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Selection of various synthetic Maize (*Zea mays* L.) genotypes on drought stress condition

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Abstract. A study was conducted with the aim of selecting synthetic maize genotypes tolerant to drought. The study was conducted at Experimental Farm, Faculty of Agriculture, Hasanuddin University from July to November 2017. The experiment was carried out in the form of Split Plot Design with irrigation as main plot and genotypes as subplot. Two irrigation conditions were applied to create normal and drought condition. Six synthetic maize genotypes and three comparative varieties (Bisma, Lamuru, and Sukmaraga) were used. The results showed that the genotypes Syn 2-15, and Syn 2-16 were the synthetic maize genotypes which produced higher yield and were classified as medium tolerant (MT) to drought with productivity of 6 $t.ha^{-1}$ and 6.48 $t.ha^{-1}$, respectively. These yields were significantly different from the varieties of Bisma and Sukmaraga in drought stress conditions. Therefore it can be concluded that adaptive synthetic maize genotypes that are provided a potential yield of $\geq$ 6.0 $t.ha^{-1}$ in environmental stresses were Syn2-15, and Syn2-16.

1. Introduction

Increasing population growth especially in developing countries such as Indonesia, making the application of various agricultural technologies and innovations a necessity, so that production can support high food demand. Realizing that food needs are increasing every year, the government seeks to acquire an increase in maize production with all efforts, including the policy of maize self-sufficiency. Corn production in Indonesia in 2016 amounted to 23.57 million tons, an increase of 3.96 million tons compared to 2015. The increase in maize production in 2016 of 20.22% occurred due to an increase in productivity of 2.45%, while the area of harvest increased significantly of 17.35% or an increase of 657 thousand hectares. Maize productivity increased by 1.27 $ku.ha^{-1}$, which was 51.78 $ku.ha^{-1}$ in 2015, up to 53.05 $ku.ha^{-1}$ in 2016. South Sulawesi's corn production in 2016 amounted to 2.06 million tons or an increase of 0.54 million tons (35.12%) compared to 2015. The increase in production occurred due to an increase in harvested area of 71.65 thousand hectares (24.28%) and productivity of 4.52 $ku.ha^{-1}$ (8.73%) [1].

Factors that led to low corn production were drought [2] which mostly driven by climate. Climate is one of the factors that can reduce the yield of maize plants. The uncertain climate conditions affect the growth process of the plants, hence, uncertain and varied conditions of rainfall result in varied maize yields from time to time and from location to location especially in maize plantations on dry land [3, 4, 5].

To increase corn production, an effort to develop superior varieties of synthetic maize tolerant to drought stress with high productivity and acceptable to farmers is necessary. Selection activities require information about the morphological character and physiology of drought tolerant maize plants so that the selection process can run efficiently and effectively. The morphological and physiological characteristics reported are related to the tolerant nature of drought stress, including deep root systems [6, 7, 8, 9, 10], efficiency of water use, rate of water loss through transpiration, stomatal density [11], and ability to protect the chloroplast apparatus and senescence [12, 13, 14], proline accumulation [15], leaf sensitivity [16], time intervals for male and female flowers (ASI, anthesis silking intervals) and male flower size [7]. Based on the results of the study of Musa and Farid [17] that Syn 2-8, Syn 2-7, and Syn 2-5 genotypes were genotypes that have better potential and productivity than controls *ie.* 9.23 ton.ha^{-1}, 8.21 ton.ha^{-1} and 7.78 ton.ha^{-1}.

2. Methodology

The study was conducted at Experimental Farm Faculty of Agriculture, Hasanuddin University, Tamalanrea, Makassar since July until November 2017. The trial was set in Split Plot Design with irrigation as the main plot consisted of normal irrigation and drought stress induced irrigation. Synthetic maize genotypes was set as Subplot consisted of 5 genotpes namely Syn 2-1, Syn 2-2, Syn 2-4, 2-15, and Syn 2-16. In addition one comparison variety also used namely var. Lamuru, resulted in total of 6 genotypes used in the experiment. Plants were planted using spacing of 70 cm x 20 cm with each plot sized of 5 m x 3 m. Fertilization applied using Urea 300 kg.ha^{-1}, SP36 200 kg.ha^{-1}, KCl 100 kg.ha^{-1}. Urea and KCl was applied twice at 7 days after planting (DAP) and 35 DAP, while SP36 was applied once at 7 DAP. Number of samples observed was 10% of the population. Parameters observed were plant height, anthesis silking interval (ASI), leaf rolling and productivity. Data was analysed using variance analysis (ANOVA) (table 1) followed by Least Significant Difference (LSD) test at 0.05. Whereas heritability in the broad sense was calculated based on the formula of Syukur *et al.,* [18]:

$$H = \frac{\sigma^2 g}{\sigma^2 p}$$

Heritability values of the characters then were grouped. Characters with values below 0.2 were categorized to have low heritability, values ranged from 0.2 to 0.5 were categorized as medium and characters having heritability values above 0.5 were categorized to have high heritability [19].

Table 1. Analysis of Variance using Split Plot Design.

Source of Variation	Degree of Freedom (df)	Mean Square (MS)	Expectation of Mean Square (EMS)
Replication	r-1	M6	$\sigma^2_e + g\ \sigma^2_\square + pg\ \sigma^2_R$
Main Plot (P)	p-1	M5	$\sigma^2_e + g\ \sigma^2_\square + r\ \sigma^2_{PG} + rg\ \sigma^2_P$
Error (p)	(r-1)(p-1)	M4	$\sigma^2_e + g\ \sigma^2_\square$
Genotype (G)	g -1	M3	$\sigma^2_e + r\ \sigma^2_{PG} + rp\sigma^2_G$
P x G	(p-1)(g-1)	M2	$\sigma^2_e + r\ \sigma^2_{PG}$
Error (g)	p(r-1) (g-1)	M1	σ^2_e
Total	rpg-1		

r = replication; g = genotype, σ^2_e = environment variation, σ^2_G = genotypic variation, σ^2_{PG} = interaction variation, σ^2_P = drought stress variation. σ^2_e= M1; $r\ \sigma^2_{PG}$= M2- M1; σ^2_G= (M3 – (M2+M1)) / (r x p);σ^2_p= σ^2_G + σ^2_e.

Stress tolerant index (STI) of each genotype was determine based on seed production and calculated using the formula proposed by Fischer and Maurer (1978) in Fernandez, [20]:

$$STI = (Ypi \times Ysi)/Yp^2$$

where:
Ysi = Mean of a drought stressed genotype
Ypi = Mean of a unstressed genotype
YP = Mean of all unstressed genotypes

The criteria for determining the tolerance level for drought stress is if the value of STI is ≤0.5, the genotype is sensitive, if 0.5 <STI≤1.0 then the genotype is medium tolerant, and if STI> 1.0 then the genotype is tolerant.

3. Results and Discussion

Table 2 shows that the Syn 2-16 (g5) genotype resulted in highest plant (187.99 cm) and was significantly different from the comparison genotype. The height performance of the maize plant influences the amount of sunlight received by the leaves, hence, the large amount of light absorbed encourages plants to carry out more photosynthetic processes so that the amount of assimilates is transported for various vegetative and generative organs. This is in accordance with the opinion of Musa and Farid [17] that the high sunlight received by the leaves will trigger the optimum photosynthesis process so as to produce assimilates which can be distributed to generative organ to support the high production of maize plants. Drought and nutrient deficiencies greatly influence the growth and development of cobs, and will even reduce the number of seeds in one cob due to reduced cob, which consequently decreases yield [21].

Table 2. Mean of plant height (cm) of Maize genotypes on various irrigation conditions.

Genotypes	Irrigation		Mean	
	p0 (Normal)	p1 (Drought Stressed)		
Syn 2-1 (g1)	162.07	150.50	156.28	
Syn 2-2 (g2)	194.70	177.40	186.05	a
Syn 2-4 (g3)	181.54	154.89	168.22	
Syn 2-15 (g4)	198.87	175.47	187.17	a
Syn 2-16 (g5)	194.53	181.45	187.99	a
Lamuru (g6) a	182.91	161.60	172.26	
$LSD_{0.05}$		10.369		

Numbers followed by the same letter (a) in the same column mean significantly different from the Lamuru comparison variety based $LSD_{0.05}$ test.

Table 3 shows that the Syn 2-16 (g5) genotype gave the shortest anthesis silking interval either on normal irrigation (p0) (1.33 days) or on stress condition (p1) (2.00 days) and was significantly different from the comparison genotype. Initiation of flowering and harvest time tend to extend the interval when plants experience water deficit so that the pollen from male flowers pollen from male flowers fails to fall on the pistils of female flowers and affect the seed formation. Drought in the flowering period causes plants to experience an increase in time intervals between male and female flowering ages so pollination is not synchronized and seed formation is not optimal or even no seeds are formed because reduction of photosynthesis results [16].

Table 3. Mean of Anthesis Silking Interval (ASI) (days) of Maize genotypes on various irrigation conditions.

Genotypes	Irrigation			
	p0 (Normal)		p1 (Drought Stress)	
Syn 2-1 (g1)	1.33	a	4.67	
Syn 2-2 (g2)	2.00		2.67	
Syn 2-4 (g3)	1.67		4.00	
Syn 2-15 (g4)	3.00		3.00	
Syn 2-16 (g5)	1.33	a	2.00	a
Lamuru (g6) a	2.33		3.00	
$LSD_{0.05}$	0.813			

Numbers followed by the same letter (a) in the same column mean significantly different from the Lamuru comparison variety based $LSD_{0.05}$ test.

Table 4 shows that the Syn 2-2 (g2) genotype showed the lowest leaf rolling score both on normal (2.10) and stressed condition (3.43) and was significantly different from the comparison genotype. Stressed maize plants will reduce the transpiration process by closing the stomata and rolling up the leaves so that the discharge of water from the plant is reduced. One of the mechanism of plants to maintain their survival in drought conditions is to reduce transpiration by leaf rolling, stomatal closure and accelerated leaf senescence, but consequently this actions decrease photosynthesis to produce photosynthates to be translocated to seeds resulted in lower seed production [22]. According to Efendi and Azrai [23], Maize plants that experience drought stress generally experience high leaf rolling. This is because the roots absorb insufficient amounts of water.

Table 4. Mean of leaf rolling score of of Maize genotypes on various irrigation conditions.

Genotipe	Irrigation			
	p0 (Normal)		p1 (Drought)	
Syn 2-1 (g1)	2.40		3.70	
Syn 2-2 (g2)	2.10	a	3.43	a
Syn 2-4 (g3)	2.37		3.57	a
Syn 2-15 (g4)	2.17		3.43	a
Syn 2-16 (g5)	2.20		3.47	a
Lamuru (g6) a	2.20		3.70	
NP $BNT_{0.05}$	0.087			

Numbers followed by the same letter (a) in the same column mean significantly different from the Lamuru comparison variety based $LSD_{0.05}$ test.

Table 5 shows that Syn 2-16 (g5) genotypes showed the highest productivity both in normal (10.74 ton.ha^{-1}) and stressed irrigation (6.48 ton.ha^{-1}) and was significantly different from Lamuru comparison variety. High productivity in Maize grown in water limited condition indicated an adaptation mechanism for plant tolerant to drought stress. According to Paliwal in Wahyudi *et al.* [24], the occurrence of drought during seed filling can delay ripening period and carbohydrate mobilization in plant stems. This resulted in a decrease in yield depending on the level of drought resistance of each genotype. This is also in line with the opinion of Aqil *et al.* [25] stating that the accuracy of water supply in accordance with the growth rate of maize plants is critical and has substantial influence on crop production.

Table 5. Mean of productivity (ton ha^{-1}) of Maize genotypes on various irrigation conditions.

Genotipe	Ketersediaan Air				
	p0 (Normal)		p1 (Cekaman)		
Syn 2-1 (g1)	8.06		5.46	a	MT
Syn 2-2 (g2)	9.47	a	5.69	a	MT
Syn 2-4 (g3)	7.92		4.50		P
Syn 2-15 (g4)	10.14	a	6.00	a	MT
Syn 2-16 (g5)	10.74	a	6.48	a	MT
Lamuru (g6) a	8.58		4.99		
NP $BNT_{0,05}$		0.354			

Numbers followed by the same letter (a) in the same column mean significantly different from the Lamuru comparison variety based $LSD_{0.05}$ test.

Table 6 shows that the characters that have a broad coefficient of genetic diversity and high heritability values are the characteristics of plant height, leaf rolling, and productivity, indicating the potential characters that can be developed in the next generation. High heritability values indicate a more significant genetic influence compared to the environment. Extensive genetic diversity indicates a genetic influence that is more dominant than environmental influences [26].

Table 6. Genetic diversity coefficient and heritability values.

No	Character	Heritability	Category
1	Plant height	68,01	High
2	Anthesis Silking Interval (ASI)	-44.71	Low
3	Leaf Rolling Score	64.68	High
4	Productivity	87.20	High

4. Conclusion

Genotypes that have adaptive potential growth and high productivity which are significantly different from control comparison varieties in drought stress environments were Syn 2-2 (5.69 $ton.ha^{-1}$), Syn 2-15 (6.00 $ton.ha^{-1}$), and Syn 2- 16 (6.48 $ton.ha^{-1}$). Characters that have a broad coefficient of genetic diversity and high heritability were plant height, leaf rolling score and productivity.

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