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Original Paper

The Influence of Shade on the Growth and Production of Butterfly Pea Plants (*Clitoria ternatea* L.)

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***Abstract*— Butterfly pea (*Clitoria ternatea* L.) is a medicinal plant known for its anthocyanin pigment content, which imparts a blue color to its flowers. This study aimed to evaluate the influence of shading on butterfly pea flower growth and production. The research design utilized a randomized complete block design (RCBD) for shading treatments. We replicated each treatment level four times, resulting in 20 experimental units, each containing four plants, for a total population of 80 plants. We conducted the experiment at the Experimental Garden of Gunadarma University Campus F7, implementing shade nets at different intensity levels (55%, 65%, 75%, and 85%), along with a control treatment without shading. We made observations on various plant growth parameters such as leaf count, plant length, days to first flower appearance, flower count, fresh weight, and dry weight. The results indicated that shading significantly influenced butterfly pea plants' growth. Plants without shading tended to exhibit better growth in several parameters, such as increased leaf count, higher plant length, and earlier days to first flower appearance. These findings underscore the importance of sunlight in supporting the growth and production of butterfly pea plants. Therefore, careful consideration of shade management is essential in agricultural practices to ensure optimal growth and maximum yield from butterfly pea plants.**

Keywords—Butterfly Pea, *Clitoria ternatea*, Plant Biomass, Plant Growth, Shading

I. INTRODUCTION

Butterfly pea (*Clitoria ternatea*) originates from Central America and has spread to tropical regions since the 19th century, particularly in Southeast Asia, including Indonesia [1]. It has been extensively cultivated in Indonesia, particularly in areas such as Depok, Bogor, Bandung, and other locations. Butterfly peas are not only ornamental plants and natural colorants, but they also offer significant health benefits and can be used as animal feed. Several countries have integrated butterfly pea into various food and beverage products, including Thailand, Malaysia, South America, and Singapore [2]. Some studies have indicated that butterfly pea has medicinal properties due to its phenol and anthocyanin content [3]. Its natural anthocyanin content is responsible for the blue-to-purple color of the flower's corolla. According to [1], butterfly pea also exhibits inhibitory properties against the growth of certain bacteria, such as *Pseudomonas aeruginosa*, *Bacillus subtilis*, and *Aeromonas formicans*, making it intriguing for exploration and research, especially in the fields of medicine and the food industry as a colorant. The demand for natural antioxidants is increasing as synthetic antioxidants have undesired side effects, such as allergies, asthma, inflammation, headaches, decreased consciousness, and disturbances in the eyes and stomach [4].

Butterfly pea (*Clitoria ternatea* L.) is a plant known for its high anthocyanin content, which is a compound with significant antioxidant activity [5]. Research also indicates that butterfly pea extract exhibits significant antibacterial activity [6]. Furthermore, butterfly pea has the potential to act as an antifungal against several types of pathogenic fungi [7]. The anthocyanin content in butterfly pea also presents potential as an antihypertensive agent [8]. Moreover, butterfly pea also holds promise as a traditional medicinal plant with various health benefits, such as antidiabetic, anti-inflammatory, and analgesic properties [9].

In addition to its aesthetic value as an ornamental plant, butterfly pea also offers potential as a source of antioxidant, antibacterial, antifungal, and antihypertensive compounds for various health and food applications. Because of these worries, scientists need to look into how shade affects the growth and yield of butterfly pea plants (*Clitoria ternatea* L.). They want to find out more about the bioactive anthocyanin compounds and plant biomass that haven't been studied yet.

Shade has a significant impact on plant growth and biomass. A study by [10] demonstrated that different levels of shade can influence the growth characteristics and biomass of Dayak onion plants. Furthermore, research by [11] highlighted that shade can increase specific leaf area (SLA) and chlorophyll content but decrease photosynthetic capacity in certain plants. Additionally, a study by [12] showed that shade and manure significantly affect the fresh biomass production of Trichanthera gigantea plants. This emphasizes that environmental factors, such as shade, can significantly influence plant biomass production.

Research on the impact of shade on the vegetative and generative growth is necessary to investigate the growth and production of these plants.

II. Materials and Methods

A. Time and Location of the Study

From February to June 2021, Gunadarma University experimental garden, F7 Ciracas, served as the research site.

B. Research Design

This study employed a randomized complete block design (RCBD) with shade treatments. We replicated each treatment level four times, resulting in 20 experimental units, each containing four plants. The total population consisted of 80 plants. The tested treatments included shading, with five levels as follows:

N0 = without shading

N1 = 55% shade net

N2 = 65% shade net

N3 = 75% shade net

N4 = 85% shade net

C. Procedures

Data collection involved preparing planting media for butterfly pea seedlings in seedling trays with a mixture of compost and soil. We soaked the seeds, selected those that sank, and sowed them in the seedling medium. After two weeks, we transplanted the seedlings into polybags and regularly watered, fertilized, and weeded them. We conducted preventive pest and disease management. We installed shade nets two weeks after planting and began flower harvesting at three months of age. We obtained primary data by directly measuring various parameters, including light intensity, plant height, leaf count, days to first flower emergence, number, fresh and dry weight of flowers, and the fresh and dry weight of plants.

D. Data Analysis

SAS Software version 9.1 analyzed the data using analysis of variance (ANOVA). We conducted Duncan's Multiple Range Test (DMRT) at a significance level of less than 5% if the analysis revealed significant differences among treatments [13].

III. Results and Discussion

A. General Conditions

The research preparation began with soil collection from the Experimental Garden at Campus F7, which would serve as the planting medium. This medium was then homogenized with compost at a ratio of 3:1. The seeds used in this study were obtained from butterfly pea plants originating from Bojong Gede, Bogor. Before planting, the butterfly pea seeds were soaked for 1 hour. After soaking, the seeds were planted in seedling trays filled with a mixture of soil and compost that had been homogenized. Subsequently, the trays were placed in the nursery. Shoots on butterfly pea seeds typically emerged at 5 days after planting (DAP), and the plants could be transplanted to the experimental garden when their length reached between 17 – 22 cm. Before transferring the plants to the experimental garden, the land was sprayed with the herbicide gramoxone to eliminate weeds growing in the area.

Climatological observations at the Gunadarma University experimental garden, Campus F7, included air temperature, air humidity, and light intensity. The average air temperature in the experimental garden with shading treatments ranged from 28.47 to 37.10 °C, with average air humidity ranging from 76.47 to 96.43%, and average light intensity ranging from 9340 to 75833 lux. Meanwhile, in the experimental garden without shading, the average air temperature ranged from 26.63 to 34.27 °C, with average air humidity ranging from 54.17 to 91.67%, and average light intensity ranging from 2345 to 37560 lux. Observations of plant length and leaf count were conducted at 1 Week After Planting (WAP).

B. Data Analysis

1) Leaf Count

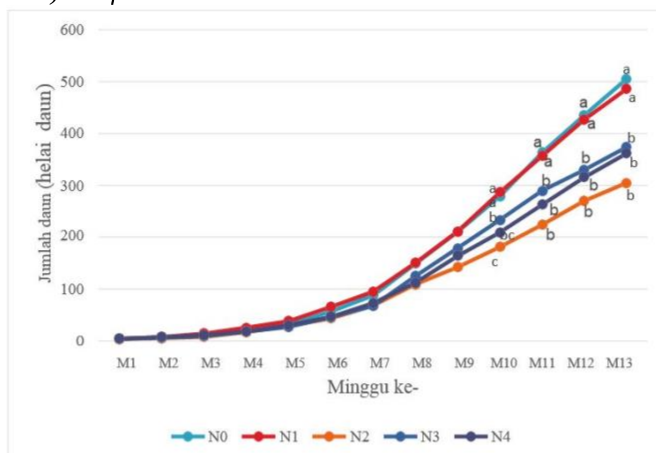

Fig 1. Effect of Shading on the Number of Leaves of *Clitoria ternatea* Plants during 13 Weeks After Planting (WAP)

Figure 1 illustrates how frequently plant development is characterized by the leaf count, an important indicator of plant growth [14]. The impact of shading on the leaf count of butterfly pea plants was noticeable from early observations at 1 Week After Planting (WAP) and persisted until 13 WAP. According to the analysis of variance, shading treatments significantly influenced the leaf count of butterfly pea plants at 13 WAP. The number of leaves in treatments without shading (505.00 leaves) and with 55% paranet shading (485.75 leaves) was higher than in treatments with shading of 65% paranet (304.75 leaves), 75% paranet (373.50 leaves), and 85% paranet (361.50 leaves) at the 13th week of WAP. This suggests that butterfly pea plants require optimal lighting for leaf count growth. According to [15], the use of low light intensity shading, such as 65% paranet shading, resulted in fewer leaves compared to other treatments. Sunlight intensity impacts plant growth; reduced sunlight intensity may lead to a decrease in leaf count, while higher sunlight intensity leads to more leaves produced [16]. Increased sunlight intensity serves as the primary energy source for photosynthesis [17], stimulating optimal plant growth, which aligns with the assertion [18] that the number of leaves reflects the plant's potential to facilitate photosynthesis. Plants cultivated under shade exhibit lower assimilation yields compared to those grown under optimal sunlight conditions.

2) Plant Length

From week 1 to week 13 of WAP, we can observe the effect of shading treatments on the growth of butterfly pea plant length (Figure 2). The graph shows that shading with 75% paranet resulted in the highest plant length compared to other treatments, as depicted in the following figure 2.

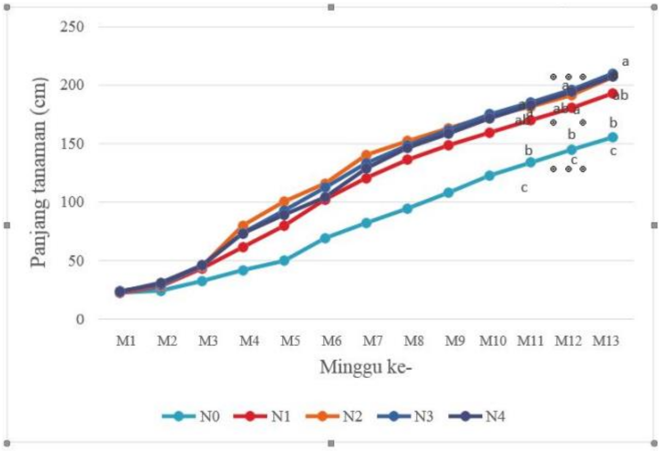

Fig 2. Graph of the Effect of Shading on *Clitoria ternatea* Plant Length over 13 WAP

Butterfly pea plants consistently exhibited increased plant-length growth until the final observation at 13 WAP. According to the variance analysis, shading significantly influenced plant length growth at 13 WAP. The highest average plant length of butterfly pea plants at 13 WAP was 210.21 cm under 75% paranet shading.

We often observe plant length, a crucial parameter in plant growth, as an indicator of growth and response to the environment or applied treatments. Each week, we measured the plant length from the base of the stem to the tip of the leaf. Butterfly pea plants continued to increase in length from the beginning to the end of the observation period at 13 Weeks After Planting (WAP) (Figure 2). Analysis of variance showed that shading had a significant effect on butterfly pea plant length. The 75% paranet shading resulted in the highest plant length, 210.21 cm, while the lowest length occurred in the treatment without shading, 155.59 cm, at the 13th week of WAP. This indicates that the stems of butterfly pea plants under 75% paranet shading experienced etiolation due to only 25% receiving sunlight, leading to increased auxin hormone that inhibits plant shoot growth [18], consistent with [19] statement on reduced root growth and etiolation symptoms under low light intensity.

3) First Flowering Day

The day of the first flowering of butterfly pea plants was measured when the plants first bloomed. Based on the analysis of variance, shading significantly influenced the first flowering day, with the unshaded treatment resulting in earlier flowering compared to other treatments, as shown in Table 1.

TABLE I. EFFECT OF SHADING ON THE FIRST FLOWERING DAY OF BUTTERFLY PEA PLANTS

Treatment	First Flowering Day (Days After Sowing, DAS)
N0	61.50 d
N1	62.94 cd
N2	71.06 a
N3	65.75 bc
N4	67.31 b

Note: Numbers followed by the same letter within the column and the same treatment indicate no significant difference based on DMRT at the 5% level, DAS = Days After Sowing.

The day of flower emergence is a crucial parameter for assessing the speed at which plants reach the generative stage. The analysis of variance indicates that shading has a significant impact on the day of first flower emergence (Table 1). Unshaded plants exhibit accelerated flower emergence, with an average time of 61.50 DAS (Days After Sowing) faster than other treatments. According to [20], providing high light intensity can increase photosynthesis rates, expediting the flowering process. However, [21] offers a different perspective, stating that shaded plants experience more ideal temperature conditions for generative development, which may accelerate the flowering process and affect the number of flowers.

4) Number of Flowers, Fresh Flower Weight, and Dry Flower Weight

The treatment without shading affects the growth values of the number of flowers, fresh flower weight, and dry flower weight. We conducted harvest observations of *Clitoria ternatea* flowers during their full bloom, which allowed for 25 consecutive days of harvesting. Table 2 displays the averaged data results.

TABLE II. THE INFLUENCE OF SHADE ON BUTTERFLY PEA HARVEST OVER 25 DAYS

Treatment	Harvesting Butterfly Pea Flowers		
	Number of Flowers (Flower)	***Fresh Weight of Flowers (g)***	***Dry Weight of Flowers (g)***
N0	65.25 a	29.85 a	4.53 a
N1	61.59 a	29.27 a	2.47 a
N2	22.75 c	11.82 c	1.74 b
N3	47.00 ab	20.22 b	3.04 a
N4	40.00 cb	18.27 ab	2.70 b

Note: Numbers followed by the same letter within the column and the same treatment indicate no significant difference based on DMRT at the 5% level, DAS = Days After Sowing.

We conducted observations on flower quantity, fresh weight, and dry weight over a series of harvests spanning 25 consecutive days. Analysis of variance reveals that shading significantly influences these parameters (Table 2). Unshaded plants produce the highest flower quantity, fresh weight, and dry weight. High light intensity in the unshaded treatment increases flower quantity to 65.25 g.plant-1 compared to shaded plants. This is due to the fact that high light intensity stimulates flowering through an increased photosynthetic energy supply. [22], which asserts an increase in flowering with higher light intensity, supports this finding. Unshaded plants also produce the highest dry weight of flowers, 29.85 g.plant-1, while plants under 65% paranet shading exhibit the lowest dry weight of flowers (Table 9). An increase in the dry weight of flowers only occurs when the light intensity received by plants exceeds the respiration rate, allowing for more photosynthesis than respiration. [20] also confirms this finding, stating that unshaded plants yield more flowers, whereas shaded plants receive insufficient light for photosynthesis, leading to fewer flowers.

5) Pod Quantity

Unshaded treatments affect the pod production of *Clitoria ternatea* compared to other treatments. Plants at 13 DAP underwent observations on pod quantity, as presented in Table 3.

TABLE III. THE EFFECT OF SHADING ON THE NUMBER OF PEA PODS OF BUTTERFLY PEA PLANTS AT 13 MST

Treatment	Harvest
	Number of Pods per Plant (pods)
N0	61.50 d
N1	62.94 cd
N2	71.06 a
N3	65.75 bc
N4	67.31 b

Note: Numbers followed by the same letter within the column and the same treatment indicate no significant difference based on DMRT at the 5% level, DAS = Days After Sowing.

We measured the variable pod count in this study by counting the total number of pods formed on plants aged 13 WAP, including both green and brown pods. Analysis of variance indicates that shading did not significantly affect pod growth (Table 3). Treatment with 65% paranet shading resulted in fewer pods, at 7.67 g.plant-1, compared to other treatments. This finding is consistent with the research by [23], demonstrating that insufficient light can reduce pod formation. [24] also pointed out that shading has an impact on plant metabolism, which in turn influences pod formation. The presence of low light can reduce the supply of assimilates to seed parts, resulting in a decrease in pod filling. Similarly, [23] found that insufficient light can reduce pod numbers and yield. Shading intensity also affects seed yield, as observed by [25].

6) Fresh Weight of Plants

Observations on plant fresh weight include leaf, stem, root, and pod weight harvested from plants at 13 WAP. The shading treatment at 13 WAP influenced the fresh weight of leaves, stems, and flowers. The shading treatment at 13 WAP did not affect the fresh weight of roots, but the 55% paranet shading treatment had the highest fresh weight of leaves and stems compared to other treatments. Treatments without shading had the most fresh weight of roots and pods compared to other treatments, as shown in Table 4.

TABLE IV. THE INFLUENCE OF SHADE ON BUTTERFLY PEA HARVEST OVER 25 DAYS

Treatment	Fresh weight of plants (g.plant-1)			
	Leaf (g)	***Stem (g)***	***Root (g)***	***Pod (g)***
N0	182.77 ab	151.97 ab	31.80 a	94.35 a
N1	200.67 a	173.29 a	24.75 b	73.77 b
N2	127.99 b	91.10 c	10.99 d	7.39 c
N3	161.44 ab	138.48 ab	16.47 c	13.54 c
N4	129.94 b	115.33 bc	15.81 c	14.59 c

Note: Numbers followed by the same letter within the column and the same treatment indicate no significant difference based on DMRT at the 5% level, DAS = Days After Sowing.

The measurement of plant fresh weight includes leaf, stem, root, and pod fresh weight per plant at the age of 13 WAP. The analysis of variance indicates that shading has a significant effect on plant fresh weight (Table 4). The 55% paranet shading treatment resulted in the highest leaf fresh weight, 200.67 g.plant-1, indicating a high leaf count. This treatment also provided the highest stem fresh weight, 173.29 g.plant-1, due to stem elongation.

Treatment without shading yielded the highest root fresh weight, 31.80 g.plant-1, due to optimal water and nutrient absorption in plants exposed to full sunlight, consistent with the views of [26]. Shading also resulted in the highest pod fresh weight, 94.35 g.plant-1. The decrease in pod or seed weight due to shading occurs because of the limited solar energy available for photosynthesis in shaded plants, as suggested by [26].

7) Dry Weight of Plants

Plant dry weight observations include the dry weight of the leaves, stems, roots, and pods of plants dried in an oven dryer. Shading treatment at 13 WAP influenced the dry weight of leaves, stems, and flowers. The shading treatment at 13 WAP did not affect the fresh weight of roots and pods, but the 55% paranet shading treatment had the highest dry weight of leaves and stems compared to other treatments. Treatments without shading had the highest dry weight of roots and pods compared to other treatments, as shown in Table 5.

TABLE V. THE INFLUENCE OF SHADE ON BUTTERFLY PEA HARVEST OVER 25 DAYS

Treatment	Dry weight of plants (g.plant-)			
	Leaf (g)	***Stem (g)***	***Root (g)***	***Pod (g)***
N0	52.17 ab	42.40 ab	11.17 a	69.33 a
N1	61.07 a	50.53 a	8.13 b	60.00 a
N2	26.53 c	23.83 c	3.33 c	7.67 b
N3	39.40 cb	33.27 cb	4.60 c	16.33 b
N4	41.37 cb	29.87 c	4.37 c	12.67 b

Note: Numbers followed by the same letter within the column and the same treatment indicate no significant difference based on DMRT at the 5% level, DAS = Days After Sowing.

Measurement of plant dry weight, including leaves, stems, roots, and pods per plant at 13 WAP, indicates that shading significantly affects plant dry weight (Table 5). The 55%

paranet shading treatment resulted in the highest dry weights of leaves and stems, 61.07 g.plant-1 and 50.53 g.plant-1. In the treatment without shading, the highest dry weight of roots reached 11.17 g.plant-1, while in the 65% paranet shading, the lowest root dry weight was 3.33 g.plant-1. Treatment without shading also yielded the highest pod dry weight, 96.33 g.plant-1, whereas in the paranet shading treatment, the lowest pod dry weight was 7.67 g.plant-1, related to pod number and fresh weight, as demonstrated by [27].

IV. Conclusion

This study aimed to evaluate the effect of shading on *Clitoria ternatea* growth and yield. The results indicate that shading significantly influences *Clitoria ternatea* is growth and yield. Shaded plants tend to have lower growth compared to unshaded plants, especially in terms of leaf count, plant length, and flower production. Additionally, unshaded plants tend to flower earlier and produce a higher pod count, fresh weight, and dry weight. These findings emphasize the importance of sunlight in supporting *Clitoria ternatea* is growth and yield. In agricultural practices, shade management should be considered to maximize the harvest yield and quality of *Clitoria ternatea* plants.

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