Buletin Peternakan 48 (2): 99-105, May 2024

ISSTAP
Indonesian Society for Sustainable Tropical Animal Production

Bulletin of Animal Science

ISSN-0126-4400/E-ISSN-2407-876X Accredited: 36a/E/KPT/2016
http://buletinpeternakan.fapet.ugm.ac.id/

Doi: 10.21059/buletinpeternak.v48i2.95016

Characteristic Morphology and Biomass Production of Napier Grass (*Pennisetum purpureum*) Cultivar Gama Umami Under Teak Tree (*Tectona grandis*) Shade in Blora, Central Java

Muhammad Zayyan Muafi[1], Nafiatul Umami[1], Bambang Suhartanto[1], Bambang Suwignyo[1], Miftahush Shirotul Haq[1], Nilo Suseno[1], Widiyatno[2], Leisa Armstrong[3], David Cook[3], and Yogi Sidik Prasojo[1*]

[1]Department of Animal Nutrition and Feed Science, Faculty of Animal Science, Universitas Gadjah Mada, Yogyakarta, 55281, Indonesia
[2]Faculty of Forestry, Universitas Gadjah Mada, Yogyakarta, 55281, Indonesia
[2]Edith Cowan University, Australia

Article history
Submitted: 9 November 2023
Accepted: 4 March 2024

* Corresponding author:
E-mail: yogi.sidik.p@ugm.ac.id

ABSTRACT

This study aims to determine the characteristic morphology and biomass production of Napier grass (*Pennisetum purpureum*) cultivar Gama Umami under teak tree (*Tectona grandis*) shade in teak tree forest area of Blora, Central Java. The grass was planted using stem cuttings and maintained for four months using the randomized block design (RBD) method with six repetitions in each treatment. This study consisted of two treatments, namely shade under teak tree stands and non-shade or open area as a control. Maintenance was carried out for 14 weeks with the addition of fertilizers, such as NPK (nitrogen, phosphor, and potassium) and urea. Parameters measured included plant height, leaf length, leaf width, first collar length, number of tiller, and stem diameter. After 14 weeks the plants were harvested, and biomass production data were obtained. The results showed that there were no differences in leaf length, leaf width, first collar length, number shoots, and stem diameter between under the shade and non-shade of teak trees. However, the plant height and biomass production of Napier grass cultivated in non-shade teak trees were higher than under the shade of teak trees. The finding showed that Napier grass cultivar Gama Umami could be cultivated under the shade of teak tree forest and introduce for silvopasture system in teak trees forest area.

(Keywords: Gama Umami, Livestock, Napier Grass, Silvopasture)

Introduction

Pursuing sustainable agriculture practices has resulted in novel approaches that optimize land usage while protecting biodiversity and ecosystem integrity. Some of the research had provided valuable insight for optimizing land usage while safeguarding biodiversity (Ricketts *et al*., 2004; Kremen *et al*., 2012; Fischer *et al*., 2017). Teak tree (*Tectona grandis*) forests provide an ideal microclimate for Napier grass cultivation. Teak tree leaves shed on a regular basis, providing the soil with organic matter and necessary nutrients, hence increasing Napier grass productivity. There was also an attempt to introduce a dwarf Napier grass (*Pennisetum purpureum* cultivar Mott) under teak forest and increased its protein content (Widodo *et al*., 2018).

Several studies have shown that cultivating Napier grass under the shade of teak trees is both feasible and effective. For the example, Singh *et al*. (2018) found that agroforestry systems combining Napier grass and teak trees outperformed monoculture systems in terms of biomass yield and soil fertility. Similarly, Kumar *et al*. (2020) found that shade from teak trees improved Napier grass growth and water-use efficiency, especially in semi-arid locations. In this study, we introduce newly Napier grass (*Pennisetum purpureum*) cultivar Gama Umami that produce by selection after treatment of Gamma radiation.

Napier grass cultivar Gama Umami is a plant that can grow in various types of soil and has high environmental adaptability and Napier grass cultivar Gama Umami has a high fresh production of 50 kg/m^2. In addition, the Gama Umami cultivar Napier grass has been recognized by farmers and is very familiar with the use of Napier grass so that farmers will choose to plant the Gama Umami grass as a stock of forage feed for ruminants. Gama cultivar Napier grass also could survive in conditions of minimal sunlight. Research related to the effect of shading on the growth of king grass grown under pine stands provides optimal growth and can survive in low lighting conditions (Fityandini, 2017). Previously research also showed that Gama Umami exhibited outstanding biomass production (6.15 kg/m^2) in alluvial type of soil in open space of teak tree forest area in Blora, Central Java (Prasojo *et al*., 2023).

Intercropping between grasses and trees is critical to promoting sustainable feed and food security programs in Indonesia. This agricultural method offers a comprehensive approach to land management, blending the cultivation of grasses like Napier grass (*Pennisetum purpureum*) with various tree species such as teak (*Tectona grandis*) or leguminous trees. Intercropping methods increase agricultural output while also supporting environmental sustainability. Intercropping not only increases land use efficiency, but it also diversifies agricultural outputs, providing a consistent and diverse feed supply for animals (Gintings and Dahlanuddin, 2019). The presence of trees in these environments promotes soil enrichment via nitrogen fixation and organic matter buildup, increasing soil fertility and resilience to degradation (Muchlish *et al*., 2017).

Furthermore, tree canopy cover reduces environmental stressors such as temperature extremes and water loss, resulting in favorable microclimatic conditions for crop growth (Suryanto *et al*., 2018). These agroforestry approaches also help to conserve biodiversity by providing habitat and food for varied flora and fauna, which improves ecosystem stability (Subekti *et al*., 2020). Intercropping systems improve farmers' socioeconomic well-being by diversifying revenue sources through the production of tree products and grass-based animals (Tiryana and Mahrup, 2018). Overall, grass-tree intercropping is a long-term strategy for increasing feed and food security in Indonesia while also promoting environmental resilience and livelihood enhancement. However, the application of intercropping system has in impact on grass growth and production due to the influence of competition for nutrients between grass, teak trees, and allelopathic substances that can inhibit plant growth. The integration of grass with woody plants such as teak trees will also block the absorption of grass sunlight. Therefore, this study aimed to determine the characteristic morphology and biomass production of Napier grass cultivar Gama umami (*Pennisetum purpureum*) under teak tree (*Tectona grandis*) shade in teak tree forest area of Blora, Central Java. This study also has benefits as information to farmers and breeders who live in teak forest areas so that they can maximizing land use in under shade of teak trees to plant Napier grass cultivar Gama Umami. Another benefits for this study is increasing feed availability in teak forest areas.

Materials and Methods

Research area. This study was conducted in teak tree (*Tectona grandis*) forest area near by *Kawasan Hutan Dengan Tujuan Khusus* (KHDTK) Universitas Gadjah Mada, which located in Megeri Village, Blora Regency, Central Java (7º21'40''S 111º26'36''E, the elevation of 100 m above sea level). The teak tree was about 7 years old and about 26 feet tall. The soil type was characterized as alluvial soil.

Cultivation and maintenance. The material used in this study was stem *Pennisetum purpureum* cultivar gama umami as long as 15 cm. This study used inorganic compost such as NPK Phonska (nitrogen, phosphor, and potassium) 15:15:15 400 kg/ha and urea 46% 150 kg/ha fertilizer. Land preparation consisted of tilling and clearing the land of weeds and other substances that could interfere with plant growth. The soil that has been processed would be formed into plots measuring 1 × 3 m^2 consisting of four plots in the unshaded area (control) and four other plots in the area shaded by teak trees. The distance between each plot was 60 cm and between plants shaded by teak trees was one meter. Stems were ready to be planted in four plots where four shaded plots have sunlight intensity conditions of 3718.3 lux and four other plots are not shaded. Each plot containing 14 stems. The spacing of the grass cultivation was 60 cm. Stems were planted approximately 2.5 cm to 3 cm deep with a slope of 30° to 45°.

Investigation of morphology and production. Plant morphology measurements include plant height, leaf length, leaf width, stem diameter, first collar length, and number of tiller. Plant height was carried by a 5 m wooden crossbar. Measurements were made by measuring from the point of plant growth to the highest part of the plant. Measurements were taken five times for each plot. Leaf length was carried by a 5 m roll meter. Measurements were made by measuring the base of the leaf to the tip of the leaf. Data were taken from each plot of five leaves from different tiller. The measurement results were presented in average. Leaf width measurements were taken using a 5 m roll meter. The leaves were measured at their bases, centers, and tips. Data was collected on each plot of five leaves from various tiller. The stem diameter was measured with a digital caliper. Measurements were taken at the base of the plant stem. Data were collected from each plot containing five distinct shoots. The stem collar length was measured using a measuring tape. Collar length might also indicate plant height. Plant height was assessed by measuring the plant from the soil surface to the highest fully formed leaf collar. Measurements were taken from the base of the plant, from ground level to the first leaf collar. Data was taken on each plot, five times repeating the data measurement. Number of tiller measurement for each plant plot was counted for the number of tiller. The number of tiller was counted by looking at the internodes of the plant stem. The number of tiller per clump was then totaled. Fresh yield production was obtained by weighing the harvested grass using a 150 kg GIGAN digital scale. Plants were collected into a bundle with the help of plastic rope and divided based on the treatment. Plants were weighed directly and the numbers on the scales were observed. The result of weighing was calculated as fresh weight production.

Statistical analysis. The data were analyzed using independent sample t-test statistical analysis by IBM SPSS Statistics 26 with a probability value of less than 5%. Data with significant differences would be tested further with Duncan's Multiple Range Test. The research design was using completely randomized design mathematical model with a unidirectional pattern (Gomez and Gómez, 1976).

Results and Discussion

Characteristic Morphology

Plant height is used as a growth indicator to assess the impact of the environment or treatments performed; plants are extremely sensitive to specific environmental elements such as light (Mangera, 2013). Table 1 reveals a substantial effect ($P<0.05$) on the height of the Napier grass cultivar Gama Umami. At week 14, plant height in the non-shaded treatment was 283.88 ± 9.55 cm, while in the shaded treatment it was 256.58 ± 17.82 cm. Table 1 compares plant height growth rates in non-shaded and shaded conditions. The non-shaded therapy showed greater growth than the shaded treatment. This is due to the difference in light intensity received by plants under the shade of teak trees versus those without. Plants in the non-shaded treatment receive more sunlight intensity for photosynthesis than shaded plants (Asbur *et al*., 2019).

Light intensity can cause physiological reactions in plants, including changes in photosynthetic activity and morphological responses such as leaf size and plant height (Suci and Heddy, 2018). Light intensity influences photosynthesis creation, resulting in an optimal amount of photosynthate production, giving plants a higher growth index and yield. The shading condition that reduces sunlight intensity cannot facilitate comprehensive photosynthesis outcomes, and the utilization of CO_2 in the leaf vicinity will compete for ATP availability, disrupting the plant's photosynthetic processes (Muyassir, 2012).

The research is in line with Guntur *et al*. study (2020), which asserts that shading nutmeg trees condition on Napier grass only produces a plant height of 1.30 m and in the treatment without shading gives a plant height of 1.65 m. Additionally, several tropical grasses experience growth reduction with decreased sunlight intensity. Fityandini (2017) stated that superior varieties of Napier grass, such as the King grass cultivar, may exhibit significant differences under shaded conditions beneath pine trees. The height of Napier grass plants of the King grass cultivar in shaded treatments under pine trees yielded lower results than those without shade. However, the growth of Napier grass plants of the King grass cultivar under shaded treatments beneath pine trees can thrive well without adversely affecting the growth of pine trees.

The measurement of leaf length in week 14 in the non-shaded treatment was 116.45 ± 7.44 cm, while in the shaded treatment it was 109.54 ± 2.60 cm. The insignificant ($P>0.05$) measurement data is due to the high environmental temperature levels occurring during the week 14 measurements. This aligns with the research environment conditions in May, which typically experience increased average environmental temperatures reaching 28.5°C. Therefore, the data in Table 2 indicates relatively similar leaf length growth figures between the shaded and non-shaded treatments.

The findings are congruent with Poai *et al*. (2019) research, which found that local Napier grass treated to shading treatment produced results of 64.97 cm in the non-shaded treatment and 68.57 cm in the shaded treatment. The data show no significant ($P>0.05$) variation in Napier grass leaf length. This is due to the influence of environmental temperature, sunshine intensity, and hormones that play an active role in plant growth. Tantalo *et al*. (2021) also reported that Napier grass cultivated in shade settings beneath rubber trees produced leaf length values that were not statistically different from Napier grass grown in locations without rubber trees. Rizaqussyihab (2018) confirmed that superior grasses, such as Taiwan Napier grass species, can survive in hot climes and withstand shadowed situations.

Leaf width in week 14 measured 4.36 ± 0.26 cm in the non-shaded treatment and 4.34 ± 0.16 cm in the shaded treatment. The difference was not significant between treatment, it might be caused by the high environmental temperature values seen during the week 14 measurements. High ambient temperatures cause less rainfall, which reduces leaf breadth by shrinking and closing stomata. Leaf stomata are essential for plant respiration and water vapour exchange between the environment and leaves. Stomata closure disrupts gas exchange in the leaf. Stomatal closure causes a decrease in CO_2 consumption, which leads to slower photosynthetic rates and leaf growth. Sunlight intensity also influences stomatal opening and shutting, which affects leaf breadth. Plant shading affects soil moisture and water content, influencing leaf expansion and stomatal distribution on the leaf surface. Hot environments cause stomatal closure, while shaded locations cause stomatal opening (Haryanti, 2010).

In week 14, collar length measured 45.82 ± 14.28 cm in non-shaded treatment and 42.76 ± 10.36 cm in shaded treatment. The measurement of collar length 1 is important in estimating plant leaf production because the shorter the length of collar 1, the more leaves are expected. Estimation of leaf production from collar length by dividing plant height and collar length. For example, the longest plant length was 86 cm for dwarf Napier grass, which produced 15 leaves with a first collar length of 5 to 6 cm (Syukran *et al*., 2023). Collar length 1 can be used to estimate the amount of leaf production. The data obtained from measuring collar length yielded relatively similar results. This is because Napier grass cultivar Gama Umami can

Table 1. Morphology characteristic of Napier grass cultivar Gama Umami under shading

Traits	Shading treatment	
	Non shading/ open space	Under shading
Plant height (cm)	283.88[a] ± 9.55	256.58[b] ± 17.82
Leaf length (cm)	116.45 ± 7.44	109.54 ± 2.60
Leaf wide (cm)	4.36 ± 0.26	4.34 ± 0.16
Length of 1st collar (cm)	45.82 ± 14.28	42.76 ± 10.36
Shoot number	3.16 ± 0.40	3.50 ± 0.54
Stem diameter (mm)	20.66 ± 0.85	19.82 ± 0.64

[a,b] Means values by the differences letter in the row are significantly different at P<0.05.

Tabel 2. Biomass production and percentage of leaf and stem of Napier grass cultivar Gama Umami under shading

Biomass production		Shading treatment	
		Non shading/ open space	Under shading
Biomass production (ton/ha)		137.2[a] ± 1.80	98.9[b] ± 1.76
Percentage	Leaf (%)	27.00[b] ± 2.10	34.88[a] ± 0.86
	Stem (%)	72.96[a] ± 2.10	66.03[b] ± 2.48

[a,b] Means values by the differences letter in the row are significantly different at P<0.05.

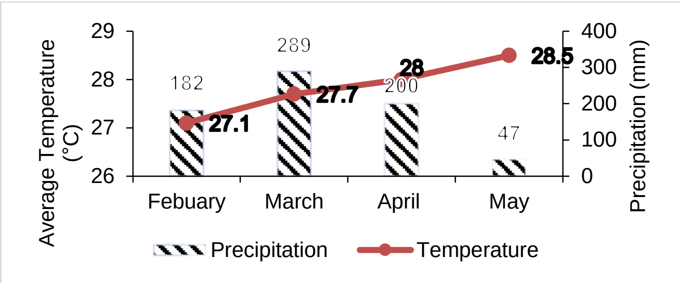

Figure 1. Average temperature and precipitation of Blora, Central Java during the study

withstand shaded conditions. Sawen (2012) stated that the height of local Napier grass plants under shading treatments of 60%, 80%, and 100% resulted in an average plant height of 141.87 cm with a total of 73 leaves. According to Guntur and Samual (2021), local Napier grass leaf counts at 80 days after planting under shaded nutmeg tree treatments were not significantly different from the leaf counts of 54 leaves in the non-shaded treatment and 44 leaves in the shaded treatment.

The measurement of tiller count in week 14 in the non-shaded treatment was 3.16 ± 0.40 tiller, while in the shaded treatment it was 3.50 ± 0.54 tiller. The increase in tillers (tillering) significantly affects the ability of grass to regenerate into new plants. The increasing number of tillers produced will affect the population density (Rellam *et al*., 2017). Table 1 shows that the increase in tiller count is relatively similar between the two treatments. This could be due to the increased environmental temperature in May, reaching around 28.5°C. As temperatures rise, plants will undergo metabolism to maintain proper moisture levels by preventing excessive water evaporation. Reduced evaporation often disturbs the photosynthesis process, which is necessary for plant growth. Plants exposed to high temperatures for an extended period will experience poor tiller growth and interruptions in flowering (Khodorova and Conti, 2013).

Plants struggle to produce growth-regulating hormone like auxins, gibberellins, and cytokinins due to a lack of available water in the soil. The synthesis of auxins will be suppressed, as will cytokinin activity and gibberellin supply to the stem. Due to changes in enzyme activity, a lack of available water causes changes in the proportion of sugars and polysaccharides. An increase in amylase in the leaves causes water stress in plants, making it harder for tillers to grow effectively (Permana *et al*., 2019). This shows that Napier grass cultivar gama umami can tolerate high temperatures and poor light conditions.

Stem diameter measured in week 14 in the non-shaded treatment was 20.66 ± 0.85 cm, while in the shaded treatment it was 19.82 ± 0.64 cm. The measurement results in week 14 showed an accumulation of data where stem diameter decreased in the non-shaded treatment compared to the shaded treatment, which experienced increased growth in the last measurement. These results are influenced by seasonal factors, temperature, and monthly rainfall. May 2023 has entered the dry season, resulting in an increase in environmental temperature. Excessive water evaporation from plants will cause the plant stem diameter to shrink to stabilize the temperature received by the plants.

The rise in stem diameter development in the shaded treatment is due to the efficient use and performance of enzyme activity in carrying out optimal plant metabolism and photosynthesis. However, the data demonstrate that the non-shaded treatment has more stem diameter growth than the shaded treatment due to the amount of photosynthate required to make carbohydrates for plant system function and metabolic activities. Wijaya *et al*. (2018) stated that local Napier grass under oil palm tree shade resulted in stem diameter measurements that were not significantly different.

This is because potassium nutrient absorption in the non-shaded treatment did not work optimally, resulting in similar stem diameter growth between the shaded and non-shaded treatments. Dewi *et al*. (2021) emphasized the significant role of potassium in stem diameter enlargement, and the availability of sufficient potassium nutrients enhances stem diameter growth, allowing the transport system for photosynthesis products and nutrients to function optimally for plant growth

Biomass Production

Table 2 shows that the fresh biomass production of Napier grass cultivar Gama umami cultivated open space or non-shade (137.,2 ton/ha) is significantly higher than that cultivated under teak tree shade (98.9 ton/ha). The result shown higher total fresh yields in the shade treatment than the research that has been done in Petungkriyono conservation forest area with production of 74.3 ton/ha (Anwar, 2023). Interestingly, the grasses that cultivated under teak trees shading exhibited higher leaf percentage than its stem percentage. In another hand, the grasses that cultivated open space or without shading exhibited higher stem percentage than its leaf percentage. The high amount percentage of stem was led to higher plant height and stem diameter. Several reasons could contribute to lower biomass production in grasses when cultivated under shade by teak trees compared to open space or without teak trees shade. Most of the reason could be the presence of sunlight, the lack of sunlight under the teak tree canopy limits photosynthesis and led to limiting biomass growth and development (Bhatt *et al*., 2020).

Shading could modify the micro-environment, resulting in lower temperatures and higher humidity levels, which can impair plant development and productivity (Kottek *et al*., 2006). Microclimate refers to the localized climate conditions within a specific area that differ from the surrounding region due to the various factors such as solar radiation, topography, vegetation, and human activities (Smith *et al*., 2023). These unique climate conditions can include variations in temperature, humidity, wind speed, and precipitation patterns (Dewi and Juliani, 2020). Furthermore, competition for resources like water and nutrients among teak trees and companion plants may limit biomass output (Kabiri *et al*., 2019). When plants are cultivated together, competition for water and nutrients can occur due to their overlapping root systems, leading to decreased availability of these resources for individual plants (Kesuma *et al*., 2020). This competition intensifies under conditions of limited water and nutrient supply, resulting in reduced growth and productivity (Emmyzar, 2004). Furthermore, the competitive interactions between plants may trigger physiological responses such as root proliferation or changes in nutrient uptake strategies to enhance resource acquisition (Hodge, 2004). In addition, the presence of allelopathic substances produced by teak trees may hinder the growth of companion plants, lowering biomass yield (Ekayanti *et al*., 2015).

Conclusion

In conclusion, napier grass cultivar Gama Umami cultivated under shade teak tree forest exhibit morphology characteristic and biomass production that could compete with non-shading cultivation. Napier grass cultivar Gama Umami could be introduce for Silvopasture planting in teak tree forest environment that make sustainable contribution to feed availability.

Conflict of interest

The authors have no conflict of interest to declare. All authors have seen and agreed with the contents of the manuscript.

Acknowledgement

The authors are grateful for support by Ulinuha Farda Qonita Thufaillah, Frista Rizki Nusangga Sribaningrum, Bayu Prasetyo, Mustafa Kamal, and Peoples in Megeri Village for contributing during preparation, investigation, and harvesting.

Author’s contribution

The authors confirm contribution to the paper as follows: study conception and design: Y. S. P., N.U., D.C., B.S., B.W., M.S.H; data collection: M. Z. M; analysis and interpretation of results: M.Z.M., Y.S.P., N.U; draft manuscript preparation: M.Z.M. and Y.S.P. All authors reviewed the results and approved the final version of the manuscript.

References

Anwar, K. 2023. Biomass production and nutrient content of Napier grass cultivars Gama Umami and Mott (*Pennisetum purpureum*) in Petungkriyono Highland Conservation Forest Area, Pekalongan, Central Java. Thesis. Gadjah Mada University. Yogyakarta.

Asbur, Y., Y. Purwaningrum, R. D. H. Rambe, D. Kusbiantoro, D. Hendrawan, and Khairunnisyah. 2019. Plant spacing and shading studies on the growth and potential of *Asytasia gangetica* (l.) t. anderson as a ground cover crop. Journal of Cultivation 18: 969-976.

Bhatt, N., C. Zhang, R. Zhang, S. Chang, and Q. Zhang. 2020. Effect of shading treatments on plant growth and physiology: A review. Acta Ecologica Sinica 40: 83-92.

Dewi, I., Basuni, and Rahmidiyani. 2021. The effect of a combination of concentration and interval of application of eggshell poc on the growth and yield of tomato plants on peat soil. Scientific Article of Tanjungpura University. Pontianak.

Dewi, E. and R. Juliani. 2020. Climatological patterns in pandan coastal waters of central tapanuli district. Einstein Journal 8: 36-41.

Ekayanti, N., Indriyanto, and Duryat. 2015. The effect allelopathy from the trees of earpod wattle, black wattle, and teak to the growth of the seedlings of earpod wattle, black wattle, and teak. Lestari Sylva Journal 3: 81-90.

Emmyzar. 2004. effect of water availability on growth and production of two patchouli clones. Littri Journal 10: 159-165.

Fityandini, P. 2017. Effect of Shade on the Growth of King Grass (*Pennisetum purpupoides*) Planted on Soil from Pine (*Pinus merkusii*) Stands. Thesis. Jendral Soedirman University. Purwokerto.

Fischer, J., B. Brosi, G. C. Daily, P. R. Ehrlich, R. Goldman, J. Goldstein, and H. Tallis, 2017. Should agricultural policies encourage land sparing or wildlife-friendly farming?. Frontiers in Ecology and the Environment 15: 322-328.

Guntur, A. and S. H. Samual. 2021. Leaf count productivity of elephant grass and Bengal grass in silvopastural system in jambola ternate. AGRIMUDA: Agribusiness Media Business and Nature Papua 1: 10-14.

Guntur, A., B. Suwignyo, and N. Umami. 2020. Growth performance of napier grass and benggala grass in silvopastoral system in jambula ternate. Journal of Tropical Animal Research (JTAR) 1: 8-13.

Gintings, A. N. A. and Dahlanuddin. 2019. The Role of Agroforestry for Sustainable Agriculture and Land Management in Indonesia. In Agroforestry for Sustainable Agriculture (pp. 197-216). Springer, Cham.

Gomez, K. A. and A. A. Gomez. 1976. Statistical Procedures for Agricultural Research. Lohn Wiley and Sons, Los Banos.

Haryanti, S. 2010. Effect of different shading on the number of stomata and stomatal porus size of zephyranthes rosea lindl leaves. Bulletin of Anatomy and Physiology 28: 41-48.

Hodge, A. 2004. The plastic plant: root responses to heterogeneous supplies of nutrients. New Phytologist 162: 9-24.

Kabiri, S., F. Malbata, and B. Majnounian. 2019. The effects of forest canopy on understory plant diversity and soil properties in the Hyrcanian forests, Iran. Journal of Forestry Research 30: 587-595.

Kesuma, A., N. Nurmauli, P. B. Timotiwu, and H. Hamim. 2020. Efficiency of urea and land fertilizer in increasing the results of “double row” maize in pump sari plant patterns with soil bean. Journal of Applied Agricultural Research 18: 153-158.

Khodorova, N. V. and M. B. Conti. 2013. The role of temperature in the growth and flowering of geoghytes. Plants 2: 699-711.

Kremen, C., A. Iles, and C. Bacon. 2012. Diversified farming systems: An agroecological, systems-based alternative to modern industrial agriculture. Ecology and Society 17: 44.

Kumar, A., D. Patel, and S. K. Singh. 2020. Impact of Tree Canopy and Soil Moisture Conservation Techniques on Napier Grass (*Pennisetum purpureum*) Productivity under Semi-Arid Conditions. Agroforestry Systems 94: 893-902.

Kottek, M., J. Grieser, C. Beck, B. Rudolf, and F. Rubel. 2006. World map of the Köppen-Geiger climate classification updated. Meteorologische Zeitschrift 15: 259-263.

Mangera, Y. 2013. Growth analysis of wheat plants at several plant densities and inorganic nitrogen fertilizer and compost nitrogen balance. Agricola 3: 102-116.

Muchlish, U., Ma’arif, B., Marimin, and Sobir. 2017. The Role of Agroforestry in Supporting Food Security and Community Welfare in Indonesia. Journal of Tropical Crop Science 4: 1-11.

Muyassir, M. 2012. Effects of spacing, age and number of seeds on yield of paddy rice (*Oryza sativa* L.) Journal of Land Resource Management 1: 207-212.

Permana, P. C., E. E. Nurlaelih, and Ariffin. 2019. Tolerance of three landscape grass species to shade intensity. Journal of Plant Production 7: 1710-1716.

Prasojo, Y. S., M. Kamal, A. R. Sukmana, B. W. Siswoko, N. Umami. 2023. Morphology, Biomass Production, and Nutrient Analysis Four Napier Grass Cultivar (*Pennisetum purpureum*) in Teak Tree Forest Area Megeri Village, Blora, Central Java. BIO Web of Conference 80, 05002.

Poai, N., Y. Mberato, and U. Nopriani. 2019. Effect of shade on the growth of local elephant grass (*pennisetum purpureum*). Agropet Journal 16: 57-61.

Rellam, C. R., S. Anis, A. Rumamba, and Rustandi. 2017. Effect of shade and nitrogen fertilization on morphological characteristics of dwarf Napier grass. Zootek Journal 37: 179-185.

Ricketts, T. H., G. C. Daily, P. R. Ehrlich, and C. D. Michener. 2004. Economic value of tropical forest to coffee production. Proceedings of the National Academy of Sciences 101: 12579-12582.

Rizaqussyihab, M. K. 2018. Effect of Weed Liquid Green Fertilizer on Productivity and Chemical Quality of Taiwan Variety Napier Grass (*Pennisetum purpureum* cv. Taiwan) at Different Cutting Ages. Thesis. Mercu Buana University. Yogyakarta.

Sawen, D. 2012. Growth of elephant grass (*Pennisetum purpureum*) and Bengal (*Panicum maximum*) due to differences in light intensity. Agrinimal Jurnal Ilmu Ternak dan Tanaman 2: 17-20.

Singh, R., R. Kumar, and P. Singh. 2018. Agroforestry Systems: A Sustainable Land Use Option for Enhancing Productivity and Soil Fertility under Rainfed Conditions. Journal of Agroecology and Natural Resource Management 5: 104-112.

Smith, C., J. C. A. Baker, and D. V. Spracklen. 2023. Tropical deforestation causes large reductions in observed precipitation. Nature 615: 270-275.

Suci, C. W. and S. Heddy. 2018. The effect of light intensity in performance of croton plant (*Codiaeum variegetum*). Production Plant Journal 6: 161-169.

Subekti, I., A. Mulyani, and A. W. Jufri. 2020. Agroforestry for Food Security in Indonesia: A Review. In IOP Conference Series: Earth and Environmental Science. IOP Publishing 423: 012086.

Suryanto, P., D. Darusman, and S. Sudirman. 2018. The Role of Agroforestry in Sustainable Land Use and Livelihood Improvement in Indonesia. In Proceedings of the 3rd International Conference on Sustainable Innovation (ICoSI) 2017 (pp. 337-342). Springer, Singapore.

Syukran, M., Y. K. Risna, C. Fadli, K. A. Adam, and S. Zubaidah. 2023. Growth of dwarf napier grass (*Pennisetum purpureum* cv. Mott) with application of liquid organic fertilizer (sheep urine). Jurnal Pertanian CEMARA 20: 73-78.

Tantalo, S., Liman, F. T. Farda, A. K. Wijaya, Y. A. Frastianto, and I. A. Pangestu. 2021. Productivity and nutrient value of several grass species under the shade of rubber trees. Journal of Applied Animal Science 4: 92-97.

Tiryana, T. and M. Mahrup. 2018. Agroforestry Systems for Climate Change Adaptation in Indonesia. In Agroforestry for Climate Resilience and Rural Livelihoods (pp. 165-182). Springer, Cham.

Widodo, S., B. Suhartanto, and N. Umami. 2018. Effect of shading and level of nitrogen fertilizer on nutrient quality of Pennisetum purpureum cv Mott during wet season. IOP. Conf. Series: Earth and Environmental Science 247: 012007.

Wijaya, A. K., Muhtarudin, Liman, C. Antika, and D. Febriana. 2018. Productivity of forage grown in the shade of oil palm trees with mixed crops. Scientific Journal of Integrated Animal Husbandry 6: 155-162.