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Utilization of Various Levels of Shading and Organic Fertilizer on Morphology, Production, and Nutrient Composition of *Panicum maximum* cv. Mombasa

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ABSTRACT

Panicum maximum cv. Mombasa is a type of grass that is known resistant to shade and responsive to fertilization. This study aimed to determine the morphology and production of *Panicum maximum* cv. Mombasa on various levels of shading and organic fertilizer. The soil used in this study was brown latosol. This study used a completely randomized design (CRD) with a factorial pattern consisting of three levels of shade (0%, 36%, and 72%) and two dose factors of organic fertilizer (0 g/pot and 500 g/pot). The parameters in this study consisted of morphology (plant height, number of leaves, number of tillers), plant production (biomass production, stem production, leaf production, and leaf/stem ratio), and nutrient composition (crude protein, extract ether, gross energy, and crude fibre). All data were observed in five replicates. The results showed that the level of shade up to 72% did not affect plant morphology. An increasing level of shading showed a significant increase ($p<0.05$) in the number of leaves of plant. Shading level decrease ($p<0.05$) biomass production, leaf, stem, LSR, and crude fibre content. The fertilizer application improved ($p<0.05$) plant morphology and production. The best interaction between growth and production was obtained in the treatment control (without shading) and fertilization of 500 g/pot. Based on the finding of this study, *Panicum maximum* cv. Mombasa can be developed into shade-tolerant grass in Indonesia.

Keywords: Growth, Organic fertilizer, *Panicum maximum* cv. Mombasa, Production, Shading

Introduction

The development of road and building infrastructure and the expansion of the palm oil plantation index, which is quite massive, are the main factors in increasing the rate of conversion of agricultural land. Agricultural land conversion has the most impact on decreasing forage area production. Based on the data released by The Ministry of Agriculture (2021), between 1980 to 2021, palm oil plantations grew from 294,560 ha to 15,081,021 ha, which has increased by more than 51 times. On the other side, the demand for forage increases significantly in quality and quantity, in line with Indonesia's increasing beef cattle population. Based on the data from the Badan Pusat Statistik (2022), the total population of beef cattle in Indonesia in 2021 was 18.053.710 heads. That population increased by 33% compared to beef cattle population in 2010.

The strategic movement that needs to be taken is to optimize the use of marginal lands, such as palm oil plantations, which are still very large. Palm oil plantation land can potentially be used for the cultivation of forage which can also be used as a cover crop (Mudhita and Badrun, 2019). Several technical approaches are needed to optimize the land, including improving the soil's biophysics and chemical and adaptive plant selection techniques for each agroecosystem. One of the efforts that can be made to improve the biophysics and chemical conditions of the soil is the utilization of organic fertilizers derived from livestock manure. Organic fertilizers will improve soil structure, texture, and pores, increasing the soil's water-holding capacity (Zulkarnain *et al.*, 2013). Providing fertilizer that contains nitrogen (N), phosphor (P), and potassium (K) to the grass has a positive effect on the number of leaves, tillers, chlorophyll content, root volume, and dry matter (DM) content (Herdiawan and Harmini, 2020). Both organic and inorganic fertilizers provide essential nutrients for the plant. However, organic and inorganic fertilizer contains different ingredients and supply these ingredients in different ways. Organic fertilizer works overtime to create a healthy growing environment, while inorganic fertilizer provides rapid nutrition (Jaja and Barber, 2017).

For the agroecosystem, such as palm oil plantations, we need to introduce types of forage that are tolerant to shade, soil acidity, drought, and low soil fertility. One type of forage that has high adaptability to drought and shade is *Panicum maximum* cv. Mombasa. This forage is a native grass species originating from Tanzania (5.20° S 38.50° E, 290 m asl, rainfall 1,050 mm), and this grass species is introduced and grows quite well in tropical areas such as Brazil. With proper cultivation management, *Panicum maximum* cv. Mombasa can produce dry matter production of 33 tons/ha per year (Galindo *et al.*, 2017).

Panicum maximum cv. Mombasa has characteristics that are suitable for use as a pasture grass and also for cut and carry systems. This grass has higher nutrient, annual production, and dry matter content than other types of *Panicum maximum*. The crude protein content of *Panicum maximum* cv. Mombasa in Thailand on less fertile soils is about 8-12%, but the crude protein can reach 12-14% on fertile soils. The optimal harvesting period for this grass is 40 to 45 days (Fernandes *et al.*, 2014). According to Wong (1990), *Panicum maximum* species are generally tolerant of moderate shade (light intensity 40-60%), while *Pennisetum purpureum* is only tolerant of light shade (light intensity >60%). Njarui *et al.* (2015) added that *Panicum maximum* cv. Mombasa is tolerant to drought and low rainfall.

Panicum maximum cv. Mombasa is very responsive to nitrogen (N) fertilization, which is indicated by the positive correlation between increasing protein content and forage dry matter (Galindo *et al.*, 2018). The N concentration of 90 kg N/ha was agronomically very efficient in increasing the crude protein and dry matter of *Panicum maximum* cv. Mombasa (Rodrigues *et al.*, 2017). Research on *Panicum maximum* cv. Mombasa on its growth ability and resistance to shade and organic fertilizer in Indonesia is limited. It is necessary to study at a laboratory scale for later application to palm oil plantations. This study aims to determine the effect of shading levels and different concentrations of organic fertilizer on the morphology, production, and nutrient composition of *Panicum maximum* cv. Mombasa.

Materials and Methods

The research was conducted in the greenhouse of the Indonesian research institute for animal production, Ciawi, Bogor. Paranet was used to imitate shade treatment. The shading level measurement was carried out using the "*Quantum Light Meter*" in µmol/m^2/second units. The organic fertilizer used in this study was rabbit manure collected from the experimental facility of the Indonesian research institute for animal production, Ciawi, Bogor. The pols of *Panicum maximum* cv. Mombasa as planting material was obtained from the collection garden of the Indonesian research institute for animal production. The soil as planting media was obtained from the palm oil area in Babulu, Penajam Paser Utara, East Kalimantan. The type of soil used in this study was brown latosol with chemical characteristics; pH 3.77, C-organic 0.42%, N total 0.07%, P 6.42 ppm, Cation-exchange capacity 1.98 cmol$^{(+)}$/kg. Fraction percentage; sand content 74.40%, dust content 22.14%, and clayey content 3.45%.

The study was arranged by 3 × 2 factorial design with 30 experimental units in five replications, whereas the first factor was shading level that was divided into three levels; 0%, 36%, and 72%, which is equivalent to 1.683, 565, and 165 µmol/m^2/sec, respectively, and the second factor was organic fertilizer with the concentration of 0 and 500 g/pot. There are 30 pots with a diameter of 50 cm divided into two main groups. Fifteen pots were filled with only soil and fifteen with soil + 500 g organic fertilizer. Then the pots were labelled and placed on iron shelves according to the treatment.

The grass was planted on the stable planting medium. Watering is done every two days in the morning and evening, and then embroidery is done one week after planting. The first harvest was done after 60 days after planting (DAP), and then the next harvest was done every 30 days. Parameters observed in this study were plant morphology (plant height, number of tillers, and number of leaves), plant production (fresh biomass, stem production, leaf production, and leaf stem index) and nutrients composition (crude protein, extract ether, gross energy, crude fibre, calcium, and phosphor). The collected data were subjected to a two-way Analysis of Variance following the completely randomized block design in a 3 × 2 factorial arrangement. The shading levels and organic fertilizer were applied as a fixed factor, while replication was a random factor. The differences between treatments were subjected to Duncan's Multiple Range Test when p<0.05 (Gomez and Gomez, 1984). Data were analysed using SPSS 23.0 software (IBM, Armonk, New York, USA).

Results and Discussion

Data on the morphology of *Panicum maximum* cv. Mombasa with shading level and organic fertilizer is shown in Table 1. Analysis of variance indicated no effect from shading levels and organic fertilizer (p>0.05) on plant height. The interaction between the shading level and organic fertilizer showed a significant difference (p<0.05) in plant height. The highest plants were shown in the combination of treatments without shade with 500 g fertilization with a height of 99.30 cm, while the lowest was in treatments without shade and fertilization with a height of 62.02 cm. The difference in height between the highest and lowest values is 37.28 cm. the growth of *Panicum maximum* cv. Mombasa showed good performance. The increase in plant height in this study can be explained as a result of improved

Table 1. Morphological parameters of *Panicum maximum* cv Mombasa on a different level of shading and organic fertilizer

Parameter	Shading (%)	Organic fertilizer (g/pot)		Average
		0	500	
Plant height (cm)	0% (without shading)	62.02^{cd}	99.30^{a}	80.66
	36%	82.42^{ab}	60.26^{d}	71.34
	72%	88.65^{ab}	77.90^{bc}	83.27
	Average	77.70	79.15	
Number of leaves (n)	0% (without shading)	16.55^{c}	15.77^{c}	16.16^{z}
	36%	20.10^{c}	50.07^{a}	35.08^{y}
	72%	35.17^{b}	48.77^{a}	41.97^{x}
	Average	23.94^{q}	38.20^{p}	
Number of tillers (n)	0% (without shading)	5.62^{c}	5.35^{c}	5.48^{z}
	36%	6.37^{c}	19.17^{a}	12.77^{x}
	72%	6.57^{c}	10.00^{b}	8.28^{y}
	Average	6.19^{q}	11.50^{p}	

^{p,q} Means in the same row with different superscripts differ significantly (p<0.05).
^{x,y,z} Means in the same column with different superscripts differ significantly (p<0.05).
^{a,b,c,d} Means in the same row and column with different superscript differ significantly (p<0.05).

soil nitrogen availability with the application of organic fertilizer. The result of this research, accordant to Leite *et al.* (2019), is the presence of fertilizer containing N on *Panicum maximum* cv. Mombasa will increase its height by 7 cm. The presence of shade affects the amount of light plants receive, causing the photosynthesis process to decrease, then directly affecting plant morphology. Amelia *et al.* (2021) stated that decreased photosynthesis in plants decreases cell formation activity and causes plants to become shorter.

Analysis of variance showed that shading levels, organic fertilizer, and their interaction resulting a significant effect (p<0.05) on the number of leaves. The shading level increases the number of leaves. The higher the shading level, the more leaves the grass has. The average number of leaves from the research was 16.16 without shading, 35.08 for 36% shading, and 41.97 for 72% shading. Low light intensity stimulates the plant to produce more leaves to capture the light, so the photosynthesis process can be done as needed. Herdiawan and Harmini, (2020) reported that shading treatment on *Trichanthera gigantea* resulted in more leaves than control. The grass without fertilizer has 23.94 leaves, while the grass with fertilizer has 38.20 leaves. The grass that received the fertilizer treatment had 15 more leaves than the control. Provision of organic fertilizer increase the micro and macro nutrient needed for leaf formation. Moula *et al.* (2018) reported that organic fertilizer from rabbit manure contains high nitrogen, kalium, and phosphor beneficial for plant growth. The interaction between 36% shading and 500 g fertilization resulted in the most plenteous number of leaves (48.77) compared to other treatments. The presence of fertilization increases nutrient availability for plants. The number of leaves is related to the plant's efforts to adapt to a low-light environment. Leaf propagation increases the amount of light the plant absorbs. Plants then use these nutrients to produce new organs in the form of leaves which plants also need under shade to gain access to light. This result is accordant to Mojeremane *et al.* (2017), who stated that using organic fertilizer could increase the number of leaves. The highest the dose, the more leaves in the plant. Edu *et al.* (2015) added that organic fertilizer macro and micro minerals stimulate plant leaf production.

The number of tillers showed a significant difference (p<0.05) with the treatment shading level, organic fertilizer, and their interaction. Shading treatment stimulates the grass to have more tillers than control. The average number of tillers from *Panicum maximum* cv. Mombasa was 5.48 for 0% shading, 12.77 for 36% shading, and 8.28 for 72% shading. The presence of shade caused the number of tillers to be more than the treatment without shade. The grass that received fertilizer treatment had more tillers than the control, with the number of tillers at 11.50 and 6.19, respectively. The best interaction was obtained at 33% shade treatment with 500 g fertilizer with the number of tillers 19.17. The number of tillers produced was 14 more than the treatment control. Decreasing the tiller with shading treatment is caused by the damage to the early-formed tiller due to the lack of light. Rodrigues *et al.* (2016) stated that shading has a negative impact on the structure and productivity of *Panicum maximum* cv. Mombasa. Macro and micro nutrient from organic fertilizer increase nutrient availability for tiller formation, so plant that receives organic fertilizer has more tillers than control. Leite *et al.* (2019) stated that using fertilizer containing N on *Panicum maximum* cv. Mombasa produces a greater number of tillers.

Production parameters of *Panicum maximum* cv. Mombasa at different shading levels and organic fertilizer are shown in Table 2. Analysis of variance showed a significantly different (p<0.05) biomass production affected by shading level, organic fertilizer, and their interaction. The presence of shade causes a decrease in biomass production. Biomass production of *Panicum maximum* cv. Mombasa was 67.53 g/clump for control, 52.86 g/clump for 36% shading, and 40.17 g/clump for 72% shading. The highest production was obtained in control, while the lowest was obtained in the shade at 72%. There is a decrease in production by 20% for an increase in the level of shading. A decrease in biomass production is correlated with

Table 2. Production of *Panicum maximum* cv. Mombasa on a different level of shading and organic fertilizer

Parameter	Shading (%)	Organic fertilizer (g/pot)		Average
		0	500	
Biomass production (g/clump)	0% (without shading)	41.00^{cd}	94.05^{a}	67.53^{x}
	36%	53.70^{b}	52.05^{b}	52.86^{y}
	72%	48.55^{c}	31.80^{d}	40.17^{z}
	Average	47.75^{q}	59.30^{p}	
Leaves production (g/clump)	0% (without shading)	19.20^{cd}	57.05^{a}	38.13^{x}
	36%	27.95^{b}	26.50^{b}	27.23^{y}
	72%	21.30^{bc}	13.40^{d}	17.35^{z}
	Average	22.82^{q}	32.32^{p}	
Stem production (g/clump)	0% (without shading)	21.80^{bc}	37.00^{a}	29.40^{x}
	36%	25.75^{b}	25.55^{b}	25.65^{y}
	72%	27.25^{b}	18.40^{c}	22.83^{z}
	Average	24.93^{q}	26.98^{p}	
Leaf/stem ratio	0% (without shading)	0.90^{cd}	1.57^{a}	1.69^{x}
	36%	1.17^{b}	1.07^{c}	1.12^{y}
	72%	0.79^{d}	0.75^{d}	0.77^{z}
	Average	0.95^{q}	1.13^{p}	

^{p,q} Means in the same row with different superscripts differ significantly (p<0.05).
^{x,y,z} Means in the same column with different superscripts differ significantly (p<0.05).
^{a,b,c,d} Means in the same row and column with different superscript differ significantly (p<0.05).

decreasing number of tillers. Villalobos *et al.* (1992) stated that shading decreases biomass production in the plant. The use of organic fertilizer increased by 24% biomass production compared to the control. Average biomass production obtained from control and organic fertilizer was 47.75 g/clump and 59.30 g/clump, respectively. The additional organic compound from fertilizer increases nutrient availability necessary by the plant to produce biomass. The best interaction was shown in the combination treatment without shade with 500 g fertilization with biomass production of 94.05 g/clump, while the lowest was shown in the 72% treatment with 500 g fertilization with biomass production of 31.80 g/clump. The presence of fertilizer in shaded conditions has not been able to maintain grass production, so more fertilizer doses are needed to maintain production. Galindo *et al.* (2017) stated that the addition of organic fertilizer containing N to *Panicum maximum* cv. Mombasa will be able to increase biomass production. The use of high doses of N fertilizer (1,200 kg/ha) in the rainy season produced a dry matter production of 5.347 kg/ha.

Shading level, organic fertilizer, and their interaction showed a significant effect (p<0.05) on leaf production on *Panicum maximum* cv. Mombasa. The result was in line with biomass production of *Panicum maximum* cv. Mombasa. Leaves production from *Panicum maximum* cv. Mombasa with shading treatment 0%, 36%, and 72% was 38.13 g/clump, 27.23 g/clump, and 17.35 g/clump, respectively. The presence of shade causes a decrease in leaf production, and lack of light inhibits photosynthesis, affecting leaf formation. The application of organic fertilizer was able to increase leaf production. Grass with organic fertilizer has 32.32 g/clump leaves production, while the control has 22.82 g/clump leaves production. Leaves production increased by 9.5 g/clump compared to the control. The best interaction was shown in the treatment without shading and 500 g of organic fertilizer with leaves production of 57.05 g/clump, while the lowest was in the treatment of 72% shade and 500 g of fertilization with leaves production of 13.40 g/clump. Villalobos *et al.* (1992) stated that low light intensity stimulates plants to enlarge specific leaf area (SLA). The SLA is highly related to the low disposition of the dry matter in the leaves.

Analysis of variance showed that shading level, organic fertilizer, and their interaction significantly affected (p<0.05) stem production of *Panicum maximum* cv. Mombasa. Stem production from *Panicum maximum* cv. Mombasa with control, 36%, and 72% level of shading was 29.40 g/clump, 25.65 g/clump, and 22.83 g/clump, respectively. Stem production decreased with increasing shading level. The stem production was associated with tillers formation because the stem is the main part of tillers. Decreasing tiller formation automatically will decrease stem production. The application of organic fertilizer had higher stem production compared to the control. Grass that received organic fertilizer had 26.98 g/clump stem production, while the control had 24,93 stem production. The stem production was effective by adding 500 g organic fertilizer per pot, which means the provision of organic fertilizer has a positive effect to increase stem production. The best interaction was shown in the treatment without shade with 500 g of fertilization with stem production 37.00 g/clump, while the lowest was in the 72% shade treatment with 500 g of fertilization with stem production18.40 g/clump. Utilization of organic fertilizer increase cell propagation rate on the plant, resulting bigger stem, which has positive correlation with stem production. Souza and Tavares (2021) reported that the development of cells and the formation of lignin in the cell wall is strongly influenced by the content of nitrogen (N).

Leaf/stem ratio (LSR) showed a significant difference (p<0.05) with the treatment of shading level, organic fertilizer, and their interaction. LSR was positively correlated with leaves and stem production. Grass that was subjected to shading had lower LSR than the control. The average LSR from control was 1.69, 36% shading was 1.12, and 72% shading was 0.77. Organic fertilizer resulted in higher LSR compared to control with 1.13 and 0.95, respectively. The highest LSR

Table 3. Nutrient composition of *Panicum maximum* cv. Mombasa on a different level of shading and organic fertilizer

Parameter	Shading (%)	Organic fertilizer (g/pot)		Average
		0	500	
Crude protein (%DM)	0% (without shading)	8.37	9.11	8.74
	36%	9.61	8.98	9.30
	72%	11.26	10.78	11.02
	Average	9.75	9.62	
Extract ether (%DM)	0% (without shading)	2.26	1.93	2.10
	36%	2.50	2.16	2.33
	72%	2.36	2.89	2.63
	Average	2.38	2.33	
Gross energy (Kcal/kg)	0% (without shading)	3,807	3,753	3,779
	36%	3,680	3,870	3,774
	72%	3,636	3,592	3,613
	Average	3,707	3,738	
Crude fibre (%DM)	0% (without shading)	38.10^{b}	38.74^{b}	38.42^{y}
	36%	40.02^{ab}	41.77^{a}	40.89^{x}
	72%	33.85^{c}	31.96^{d}	32.90^{z}
	Average	37.32	37.49	

^{x,y,z} Means in the same column with different superscripts differ significantly (p<0.05).
^{a,b,c,d} Means in the same row and column with different superscript differ significantly (p<0.05).

value was obtained in the combination of treatment without shade and 500 g of fertilization with LSR 1.57, while the lowest was in the treatment of 72% shade and 500 g of fertilization with LSR 0.75. LSR is influenced by the production of leaves and stems from the plant. Based on the finding of this study, the plant that received shading treatment has lower leaves and stems than the control. That result is also in line with biomass production. Lin *et al.* (2001) stated that 50% shading on Cody and 'Vernal' alfalfa reduced LSR by 20% to 30%.

Nutrient composition of *Panicum maximum* cv. Mombasa on different levels of shading and organic fertilizer are shown in Table 3. Analysis of variance indicated that the shading level did not detect a significant effect (p>0.05) on crude protein, extract ether, and gross energy. Application of organic fertilizer did not affect (p>0.05) on crude protein, extract ether, gross energy, and crude fibre. There is also no interaction effect (p>0.05) from shading level and organic fertilizer on crude protein, extract ether, and gross energy.

The shading level decreased (p<0.05) crude fibre content compared to the control. The average crude fibre content from *Panicum maximum* cv. Mombasa was 38.42% DM for control, 40.89% DM for shading 36%, and 32.90 DM for shading 72%. Crude fibre content decreases by almost 8% compared to the control. The plant exposed to light without inhibitors such as shading would perform photosynthesis better than under shading. Photosynthesis would result in thicker cell walls that consist of crude fibre, especially lignin. Widodo *et al.* (2019) reported that *Pennisetum purpureum* cv. Mott planted on open land have higher crude fibre content than those planted under shading. Muhtarudin *et al.* (2020) added that grass's photosynthesis rate under shading conditions is highly influenced by light intensity. Interaction between shading level and organic fertilizer detects a significant effect (p<0.05) on crude fibre content. The best interaction was shown by a shading level of 72% and 500 g organic fertilizer, resulting in the lowest crude fibre content of 31.96% DM. This finding indicated that plants are unable to utilize organic fertilizer under shading conditions.

Conclusions

We can conclude that the effect of the combination between shading level and the application of organic fertilizer has an essential role for the maximum production of *Panicum maximum* cv. Mombasa. Shading levels affect morphological, and decrease plant production and crude fibre content. The application of organic fertilizer improves plant morphology and production. Plant without shading and receiving 500 g organic fertilizer showed best morphology and production. The lowest crude fibre content showed by plant with 72% shading and 500 g organic fertilizer.

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