant response to Al toxicity was root growth inhibition, especially in the root tip by inhibiting the cell division and nutrition and water absorption, thus detain the overall growth and productivity of the plant (Foy *et al.,* 1978; Kochian *et al*., 2004; and Zhang *et al*., 2007).

Low productivity of soybean plant in high Al content acid area caused the plant ability to absorb nutrition low. It was also driven by the very limited availability of nutrition. Calcification could increase soil pH, but with high cost. Therefore, other alternative was needed for soil pH to increase, such as ameliorant application.

Ameliorant was material that could be used to improve soil properties thus might support growth and productivity of the cultivated land. Ameliorant source might be derived from peaty mineral soil water. Peaty mineral soil water consisted of humic acid that could be used and interacted with metal ion thus would improve the soil quality. Chotimah's (2009) study result found that peaty mineral soil water watering of 2.4 L kg^{-1} area might lower Al-dd and increase the acid area pH. Afterward, humic compound addition might decrease Al-dd from 5.99 me $(100\ g)^{-1}$ to 5.33 me$(100\ g)^{-1}$ (Manfarizah, 1999).

Accredited SK No.: 81/DIKTI/Kep/2011
http://dx.doi.org/10.17503/Agrivita-2015-37-3-p284-289

This research objectives were (1) to identify growth and yield of black soybean at several depths of water table, (2) to identify growth and yield of black soybean as effected by application of several ameliorants, (3) to identify growth and yield of several black soybean varieties, (4) to identify interaction between depth of water table, type of ameliorant, and black soybean variety for growing black soybean on tidal mineral soil under saturated water culture.

MATERIALS AND METHODS

This research was conducted on mineral land, overflow type B, the tidal area was Banyuasin, South Sumatera, located between 1.30^o – 4.0^o south latitude and 104^o 00'' – 105^o 35'' east longitude. It was started from May to August 2014.

The method used was Split-Plot Design with three factors and three replications. The first factor was water depth level, namely: water depth level of 10 cm and 20 cm under soil surface in saturated water culture. The second factor was variety, namely: Tanggamus (as control), Cikuray, Ceneng. The third factor was ameliorant types, namely: river water, peaty mineral soil water and tide water.

The research procedures conducted were described as follows: topsoil was lightly processed. Ameliorant was given a dose of 4800000 L ha^{-1} once a week. The river water ameliorant was from river in primary channel of tidal land, peaty mineral soil water ameliorant from type B tidal land. Tide water ameliorant was from tertiary channel river when the water tided. Peaty mineral water was taken from peaty mineral soil type B tidal land. Decision was made by digging the soil at a depth of 50 cm. Basic fertilizer was given a week before planting. Basic fertilizer consisted of: 100 kg ha^{-1} KCl and 200 kg ha^{-1} SP36. Urea fertilizer was applied to the leaf 10 g L^{-1} (400 L ha^{-1}) water given at 2 and 4 weeks after cultivation. Seed treatment was *Rhizobium* sp (5 g kg^{-1} seed) and Marshal (insecticide with active carbosulfan 25.53%) and soybean was planted 40 cm x 12.5 cm. Treatment plot size was 2 x 4 m and observations on the harvest of seeds per plot was 1 m^2.

During the research, water level in the channel was maintained at 10 and 20 cm under soil surface in saturated water. Scaled bamboo was installed in each water channel to help controlling the water depth level.

Parameter observed were described as follows: plant height, leaves number, seed weight per plant, harvest seed weight (1 m^2). Soil analysis was conducted before the research and Al content measurement in plant root on 8 *Week After Planting* (WAP). Research data was analyzed by variance analysis in 5% and Duncan Multiple Range Test *(DMRT).*

RESULTS AND DISCUSSION

Soil Fertility with High Al Content Soil

Soil analysis result before the research showed that pH in research area was 4.30. Kochian (1995) stated that soybean plant might grow well in pH between 6.0 and 7.0. The decline of pH in mineral soil led to Al content rising. Al-dd content was 8.90 me (100 $g)^{-1}$ (high). This high Al content caused cation became dominant in soil complex sorption. Al toxicity in plant was a limiting factor for plant growth in acid area, by inhibiting the growth only in the root meristem.

Soybean Growth with Varied Water Depth Level S and Ameliorants

Variance result showed that there was no interaction between water depth level, ameliorant and variety in entire observation variables, other than the leaf at 10 WAP. Variety affected all observation variables, in both vegetative and generative phase, except in 4 WAP branch number and seed weight per plant. Ameliorant affected the plant height in 6 WAP, leaf number in 6 and 10 WAP, branch number in 12 WAP, seed weight per plant and seed weight of harvest seed weight (1 m^2). Water depth level affected the plant height and leaf number in 4 and 6 WAP, and branch number in 12 WAP.

Research results indicated that water depth level treatment of 20 cm was better than 10 cm shown by plant height 6 and 8 WAP, and leaf number 6 WAP (Table 1). There was no data of leaf number on 12 WAP.

Table 1. Average plant height, leaves number and branch number with varied water depth level treatments

Water depth level	Plant age (WAP)				
	4	**6**	**8**	**10**	**12**
			Plant height (cm)		
Water depth level of 10 cm	15.96	30.35 b	38.54 b	40.87	41.28
Water depth level of 20 cm	15.93	34.05 a	44.34 a	47.60	47.84
			Leaves number		
Water depth level of 10 cm	3.77 b	8.02 b	10.74	11.68	-
Water depth level of 20 cm	4.09 a	8.98 a	11.14	12.29	-
			Branch number		
Water depth level of 10 cm	0.00	0.77	1.35	2.43 a	1.43
Water depth level of 20 cm	0.00	1.10	1.43	1.93 b	1.38

Remarks: Numbers followed by the same letter in the same column indicated no significant difference in DMRT test with degree of 5%.

Seed weight per harvest plot (1 m^2) was better in water depth level treatment of 20 cm (Table 2). This was corresponding to previous study by Sagala *et al.* (2010); Sahuri (2010); Welly (2013) which showed productivity of 4.16, 4.15, 4.13 ton ha^{-1}, respectively. Based on Adisarwanto and Sunarlim (2000), plant root inhibited respiration in excessive water condition (water saturated) might inhibit nutrient absorption. Ghulamahdi *et al.* (2006) stated that saturated water cultivation system was able to increase nitrogenase activity, N, P, K absorption, and nodule, root, stem, leaf, pod and seed dry weight compared to dry cultivation.

Table 2. Seed weight per plant and seed weight per harvest plot (1 m^2) in varied water depth level treatments

Water depth level	Seed weight per plant (g)	Seed weight per harvest plot (g)
Water depth level of 10 cm	1.36	36.06
Water depth level of 20 cm	1.33	39.68

Remarks: Numbers followed by the same letter in the same column indicated no significant difference in DMRT test with degree of 5%

Ameliorant treatments indicated that peaty mineral soil water ameliorant increased soybean plant growth and it got higher compared to river water and tide water ameliorant (Table 3 and 4). These results were supported by the results of the analysis that indicated that ameliorant the C-organic content in peaty mineral water at 172.8 ppm, while the river water and the tide water was 51.7 and 51.4 ppm, respectively. Hue *et al.* (1985) stated that peaty mineral soil water consisted of organic acids. Organic acids could reduce Al toxicity such as: 1) organic acids with high influence in Al toxicity reduction like citric, oxalate and tartrate acid, 2) organic acids with medium influence in Al toxicity reduction like malate, malonate and salicylate acid, 3) organic acids with low influence in Al toxicity reduction like acetate, formic, lactate acid. Based on these acids configurations, in relation to detoxicity, Al was corresponded with carbon chain of OH and COOH group. Effective acids in Al detoxicity were those who had two pairs of OH and COOH in two closed carbons or two pairs of linked COOH, acids with medium ability had one pair of OH or COOH, whereas acids with low acidity ability did not have any of those configuration structure. Furthermore, Ernawati *et al.* (2007) stated that the peaty mineral soil water containing organic acids was acetic acid, propionic acid, butyric acid, succinic acid, ferulic acid, p-coumaric acid, p-hydroxybenzoic acid, sinapic acid, and the syringic acid. This research result was corresponding to Chotimah (2009) which indicated that peaty mineral soil water addition of 2.4 L kg^{-1} soil might reduce Al-dd and increase the number and midrib width of aloe vera plant.

Table 3. Average plant height, leaves number and branch number in varied ameliorant treatments

Ameliorant	Plant age (WAP)				
	4	6	8	10	12
			Plant height (cm)		
River water	15.68	30.34 b	39.61	45.43	45.78
Peaty mineral soil water	15.82	33.62 a	43.43	45.00	45.69
Tidal water	16.34	32.63 ab	41.28	42.28	42.21
			Leaves number		
River water	3.76 b	7.96 b	10.97	12.99 a	-
Peaty mineral soil water	4.07 a	9.03 a	11.37	12.46 a	-
Tidal water	3.96 ab	8.51 ab	10.49	10.51 b	-
			Branch number		
River water	0.01	0.77	1.49	2.35	1.40
Peaty mineral soil water	0.00	1.07	1.42	2.16	1.68
Tidal water	0.00	0.95	1.26	2.03	1.13

Remarks: Numbers followed by the same letter in the same column indicated no significant difference in DMRT test with degree of 5%

Table 4. Seed weight per plant and seed weight per harvest plot (1 m^2) with varied ameliorant treatments

Ameliorant	Seed weight per plant (g)	Seed weight per harvest plot (g)
River water	1.12 b	24.32 b
Peaty mineral soil water	1.97 a	53.43 a
Tide water	0.94 b	35.86 b

Remarks: Numbers followed by the same letter in the same column indicated no significant difference in DMRT test with degree of 5%

Seed weight per harvest plot (1 m^2) of Cikuray variety was higher than Ceneng variety (Table 5 and 6). Preliminary research result conducted in nutrient culture indicated that Cikuray variety was the variety classified as tolerant and whereas Ceneng was classified to be sensitive to Al stress.

Al Content in Varied Varieties in 8 WAP

The highest Al content was in Ceneng variety (sensitive variety) and Cikuray (tolerant variety) that was indicating lower Al content (Table 6). It could be seen in Cikuray variety that plant growth and production increased (Table 5 and 6). This research result showed that there was corresponding to Noya (2014) in which indicated that tolerant genotype had lower root Al content compared to sensitive genotype. Tolerance mechanism toward Al stress consisted of internal (tolerant) and external (avoidance) mechanism. Internal mechanism was a mechanism that led the plant hold the tolerance power of Al accumulation in cell including metal detoxification by binding in cytosol or compartment into the vacuole (Siedlecka *et al.,* 2001). Al toxicity in plant was the major inhibiting factor for plant growth in acid area (Basu *et al*., 1994; Jones and Kochian 1995). Al toxicity symptoms generally found in the plant were root growth inhibition (Foy *et al.,* 1978). Based on Ryan *et al.,* (1993) and Sasaki *et al.,* (1995), Al inhibited the growth only in root meristem tip. Al effect in nutrient absorption occurred because of rooting system disturbance, and nutrient absorption disturbance that was also occurred because of Al direct interaction influence with phosphor (P) thus P became unavailable for the plant. This P phenomenon highly inhibited the photosynthesis body cell division (Marschner, 2012) as a result it became a constraint in plant production in acid area (Kochian *et al.,* 2004; Zheng, 2010).

Tabel 5. Average plant height, leaves number and branch number in varied varieties treatments

Varieties	Plant age				
	4 WAP	6 WAP	8 WAP	10 WAP	12 WAP
			Plant height (cm)		
Tanggamus	14.94 c	29.83 b	40.34 b	48.12 a	48.01 a
Cikuray	15.70 b	29.80 b	36.20 c	36.56 b	37.76 b
Ceneng	17.19 a	36.97 a	47.77 a	48.03 a	47.91 a
			Leaves number		
Tanggamus	3.28 b	7.61 b	10.23 b	12.63 a	-
Cikuray	4.17 a	8.68 a	10.40 b	10.34 b	-
Ceneng	4.34 a	9.20 a	12.19 a	12.98 a	-
			Branch number		
Tanggamus	0.00	0.36 b	0.93 c	2.55 a	1.38 b
Cikuray	0.01	1.13 a	1.52 b	1.69 b	1.04 b
Ceneng	0.00	1.29 a	1.73 a	2.29 a	1.80 a

Remarks: Numbers followed by the same letter in the same column indicated not significantly difference in DMRT test with degree of 5%

Table 6. Seed weight per plant and seed weight per harvest plot (1 m^2) and Al content in root with different varieties treatments

Varieties	Seed weight per plant (g)	Seed weight per harvest plot (g)	Al content 8 WAP in root (ppm)
Tanggamus	1.11 b	28.08 b	798.61 c
Cikuray	1.28 ab	44.56 a	889.16 b
Ceneng	1.64 a	40.98 a	984.23 a

Remarks: Numbers followed by the same letter in the same column indicated not significantly difference in DMRT test with degree of 5%

CONCLUSIONS

The experiment concluded that water depth level of 20 cm was better than 10 cm. Peaty mineral soil water ameliorant was better compared to river water and tide water ameliorant. Ceneng variety generated the highest seed weight per plant but it got no significant difference than Cikuray variety. There was no interaction between water depth level, ameliorant and variety.

ACKNOWLEDGEMENT

This manuscript is a part of the first authors dissertation for Doctoral Program at Bogor Agricultural University.

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