RESPONSE OF UNPAD MAIZE GENOTYPE TOLERANT SHADE IN ARTIFICIAL SHADE WITH PARANET (SHADING NET) CONDITIONS BASED ON TOLERANCE COMPONENT

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ABSTRACT

Maize development through new varieties release program is a stratetgical step to support the National Self-Sufficient Food Program. Constraints increasingly reduced agricultural land, especially corn fields should be made concrete steps. Marginal and shading land use and the use of hybrid varieties of shade tolerant superior hybrids are the main alternative to solving limited land problems. Research conducted at the Experimental Station, Village of Pasir Talang, District Rancakalong Sumedang district from September 2014 to February 2015 at an altitude of 750 meters above sea level, with climate type C3 according to the classification Oldeman using design split-plot design is repeated 2 times, factors main plot is shade 15% (Light received plant canopy 366.94 ft cd) and control; Factor of subplot is 48 genotype of DR Unpad. The objective of the study was to determine the tolerant and stable genotype of various levels of paranet shade. The results showed that based on the tolerance component values at various paranet shading conditions indicated by MP, GMP, and STI values, the shade tolerant genotypes were M7DR3.1.4, DR4, DR7, DR8, DR9, DR10, DR, 11, DR14, DR17 , DR20, BR153, M7DR3.1.10, M7DR3.6.1, M7DR4.8.8, M7DR5.4.1, M7DR5.5.1, M7DR7.1.9, M7DR7.4.1, M7DR9.1.3, M7DR10.2.2, M7DR14.1.1, M7DR14.2.2, M7DR16 .1.1, M7DR16.6.14, M7DR16.7.1, M7DR18.2.1, M7DR18.4.1, and M7DR18.8.1; shade-sensitive genotype was DR6, DR18, M7DR1.1.3, M7DR3.1.2, M7DR72.5, M7DR7.3.2, M7DR7.4.2, M7DR14.2.1, M7DR16.5.15, M7BR153.10.2; M7BR153.11.1, G-632, G-2031, DR21, G-634, G-3075, G-20B3077, G-207 and G-622.

Keywords: corn, paranet, tolerance of shade

INTRODUCTION

Maize (*Zea mays* L.) is the second most important food crop in the world as source of carbohydrate after rice. The current demand for corn is getting higher as the increase of corn consumption in the food, industrial and pharmaceutical sectors. Efforts to increase maize production are carried out by assembling the adaptive superior varieties of the environment and utilizing suboptimal land use (Syafii *et al.*, 2015). Marginal and shading land use and hybrid tolerance of shade tolerant hybrid varieties are the main alternative to solving limited land problems.

Differences in shade levels will affect the intensity of light, air temperature and humidity under shade conditions, so that the intensity of light received by plants will be different and affect the availability of light energy that will be converted into photosynthesis and chemical energy. This research is a continuation of tested of tolerant maize lines in agroforestry system with Albizia, then confirmation test to know the level of tolerance to shade condition at heavy shade level using paranet 15% and without shade 100% (control). The 15% paranet shade density level causes the light received by the plant canopy by 22% or by 366.94 ft cd of normal light, whereas in the normal light received by the plant canopy 1443.41 ft cd.

The higher the shade density level, the smaller the light intensity the plant receives, the lower the temperature, the higher the air humidity. Humidity of environment that is too low or too high will inhibit the growth and flowering of plants (Kramer & Kozlowski, 1960). This is explained by Sundari *et al.*, (2005) that shade decreases dry weight of seeds, weight of pods, and dry weight of pods on green beans. Yuan *et al.* (2012) also reported on maize that shade stress decreases plant height, tuna height, stem diameter, and slows down the age of female and male flowering and increases the time interval between anthesis and silking (anthesis-silking interval).

Shade treatment in maize plants in the flowering phase caused decreased photosynthetic activity and failure of seed formation (kernel abortion) increased (Reed *et al.*, 1988), decreased seed weight, number of seeds, weight of pipil and crop yield (Early *et al.*, 1967 , Kiniry *et al.*, 1985), decreasing the length of the segment and the weight of the seeds (Fournier & Andrieu, 2000), slowing the flowering time and silking (Struik, 1983), decreasing the number of seed lines and the rate of seed shelling (Stinson, 1960; Setter *et al.*, 2001), inhibit the elongation of silk (Edmeades *et al.*, 2000), decrease plant height, slow the appearance of new leaves (Struik, 1983) and decrease leaf thickness (Ward *et al.*, 1986).

The tolerance level of maize genotype to shade is determined by the values of MP, GMP, and STI according to the formula suggested by Sundari *et al.* (2005) and Khumar *et al.* (2015). The tolerant genotype is a genotype with high MP, GMP and STI values, and has an STI value above the mean STI, where the higher the STI value of a genotype, the higher the yield potential and the genotype tolerance to shade stress. The tolerance index for shade stress is calculated based on the potential yield on optimum condition (Yp) and yield on shelf stress condition (Ys). The tolerant genotype was to have an STI value of 0.52 to 1.49 and a susceptible genotype had a STI value of 0.04 - 0.51.

The objective of the study was to select and determine the tolerant and stable genotype of various levels of heavy shading using paranet.

MATERIALS AND METHODS

The experiment was conducted by experiment in Experimental Garden, Pasir Talang Village, Rancakalong Subdistrict, Sumedang District, September 2014 until February 2015 at 750 masl (meter above sea level), with C3 type according to Oldeman classification using split-plot design design repeated 2 replications, main plot factor is a shade of 15% (accepted light 366.94 ft cd) and without shade as a control; factor of subplot is 48 genotype of DR Unpad maize.

Agricultural equipment used is Urea 300 kg ha^{-1}, PONSKA 200 kg fertilizer, chicken manure 3000 kg ha^{-1}, Furadan 3G, Antracol 80 WP and Decis 50 EC. The observed characters are the agronomic characters consisting of the diameter of the ear (cm), the length of the cob (cm), the number of lines per ear (cm), the weight of the cob per plot (g), the weight of the pipil seed (g), the weight of 1000 seeds (g) harvest index and yield (ton ha^{-1}).

The statistical test used to determine at least a pair of different treatments was significantly different from the F test at 5% level, if the F test results were significantly different then continued with the average test of Scott-Knott button on the 5% level.

The determination of tolerant or susceptible maize lines was performed based on parameters of MP, GMP, TOL, SSI, STI according to Fischer and Maurer (1978), Rosielle and Hamblin (1981), and Fernandez (1992), as follows:

Succeptibility Index (SI) = $\left[1 - \frac{(Ys)}{Yp}\right]$ (Fischer & Maurer, 1978)

Stress Succeptibility Index (SSI) = $\frac{1 - \frac{Ys}{Yp}}{SI}$ (Fischer & Maurer, 1978)

Tolerance Index (TOL) = (Yp – Ys) (Rosielle & Hamblin, 1981)

Mean Production (MP) = $\left[\frac{Ys + Yp}{2}\right]$ (Rosielle & Hamblin, 1981)

Geometric Mean Production (GMP) = $\sqrt{(Ys\ x\ Yp)}$ (Fernandez, 1992)

Stress Tolerance Index (STI) = $\left[\frac{(Yp)(Ys)}{(Yp)^2}\right]$ (Fernandez, 1992)

Remaks :
Yp = Yeld in normal condition
Ys = Yield in shade stress condition
$\overline{Yp}$ = Mean yield in normal condition
$\overline{Ys}$ = Mean yield in shade stress condition

RESULTS AND DISCUSSION

The shade-tolerant treatment of maize genotypes resulted in changes to sunlight received by plants, both in intensity and quality. The effect of light on plants is very complex resulting in photochemical processes as well as the shape and size of plants (Woodward & Sheely, 1983), so that it will affect the yield of the plant. This is as reported by Sundari *et al.*, (2005), that shade decreases dry weight of seeds, pod weight, and dry weight of pods on green beans. Yuan *et al.* (2012) also reported on maize that shade stress decreased plant height, cob height, stem diameter, and slowed down the age of female and male flowering and increased the time interval of anthesis and silking (anthesis-silking interval).

Analysis of the combined variation of yield components (Table 1) shows that genotype (G), shade (E) and interaction between genotype and shade (G×E) have significant effect on crop yield. Response to shading treatment for each maize genotype differed greatly depending on genetic factors and shade density compared with no shade (100% of the light received by the canopy). The shade density level is 15%, causing high shade stress intensity, thus the lower the intensity of light received by the plant canopy.

Table 1. Analysis of variance of yield component under 15% shading net condition

Sources of variation	df	Ear Diameter (cm)		Ear lenght (cm)		Number row per ear		Ear weight per plot (kg)	
		MS	F-count	MS	F-count	MS	F-count	MS	F-count
Replication	1	0.0		7.5		0.9		84520.3	
Shading (E)	3	3191.0	25.9*	780.4	73.4**	246.6	36.3**	4857150.1	167.6**
Errors (e)	3	123.1		10.6		6.8		28977.7	
Genotype (G)	47	119.8	9.7**	20.2	19.1**	12.3	10.5**	108165.0	31.5**
G x E	141	23.3	1.9**	5.4	5.1**	2.8	2.4**	19302.0	5.6**
Errors (g)	188	12.4		1.1		1.2		3430.2	
Corrected total	383								
CV-e (%)		28.8		29.5		21.3		40.3	
CV-g (%)		9.1		9.3		8.8		13.9	
CV (%)		9.1		9.8		8.8		12.7	
		Grain weight per plot (kg)		Weight 1000 seeds (g)		Harvest index		Yield (ton.ha^{-1})	
		MS	F-count	MS	F-count	MS	F-count	MS	F-count
Replication	1	518.0		6168.0		0.01		0.9	
Shading (E)	3	44091.7	219.5**	36159.1	45.1**	0.06	2.2^{ns}	78.5	206.5**
Errors (e)	3	200.9		802.2		0.03		0.4	
Genotype (G)	47	2111.3	73.9**	8399.1	7.0**	0.05	12.5**	3.9	67.6**
G x E	141	419.5	14.7**	2166.7	1.8**	0.02	5.6**	0.7	13.0**
Errors (g)	188	28.6		1205.1		0.00		0.1	
Corrected total	383								
CV-e (%)		30.3		11.5		32.87		30.7	
CV-g (%)		11.4		14.1		12.03		12.0	
CV (%)		11.1		14.0		11.84		11.8	

** : significant at 1% *: significant at 5%

Table 2. Tolerance component of yield under shading net stress 15%

No	Genotype	Tolerance component of yield under shafing net 15%									Category
		Yp	Ys	SSI	TOL	MP	GMP	STI	YSI	YI	
1	M7DR 3.1.4	3,49	1,83	1,05	1,66	2,66	2,37	0,70	0,55	1,00	T
2	DR 4	5,02	1,30	3,61	3,72	3,16	2,48	0,70	0,28	0,85	T
3	DR 6	3,23	1,16	2,39	2,07	2,19	1,70	0,44	0,36	0,52	R
4	DR 7	4,61	1,69	3,10	2,92	3,15	2,75	0,86	0,38	1,16	T
5	DR 8	2,52	2,45	-1,05	0,07	2,48	2,46	0,70	0,97	1,65	T
6	DR 9	3,89	2,25	0,58	1,64	3,07	2,79	0,95	0,61	1,28	T
7	DR 10	4,11	2,44	1,20	1,67	3,28	3,10	1,13	0,60	1,55	T
8	DR 11	3,75	1,18	3,65	2,57	2,47	2,09	0,51	0,31	0,81	T
9	DR 14	4,04	1,92	1,84	2,12	2,98	2,68	0,85	0,49	1,17	T
10	DR 17	3,79	2,59	-0,46	1,20	3,19	2,91	1,09	0,71	1,37	T
11	DR 18	3,24	1,13	2,79	2,11	2,19	1,85	0,39	0,38	0,75	R
12	DR 20	4,36	2,57	1,39	1,79	3,46	3,27	1,31	0,58	1,55	T
13	BR 153	4,35	2,04	1,98	2,31	3,19	2,84	1,05	0,46	1,11	T
14	M7DR 1.1.3	1,09	1,29	-5,01	-0,20	1,19	1,01	0,18	1,09	0,53	R
15	M7DR 3.1.10	3,84	2,28	1,01	1,56	3,06	2,82	1,06	0,57	1,21	T
16	M7DR 3.1.2	2,39	1,94	-3,10	0,45	2,16	1,97	0,45	1,00	1,12	R
17	M7DR 3.6.1	2,32	2,38	-3,46	-0,06	2,35	2,13	0,66	1,00	1,12	T
18	M7DR 4.8.8	2,59	1,79	0,33	0,81	2,19	2,08	0,54	0,68	1,04	T
19	M7DR 5.4.1	3,05	1,50	2,46	1,54	2,27	2,13	0,51	0,50	1,11	T
20	M7DR 5.5.1	4,12	1,93	2,03	2,18	3,02	2,74	0,89	0,48	1,20	T
21	M7DR 7.1.9	3,89	1,64	2,41	2,25	2,76	2,43	0,74	0,42	0,94	T
22	M7DR 7.2.5	2,00	1,73	-2,07	0,27	1,87	1,76	0,37	0,93	1,01	R
23	M7DR 7.3.2	1,62	1,68	-2,30	-0,06	1,65	1,57	0,35	0,95	0,85	R
24	M7DR 7.4.1	3,99	2,48	1,73	1,50	3,23	3,13	1,13	0,62	1,75	T
25	M7DR 7.4.2	2,00	1,89	-0,46	0,11	1,94	1,93	0,42	0,96	1,42	R
26	M7DR 9.1.3	4,27	3,00	0,61	1,27	3,63	3,51	1,49	0,69	1,86	T
27	M7DR 10.2.2	5,09	1,21	3,86	3,87	3,15	2,39	0,69	0,24	0,72	T
28	M7DR 14.1.1	3,41	1,61	2,12	1,80	2,51	2,28	0,62	0,47	0,99	T
29	M7DR 14.2.1	2,59	1,11	1,35	1,48	1,85	1,46	0,31	0,46	0,50	R
30	M7DR 14.2.2	3,50	1,46	1,60	2,04	2,48	1,97	0,56	0,44	0,67	T
31	M7DR 16.1.1	2,95	1,69	1,34	1,26	2,32	2,16	0,57	0,57	1,00	T
32	M7DR 16.5.15	2,18	1,65	0,89	0,53	1,91	1,89	0,40	0,76	1,21	R
33	M7DR 16.6.14	2,98	1,81	1,44	1,16	2,40	2,29	0,63	0,60	1,16	T
34	M7DR 16.7.1	4,76	1,99	2,51	2,76	3,37	3,00	1,06	0,43	1,25	T
35	M7DR 18.2.1	2,27	2,03	-2,42	0,24	2,15	2,00	0,51	0,94	1,09	T
36	M7DR 18.4.1	3,56	2,31	-0,45	1,24	2,93	2,57	0,92	0,67	1,10	T
37	M7DR 18.5.1	2,42	0,87	2,32	1,55	1,65	1,31	0,23	0,38	0,43	R
38	M7DR 18.8.1	3,33	1,66	2,61	1,66	2,49	2,34	0,63	0,50	1,19	T
39	M7BR 153.10.2	1,84	0,76	2,75	1,08	1,30	1,17	0,15	0,43	0,54	R
40	M7BR 153.11.1	2,09	1,03	2,52	1,06	1,56	1,46	0,25	0,48	0,69	R
41	G-632	1,41	2,00	-6,14	-0,59	1,70	1,55	0,35	1,32	0,95	R
42	G-203-1	2,29	1,05	1,34	1,24	1,67	1,36	0,27	0,47	0,47	R
43	DR 21	2,14	1,68	-0,61	0,46	1,91	1,80	0,43	0,76	0,90	R
44	G-634	1,64	1,69	-3,73	-0,06	1,66	1,52	0,32	1,04	0,82	R
45	G-3075	0,65	1,02	-7,78	-0,38	0,83	0,77	0,07	1,60	0,56	R
46	G-20B3077	1,56	1,22	-1,02	0,34	1,39	1,21	0,25	0,71	0,52	R
47	G-207	2,19	1,38	-0,21	0,80	1,79	1,49	0,36	0,62	0,58	R
48	G-622	1,48	1,75	-7,68	-0,27	1,62	1,31	0,27	1,36	0,75	R

Yp: yield at optimum condition; Ys: yield in shady stress conditions; SSI: sensitivity index against shade stress; TOL: tolerance to shade stress; MP: average yield; GMP: average geometric yiled; STI: index of tolerance to shade stress; YSI: yield stability index; YI: yiel index

Tolerance of maize genotype to shade is determined by MP, GMP, and STI values (Ariffin, 1988; Sundari *et al.*, 2005). The tolerant genotype is a genotype with high MP, GMP and STI values, and has an STI value above the mean STI, where the higher the STI value of a genotype, the higher the yield potential and the genotype tolerance to shade stress. The tolerance index for shade stress is calculated based on the potential yield on optimum condition (Yp) and yield on shade stress condition (Ys). The tolerant genotype was to have an STI value of 0.52 to 1.49 and a susceptible genotype had a STI value of 0.04 - 0.51. According to Fu *et al.*, (2011) that genetic variations can cause differences in sensitivity or genotype sensitivity to low-intensity radiation stress.

Based on tolerance component analysis presented in Table 2 on 48 genotypes of DR Unpad maize tested at 15% shade density level and no shading based on MP, GMP, and STI values showed that tolerant genotypes were M7DR3.1.4, DR4, DR7, DR8, DR9, DR10, DR20, BR153, M7DR3.1.10, M7DR3.6.1, M7DR4.8.8, M7DR5.4.1, M7DR5.5.1, M7DR7.1.9, M7DR7.4.1, M7DR9.1.3, M7DR10.2.2, M7DR14.1.1, M7DR14.2.2, M7DR16.1.1, M7DR16.6.14, M7DR16.7.1, M7DR18.2.1, M7DR18.4.1, and M7DR18.8.1; while the susceptible genotypes are DR6, DR18, M7DR1.1.3, M7DR3.1.2, M7DR72.5, M7DR7.3.2, M7DR7.4.2, M7DR14.2.1, M7DR16.5.15, M7BR153.10.2; M7BR153.11.1, G-632, G-2031, DR21, G-634, G-3075, G-20B3077, G-207 and G-622.

This suggests that the genotypes have high adaptability with efficient use of sunlight for photosynthesis and metabolism in low light conditions with a maximum.

CONCLUSION

The genotype tolerance level can be determined by the components of MP, GMP, and STI. Tolerant genotypes mean having the ability to adapt to low light environments by efficiently utilize limited light to carry out the process of maximum photosynthesis. The tolerant genotype is M7DR3.1.4, DR4, DR7, DR8, DR9, DR10, DR15, M7DR3.1.10, M7DR3.6.1, M7DR4.8.8, M7DR5.4.1, M7DR5.5.1, M7DR7 .1.9, M7DR7.4.1, M7DR9.1.3, M7DR14.2.2, M7DR14.1.1, M7DR14.2.2, M7DR16.1.1, M7DR16.6.14, M7DR16.7.1, M7DR18.2.1, M7DR18.4.1, and M7DR18.8.1

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REFERENCES

Ariffin. 1988. Pengelolaan naungan dalam pertumbuhan dan produksi tanaman kacang hijau (Phaseolus radiatus L.). Agrivita. 11:17-20.

Early, E.B., W.O. McIlrath, R.D. Seif, R.H. Hageman. 1967. Effects of shade applied at different stages of plant development on corn (*Zea mays* L.) production. *Crop Sci*. 7:151–156.

Edmeades, G.O., J. Bolanos, A. Elings, J.M. Ribaut, J.M. Banziger. 2000. The role and regulation of the anthesis-silking interval in maize. *In* Westgate M. E., Boote K. J. (*Eds.*) Physiology and modeling kernel set in maize. CSSA, Madison, WI.

Fernandez, G.C.J. 1993. Effective selection criteria for assessing plant stress tolerance. pp. 257-270. *In* C.G. Kuu (Eds.) Adaptation of Food Crops to Temperature and Water Stress. Proc. of an Inter. Sym., Taiwan, 13-18 August 1992. AVRDC

Fischer, R.A., R. Maurer. 1978. Drought resistance in spring wheat cultivars.I. Grain yield responses. Austral. J.Agr.Res. 29:897-917.

Fournier C., B. Andrieu. 2000. Dynamics of the elongation of internodes in maize (*Zea mays* L.). Effects of shade treatment on elongation patterns. Annals of Botany. 86:1127–1134.

Kiniry, J.R., J. Ritchie. 1985. Shade-sensitive interval of kernel number of maize. *Agron. J*. 77:711–715.

Kramer, D.J., T.T Kozlowsky. 1960. Physiology of Trees, dalam Pengkajian Penerapan Teknik Budidaya Rhizophoramucronata dengan Stek Hipokotil, Mulyani, N., C. Kusmana, dan Supriyanto. 1999. Jurnal Manajemen Hutan Tropika. 5:57-65.

Kumar, R., J. Kaul, R.B. Dubey, A. Singode, G.K. Chikkappa, A. Manivannan, M.K. Debnath. 2015. Assessment of drought tolerance in maize (Zea Mays L.) based on different indices. *SABRAO Journal of Breeding and Genetics* 47 (3):291–98.

M. Syafii, I. Cartika, D. Ruswandi, 2015. Multivariate Analysis of Genetic Diversity among Some Maize Genotypes under Maize-Albizia Cropping System in Indonesia. *Asian Journal of Crop Science*. 7(4):244–55.

Reed, G.H., J. O. Kent, C. T. Wittwer. 2007. High-Resolution DNA Melting Analysis for Simple and Efficient Molecular Diagnostics. Pharmacogenomics 8(6):597–608.

Rosielle, A.A., J. Hamblin. 1981. Theoretical aspects of selection for yield in stress and non-stress environments. Crops Sci. 21:943-946.

Sundari, Titik, Tohari, W. Mangoendidjojo, Soemartono. 2005. Yield Performance and Tolerance of Mungbean Genotypes to Shading. Ilmu Pertanian. 12(1): 12–19.

Stinson, H.T., D.N. Moss. 1960. Differential Response of Corn Hybrids to Shade. Ecologist The. 1: 416–18.

Setter, T. L., B.A. Flannigan, J. Melkonian. 2001. Loss of kernel set due to water deficit and shade in maize: carbohydrate supplies, abscisic acid, and cytokinins. *Crop Sci*. 41: 1530–1540.

Yuan, Liuzheng and others. 2012. QTL Analysis of Shading Sensitive Related Traits in Maize under Two Shading Treatments', 7.6 (2012)

Ward, A., H.W. Woolhouse. 1986. Comparative effects of light during growth on the photosynthetic properties of NADP-ME type C4 grasses from open and shaded habitats. I. Gas exchange, 1eaf anatomy and ultrastructure. Plant Cell and Environment. 9:261–270

Woodward, F.I., J.E. Sheely. 1983. Principles and Measurements in Environmental Biology. Butterworth & Co (Publishers) Ltd.