Stomatal Performance Of Soybean Genotypes Due To Drought Stress And Acidity

Rini Widiati, Yunus Musa, Ambo Ala, Muh. Farid Bdr

Abstract: This research aims to classify soybean genotypes tolerant and susceptible to drought and acidity and to determine level of water content and observation parameters which can be used as an indicator of genotypes selection againts drought stress and acidity. The results are expected to give contribution in the development of soybean plants on acid dry land. Research was carried out as experimental study using a Split Plot design (SPD) with soil moisture levels (k) as main plot (MP) and soybean genotypes (g) as sub plot (SP). The soil moisture levelswere set based on the percentage of soil water content consisted of four levels e.g. 100% field capacity (k0), 80-100% field capacity (k1), 60-80% of field capacity (k2), 40-60% of field capacity (k3). Soybean genotypesused as the sub plot were g1 (variety Menyapa, 50 Gy); g2 (var. Orba, 25 Gy); g3 (var. Tanggamus, 0 Gy); g4 (var. Tanggamus, 25 Gy); g5 (var. Tanggamus, 50 Gy); g6 (var. Orba, 50 Gy); g7 (var. Menyapa, 0 Gy) and g8 (var. Orba, 0 Gy). A total of 32 teratment combination was obtained and planted on acid dry land. The data was analyzed using statistical software (Excel). Study results indicate that 1) genotype tolerant to drought and acidity were g1 (var. Menyapa, 50 Gy); g2 (var. Orba, 25 Gy); g3 (var. Tanggamus, 0 Gy); g4 (var. Tanggamus, 25 Gy); g5 (var. Tanggamus, 50 Gy); 75Gy) and g6 (var. Orba, 50 Gy), while sensitive genotypes were g7 (var.Menyapa, 0 Gy) and g8 (var. Orba, 0 Gy); 2) soil moisture content of 40-60% field capacity can be used an indicator of resistance to drought and acidity; 3) The parameter of the root volume, length of stomata, stomatal pore width, number of stomata and relative chlorophyll index can be used as an indicator of selection for soybean genotypes againts drought stress and acidity.

Index Terms: variability, genotype, stress, indicators, soybean

1 INTRODUCTION

Soybean is one of the major food commodities after rice and maize. Soybean is a food crop that is popular as source of vegetal protein for the people. In Indonesia, needs for soybean-based industrial materials for processed food such as tofu, soy sauce, soy milk, tauco, snacks etc. increase with the number of population resulted in increase for soybean production each year. However, this increment is not supported by sufficient production. Soybean production in 2013 decreased by 62.99 thousand tons (7,47%) compared to 2012 production due to productivity decline of 0.00069 tonnes / hectare (4.65 percent) and a decrease in harvested area of 16.83 thousand hectares (2.96 percent). To meet the needs of soybeans in 2013 amounted to 1.96 million tonnes, the government imported 1.810 million tons which decreased about 14.94% or 0.32 million tons compared to 2012 (BPS, 2014)[1]. To decrease the volume of soybeans imports the government continues to increase production, especially by utilizing marginal lands, such as dry land, acid dry land and saline land.

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Mulyani et al., (2009)[2] have identified dry land based on the exploration resource data scale of 1: 1,000,000, i.e.from the total of 1.48 million hectares dry land the land can be divided into acid dry land (102.8 million ha) and non acid dry land (45.2million ha). However, plantation expansion efforts in opening new areas often face the ecological limiting factors, such as drought, acidity and high Al content. Dry land in Indonesia is dominated by acid soils Podsolic Red Yellow classified in Ultisol. Land with this type of soil is constrained by the low pH (4.6 to 5.5), low cation exchange capacity (CEC), susceptible to erosion and poor biotic elements (Mulyani, 2006)[3], and high levels of aluminum (Al) (Utama, 2008)[4], this condition can cause toxicity in plants damaging plant roots hence hamper the ability of water and nutrient uptake result in low content of macro and micro nutrients like N, P, K, Ca, Mg, and Mo which causes stunted plant growth and death (Ma et al ., 2001; Sutjahjo, 2006)[5,6]. Soil acidity factor that has the most important contribution to decline in plant production is Al toxicity (Adam and Moore, 1983). 67% of acid land is affected by Al toxicity (Hede et al., 2007)[7]. Al toxicity can inhibit root development (Budiarti et al., 2004)[8] which causes the root system confined to the topsoil layer and affecting the capability of the roots in utilizing water and nutrients in the subsoil layer (Rusman, 1991)[9]. As a result the plants become susceptible to water stress and hence decrease in production. According to Blum (2005)[10] maintenance of the turgor or water status is very important in drought stress tolerance. This capability can be controlled by the constitutive characters (such as length and root weight) which quantitatively have greater role in tolerance to drought. On stressed conditions (Al 75% of soil moisture content 40% FC), Malabar genotype showed increase in root dry weight and length thought to be caused by the ability of this genotypes to adapt to the high Al and limited availability of ground water (Hanum et al., 2009)[11].

Materials and Methods

The study was conducted on acid dry land in the village of Baku, district of Tanralili, Maros regency of South Sulawesi Province since July 2013 to May 2014.Soil analysis of the land used in the study was pH 4.7 and Al-dd 1. 75 (cmol (+) kg^{-1}) / 100 g. Trial was set based on Split plot design (SPD) with soil moisture content as main plot and soybean genotypes as sub plot. The soil moisture levels were set as the percentage of soil water content consisted of four levels as follows: 100% field capacity (k0), 80-100% field capacity(k1), 60-80% of field capacity (k2) and 40-60% of field capacity (k3). The soybean genotypes (g) used were g1 (variety Menyapa, 50 Gy); g2 (var. Orba, 25 Gy); g3 (var. Tanggamus, 0 Gy); g4 (var. Tanggamus, 25 Gy); g5 (var. Tanggamus, 50 Gy); g6 (var. Orba, 50 Gy); g7 (var. Menyapa, 0 Gy) and g8 (var. Orba, 0 Gy). A total of 32 teratment combination was obtained and planted on acid dry land.Analysis of variance (ANOVA) was performed to test the hypothesis followed by the Least Significance Difference test (LSD) at the level of 5% or 1%. The ANOVA was carried out following Gomez and Gomez, 2007. The water content treatment was measured using a soil moisture gauge and the moisture levels were maintained by adding water based on scale readings on water gauges. Observation of leaf stomata and chlorophyll were performed in the third leaf from the top (youngest fully expanded leaf). The steps for the stomata preparation were conducted by making an incision on the leaf surface followed by application of aceton on the upper surface of the leaf in an area of 1 cm^2 then sealed with a cello tape. The leaf surface was left standing for 2 minutes before the tape was exfoliated. Masking tape and attached acetone given on preparations was observed under a microscope. Observation of the relative chlorophyll concentration was made at the vegetative phase, flowering, pod filling phase, and maturation phase using gauges PLUS CCM 200 Chlorophyll Content Meter (measuring instrument or green leaf chlorophyll levels in plants).

Results and Discussion

Plant Height and Number of Leaves of Soybean Genotypes

Observations on the average plant height and number of leaves of 8 soybean genotypes showed that the average plant height decreases with decreasing soil water content. Genotype 2, 3, 6, 7 and 8 showed the best average plant height and number of leaves compared to other 3 genotypes (Tables 1 and 2). This could be related to the difference in capability of the genotypes to alter the impact of declining soil moisture that affecting the root growth. Hanum, et al., (2007)[13] states that decrease in soil water content from 80% FC to 40% FC causes a decrease in soybean root dry weight. The decrease is due to limited plant root growth due to Al stress and coupled with the inadequate number of ground water. Inhibited root growth of the plant experiencing drought stress is due to the plant is not able to regulate their growth completely (Robert, 2004)[14].

Table 1. Average plant height (cm) of soybean genotypes on different soil moisture levels

Genotype (g)	Water Content Level (k)				$LSD_{0.05}$
	k0	k1	k2	k3	
g1	50,76 ab p	45,58 ab pq	45,49 a pq	37,03 b q	
g2	44,45 b p	45,02 ab p	36,23 b p	38,63 ab p	
g3	55,99 a p	50,86 a pq	46,25 a pq	40,77 ab q	
g4	44,53 b p	40,13 b pq	44,02 ab pq	27,62 c q	9,08
g5	42,90 b p	41,43 b p	45,33 a p	25,95 c q	
g6	48,32 ab p	40,87 b p	43,20 ab p	37,99 ab p	
g7	45,35 b p	45,84 ab p	46,88 a p	46,68 a p	
g8	45,60 b p	40,48 b p	46,28 a p	38,05 ab p	
$LSD_{0.05}$	12,86				

Values follow by same letter in the column (abc) and row (pqr) are not significantly different (p=0.05)

Table 2. Average of leaf numbers (sheets) of soybean genotypes on different soil moisture levels.

Genotype (g)	Water Content Level (k)				Average	$LSD_{0.05}$
	k0	k1	k2	k3		
g1	11,17	11,50	10,92	15,08	$12,17^{c}$	
g2	19,67	20,17	19,92	20,67	$20,10^{a}$	
g3	18,67	22,67	20,50	20,67	$20,63^{a}$	
g4	21,20	12,83	17,50	16,08	$16,90^{ab}$	3,84
g5	19,17	11,83	15,42	15,08	$15,38^{bc}$	
g6	18,67	19,67	18,17	21,92	$19,60^{a}$	
g7	23,00	17,42	17,92	15,92	$18,56^{ab}$	
g8	20,42	14,83	17,83	17,08	$17,54^{ab}$	

Values follow by same letterare not significantly different (p=0.05)

Weight of Crown/Root and Root Volume of Soybean Genotypes

The average weight of crown/root $plant^{-1}$of soybean genotypes declined with decreasing soil water content which is correlated with grain weight $plant^{-1}$. Figure 1 shows that no significant difference was found between field capacity water content treatment and the 80-100% FC treatment but significantly differed with the 60 to 80% FC and 40-60% FC treatments (Table 3). Drought stress conditions affect the plant canopy growth more than root growth indicated by stunted growth of the canopy compared to root growth (Wu and Cosgrove 2000;[15] Hamdy 2002)[16].Ojo and Ayuba (2012)[17] states that diversity of soybean genotypes has a very significant effect on the capability of the plant to adapt the aluminum stress on characters of the length of primary root, root dry weight and dry weight of the canopy. Adaptation form of the plants to sustain growth is by using more energy for root growth than for the growth of the canopy (Rengel, 2000[18]; Utama, et al., 2009[19]). Al stress will lead to inhibition of the cell division process and root elongation result in reduction in the absorption of water and nutrients (Samac and Tesfaye, 2003[20]).

Table 3. Average of Crown/root dry weight (g) of soybean genotypes at different soil moisture levels

Genotype(g)	Water Content Level (k)			
	k0	k1	k2	k3
g1	1,24	1,04	0,71	0,74
g2	1,26	0,98	0,94	0,75
g3	0,81	1,16	0,89	0,78
g4	1,18	1,02	0,98	0,92
g5	1,28	0,74	0,72	0,71
g6	0,88	1,28	0,91	0,75
g7	0,75	0,90	0,83	0,67
g8	0,94	0,90	0,73	0,66
Total	$1,04^{p}$	$1,00^{p}$	$0,84^{q}$	$0,75^{r}$
LSD $k_{0.05}$		0,06		

Values follow by same letter in the column (abc) and row (pqr) are not significantly different (p=0.05)

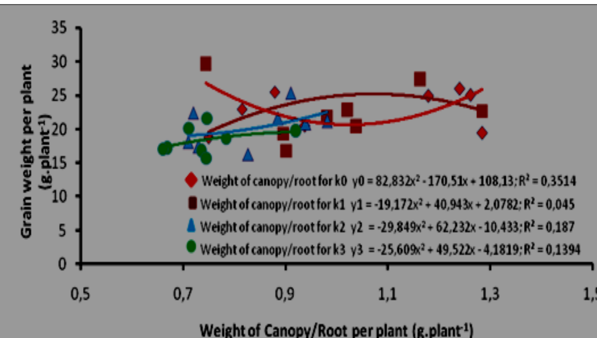


Fig 1. Relationship between weight of canopy/root per plant and grain weight per plant

The results of the average of root volume show that genotype g1 had the highest root volume than the other genotypes but not significantly different from g3, g5, g7, and g8 at moisture content of 40-60% FC (Table 4). According to Blum (2005)[10] that ability in maintaining the plant turgor pressure or water status is very important in drought stress tolerance. This ability can be controlled by the constitutive characters (such as length and root weight) that has quantitatively greater role in tolerance to drought stress than adaptive characters. This has implications for the method of selection, where the selection of the root length or root dry weight can be carried out at optimum conditions. Bakhtiar et al. (2009)[21] states that the tolerance to Al was associated with at least a reduction in root growth, higher canopy dry weight, a higher Si content in the canopy and the higher Si/Al ratio in the roots.

Table 4. Average of root volume (ml) of soybean genotypes at different soybean genotype at different soil moisture levels

Genotype (g)	Water Content Levels (k)				LSD $g_{0.05}$
	k0	k1	k2	k3	
g1	15,80$^{ab}_{p}$	15,60$^{abc}_{p}$	13,20$^{b}_{p}$	14,60$^{ab}_{p}$	
g2	16,80$^{ab}_{p}$	16,80$^{a}_{p}$	12,40$^{b}_{q}$	11,20$^{c}_{q}$	
g3	18,20$^{a}_{p}$	16,20$^{ab}_{p}$	16,40$^{a}_{p}$	15,40$^{a}_{p}$	
g4	14,20$^{bc}_{p}$	13,20$^{bcd}_{p}$	12,60$^{b}_{p}$	12,20$^{bc}_{p}$	3,18
g5	17,60$^{a}_{p}$	15,80$^{abc}_{p}$	13,80$^{ab}_{q}$	12,80$^{abc}_{q}$	
g6	15,40$^{ab}_{p}$	13,00$^{cd}_{pq}$	13,60$^{ab}_{pq}$	11,50$^{bc}_{q}$	
g7	11,80$^{c}_{q}$	10,80$^{d}_{q}$	16,50$^{a}_{p}$	13,20$^{abc}_{pq}$	
g8	15,80$^{ab}_{pq}$	17,20$^{a}_{p}$	14,00$^{ab}_{pq}$	13,20$^{abc}_{q}$	
LSD $k_{0.05}$	3,78				

Values follow by same letter in the column (abc) and row (pqr) are not significantly different (p=0.05)

Stomata pores length and width

Calculation of observed average length of stomata on soybean genotypes indicates that generally at field capacity moisture content and water content of 80-100% FC all genotypes were not significantly different, whereas the water content of 60-80% FC and 40-60% FC showed consistently longer stomata in genotype 3 and 6 are than in the other genotypes with values of 23 μmand 18 μm, respectively (Table 5). This is consistent with study of Lestari (2006)[22] which states that the genetic character of stomata that determined the level of plant adaptation to a dry environment and lower stomatal density are a potential genetic character to increase tolerance to water deficit. Dickison (2000)[23] that ionization radiation can cause a change in the palisade cells, spongy cells or an increase or decrease in the vascular tissue, any changes in anatomy are generally accompanied by changes in physiological activity.

Table 5. Average stomatal length (μm) of soybean genotype at different soil moisture levels

Genotype (g)	Water Content Levels (k)				LSD $g_{0.05}$
	k0	k1	k2	k3	
g1	18,00$^{a}_{p}$	16,00$^{a}_{pq}$	13,00$^{b}_{pq}$	9,00$^{d}_{q}$	
g2	18,00$^{a}_{p}$	16,00$^{a}_{p}$	13,00$^{b}_{p}$	18,00$^{ab}_{p}$	
g3	19,00$^{a}_{pq}$	15,00$^{a}_{q}$	20,00$^{a}_{pq}$	23,00$^{a}_{p}$	
g4	20,00$^{a}_{p}$	20,00$^{a}_{p}$	17,00$^{ab}_{pq}$	12,00$^{cd}_{q}$	5,26
g5	21,00$^{a}_{p}$	15,00$^{a}_{p}$	15,00$^{ab}_{p}$	15,00$^{bc}_{p}$	
g6	18,00$^{a}_{p}$	20,00$^{a}_{p}$	18,00$^{ab}_{p}$	18,00$^{ab}_{p}$	
g7	21,00$^{a}_{p}$	19,00$^{a}_{p}$	20,00$^{ab}_{p}$	8,00$^{d}_{q}$	
g8	20,00$^{a}_{p}$	15,00$^{a}_{pq}$	13,00$^{b}_{pq}$	9,00$^{d}_{q}$	
LSD $k_{0.05}$	7,11				

Values follow by same letter in the column (abc) and row (pqr) are not significantly different (p=0.05)

Calculation of stomata pore width of the soybean genotypes indicates that the width of stomata pores of soybean genotypes at different level of water content treatments varies each genotype (Table 6). This is consistent with research of Mabhaudhi (2013) which states that among the responses of Bambara groundnut (*Vignasubterranea* L. Verdc) to limited water availability were through stomatal closure therefore reducing the loss from transpiration and resulting in a decrease in plant height growth index, number of leaves and leaf area index, thus minimizing water loss. In addition, water stress resulted in earlier flowering, reduction in the length of flowering and premature aging. These are a typical response of plants to drought and known as avoidance mechanism. Water loss increases with transpiration rate. This loss of water causes turgor pressure in the guard cells decreases. In this condition, ABA will enter and causes stomata to close. This closure aims to reduce excessive water loss (Taiz and Zeiger2010)[25]. Makbul*et al.* (2011)[26] reported that the leaf water status was an interaction between leaf water potential and stomatal conductance, drought will induce roots to send signals to canopy to reduce the transpiration rate so that stomata close when the water supply decreases.

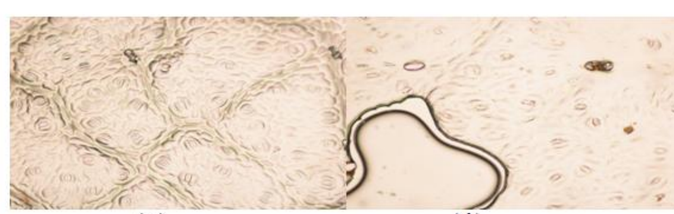
Table 6. Average of stomata pore width (μm) of soybean genotypes at different soil moisture levels

Genotype (g)	Water Content Levels (k)				LSD $g_{0.05}$
	k0	k1	k2	k3	
g1	5,00$^{a}_{p}$	1,00$^{b}_{q}$	1,00$^{b}_{q}$	1,00$^{a}_{q}$	
g2	2,50$^{b}_{p}$	1,00$^{b}_{p}$	2,00$^{b}_{p}$	1,00$^{a}_{p}$	
g3	1,50$^{c}_{p}$	2,70$^{a}_{p}$	2,00$^{b}_{p}$	1,50$^{a}_{p}$	
g4	1,50$^{c}_{p}$	1,00$^{b}_{p}$	2,00$^{b}_{p}$	1,00$^{a}_{p}$	5,26
g5	3,00$^{b}_{q}$	1,50$^{ab}_{q}$	7,00$^{a}_{p}$	1,00$^{a}_{q}$	
g6	1,50$^{c}_{p}$	2,00$^{ab}_{p}$	1,00$^{b}_{p}$	1,00$^{a}_{p}$	
g7	1,00$^{c}_{p}$	2,00$^{ab}_{p}$	1,00$^{b}_{p}$	2,00$^{a}_{p}$	
g8	2,00$^{b}_{p}$	2,00$^{ab}_{p}$	2,00$^{b}_{p}$	1,50$^{a}_{p}$	
LSD $k_{0.05}$	7,11				

Values follow by same letter in the column (abc) and row (pqr) are not significantly different (p=0.05)

(a) (b)

Fig 2a. Stomata of genotype 6 at water content treatment (Field Capacity)
Fig 2b. Stomata of genotype 6at water content treatmentof 80-100% FC



(c) (d)

Fig 2c. Stomata of genotype 2 at water content treatment of 60-80% FC
Fig 2d. Stomata of genotype 6at water content treatment of40-60% FC

Number of Stomata

Ingeneral, it was found that number of stomata of soybean genotypes declined with decreasing in soil water content. In the water content treatment of 40-60% FC genotypes tested were not significantly different, but in the water content of 60-80% FC, genotypes 2 showed the highest number of stomata (10 stomata) compared to genotypes 4 and 6 which showed the lowest number of stomata (6 stomata) on the fields of view (Table 7). The number of stomata of genotypes 2 and 6 at different levels of soil moisture can be seen in Fig 2. This is consistent with Lestari (2006) research which found that somaclone Gajah mungkur, Towuti, and IR 64, somaclones considered to be resistant to drought, generally have lower stomatal density than the parent plant. These considered resistant plants were generally derived from callus which has been induced for a mutation using gamma-ray irradiation. Increase in transpiration rate will result in higher water loss. Loss of water alters the turgor pressure in the guard cells. In this condition ABA will enter the apoplast resulting in stomatal closure. The closure of stomata is aimed to reduce excessive water loss (Taiz and Zeiger 2010)[24]

Table 7. Average of stomata number of soybean genotypes at different soil moisture levels

Genotype (g)	Water Content Levels (k)				NPg BNT
	k0	k1	k2	k3	
g1	$11{,}00^{bc}_{p}$	$9{,}00^{bcd}_{p}$	$9{,}00^{ab}_{p}$	$8{,}00^{a}_{p}$	
g2	$14{,}00^{a}_{p}$	$12{,}00^{a}_{pq}$	$10{,}00^{a}_{qr}$	$8{,}00^{a}_{r}$	
g3	$10{,}00^{c}_{p}$	$8{,}00^{bcd}_{pq}$	$7{,}00^{bc}_{pq}$	$6{,}00^{a}_{q}$	
g4	$12{,}00^{abc}_{p}$	$9{,}00^{bcd}_{pq}$	$6{,}00^{c}_{q}$	$6{,}00^{a}_{q}$	2,717607
g5	$13{,}00^{ab}_{p}$	$7{,}00^{d}_{p}$	$7{,}00^{bc}_{q}$	$6{,}00^{a}_{q}$	
g6	$12{,}00^{abc}_{p}$	$11{,}00^{ab}_{p}$	$6{,}00^{c}_{q}$	$6{,}00^{a}_{q}$	
g7	$10{,}00^{c}_{p}$	$10{,}00^{abc}_{p}$	$8{,}00^{abc}_{p}$	$7{,}00^{a}_{p}$	
g8	$11{,}00^{bc}_{p}$	$10{,}00^{abc}_{pq}$	$8{,}00^{abc}_{pq}$	$7{,}00^{a}_{q}$	
NPkBNT		3,89268			

Values follow by same letter in the column (abc) and row (pqr) are not significantly different (p=0.05)

Relative ChlorophyllIndex

Further test on the mean of relative chlorophyll index of soybean genotypes showed that genotype 6 showed the highest relative chlorophyll index compared with the other genotypes (Table 8). Considered drought tolerant genotypes generally have relatively chlorophyll index higher than the susceptible ones. This is consistent with Proklamirsininsih (2012)[26] which states that the leaf area, photosynthetic rate and chlorophyll content decreased by application of Al. Furtherly, it is stated that the chlorophyll content decreased allegedly due to the decreased concentration of Mg in the leaves. Chen *et al.* (2005)[27] states that increasing in Al content in the roots and leaves causes the concentration of Mg in both organs decreases results in decreasein *photosyntetic active radiation* (PAR).

Table 8. Average of relative chlorophyll index of soybean genotypes at different soil moisture levels

Genotype (g)	Water Content Levels (k)				Average	$LSD_{0.05}$
	k0	k1	k2	k3		
g1	102924,13	93203,87	95728,00	92421,73	$96069{,}43^{c}$	
g2	100708,60	94220,47	97940,07	92688,73	$96389{,}47^{bc}$	
g3	104832,47	95531,60	95465,27	95319,67	$97787{,}25^{bc}$	
g4	103827,67	94938,80	97048,93	97185,33	$98250{,}18^{bc}$	3123,88
g5	103789,47	91860,40	95845,20	97810,93	$97326{,}50^{bc}$	
g6	110077,93	95034,67	95949,07	106436,27	$101874{,}48^{a}$	
g7	105419,47	96307,60	99134,73	93913,47	$98693{,}82^{b}$	
g8	106458,20	94929,33	98190,07	95072,27	$98662{,}47^{b}$	
Average	$104754{,}74^{p}$	$94503{,}34^{q}$	$96912{,}67^{q}$	$96356{,}05^{q}$		
$LSD_{0.05}$	2456,51					

Values follow by same letter in the column (abc) and row (pqr) are not significantly different (p=0.05)

Grain Weight of Soybean Genotypes

The average weight of grain per plant declined with decreasing in soil water content. The average grain weight per plant for genotypes 5 and 6 were the highest (22.92 g and 23.81 g, respectively) and are not different significantly with genotype 1, 2, 3, and 4 but differed significantly with genotype 7 and 8 (Table 9). In terms of photosynthesis, in plants experiencing water stress, the stomata will close early to reduce water loss. Stomatal closure will alter CO_2 fixation, so the rate of photosynthesis is reduced consequently reduce the photosynthate produced. As a result, food reserves for seed formation are reduced (Soverda et al., 2007)[28]. The closure of leaf stomata will result in inhibition of CO_2 and O_2exchanges from plant tissue to the atmosphere. In addition, it will also inhibit the absorption of nutrients. This condition make soybean plant reduces its metabolic mechanism activity to avoid drought stress and prepare for further growth when sufficient water is available (Liu et al., 2003)[30]. Stomatal opening associated with the metabolic processes of the plant e,g, transpiration and photosynthesis. Stomata plays role in the diffusion of CO_2 during photosynthesis. In addition, stomata also act as discharge doors of the cells in the process of transpiration (Taiz and Zeiger 2002;[30] Hopkins 2004)[31]. Detrimental effect of Al causes reduction in chlorophyll and the rate of photosynthesis in rice (Shi 2004)[32]. The rate of photosynthesis and chlorophyll content are the key factors in relation to plant production. Chlorophyll is pigment contained in the chloroplast and absorp light as energy for photosynthesis (Taiz and Zeiger 2002)[30]. Among all existing constraints, aluminum toxicity (Al) is a major limiting factor for crop productivity. (Kertesz, 2002; Li-Song, 2006)[33]. Water stress was proved to reduce grain yield by reducing the number of pods and biomass in Bambara groundnut (*Vignasubterranea* L. Verdc) although the plant was still productive in limited water conditions (Mabhaudhi 2013)

Table 7. Average of grain weight (g) of soybean genotypes at different soil moisture levels

Genotype (g)	Water Content Levels (k)				Average	$LSD_{0.05}$
	k0	k1	k2	k3		
g1	26,01	20,34	18,11	16,77	$20{,}31^{ab}$	
g2	25,01	21,73	20,82	15,75	$20{,}83^{ab}$	
g3	22,95	27,35	21,58	18,67	$22{,}64^{ab}$	
g4	24,94	22,74	21,18	19,71	$22{,}14^{ab}$	4,08
g5	19,43	29,63	22,44	20,18	$22{,}92^{a}$	
g6	25,53	22,69	25,36	21,64	$23{,}81^{a}$	
g7	18,79	16,83	16,30	17,13	$17{,}26^{b}$	
g8	20,51	19,34	17,39	17,06	$18{,}57^{b}$	
Average	$22{,}90^{p}$	$22{,}58^{p}$	$20{,}40^{pq}$	$18{,}36^{q}$		
$LSD_{0.05}$	3,39					

Values follow by same letter in the column (abc) and row (pqr) are not significantly different (p=0.05)

CONCLUSION

1) genotypes tolerant to drought and acidity were g1 (var. Menyapa, 50 Gy); g2 (var. Orba, 25 Gy); g3 (var. Tanggamus, 0 Gy); g4 (var. Tanggamus, 25 Gy); g5 (var. Tanggamus, 50 Gy); g6 (var. Orba, 50 Gy), while sensitive genotypes were g7 (var. Menyapa, 0 Gy) and g8 (var. Orba, 0 Gy).
2) soil moisture content of 40-60% FC can be an indicator of resistance to drought and acidity.
3) The characters of the root volume, length of stomata, stomatal pore width, number of stomata, the relative chlorophyll index can be used as an indicator of selection of soybean genotypes against drought and acidity.

REFERENCE

[1] BPS, 2014. Laporan Bulanan Data Social Ekonomi (Monthly Report of Social Economic Data) , Badan Pusat Statistik, Edisi 49 Maret 2014.

[2] Mulyani, A., Rachman, A., Dairah, A. 2009. Penyebaran Lahan Masam, Potensi dan Ketersediaannya Untuk Pengembangan Pertanian. Acid Land Spreading, Potential and its availability for Agricultural Development.

[3] Mulyani, A. 2006. Potensi Lahan Kering Masam Untuk Pengembangan Pertanian.Potential for Acid Drylandfor Agriculture Development. Jurnal Warta Penelitian dan Pengembangan Pertanian vol. 28 No. 2.

[4] Utama, M.Z.H. 2008. Mekanisme fisiologi toleransi cekaman aluminium pada spesies legum penutup tanah terhadapmetabolisme nitrat, amonium dan nitrit (Physiological Mechanism in tolerant to Al stress in legume cover crop on nitrat, ammonium and nitrit metabolism). Bul. Agron. 36:175-179.

[5] Ma, J.F., R.R. Peter, & D. Emmanuel. 2001. Aluminium tolerance in plants and the complexing role of organic acids. Trends in Plant Sci. 6 (6): 273– 276.

[6] Sutjahjo S. H. 2006. Seleksi *in vitro* untuk ketenggangan terhadap Aluminium pada empat genotype jagung. (*In vitro* Selection of tolerance to Aluminium of four Maize genotypes). Akta Agrosia 9 (2): 61-66.

[7] Hede, A.R., B. Skovmand dan J. Lopez-Cesati. 2007. Acid soil and Aluminium toxicity. Chapter 15. CIMMYT Wheat Program, CIMMYT Soil and Plant Nutrition Laboratory. pp. 172-182.

[8] Budiarti, S.G., T.S. Silitonga, T. Suhartini, Sutoro, Asadi, dan Hadiatmi. 2004. Evaluasi toleransi plasma nutfah padi, jagung, dan kedelai terhadap lahan bermasalah/lahan masam (keracunan Al dan Fe) dan pemupukan rendah (*Evaluation of the tolerance of rice, corn, and soybeans germplasmson marginal land / acid land (toxicity of Al and Fe) and low fertilization*). Kumpulan Makalah Seminar Hasil Penelitian BB-Biogen Tahun 2004. Hlm.51-61.

[9] Rusman, Sutiasumarga. 1991. Aneka Pustaka. Jakarta ; Balai Pustaka

[10] Blum A. 2005. Drought resistance, water-use efficiency, and yield potential—are they compatible, dissonant, or mutually ex-clusive?. Aus. Agri. Research, 56: 1159–1168.

[11] Hanum, C., Mugnisjah, W.Q., Yahya, S., Sopansie, D., Idris, K., dan Sahar, A. 2009. Penapisan Kedelai Toleran Cekaman Aluminium dan Kekeringan (*Screening of Soybean Tolerant to Aluminium and Drought Stress*). Forum Pascasarjana Vol. 32 No; 4 Oktober 2009: 295-305.

[12] Cambell et al, 2003. Biologi Jilid 2. Jakarta. Erlangga

[13] Hanum, C., W.Q. Muqnisjah, S. Yahya, D.Sopandy, K. Idris, dan A..Sahar.2007. PertumbuhanAkarKedelaipadaCekamanAluminium,KekeringandanCekamanGandaAluminiumdanKekeringan (*Soybean Root Growth in Aluminum and Drought Stress and Dual Stress of Drought and Aluminum*).JurnalAgritrop, 26 (1) : 13 – 18.

[14] Robert W. 2004. Recognizing Water Stress in Plant. The Arboretum at Flagstaff Extension Bulletin No.91-01http:www.thearb.org/water_stress.htm. 3p

[15] Wu Y. and D.J. Cosgrove. 2000. Adaptation of root to low water potentials by changes in cell wall extensibility and cell wall proteins. J. Exper. Botany (51):1543-1553.

[16] Hamdy M. 2002. Employment of maize immature embryo culture for improving drought tolerance. In : Proceeding of the 3rd Scientific Conference of Agriculture Sciences, Fac. of Agric., Assiut Univ., Assiut, Egypt, 20-22. October. 2002, pp. 463-477.

[17] Ojo dan Ayuba., Screening of tropically adapted genotypes of soybean (Glycine max (L.) Merrill) for aluminium stress tolerance in short-term hydroponics. Journal of Animal & Plant Sciences, 2012. Vol. 14, Issue 2: 1921-1930 (2012).

[18] Rengel, Z. 2000. Mineral Nutrition of Crops, Fundamental Mechanisms and Implications. Food Products Press. Binghamton, New York.

[19] Utama, dkk. 2009. Mekanisme fisiologi toleransi terhadap cekaman salinitas dan Al pada spesies legum penutup tanah (Physiological Mechanism tolerant to salinity and Al stress in legume cover crop). Jur. Stigma XII (2):186-191.

[20] Samac DA, Tesfaye M. 2003. Plat improvemnt for tolerance to aluminum in acid soil _a_review. Plat Cell Tissue Organ Cult 75 : 189-207

[21] Bakhtiar, Purwoko BS, Trikoesoemaningtyas, Dewi IS. 2009. Konstribusi akumulasi silikat, nitrogen dan

aluminium terhadap ketenggangan aluminium dan ketahanan terhadap penyakit blas pada padi gogo (*Contribution of silikat, nitrogen and aluminium accumulation on tolerance against aluminium and resistance to blast disease of upland rice*). Agron. Indonesia 37 : 194 – 201

[22] Lestari E.G. 2006.Hubungan antara Kerapatan Stomata dengan KetahananKekeringan pada Somaklon Padi Gajahmungkur, Towuti, dan IR 64. (The relationship between stomataldensity and tolerance of Rice somacloneGajahmungkur, Towuti, and IR 64againts drought).Jurnal Biodiversitas Vol 7, No 1 :44-48 ISSN: 1412-033X

[23] Dickison, W.C. 2000. Integrative Plant Anatomy . New York: John Wiley & Sons.

[24] Taiz L. and ZeigerE. 2010. Plant Physiology, Fifth Edition on line, Created by Sinauer Associates Inc

[25] Makbul SN, Saruhan Guler N, Durmus N, Guven S. 2011. Changes in anatomical and physiological parameters of soybean under drought stress Turk J Bot. 35:369-377.

[26] Proklamirsininsih, E., Prijambada , I.D., Rachmawati, D., Sancayaningsih, R. 2012. Laju Fotosintesis dan Kandungan Klorofil Kedelai pada Media Tanam Masam dengan Pemberian Garam Aluminium. (The rate of Photosynthesis and Chlorophyll Content in Acid Growing Media of Soybean with application of Aluminum Salts. AGROTROP, 2(1): 17-24. ISSN : 208 -155X.

[27] Chen, L.S., Qi, Y.P., Smith, B.R. & Liu, X.H.2005. Aluminum Induced Decrease inCO_2 Assimilation in Citrus Seedlings is Unaccompanied by Decreased Activitiesof Key Enzymes Involved in CO2 Assimilation. *Tree Physiol.* 25: 317-324.

[28] Soverda, N.; Mapegau dan Destri, F. 2007. Pengaruh Berbagai Kadar Air Tanah Terhadap Pertumbuhan dan Hasil Tanaman Kedelai Yang Diberi Mikoriza Vesikular Arbuskular. (Effect of Different Soil Water Content on growth and production of Soybean Crop due to vesicular arbuscularMycorrhiza. Jurnal Agronomi Vol. 11 No. 2, Juli – Desember 2007

[29] Liu, F., Jensen, C.R., and Andersen, M.N. 2003. Drought Stress Effect on Carbohydrate Consentration and Pods During Early Reproductive Developed Pod Set. J. Crops Researh. 86 (10)

[30] Taiz, L. and E. Zeiger. 2002. Plant Physiology. Third Edition. Sinauer Associates Inc. Publisher. Sunderland, Massachusetts. 667 p

[31] Hopkins WG. 2004. Introduction to PlantPhysiology. New York: John Wiley & Sons. Inc.

[32] Shi, G.Y. 2004. Effect of Aluminium on Growth and Some Physiological Function of Rice

[33] Seedlings. *Guihaia* 24: 77-80.

[34] Kertesz, S., Fabian, A., Zsoldos, F., Vashegy, A.,Labady, I., Bona, L. & A. Pecsvaradi. 2002. Changes in glutamine synthetaseactivity in presence of aluminiumcomplexes. Proceedings of the 7th.Hungarian Congress on Plant Physiology,46: 103–104.