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Screening of several sorghum genotypes on acid soil tolerance

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Abstract

Genotypes with contrasting tolerance level to acid soil is very important as genetic source in breeding activity. This study was aimed to obtain sorghum genotypes that tolerant and sensitive to acid soil. This study was conducted in Bagoang Village, Jasinga, Bogor District, from March to August 2012. A randomized completely block design was used as experimental design. Seven sorghum genotypes that were used in this study included 4 sorghum lines of [ICRISAT] collection (150-21-A, 5-193-C, 10-90-A, 150-20-A), 1 local sorghum (WHP), and 2 national varieties (Numbu, UPCA). Numbu is a known as an acid soil tolerant variety and was used as positive control. Our results showed that WHP genotype had significantly higher plant height and panicle length, and similar number of leaves, shoot fresh weight, root fresh weight, and yield that of Numbu. In contrast, 150-20-A genotypes had significantly lower plant height, number of leaves, shoot fresh weight, root fresh weight, and shorter panicle than that of WHP genotype. It can be concluded that from agronomy caracter of the seven sorghum genotypes used in this study, WHP and Numbu could be classified as acid soil tolerant genotypes while 150-21-A and UPCA genotypes were sensitive to acid soil. Biplot analysis showed genotypes x caracter, shoot fresh weigh caracter and root fresh weight caracter were classified determinant caracter different response to acid soil stress.

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Introduction

Sorgum (*Sorghum bicolor* (L.) Moench) is one of carbohydrate source potentially develop to fulfill food, feed, and fuel demand. In Indonesia, sorghum planting area should be addressed to areas with less favourable conditions such as acid soils and drought-prone areas to minimize competition with rice and corn planting area. Dry lands with acid podsolic soils reach 29% of the total arable lands in Indonesia (Mulyani *et al*., 2010) .Acid soil characterized by fertility and low soil pH (pH <5.5) so that the solubility of Al be high. Al solubility is high may result in toxicity to plants. Besides, also caused an important nutrients deficiency, such as magnesium, calcium and phosphor (Kochian *et al*., 2005; Kochian *et al*., 2004). Toxicity Al can disturb growth and development of plant (Caniato *et al*., 2007). Therefore it is very important to improve sorghum adaptation to acid soil which could be achieved through the use of sorghum varieties with better tolerance to acid soil with high Al toxicity and P defficiency problems.

The condition of land in Indonesia for the development of plants is large a land that is acid with aluminum stress. Besides the influence of Al on nutrient uptake by the root system impaired nutrient absorption disorders also occur due to the direct influence of the interaction of Al with phosphorus (P) so that P becomes unavailable for plants (Marschner, 2012). According to Agustina (2010), varieties Numbu provide the highest value for all variables tested in the face of Al stress and deficiency of phosphorus in acid soils. In terms of agronomy, nutrient efficiency is usually expressed through differences in the results of the genotypes grown on land that is not enough nutrients. So efficient plants are defined as plants that have better growth, producing more dry matter and nutrient deficiency symptoms develop much less than other plants when planted in a low nutrient level or less (Marschner, 2012).

To achieve the goal of developing sorghum in acid soils with low P availability of the necessary attempt develop sorghum varieties are adapted to the agro-ecological conditions. Acid soil tolerant sorghum varieties have been developed in several countries (Kochian *et al*., 2004), but in Indonesia has not been active development. Given the extent of acid soils with low P in Indonesia, development of sorghum varieties that are tolerant to these conditions is considered highly strategic.

This study was aimed to obtain sorghum genotypes tolerant and sensitive to acid soil. Genotypes with contrasting tolerance level to acid soil is very important as genetic source in breeding activity.

Materials and methods

This study was conducted in Bagoang Village, Jasinga, Bogor District, from March to July 2012. The soil in the study site had pH of 4.4, CEC of 14.34 $cmol_c/kg$, P of 5.8 ppm and exchengeable Al of 2.79 $cmol_c/kg$. Randomized completely block design was used as experimental design. Seven sorghum genotypes that were used in this study include 4 sorghum lines of ICRISAT collection (150-21-A, 5-193-C, 10-90-A, and 150-20-A), 1 local sorghum line (Watar Hammu Putih/WHP), and 2 national varieties (Numbu and UPCA). Numbu is a known as acid soil tolerant variety and was used as positive control. The study was conducted with the experimental design used was Randomized Block Design (RAK) with 7 genotypes of sorghum. Data were analyzed using analysis of variance form the level of 95% and Biplot analysis.

Planting is done by direct seeding with two seeds per planting hole, using a spacing of 70 cm x 10 cm. Given basic fertilizer at planting with a dose 100 kg urea/ha, SP_{-36} 60 kg/ha, and KCl 60 kg/ha. Urea was given two times, 2/3 was applied at planting and the third the remainder applied after a seven-week-old plants. Thinning is done at two weeks old sorghum plants, and the plants are left to be grown in each planting hole. Observations were made on plant height, number of leaves, canopy fresh weight, panicle length, panicle weight, panicle dry weight, seed weight per panicle, total dissolved solids, and harvest index at harvest ie 14 weeks after planting (MST).

Results and discussion

Observations on the response of sorghum to fertilizer P in acid soils conducted at 7 genotypes of sorghum consists of: 4 lines ICRISAT sorghum collection (A) 150-21-A, (B) 5-193-C, (C) 10-90-A , (E) 150-20-A, 1 local strain (D) (Watar Hammu Putih/WHP) from the East Nusa Tenggara and 2 national varieties (Numbu and UPCA). There is a very real difference to all observed variables except the variable weight of panicle, seed weight per panicle and weight of 1000 seeds.

Table 1. Effect of sorghum genotypes for plant height, number of leaves, shoot fresh weight, root fresh weight and shoot root ratio at 14 WAT.

Genotipe	Plant Height (cm)	Number of leaves	Shoot Fresh Weight (g)	Root Fresh Weight (g)	Shoot Root Ratio
(U) UPCA	141.11d	9.00c	256.90b	43.63b	5.89
(B) 5-193-C	336.67a	12.34a	410.30ab	88.19ab	4.65
(D) WHP	323.00ab	11.00ab	542.40a	106.46a	5.09
(N) NUMBU	213.00c	9.78bc	341.20ab	62.15ab	5.49
(C) 10-90-A	279.00b	10.17bc	434.80ab	95.00a	4.58
(E) 150-20-A	119.00d	9.00c	208.50b	38.63b	5.40
(A) 150-21-A	274.00b	10.50bc	267.40ab	75.94ab	3.52

Description: The numbers followed by the same letter in the same column are not significantly different by DMRT at level $\alpha = 5\%$.

In this experiment, genotype significantly affected the growth of sorghum in the vegetative phase, yiatu plant height, number of leaves, and the wet weight of the canopy at 14 MST (Table 1). 5-193 genotype-C and WHP is a tall plant genotype and the highest number of leaves when grown in acid soil conditions.

The sorghum plant height, leaf number, and fresh weight canopy high potential to be developed as a food source. Sorghum genotypes developed for food crops are expected to have high character which is not too high to be more easily harvested. Yield components and yield and quality of grain is a more major character in the development of strains of acid soil tolerant sorghum as a food source. Dicko *et al.* (2006) according sorghum is a staple food in Africa that has a high environment tolerance and a great (bio) chemical diversity. The content of starch as well as amylase is highly polymorph among sorghum varieties. These findings show that it is possible to use the content of starch and starch degrading enzymes to give directions for selecting the most suitable sorghum varieties for specific food processing.

In Table 1 shows the genotypes of sweet sorghum showed phenotypic appearance of good in terms of verification and selection of strains tolerant to high P deficiency is acid soil shows parameters plant height, number of leaves, canopy wet weight and wet weight of roots. Genotypes were entered into that category is Watar Hammu Putih/WHP. While 150-20-A (E) shows the growth rate is low compared with other genotypes. Known genotypes of sweet sorghum biomass has the character weight is a character of the highest correlation values of the source-sink balance.

Our results showed that WHP genotype had significantly higher plant height and panicle length than Numbu, and similar number of leaves, shoot fresh weight, root fresh weight, and yield as Numbu. In contrast, 150-21-A genotypes had significantly lower plant height, number of leaves, shoot fresh weight, root fresh weight, and shorter panicle than WHP genotype.

Plant height is an indicator of growth is the result of the interaction between genetic and environmental factors (Taiz and Zeiger, 2002). Plant height is also one important variable in determining the differences in the growth of sorghum genotypes tolerant and sensitive. In this study, sensitive genotype (UPCA and (A) 150-21-A) suffered stunted growth due to Al stress. Impaired growth and development due to stress-sensitive genotype aluminum high. Al stres acid soils and high efficiency of nutrient causes plants to be stunted (Kochian *et al.*, 2004).

Known genotypes of sorghum that have character biomass weight rod/canopy is the character of the highest correlation to the value of source-sink balance. The relationship between the formation of the stem and leaf width showed that genotypes with leaf buds larger main and leaf area growth and thus greater demand for assimilate, produced fewer tillers Kim *et al.* (2010b). This supports the hypothesis that genotypic differences affect the formation of rod-related differences in the assimilation of internal plant competition. Therefore, the S/D index was developed by Kim *et al.* (2010a) enhanced by incorporating the main factor that controls the formation of genotypes in representing growth of stem length and leaf area assimilate the request.

Table 2. Sorghum genotypes influence the character of the panicle length, panicle weight, weight of seed per tassel and 1000 seed weight (14 WAT).

Genotipe	Panicle length (cm)	Panicle Weight (g)	Weight of seed per tassel (g)	1000 seed weight at harvest
(U) UPCA	21.67b	92.06	58.32	26.77
(B) 5-193-C	24.00b	110.55	45.17	56.97
(D) WHP	28.67a	99.45	68.45	31.73
(N) NUMBU	20.22b	94.61	57.10	32.62
(C) 10-90-A	23.67b	81.74	64.69	25.62
(E) 150-20-A	23.67b	92.49	55.36	25.40
(A) 150-21-A	32.33a	84.43	48.86	26.79

Description: The numbers followed by the same letter in the same column are not significantly different by DMRT at level $\alpha = 5\%$.

Tillering is generally recognized as one of the most plastic traits affecting accumulation of biomass and ultimately grain yield in many field crops. Kim *et al.* (2010b), include the results of crop growth simulation models can provide insight into the interaction of genotype with complex environmental management related to drought adaptation.

In Table 2 sweet sorghum genotypes obtained showing that both phenotypic appearance panicle length parameters indicate a very real difference. Genotypes were entered into the category of the highest panicle length is (A) 150-21A and Watar Hammu Putih/WHP. While the genotype into the category of the highest panicle weight was 5-193-C and Watar Hammu Putih/WHP. Grain weight per panicle was highest in genotype Watar Hammu White (WHP) and the lowest (B) 5-193-C, whereas the highest weight of 1000 seeds is (B) 5-193-C.

Sweet sorghum exhibit different physiological characters TST parameters, harvest index and greenery leaves showed a highly significant difference (Table 3). Genotypes were entered into the category of TST (Total Dissolved Solids) is the highest Hammu Watar Putih/WHP. While genotypes that fall within the highest harvest index was 10-90-A and Watar Hammu Putih/WHP. Tolerant sorghum (WHP and Numbu) able to have a source-sink balance by showing the highest value of the difference between the mean green leaves, and the opposite is happening in sensitive sorghum (150-21-A).

Genotype was highly significant for panicle length (Table 2). This suggests that more panicle length is determined by genotype. In acid soil, genotype (D) WHP produce the highest panicle length and panicle length significantly different from other genotypes including Numbu. Panicle length is to be filled by the sink photosynthate resulting grain weight per panicle or panicle weight is high. However, in this study panicle length genotypes (A) 150-21-A tall but produces a low yield panicle weight. This is caused by the high stress where the inability Al genotype (A)

150-21-A to fill a large sink due to the high toxicity of Al.

Panicle length was an important component in sorghum as correlated with the results, because it is a space where the panicles grow sorghum seeds (sink). According Sungkono (2010) the number of seeds panicle length then the more that will be followed by an increase in grain weight per panicle. Panicle length is also an important part of sorghum in supporting the massive weight of panicle.

Table 3. Effect of sorghum genotypes for harvest index, Total Dissolved Solids (TST) and SPAD value at harvest (10 WAT and 14 WAT).

Genotipe	Harvest Index 14 WAT	PTT (°Brix) 14 WAT	Greenery leaves 14 WAT	Greenery leaves 10 WAT
(U) UPCA	67.18ab	5.84c	41.63a	50.61ab
(B) 5-193-C	52.39b	-	35.74abc	41.12d
(D) WHP	78.15ab	13.83a	28.94bc	50.61ab
(N) NUMBU	66.42ab	9.17b	24.78c	44.28cd
(C) 10-90-A	86.72a	9.16b	36.92ab	47.03bc
(E) 150-20-A	66.42ab	5.96c	37.11ab	52.53a
(A) 150-21-A	58.62ab	11.17b	34.13abc	49.19ab

Description: The numbers followed by the same letter in the same column are not significantly different by DMRT at level α = 5%.

Where the appearance of the shape and color of the panicle phenotype sorghum genotypes different. Sweet sorghum exhibit different physiological characters TST parameters, harvest index and greenery leaves showed a highly significant difference (Table 3). Genotypes were entered into the category of TST (Total Dissolved Solids) is the highest Watar Hammu Putih/WHP. While genotypes that fall within the highest harvest index was 10-90-A and Watar Hammu Putih/WHP. Tolerant sorghum (WHP and Numbu) able to have a source-sink balance by showing the highest value of the difference between the mean green leaves, and the opposite is happening in sensitive sorghum (150-20-A).

Weight is one of the parameters panicle production in sweet sorghum. Panicle production demonstrated the ability of plants to convert available nutrients into economic products. However, not all plants are able to maintain a high yield potential in an environment gripped aluminum. Observations on panicle weight is important to determine the ability of each genotype sorghum maintain yield potential.

Grain weight per panicle is an important observation parameter in acid soil. Plants were able to maintain production remained high despite gripped aluminum plants showed tolerance to Al stress. According Sungkono (2009) that grain weight per panicle represent the accumulation of the growth and development of the generative phase, and is the result of an individual plant so that it becomes a very important character in determining grain yield per unit area. Therefore, the character of grain weight per panicle determine tolerance.

Factor limiting crop growth in acid soils is a high aluminum poisoning. Aluminum toxicity is affected by changes in media pH. At low pH conditions, trivalent aluminum (Al^{3+}) is the most dominant form and is toxic to many plants. The main characteristic is the toxicity of aluminum servitude root growth, which in turn will reduce the productivity of plants (Zheng 2010).

From the standpoint of mineral nutrients, a genotype is said to be more efficient than the other genotypes if it is able to mobilize and absorb more P and or using P is absorbed better to produce dry matter or biomass plants. In terms of agronomy, nutrient efficiency is usually expressed through differences in the results of genotypes grown on land that is not enough nutrients.

So efficient plants are defined as plants that have better growth, producing more dry matter and nutrient deficiency symptoms develop much less than other plants when grown at low nutrient levels or less (Marschner 2012).

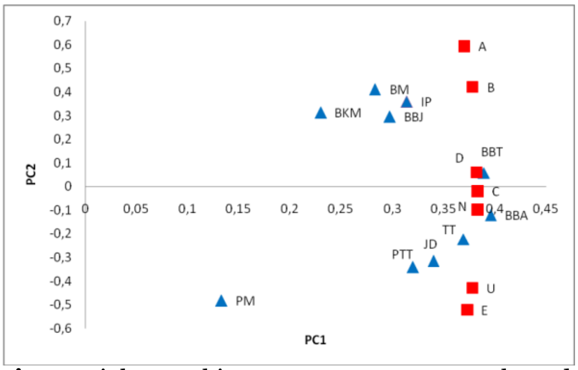

Fig. 1. Biplot graphic genotypes x caracter to showed determinant caracter andtolerant genotypes.

Description: Red color: genotypes (A=150-21-A; B=5-193-C; C=10-90-A; D=WHP; E=150-20-A; N=Numbu; U=UPCA). Blue color: caracter (TT=plant height; JD=number of leaves; BBT=shoot fresh weight; BBA=root fresh weight, PM=panicle length; BM=panicle weight; BKM=weight of seed per tassel; BBJ=1000 seed weight at harvest; IP=harvest index; PTT=total dissolves solids).

Genotype adaptive plants generally develop adaptation strategies to get certain nutrients from the soil, while genotypes that are not generally rely adaptive fertilizer as a source of nutrients available. Adaptation strategies are generally in the form of carbon translocated to the roots of the plant canopy (Wang *et al.*, 2008).

Grouping of genotypes tolerant and susceptible genotypes in sorghum is generally done only using a character-by-character analysis (analysis univariet) (Sungkono, 2009; Agustina, 2010). From the results of these studies indicate each genotype at each character has a different tolerance values that univariet analysis has some drawbacks in the estimation of tolerance. Biplot analysis is an analysis that constructs all the characters with all genotypes in a biplot constructed using the value of the main component. The results of the study in 2012 successfully classify Natawijaya tolerant and susceptible genotypes on wheat plants using all the characters. According to the 2012 grouping tolerance Natawijaya plant genotypes using biplot analysis showed results more comprehensive.

The spread of genotypes and the character based on the main components of the first and second main component is presented in Figure 1 This figure shows that the character of the BBT (Shoot Fresh Weight) and BBA (Root Fresh Weight) is a determinant of characters that can distinguish tolerant genotypes and genotypes sensitive. Genotype C (10-90-A), D (WHP) and genotype N (numbu) are grouped into genotypes tolerant and has the appearance and character of BBT (Shoot Fresh Weight) best BBA (Root Fresh Weight) than other characters.

Conclusions

Sorghum genotypes significantly affect all variables, except panicle weight, grain weight per panicle and weight of 1000 seeds. WHP genotype showed the highest value for all variables tested, except panicle length, weight of 1000 seeds, SPAD value. WHP, 10-90-A and Numbu genotype were determined as tolerant genotype, while genotype UPCA and 150-21-A was determined as sensitive genotype under acid soil stress condition.

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