Sensitivity Index of Several Drought-Tolerant Maize Genotipes on the Drought Stress

St. Subaedah, Sudirman Numba, Saida, and Farizah Dhaifina Amran
Faculty of Agriculture, University Muslim Indonesia, Makassar, South Sulawesi, Indonesia
Email: st.subaedah@umi.ac.id, {numbasudirman, farizahd.amran}@yahoo.com, saidawahid@yahoo.co.id

***Abstract*—One of the efforts that can be done in the development of maize in dry land is the use of drought-tolerant varieties. This study was conducted with the aim of analyzing the sensitivity index of several drought-tolerant corn genotypes in an environment that suffered from drought stress. The study was conducted from June to August 2016 in Gowa District, South Sulawesi. The treatments were arranged in Split Plot Design. The main plot was the treatment of stress consisting of two levels ie without stress (optimal water delivery) and the treatment of stress (watering was stopped when the plants are 35 to 70 days old). Subplot was maize genotypes consisting of 8 hybrid candidate maize genotypes ie G1, G2, G3, G4, G5, G6, G7, G8 and two checked varieties (Bima7 and Lamuru). Result of observation on drought sensitivity index from plant height variables showed that genotype G2 and G5 were included in the drought tolerant genotype category, while genotype G6, G7, and G8 medium tolerant. For dry seed weight parameter per ha indicated that genotype G6, G7, and G8 have Sensitivity index value in medium tolerant to tolerant category. The production rate of G6, G7 and G8 genotypes under drought-stressed conditions was still quite high between 6.92-7.47 t.ha^{-1}.**

***Index Terms*—sensitivity index, genotype, tolerant, drought-stressed**

I. Introduction

Depreciation of the optimal land becomes an obstacle in the provision of maize, while the requirement of corn from year to year increasingly in line with the increasing need for raw materials for food, feed and biofuel industries as renewable fuel which is alternative energy. On the other hand some countries like India and China, The United States, and Australia, as the world's largest corn producers, are currently unable to meet their domestic corn requirements [1]. This opens up great opportunities for corn development in the future.

The development of Indonesian maize is directed to the use of dry land, while the development of maize in dry land is faced with various problems, including the limited available water that will cause the plants to become drought stress [2]. The occurrence of drought stress, especially in the period of 1 week before flowering up to 2 weeks after flowering causes the plant increased ASI (anthesis silking interval) so pollination is not synchronized [3] and the formation of seeds that are not optimal or even in the absence of any seed formed by the reduction of photosynthesis [4]-[7].

The effects of drought stress depend on plant genetics, where morphological differences, anatomy and metabolism will produce different responses to drought stress [8], [9] explained that drought tolerant of a plant variety have genetic diversity that can be labeled in 3 domains: (a) plant cells and tissues can retain hydration so that the plant become slow withered by various mechanisms; (b) plants can retain their function although the status of water in plants is low, and (c) the plants recover after drought stress. In general, plants with drought stress will use more than one such mechanism to maintain their survival [10].

Selection of drought of corn plants based on CIMMYT procedure with drought stress treatment during the flowering phase or seed filling phase, the yield is only 30-60% of the yield under optimum conditions. If the plants dryness in the flowering phase until physiological ripening, the yield is 15 - 30% of the yield under optimum conditions, while the dryness in the vegetative period does not directly result to yield. The evaluation of drought stress can be seen from observations of plant morphology and physiology [11]. The drought sensitivity index (S) criteria for drought stress is if the value of $S \leq 0.5$ then the genotype is tolerant, if $0.5 < S \leq 1.0$ then the genotype is medium tolerant, and if $S > 1.0$ then the genotype is sensitive [12], the Drought Sensitivity Index is as follows:

$$S = \frac{(1 - Yp / Y)}{(1 - Xp / X)} \quad (1)$$

where:

Yp = The average of a genotype that gets drought stress

Y = The average of a genotype that does not gets drought stress

Xp = The average of all genotypes that get drought stress X = The average of all genotypes that do not get drought stress

This study was conducted with the aim to assess the response of several genotypes of maize to drought stress and to analyze the index of plant sensitivity to drought stress.

II. Methodology

This research was conducted in Gowa regency of South Sulawesi, which lasted from June to August 2016.

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Materials used include: hybrid corn seed of 8 genotypes and two check varieties (Bima7 and Lamuru). The population of the basic population genetic material originated from CIMMYT Mexico from the drought-tolerant group. The treatments were arranged in split plot design. The main plot was the treatment of stress consisting of two levels ie without stress (optimal water delivery = C0) and the treatment of stress (giving water is stopped when the plant is 35 to 70 days old after planting = C1). The subplot is genotype Maize consisting of 8 genotypes namely G1, G2, G3, G4, G5, G6, G7, G8 and two check varieties (Bima7 and Lamuru).

Watering was done according to the treatment as follows: treatment without stress, watering every 10 days, the treatment of stress was stopped at 35-65 days after planting (DAP). The first fertilization was done at 7-10 DAP with NPK Phonska 15:15:15 with dose 350 kg ha^{-1}, Urea with dose 150 kg ha^{-1}. The second fertilization was done at 30 DAP by applying Urea with dose 250 kg ha^{-1} and NPK Phonska 15:15:15 with dose 100 kg ha^{-1}, while the third fertilization given at age 45-50 days after planting with dose 150 kg Urea ha^{-1}, depending on the results of leaf analysis using leaf color chart. Weeding was done 2 times that was at 2-3 weeks after planting (WAP) and 4-6 WAP. The variables observed in this study include: plant height, time of 50% tasseling, time of 50% silking, ASI, cob weight, seed weight, and Drought Sensitivity Index (S).

III. Results

A. Plant Height

Results of data analysis of plant height at 8 WAP showed that the occurrence of stress resulted in shorter plants (plant height 228.62 cm) and significantly different than optimal watering with plant height 249.59 cm. Differences in genotypes showed that the genotypes G7 and G8 resulting the highest plants (258.00 cm and 261.50 cm respectively) compared to other genotypes and significantly different from the Bima 7 with a height of 236.50 cm.

The drought sensitivity index (S) of of plant height in the treatment of stress indicated that the G2 and G5 genotypes were drought tolerant. While genotype G6, G7, and G8 as well as the two check varieties (Bima7 and Lamuru) in the tolerant to drought stress tolerance category. While genotype G1, G3, and G4 as well as Bima7 were susceptible to drought stress. (Table I)

TABLE I. Plant Height at 8 Wap and Sensitivity Index of Several Maize Genotypes to Drought Stress

Genotype	Drought Stress		Average		Sensitivity Index (S)	
	Optimum	Stress				
	Plant Height (Cm)					
G1	260.56	231.56	246.06		1.3	S
G2	206.11	197.22	201.67	ab	0.5	T
G3	263.33	233	248.17	ab	1.4	S
G4	255.11	215.22	235.17	b	1.9	S
G5	221.44	220.33	220.89	ab	0.1	T
G6	237.00	221.44	229.22	b	0.8	MT
G7	269.33	246.67	258.00	ab	1.0	MT
G8	270.22	252.78	261.50	ab	0.8	MT
Bima 7	250.22	222.78	236.50		1.3	S
Lamuru	262.56	245.22	253.89		0.8	MT
Average	249.59 x	228.62 y				
LSD 0.05	17.76		11.23			

Note:
- The values followed by the different letters in the row (x; y) are significantly different based on the LSD test at 0.05 level.
- The value followed by the letters in the column: a means to differ significantly from Bima7; b means significantly different with Lamuru based on LSD test at 0.05 level.
- S: susceptble; MT: medium tolerant; T: tolerant.

B. Leaf Area

The results of analysis of leaf area of maize plant at 8 WAP showed that stress affected the leaf area. The drought sensitivity index (S) of the leaf area on the stress treatment showed that the genotypes tested were genotypes belonging to the medium tolerant to tolerant category, except the genotype G1 and G2 belonging to the sensitive genotype category. (Table II)

TABLE II. Leaf Area (cm^2) at 8 Wap and Sensitivity Index of Several Maize Genotypes to Drought Stress

Genotype	Degree Of Drought Stress		Sensitivity Index	
	Optimum	Stress		
G1	1141.11	897.96	2.0	S
G2	1106.67 ab	764.66 ab	2.9	S
G3	931,41	928.52	0.0	T
G4	1041.69	936.67	0.9	MT
G5	993.26	902.13	0.8	MT
G6	923.78	870.48	0.5	T
G7	920.30	847.90 ab	0.7	MT
G8	997.26	917.41	0.7	MT
Check varieties				
Bima 7	907.89	883.70	0.2	T
Lamuru	907.85	853.78	0.6	MT
Average	987.11 x	880.32 y		
LSD 0.05	77.77			

Note:
- The values followed by the different letters in the row (x; y) are significantly different based on the LSD test at 0.05 level.
- The value followed by the letters in the column: a means to differ significantly from Bima7; b means significantly different with Lamuru based on LSD test at 0.05 level.
- S: susceptble; MT: medium tolerant; T: tolerant.

C. Anthesis Silking Interval (ASI)

The average value of ASI in Table III shows that in optimum watering, the ASI value of the genotypes tested reached between 1.33 - 2 days, while in the treatment of stress obtained a range of large ASI values were between 1.33 to 3 days. The S value to ASI value in treatment of stress showed that there were several genotypes that have tolerance index of drought categorized as tolerant, such

as G1, G2, G6, and G8. As well as the two check varieties used (Bima7 and Lamuru).

TABLE III. ASI VALUE AND SENSITIVITY INDEX OF SEVERAL MAIZE GENOTYPES TO DROUGHT STRESS

Genotypes	Degree of Drought Stress		Sensitivity Index
	Optimum	Stress	
G1	2.00	2.00	0.0 T
G2	1.33 ab	1.33 ab	0.0 T
G3	2.00	2.33	1.3 S
G4	1.67	2.00	1.5 S
G5	1.67	2.00	1.5 S
G6	2,00	2.00	0.0 T
G7	1.67	3.00 ab	6.2 S
G8	1.67	1.67	0.0 T
Check varieties			
Bima 7	2.00	2.00	0.0 T
Lamuru	2.00	2.00	0.0 T
LSD 0.05	0.53		

Note:
- The value followed by the letters in the column: a means to differ significantly from Bima7; b means significantly different with Lamuru based on LSD test at 0.05 level.
- S: susceptble; MT: medium tolerant; T: tolerant.

D. Cob Weight

TABLE IV. COB WEIGHT PER PLANT (G) AND SENSITIVITY INDEX OF SEVERAL MAIZE GENOTYPES TO DROUGHT STRESS

Genotypes	Degree Of Drought Stress		Sensitivity Index
	Optimum	Stress	
	Cob Weight Per Plant (G)		
G1	199.53	173.53	1.6 S
G2	213.47	199.93	0.8 MT
G3	188.13	180.60	0.5 T
G4	191.80	165.13	1.7 S
G5	209.73	175.33	2.1 S
G6	226.33	214.27	0.7 MT
G7	201.87	191.27	0.7 MT
G8	220.27	209.40	0.6 MT
Check varieties			
Bima 7	219.47	191.60	1.6 P
Lamuru	206.97	210.80	-0.2 T
Average	207.76 x	191.19 y	
LSD 0.05	12.7		

Note:
- The values followed by the different letters in the row (x; y) are significantly different based on the LSD test at 0.05 level.
- S: susceptble; MT: medium tolerant; T: tolerant.

The result of the observation of cob weight in Table IV shows that the heaviest cob average was found in the non-stress treatment with 207.76 g of cob weight and was significantly different from the weight produced from corn crops that experienced the stress. The results of the index value analysis of Drought Sensitivity (S) on the tuna weights on the stress treatment showed that the genotype G6, G7, and G8 belongs to the category of tolerant medium. While the genotype G3 and Lamuru varieties fall into the tolerant genotype category.

E. Kernel Weight per Ha

Results of kernel weight analysis per ha showed that the average heaviest weight of kernel per hectare was found in G8 (7.90 tons ha^{-1}) and significantly heavier than Lamuru but not significantly different from Bima7. Followed by genotype G6 and G7 with cob weight was 7.39 and 7.32 tons ha^{-1} respectively. In the treatment without stress obtained weights of 7.28 t ha^{-1} and significantly different from the weight of the seeds produced by the treatment of stress that only produce 6.16 t/ha. Result of analysis of drought sensitivity index value to kernel weight per ha showed that in treatment of stress showed that there were several genotypes included in category of medium tolerant that was G6, G8, and Lamuru as well as Bima7. While G7 was categorized as tolerant.

TABLE V. KERNEL WEIGHT PER HA AND SENSITIVITY INDEX OF SEVERAL MAIZE GENOTYPES TO DROUGHT STRESS

Genotypes	Degree Of Drought Stress		Average	Sensitivity Index
	Optimum	Stress		
	Kernel Weight ($t.ha^{-1}$)			
G1	7.29	5.46	6.37	1.6 S
G2	6.99	5.87	6.43	1.0 MT
G3	6.44	5.27	5.86 a	1.2 S
G4	7.11	4.61	5.86 a	2.3 S
G5	6.80	5.66	6.23 a	1.1 S
G6	7.87	6.92	7.39	0.8 MT
G7	7.41	7.23	7.32	0.2 T
G8	8.32	7.47	7.90 b	0.7 MT
Check varieties				
Bima 7	7.85	7.05	7.45	0.7 MT
Lamuru	6.72	6.04	6.38	0.7 MT
Average	7.28 x	6.16 y	1.19	
LSD 0.05	0.61			

Note:
- The values followed by the different letters in the row (x; y) are significantly different based on the LSD test at 0.05 level.
- The value followed by the letters in the column: a means to differ significantly from Bima7;
  b means significantly different with Lamuru based on LSD test at 0.05 level.
- S : susceptble; MT: medium tolerant; T: tolerant.

III. DISCUSSION

The drought-tolerant maize genotype indicator may be evaluated directly based on the relative decrease in growth and seed production compared to the optimum conditions [11]. The results of the analysis of the plant height variables in Table I showed that the genotypes G7 and G8 showed the tallest plants and significantly different from the Bima7. The plant height on treatment of stress was significantly taller compared to stressed treatments. Giving water was stopped at 35 DAP. This condition causes the growth of plant height was

hampered because at this period the plant was still in vegetative growth phase. According to [13], watering is very influential on the period of plant growth, especially in the initial growth phase (15-20 days) and vegetative phase (25-40 days).

The value of the drought stress sensitivity index calculated based on the parameters of plant height increase showed that the genotype G2, G5, G6, G7, and G8 were more tolerant to drought stress than other genotypes shown by index values of drought sensitivity between 0.1 and 1.0. While on the leaf area parameter showed that the drought stress condition significantly decreased the leaf area, but the medium tolerant tolerant to tolerant genotypes (G3, G4, G5, G6, G7 and G8) were able to maintain the growth rate with the decrease rate of leaf area is smaller. This tolerant nature is more dominantly influenced by the basic population-forming genotype parents in which the parent population are from the drought-tolerant and early mature genotype. The tolerant and early mature genotype is faster in flowering, making it possible to develop in areas with prolonged drought stress [14]. Plant breeding aims to improve the character of plants according to human needs bexploiting the genetic potential and genotype interaction with the environment.

The condition of drought stress causes the difference between the timing of anthesis and silking longer. This can be seen from the value of anthesis silking interval (ASI) of genotypes tested at optimum condition has the value of ASI between 1.33 - 2 days, whereas in the stress condition the ASI ranged from 1.33 - 3 days. This means that watering greatly affects the flowering of plants. Water is part of the protoplasm, photosynthetic raw material, nutrient solvent and transport of photosynthesis results from leaves [15].

The Drought Sensitivity Index (S) of ASI values in the treatment of stress indicated that the G8 genotype was tolerant to drought stress. This is because the genotype has a genetic ability to tolerate the stress environment in a less optimum environmental conditions through adaptation mechanisms so that the difference between anthesis and silk in normal limits, thus allowing the pollination to take place optimally and in the end will produce maximum yield. This is consistent with [16] argued that the effects of drought stress depend on plant genetic where morphological, anatomical, and metabolic differences produce different responses to drought stress.

Drought stress had a direct effect on the decrease of dry kernel of maize [17]. This is in accordance with the results of this study that in case of drought stress, the production of dry kernel is significantly lower than the optimum condition. However, in several tested genotypes showing the medium tolerant to tolerant categories, the G6, G7, and G8 genotypes obtained a still high yield of 6.92-7.47 t .ha^{-1}. According to [18] the yield per hectare is largely determined by the ASI. Where the higher the value of ASI the lower the yield because no flowering synchronization occur. Negative ASI is defined that the silk is ready to be pollinated before anthesis is available. From the observation showed that the interval between anthesis and silking between 1-3 days. This condition allows synchronization in the process of pollination and fertilization so that the potential to produce maximum yield.

IV. Conclusion

The drought sensitivity index (S) and plant height in the stress treatment showed that the G2 and G5 genotypes were drought tolerant. While genotype G6, G7, and G8 were medium tolerant to drought stress. For dry kernel weight parameter per ha showed that genotype G6, G7, G8 had sensitivity index value in medium tolerant to tolerant category to drought stress.

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St. Subaedah was born in 1964. She graduated her bachelor degree in agronomy in 1987 and her master degree specialized in agricultural systems in 1993 both from Hasanuddin University, Makassar, South Sulawesi, Indonesia. She had her doctoral degree in Brawijaya University, Malang, East Java, Indonesia majoring in agricultural sciences.
She is a teaching staff for bachelor students in Agrotechnology Study Program, Faculty of Agriculture, Moeslem University of Indonesia. She is responsible for a position as the chair of Agrotechnology Study Program for master degree at Moeslem University of Indonesia.