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Effect of Shade Level on Some Maize Varieties: Yield and Growth

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Abstract

One of the efforts to increase maize production is by expanding the maize planting area by using land under the canopy of annual crops for intercrops. The purpose of this study was to obtain maize varieties that can grow and produce high in shaded conditions. The experimental design used was a split-plot design arranged in a randomized block design consisting of two factors. The first factor in the main plot was shading which consisted of 3 levels (N1 = unshaded, N2 = 25% shade, and N3 = 50% shade). The second factor in the subplots was the variety which consisted of 6 levels (V1 = NK Sumo, V2 = Bisi18, V3 = Sukmaraga, V4 = IBF lines, V5 = Sinhas5, and V6 = Agam local variety). The results showed that there was an interaction between several maize varieties at several levels of shade on the harvest time (at 50% shade, the harvest time for local varieties of Agam and Sinhas5 composite was the shortest compared to other varieties). In observing the yields, 50% shade significantly reduced the average dry-shelled grain weight of maize. The highest production was produced by the NK Sumo hybrid variety with an average dry weight of 8.26 tonnes/ha. The cob length, cob diameter, and stalk diameter decreased significantly at 50% shade level, and each maize variety showed a significantly different response to its growth.

Keywords: *Growth, Hybrid, Maize, Shading, Yield.*

INTRODUCTION

Maize is one of the most important crops globally providing food, feed, and bioenergy (Gao et al. 2017). Maize is the third most important crop in the world after wheat and rice and is considered one of the fastest-growing commercial crops in the world, which is the largest component of the global coarse-grain trade (Murdia et al. 2016). The demand for maize which continues to increase every year makes it great potential to be developed (Panikkai et al. 2017). One of the problems in the agricultural sector in Indonesia is the diminishing availability of land. Currently, 100,000 hectares a year of agricultural land are being converted in Indonesia (Harini *et al.* 2019). Reduced arable land due to population growth and environmental changes causes increased losses from plant growth and challenges food security (Pires et al. 2011). so in this

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case there is a need to increase production through extensification and intensification (Mulyani and Agus 2017).

One of the opportunities to expand the maize planting area is to make maize crops as an intercrop. To efficiently the land use, is a need to utilize land under the canopy of plantation crops (Syafruddin et al. 2014) and space in agroforestry (Suryanto et al. 2014). However, in this case, light (shaded conditions) will be a limiting factor that will affect the growth and development of maize (Baligar et al. 2020). Maize growth and development can be inhibited by increasing the intensity of the shade, causing a decrease in maize production (Zhang *et al.*, 2008; Cui *et al.*, 2014)

As a C4 plant, light is an important factor in the growth and yield of maize (Yang *et al.*, 2019; Li et al. 2005). C4 plants are very sensitive to inhibited light-intensity conditions due to the complexity of anatomy, biochemistry, and specific energy of the plant itself (Ubierna et al. 2013). Under low light conditions, there is a quality change in the physiological mechanism of maize which has significance for the yield (Jia et al. 2011). Assimilation supply to the developing cob (the post-initial silking period when the formation of endosperm cell numbers) determines the number and weight of grains (Cui et al. 2014). Meanwhile, under changing solar radiation conditions, the number and weight of grains can fluctuate (Li et al. 2010).

Shade provided during the production period (Zhang et al. 2006) and vegetative period (Cui et al. 2014) affect grain yield. Several previous studies reported that in shaded conditions the number of grains decreased (Chen et al. 2014) and reduced grain filling, grain weight, and yield (Cui et al. 2014). So to obtain maize plants that can adapt well to environmental factors (solar radiation, temperature, etc.) is an important innovation in increasing yields (Yang et al. 2019).

METHODS

This research was conducted in Pariaman City, West Sumatra, Indonesia (altitude ±32 masl) from November 2020 to April 2021. The used maize seeds consisted of 2 hybrid varieties (NK Sumo and Bisi18), 3 composite varieties (Sukmaraga, IBF lines, and Sinhas5), and the local variety from Agam. Other materials used are manure, urea and NPK fertilizer, herbicides, paranets (sun shade net), battens, nails, and rope. The tools used are meters, lux meters, digital cameras, digital scales, spectrophotometers, moisture meters, stationery, etc.

The experimental design used was a split-plot design arranged in a randomized block design consisting of two factors. The first factor in the main plot was shading which consisted of 3 levels (N1 = unshaded, N2 = 25% shade, and N3 = 50% shade). The second factor in the subplots was the maize variety which consisted of 6 levels (V1 = NK Sumo, V2 = Bisi18, V3 = Sukmaraga, V4 = IBF lines, V5 = Sinhas5, and V6 = Agam local variety). Each treatment was repeated in 3 groups so that there were 45 experimental plots. Each experimental unit was planted with 20 plants with a spacing of 75 x 25 cm. The size of 1 main plot is 15 x 13.75 m. Shading treatment was carried out using paranets as high as 4 m with an intensity of light barriers of 25% and 50%.

The yield characteristics observed were the dry weight of dry-shelled grains, cob length, and cob diameter. While observations of plant growth included plant height, stalk diameter, harvest time, and chlorophyll content. Stalk diameter was observed using a caliper. Observation of plant height was measured from the soil surface to the base of the panicle stalk when the pollen bursts out of the flower. Harvest time was measured when the physiological maturity is reached, which was characterized by dry cobs and husks, a black layer forming at the tip of the kernels, if the kernels is pressed with a fingernail that left no marks, and the kernels were dark yellow.

Chlorophyll content was measured using a spectrophotometer. Chlorophyll content in acetone solvent is calculated by the Arnon formula, which is:

$$Chlorophyll\ a\ (mg/L) = (12.7 \times OD\ 663) - (2.69 \times OD645)$$

$$Chlorophyll\ b\ (mg/L) = (22.9 \times OD\ 645) - (4.68 \times OD663)$$

To determine the effect of the treatment of observation variables, a statistical test is carried out with the F test. If the F count of the treatment is greater than the F table, it is followed by Duncan's New Multiple Range Test (DNMRT) at a significance level of about 5%.

RESULTS AND DISCUSSION

The weight of dry-shelled grain

The weight of dry-shelled grain is not influenced by the interaction between several shade levels and maize varieties, which is shown through variance analysis. But there is a singular influence of each treatment on the dry-shelled grain weight (Table 1).

Table 1. The weight of dry-shelled grain (ton/ha) on several shade levels and maize varieties

Shade level (%)	Variety						Mean
	NK Sumo	Bisi18	Sukmaraga	IBF Lines	Sinhas5	Agam local variety	
0	8.65	7.38	6.92	4.82	6.29	5.5	6.60 A
25	8.46	7.32	6.82	6.48	6.22	4.65	6.66 A
50	7.67	5.82	4.86	4.11	5.668	4.71	5.48 B
Mean	8.26 a	6.84 b	6.20 bc	5.14 d	6.07 c	4.96 d	

Numbers followed by the same lowercase letter in the row and the same uppercase letter in the column showed no significant difference based on the DMRT test (α = 5%).

There is a significant effect between the percentage of shade on the dry-shelled grain weight. Where there was a decrease in the weight of dry-shelled grain at a higher shade level. Table 1 shows the average weight of dry-shelled grain at 50% shade is 5.48 tons/ha. This was significantly different from the weight in unshaded (6.60 tonnes/ha) and under 25% shade (6.66 tonnes/ha) conditions. This is in line with research by Yang *et al.* (2019) and Liang *et al.* (2020) which reported that a reduction in solar radiation resulted in a decrease in maize yields, and the lowest weight of maize grain was found in the 50% shade level.

Several studies also reported that there was a decrease in grain yield, the number of grains per cob, and the number of cobs harvested under shaded conditions (Cui et al. 2012). The decline in maize productivity in shaded conditions is caused by several factors, including a significant reduction in the rate of leaf photosynthesis (Liang *et al.*, 2020; Yuan *et al.*, 2022). Then there is a decrease in $C0_2$ fixation which causes the allocation of C to the production network to be inhibited so that cob growth is also inhibited. (Liang et al. 2020). Then there was a change in the morphology of the photosynthetic transfer cell in the endosperm (Yuan et al. 2022). As well as the reduced number of mitochondria which play a role in forming energy, causing obstruction to the flow of nutrients and reducing the weight of grains (Jia et al. 2011). In the study of Cui et al. (2014), 40% of shaded conditions caused the number of grains per cob and the weight of grains to decrease significantly. The yield of grain and biomass decreased by 66.36 and 93.00 % compared to the control.

In addition, each variety of maize also showed a single effect on the dry-shelled grain weight. The NK Sumo hybrid variety showed the highest production rate of 8.26 tons/ha. Meanwhile, the lowest production rate was obtained for the Agam local variety (4.96 tons/ha). Hybrid varieties have better growth and yield potential than local and composite varieties. The level of tolerance of varieties to stress is different for each, depending on the level of stress experienced during plant growth (Bonea and Urechean 2011). The level of grain filling is influenced by genotype and environmental conditions, as well as the response of genotypic variations to environmental stress (Andayani *et al.*, 2014; Li *et al.*, 2005)

Length of Cobs

There was no interaction between several levels of shade and maize varieties on the length of the cobs, but each treatment has a singular influence (Table 2).

Table 2. Cobs length (cm) of several maize varieties at different shade levels

Shade level (%)	Variety						Mean
	NK Sumo	Bisi18	Sukmaraga	IBF Lines	Sinhas5	Agam Local variety	
0	20.62	19.99	20.86	18.50	17.84	18.05	20.0 A
25	19.25	19.71	19.44	16.60	19.27	16.43	18.8 A
50	17.65	18.06	17.62	15.90	16.95	17.84	16.5 B
Mean	19.17 ab	19.26 ab	19.31 A	17.00 b	18.02 ab	17.45 ab	

Numbers followed by the same lowercase letter in the row and the same uppercase letter in the column showed no significant difference based on the DMRT test (α = 5%).

The results showed that the higher the shade level, the shorter the cobs. The shortest cobs were found in crops with 50% shade, with an average of 16.5 cm. Significantly different from the cob length of crops at 25% shade level (18.8) and unshaded (20.0 cm). This is in line with a study conducted by Zhong et al. (2013), where the cob length of several maize varieties decreased as the percentage of provided shade increased. Low light intensity (shade conditions) can cause a slowdown in the development of cobs, reduced cob length, a decrease in the number of florets, and a significant decrease in the number of flower tassels (Cui *et al.*, 2014).

Each variety of maize showed significantly different average cob length. The Sukmaraga hybrid variety showed the longest cob growth (19.31 cm). Significantly different from the IBF lines which have the shortest cob, which is 17.00 cm. Genetic characteristics and changes in the external environment can affect maize plant tolerance to shade and affect yields (Jia *et al.*, 2011; Wang *et al.*, 2009; Liang *et al.*, 2010).

Diameter of cobs

The results showed that there was no interaction between several varieties of maize with several levels of shade on the diameter of the cobs, but there was a singular influence from each treatment (Table 3).

Table 3. Cobs diameter (cm) of several maize varieties at different shade levels

Shade level (%)	Variety						Mean
	NK Sumo	Bisi18	Sukmaraga	IBF Lines	Sinhas5	Agam Local variety	
0	4.73	4.07	4.56	4.75	5.10	4.63	4.64 A
25	4.90	4.28	4.59	4.58	4.36	4.66	4.56 A
50	4.72	4.09	4.24	4.48	4.44	3.96	4.32 B
Mean	4.79 A	4.15 c	4.47 abc	4.61 ab	4.64 ab	4.42 bc	

Numbers followed by the same lowercase letter in the row and the same uppercase letter in the column showed no significant difference based on the DMRT test (α = 5%).

Table 3 shows that the cobs diameter decreased with increasing shade level. The shading level of 50% resulted in the smallest average cob diameter, which was 4.32 cm. Significantly different from 25% shade and unshaded condition, the cob diameters were 4.56 cm and 4.64 cm, respectively. The growth of the cob and grains is greatly affected by shade level. Shaded conditions in maize plants cause a decrease in cobs diameter, silk differentiation, tassel branches, pollen vitality, grain dry weight accumulation, and kernel hardening percentage. Which in turn has implications for decreasing yields (Cui et al. 2014).

Besides shade levels, the type of maize variety also has a significant effect on the average cob diameter. The NK Sumo variety has the largest cob diameter (4.79 cm). Not significantly different from Sukmaraga, Sinhas5, and IBF lines. But it is significantly different from the local variety of Agam and Bisi18 variety. This suggests that genetic factors also play a role in responding to shade on the development of the cobs. Genetic factors are the main reason for shade sensitivity in the growth of maize varieties (Yun *et al.* 2014).

Plant height

The analysis of variance showed that there was no significant interaction between the several shade level and varieties of maize on the plant height characters. But there is a singular influence of the varieties. The average value of maize plant height can be seen in Table 4.

Table 4. The height of maize plants at different shade levels

Shade level (%)	Variety					
	NK Sumo	Bisi18	Sukmaraga	IBF Lines	Sinhas5	Agam local variety
0	263.73	273.67	296.20	308.40	255.20	283.07
25	281.00	285.33	308.40	326.47	246.60	302.53
50	273.13	280.53	276.40	344.73	251.60	288.20
Mean	272.62 c	279.84 bc	293.67 b	326.53 a	251.13 d	291.27 bc

Numbers followed by the same lowercase letter in the row show no significant difference based on the DMRT test (α = 5%).

IBF lines showed the highest growth of 326.53 cm which was significantly different from other varieties. Meanwhile, the Sinhas5 variety had the lowest growth (251.13 cm). This difference in plant height is estimated to be caused by genetic differences that determine the plant height character of each maize variety. Differences in maize genotypes will also respond to different growth under shaded conditions (Yuan et al., 2022). Maize plants have substantial genetic diversity in tolerance to abiotic stresses which cause decreased plant growth (Borrás and Vitantonio-Mazzini, 2018).

Table 4 shows that shading with different light intensities on several maize varieties has no significant effect on the height of the plants. However, Table 3 shows that there was an increase in height under 50% shade conditions in several maize varieties, including the NK Sumo, Bisi18, and IBF lines. Under shaded conditions, some plants show stem elongation responses due to increased auxin activity which plays a role in cell elongation (Ma and Li, 2019).

Stalks diameter

The analysis of variance showed that there was no significant interaction between the several shade level and maize varieties on the stalks diameter. But there is a singular influence of the varieties. The stalks' diameter can be seen in Table 5.

Table 5. The stalks diameter (cm) of maize plants at different shade levels

Shade level (%)	Variety						Mean
	NK Sumo	Bisi18	Sukmaraga	IBF Lines	Sinhas5	Agam Local variety	
0	2.03	1.96	2.10	1.90	1.84	2.14	2.00 A
25	1.90	1.95	1.82	1.82	1.84	1.93	1.88 A
50	1.71	1.61	1.72	1.65	1.59	1.61	1.65 B

Numbers followed by the same capital letters in the column are not significantly different based on the DMRT test (α = 5%).

The level of shade has a significant effect on the diameter of the stalks. Table 6 shows that the higher the shade level, the smaller the diameter of the stalks. Where at 50% shade level the average diameter of stalks is 1.65 cm. Significantly different with unshaded (2.00 cm) and 25% shade (1.88 cm) conditions. In shaded maize plants, there was a decrease in the thickness of the bark and the number of vascular bundles as well as a decrease in the size of the xylem and phloem (Cui *et al.*, 2012). In shaded conditions, there was also a decrease in temperature which later became the cause of inhibition of maize plant growth as indicated by thin stalks (Rogi et al. 2010).

There is a positive correlation of 0.38 between the diameter of the stalk and the weight of the dry-shelled grains (Table 1). In shaded conditions, the smaller the diameter of the stalks, the lower the yields. Each maize variety did not show a significant difference in stalk diameter character.

Harvest time

As a C4 plant that requires optimal sunlight for its growth and development, shade has a significant effect on maize harvest time (physiological maturity). There is an interaction between several levels of shade and maize varieties to harvest time (Table 6).

Table 6. Harvest time (DAP) of several maize varieties at different shade levels

Shade level (%)	Variety					
	NK Sumo	Bisi18	Sukmaraga	IBF Lines	Sinhas5	Agam local variety
0	107.00 A b	104.68 A c	98.49 B d	116.06 A a	98.92 A d	97.68 A D
25	103.86 B b	102.42 AB b	98.27 B c	116.46 A a	98.47 A c	97.75 A C
50	104.51 B b	101.59 B c	100.85 A c	114.99 A a	98.12 A d	98.16 A D

Numbers followed by the same lowercase letter in the row and the same uppercase letter in the column were not significantly different based on the DMRT test (α = 5%).

The shortest harvest time was found in local varieties of Agam under unshaded conditions, which is 97.68 DAP (days after panting). At 50% shade condition, Agam local variety and Sinhas5 composite had the shortest harvest time compared to other varieties. This shows that each variety has a different growth and development response to light stress conditions. While in the Sukmaraga variety, there was a delay in harvest time under 50% shaded conditions, namely 100.85 DAP.

Several studies have reported that maize in shaded conditions experiences delays in growth (Li et al., 2005) and productive periods (delays in flowering and maturity time) (Cui et al., 2014; Wang et al., 2020). However, a different response was shown by the hybrid varieties NK Sumo and Bisi18. In shaded conditions, the harvest time for the two varieties is shorter than in unshaded conditions. Then between IBF lines, Sinhas5, and Agam local variety with shade levels, some interactions were not significantly different.

Leaf chlorophyll content

One of the physiological effects that are very sensitive to low light intensity is the chlorophyll content of leaves which plays a role in the process of photosynthesis. Table 7 shows changes in chlorophyll content in 6 varieties of maize with different light intensities.

Table 7. Chlorophyll content of several maize varieties at different shade levels

Shade level (%)	Variety					
	NK Sumo	Bisi18	Sukmaraga	IBF Lines	Sinhas5	Agam local variety
Chlorophyll a						
0	0.55	0.35	0.57	0.18	0.4	0.47
25	0.45	0.35	0.44	0.36	0.38	0.5
50	0.51	0.48	0.41	0.49	0.5	0.41
Chlorophyll b						
0	0.19	0.1	0.21	0.11	0.51	0.14
25	0.15	0.1	0.13	0.11	0.11	0.17
50	0.19	0.15	0.13	0.20	0.16	0.13
Ratio a/b						
0	2.86	3.42	2.69	1.6	3.33	3.32
25	2.99	3.37	3.32	3.19	3.42	2.87
50	2.74	3.09	3.23	2.39	3.13	3.15

The test results showed that there were differences in the content of chlorophyll a, chlorophyll b, and the ratio a/b in each type of maize variety at different shade levels. In general, the content of chlorophyll a was higher than chlorophyll b for each maize variety and the level of shade. Under conditions of 50% shade, the chlorophyll a content of several varieties had increased including Bisi18, IBF lines, and Sinhas5.

Then in 50% shaded conditions, Sukmaraga, Sinhas5, and Agam local varieties experienced a decrease in the content of chlorophyll b. Meanwhile, there was an increase in IBF lines. An increase in the content of chlorophyll a and chlorophyll b and a decrease in the a/b ratio is a response of maize plant chlorophyll to low light conditions (Dai *et al.*, 2009). Where the increase in chlorophyll b has a positive impact on the effectiveness of absorbing radiation energy in shaded conditions (Sirait, 2008).

Table 7 shows a decrease in the value of the a/b ratio in NK Sumo, Bisi18, Sinhas5, and Agam local varieties. This is in line with research by Zhang et al. (2019) which reported that maize crops responded to a significant reduction in the value of chlorophyll a/b ratio in 44% shaded conditions. On the other hand, for the Sukmaraga and IBF lines, there was an increase in the value of the a/b ratio.

CONCLUSION

The results showed that there was an interaction between several maize varieties at several shade levels to the maize harvest time. Under 50% shade conditions, the harvest time for Agam local varieties and Sinhas5 composite was the shortest compared to other varieties. In observing the yields, 50% shade condition significantly reduced the average weight of dry-shelled grains. The highest yield at 50% shade conditions was produced by the NK Sumo hybrid variety with an average dry-shelled grain weight of 8.26 tons/Ha. The cob length, cob diameter, and stalk diameter significantly decreased at 50% shade conditions. Each maize variety showed a significantly different response to yield and growth. There are also differences in the content of chlorophyll a, chlorophyll b, and the ratio a/b in each maize variety and different shade levels.

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