

Morphological Traits of Brazilian Spinach (*Alternanthera sissoo*) on Different Shading intensities and Organic Fertilizer

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Abstract: Environmental growth will have an impact on plant morphology. This condition also involves shading and nutrient availability for Brazilian spinach as an introduced leafy vegetable. The study aimed to evaluate Brazilian spinach growth and yield on different shading intensities and organic fertilizers. The study adopted a split-plot design with artificial shading intensities (0%, 50%, and 70%) as the main plot and the type of organic fertilizer (guano, vermicompost, liquid organic fertilizer) as the subplot. The results showed that Brazilian spinach could adapt to canopy areas. However, the Brazilian spinach growth was dominant in a no-shade environment (S0). It was evident by shoot fresh weight (SFW), stem dry weight (SDW), branch dry weight (BDW) and leaf dry weight (LDW). Guano fertilizer (F1) was an organic fertilizer that increased the observed variables, including canopy growth, nutrient and water absorption ability and absolute growth of Brazilian spinach. Although the shoot-root ratio for each single treatment did not show a significant effect. There was a significant interaction between shade and organic fertilizer in Brazilian spinach growth for all morphological traits including shoot-root ratio. Generally, leaf growth was a positive correlation to stem ($R^2 = 0.9918$), branches ($R^2 = 0.7258$) and shoots ($R^2 = 0.9105$). In conclusion, the most suitable growing environment for Brazil spinach growth and yield is in no-shading areas, while guano fertilizer application is recommended to be selected to enhance Brazil spinach growth and yield.

Keywords: cultivated procedure; environment adaptation; morphological trend; tropical plant; suitable substrate

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1. INTRODUCTION

Brazilian Spinach (*Alternanthera sissoo*) is an introduced leafy vegetable yet to be widely cultivated in Indonesia. Brazilian spinach contains antioxidants and other compounds that benefit human health (Sommai et al. 2021). Meanwhile, Brazilian spinach has a perennial plant that allows harvested repeatedly. Limited space becomes several problems, including in cultivation activities. It requires an alternative

to carrying out cultivation activities in narrow spaces, especially concerning plant adaptation under shading and adequate nutrition by fertilizer application. (Ellya et al. 2021) reported that Brazilian spinach has the potential to be cultivated in narrow spaces through vegetative propagation by stem cuttings and can be cultivated in narrow areas.

Applying organic fertilizers can trigger Brazilian spinach growth and improve morphological traits. Sani and Awang (2021) reported that adding organic matter could increase Brazilian spinach growth in limited media. The effect of adding organic matter on plant growth has occurred in leafy vegetables such as spinach (Pyakurel et al. 2019), lettuce (Durak et al. 2017) and pakcoy mustard (da Silva et al. 2019).

Shading is a limiting factor in cultivation in limited spaces. This condition was related to the light portion for carrying out metabolic processes. However, some plants were indicated to be able to have low light. It was happened to leaf celery (Lakitan et al. 2021), basil (Niazi et al. 2022) and cabbage (Daniel et al. 2022).

Research related to shade adaptation with the selection of organic fertilization has yet to be carried out extensively, especially on Brazilian spinach. This is mainly associated with morphological traits that differ from other leafy vegetables. Shade considerations and selection of type organic fertilization will obtain organic spinach potential to be cultivated in narrow areas and suboptimal land. The research aims to determine the adaptation of Brazilian spinach to shade, the type of organic fertilization and its interaction to Brazilian spinach morphology traits.

play a crucial role in the immune system. These leukocytes are divided into two groups: the first group functions in innate immunity, including macrophages, neutrophils, eosinophils, and dendritic cells, collectively known as antigen-presenting cells (APCs).

2. MATERIALS AND METHODS

The research was conducted in June to August 2022 in Indralaya (3°13'23"S-104°38'49"E), South Sumatra, Indonesia.

Research procedure

Preparing planting materials and planting media

The planting material was stem cuttings derived from healthy mother plants. The stem cuttings have 2 leaves, 5 cm in length and 4 buds. The planting material was planted in plastic pots sized 5 kg (v) filled with topsoil as planting media. Each planting material was planted with 2 buds above and ground one of the planting media.

Treatment application

All plant was arranged by a split-plot design. Shade intensity was the main plot and the kind of organic fertilizer was a sub-plot.

Shading intensity consist of 0%, 50% and 70% shading, symbolized by S0, S1 and S3, respectively. Meanwhile, type of organic fertilizer consists of guano (F1), vermicompost (F2) and liquid organic fertilizer (F3). The shading made from polyethylene terephthalate (PET) with density according the treatment.

The organic fertilizer was applied at a dosage of 10 g/plant for guano, 25 g/plant for vermicompost and 100 ml/plant for liquid organic fertilizer. The guano and vermicompost was solid fertilizer that applied by showing. Meanwhile, the liquid organic fertilizer was applied by sprayed with concentration 2 ml/L.

Each organic fertilizer contains different nutrients. The guano containing 8.98% N, 2.76% P and 1.03% K (Midwest Laboratories). The vermicompost containing 1.54% N, 0.64% P and 6.31% K (Mahmud et al. 2020). While, the liquid organic fertilizer containing 4.15% N, 4.45% P and 5.66% K (Prizal and Nurbaiti 2017).

The application was carried out weekly, starting at 2 weeks after planting (WAP) to 7 WAP.

Data collection

The data collected consist of weekly and destructive observation. The weekly da-

ta such as canopy area growth starting 2 WAP to 8 WAP. Meanwhile, the destructive observation was carried out at 8 WAP. The destructive data consist of leaf fresh weight (LFW), leaf dry weight (LDW), branch fresh weight (BFW), branch dry weight (BDW), stem fresh weight (SFW), stem dry weight (SDW), root fresh weight (RFW) and root dry weight (RDW).

The canopy area was measured using easy leaf area (Easlon and Bloom 2014). On the other hand, dry weight was dried by oven 70°C for 48 hours.

Statistical analysis

All data was analysed with analysis of variance (ANOVA). Furthermore, the significance difference on treatment was analysis with LSD ($p < 0.05$). The analysis using Rstudio software version 1.14.1717 for Windows developed by Rstudio team, PBC, Boston, MA. The regression analysis was carried out to determine the relationship between selected variables with strength level showed by coefficient determination (R^2).

3. RESULTS AND DISCUSSION

Brazilian spinach growth

Brazilian Spinach has continued growth shown by the canopy indicator, which follows an exponential trend. The canopy growth was indicated up to 8 WAP. Although the canopy grew between treatments, shading showed a low significance level. It was indicated that shading intensities did not affect to Brazilian spinach canopy growth. In contrast, related to the organic fertilizer applied, the growth response of the Brazilian spinach canopy occurred significantly, especially starting at 3 WAP until the end of the observation (Figure 1).

Some leafy vegetables can adapt to shading conditions, especially regarding leaf growth, which is the main component of the plant canopy. Rezai et al. (2018) reported that a 30% shading on *Salvia officinalis* could adapt to increasing the leaf number. Red let-

tuce also revealed that 35% shading could increase the leaf length. Meanwhile, applying fertilization using organic matter on leafy vegetables showed a rapid response to leaf growth. Ju et al. (2022) reported that leafy vegetables such as lettuce and chicory could trigger the number of leaves and the canopy area will improve more.

Applying organic guano fertilizer (F1) proved to be the best type of organic fertilizer capable of increasing the canopy growth. The F1 provides an adequate nutrient content essence positive impact on leaf growth. Kim et al. (2019) reported that applying guano fertilizer significantly improves canopy growth by increasing leaf area. On the other hand, it takes time for the interaction of shading intensities and organic fertilizer significantly. This interaction started at 4 WAP with 0% shading (S0) and F1 was confirmed as the best interaction.

Paciullo et al. (2017) reported that leaf growth was affected by the interaction of shading and fertilization. Bande et al. (2013) confirmed that the interaction between shading intensities and fertilization occurs and impacts leaf area expansion.

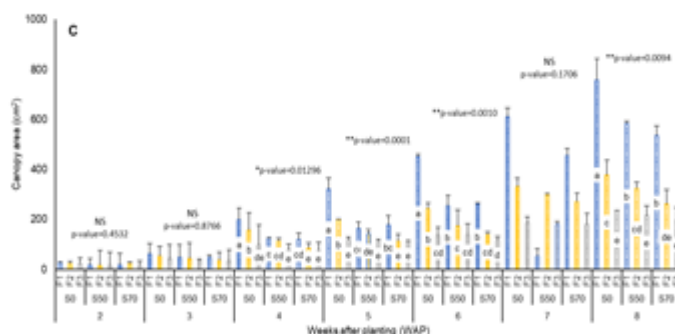


Figure 1. Canopy area growth on different shading (A), organic fertilizer (B) and interaction between treatment (C). The shading intensity consist of 0% shading (S0), 50% shading (S50), 70% shading (S70) and the organic fertilizer consist of guano (F1), vermicompost (F2), liquid organic fertilizer (F3).

The Brazilian spinach shoot fresh weight could reflect each plant organ's

growth ability. There was a tendency for 0% shade (S0) to be the highest shoot fresh weight. Brazilian spinach is among the leafy vegetables that are intolerant of shaded environments. Muda et al. (2024) reported that Brazilian spinach growth was inhibited at several shade densities tested. Several leafy vegetables have also been confirmed to experience stunted growth such as Swiss chard (Ria et al. 2023), Indian spinach, and red amaranth (Habib et al. 2020). Meanwhile, the type of organic guano fertilizer (F1) can trigger plants to grow well, evidenced by the shoot fresh weight being significantly different from vermicompost (F2) and liquid organic fertilizer (F3) (Figure 2).

The growing substrate directly contributes to the Brazilian spinach growth ability. Growing substrate applied guano organic fertilizer can improve substrate

plant growth. Dimande et al. (2023) revealed that guano is classified as an organic fertilizer that can provide nitrogen and phosphorus quickly. Some plants such as carrot (Poliquit and Calong 2018), chilli (Mulia et al. 2024), porang (Purnama et al. 2023), and tomato (Korn et al. 2023) have been shown to have a positive impact after being applied guano organic fertilizer. The interaction between shading intensity and organic fertilizer confirmed this condition. Applying organic guano fertilizer (F1) in a no-shade environment (S0) was a combination of interactions to trigger the Brazilian spinach growth.

The plant's fresh weight shows growth ability and plant metabolism role carries out. Sim et al. (2021) stated that the kimchi cabbage plant was a leafy vegetable that experienced increasing growth indicated by shoot fresh weight. Furthermore, Muda et al. (2024) reported that *Sedum zokuriense* showed adaptability to 65% shade which was indicated by shoot fresh weight.

An adequate nutrient content causes plants to play a role by increasing fresh

weight. Ria et al. (2023) reported that applying organic matter would increase the planting media nutrient content, increasing shoot fresh weight. In this regard, guano has sufficient nutrient content, which triggers nutrients and water absorption.

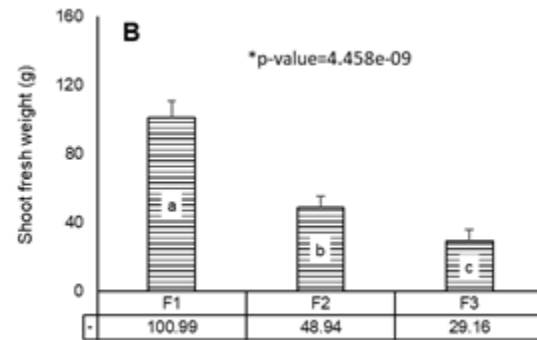


Figure 2. Shoot fresh weight on different shading (A), organic fertilizer (B) and interaction between treatment (C). The shading intensity consist of 0% shading (S0), 50% shading (S50), 70% shading (S70) and the fertilizer consist of guano (F1), vermicompost (F2), liquid organic fertilizer (F3).

The Brazilian spinach canopy appearance was different in each treatment. The interaction of S0 (no-shading) and F1 (guano) showed a compact canopy. This phenomenon indicated that the branch and leaf growth was higher than in other treatments (Figure 3). The increasing photosynthetic rate in S0 and supported by nutrients provided by F1 caused the growth of leaves and branches to increase. Yusof et al. (2021) reported that the photosynthetic rate in the unshaded environment was higher than the shaded one. Photosynthesis products play an important role in plant growth including leaf and branch. Meanwhile, nutrients provided by guano also promote plant growth. Kumar et al. (2021) stated that there was an interaction of macro and micro nutrients that were very important for plant growth.

Brazilian spinach root growth was seen to differ between each treatment. The

interaction of S0 and F1 impacts increasing root growth, especially on root hair. The S0 creates a suitable growing environment for roots to grow. Meanwhile, adequate nutrition on F1 allows root growth not to elongate but improves root hair (Figure 4). This phenomenon is similar to Muda et al. (2024) that shading inhibited Brazilian spinach root growth. Meanwhile, root growth performance is also affected by the adequacy of nutrients in the growing substrate (Sathiyavani et al. 2017).

The canopy and root growth as an impact of shading and organic treatment have been reported in several cultivars. Although several cultivars were confirmed to have adapted under shade, purple pakchoy was reported unable to adapt under shade (Habib et al. 2020). It was also reported by Hussain et al. (2021) that plant growth would decrease in shaded conditions indicated by the canopy and root growth.

Applying organic fertilizers, including guano (F1) was also clearly stated to increase the canopy and roots. Poliquit and Calong (2018) reported that adding guano will trigger branches and stems growth as part of the canopy. Mulia et al. (2024) confirmed that adding guano also triggered an improved root volume besides an increase the number and leaf area.

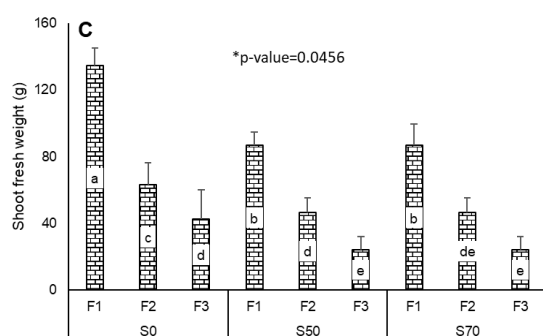


Figure 3. Visual observation of Brazilian spinach canopy on different treatment. The shading intensity consist of 0% shading (S0), 50% shading (S50), 70% shading (S70) and the fertilizer consist of guano (F1), vermicompost (F2), liquid organic fertilizer (F3).



Figure 4. Visual observation of Brazilian spinach root on different treatment. The shading intensity consist of 0% shading (S0), 50% shading (S50), 70% shading (S70) and the fertilizer consist of guano (F1), vermicompost (F2), liquid organic fertilizer (F3).

The absolute growth of Brazilian spinach in each treatment was indicated by plant organ dry weight. Each treatment played a role in the growth of root, branch and leaf. The shading intensities did not improve stem growth. The growth phenomenon is in line Sulistiani et al (2023) who reported that the stem growth of Brazilian spinach was not significant in the different shading compared. However, it was more dominant to the adequacy of nutrients through organic fertilizers treatment (Table 1).

The interaction of S0 and F1 impacts increasing each plant organ growth. This condition proved that treatment improves each plant organ growth and becomes the most dominant except for stem growth.

The Brazilian spinach's absolute growth indicated a photosynthesis role in the treatment applied. Purnama et al. (2023) reported that plants experience a high photosynthetic rate and rubisco enzyme activation in no-shade conditions. However, this condition depended on the plant cultivar. Korn et al. (2023) stated that kaffir lime has active photosynthesis in moderate shade. It was also in line with Sim et al. (2021) that *Passi-*

3Treatment nt	Root dry weight (g)		Stem dry weight (g)		Branch dry weight (g)		Leaf dry weight (g)	
Shading intensity								
S0	9.84	a ^z	1.50		6.37	a	10.08	a
S50	1.66	b	0.99		1.97	b	5.14	b
S70	1.64	b	1.08		1.59	b	4.34	b
Sign.	*		ns		*		*	
p-value	0.01634		0.3311		0.0159		0.0453	
Organic fertilizer								
F1	6.77	a	1.59	a	5.85	a	10.89	a
F2	4.29	b	1.13	b	2.70	b	5.41	b
F3	2.10	c	0.85	c	1.38	c	3.27	c
Sign.	**		*		**		**	
p-value	0.00035		0.00003		0.0000001		0.0000001	
Shading intensity x fertilizer								
S0:F1	16.01	a	2.05		11.78	a	16.83	a
S0:F2	9.07	b	1.45		4.72	b	8.10	b
S0:F3	4.45	c	1.00		2.62	cd	5.30	cd
S50:F1	1.70	cd	1.33		3.47	bc	8.43	b
S50:F2	2.48	cd	0.93		1.68	de	4.50	de
S50:F3	1.10	d	0.70		0.77	e	2.50	ef
S70:F1	2.58	cd	1.40		2.31	cd	7.40	bc
S70:F2	1.31	d	1.00		1.70	de	3.62	def
S70:F3	0.75	d	0.85		0.77	e	2.00	f
Sign.	**		ns		**		**	
p-value	0.0010		0.3625		0.00001		0.00911	

flora has a dominant dry weight in shading than no-shade

The photosynthesis results were also determined by nutrient availability. Chatzistathis et al. (2020) stated that organic fertilizers could be related to physiological activity. Lanna et al. (2018) reported that applying guano can increase the nutrient adequacy in growing media implicated to increase photosynthetic rate indicated by plant dry weight.

The shoot and root ratio reflect the Brazilian spinach growth effectiveness. The interaction of S0 and F1 improved shoot growth and was followed by root growth. This condition causes a drop in shoot and root ratio value. On the other hand, the treatment showed no significant growth effectiveness, respectively (Table 2).

The shoot growth will be followed by root growth due to plant metabolism. A high shoot-root value indicates that the above media dominated growth activity. Yusof et al. (2021) reported that adding fine roots would lower the shoot and root ratio. Shoot-root ratio in interactions between no-shade (S0) and F1 describes the healthy plant condition. According to Kumar et al.

(2021), a balanced shoot-roots ratio indicates an optimum plant healthy.

Table 1. Dry weight of Brazilian spinach organ on different treatments.

^zMean followed the different letters in a column are significantly different (LSD, $p < 0.05$).

Treatment	Shoot and root ratio
<i>Shading intensity</i>	
S0	5.64
S50	4.66
S70	2.26
Significance	ns
p-value	0.18275
<i>Organic fertilizer</i>	
F1	4.72
F2	3.99
F3	3.84
Significance	ns
p-value	0.50489
<i>Shading intensity x fertilizer</i>	
S0:F1	1.92 c ^z
S0:F2	2.31 c
S0:F3	2.55 c
S50:F1	7.92 a
S50:F2	3.01 c
S50:F3	5.97 bc
S70:F1	4.31 bc
S70:F2	6.19 ab
S70:F3	3.47 bc
Significance	*
p-value	0.02494

^zMean followed the different letters in a column are significantly different (LSD, $p < 0.05$).

Brazilian spinach traits

Brazilian spinach shoot organs have specific traits. The leaf was dominant portion on Brazilian spinach shoot. It was confirmed by the high coefficient determination ($R^2=0.9918$). On the other hand, the leaf growth has positively correlation on branch and stem growth with $R^2= 0.7258$ and $R^2= 0.9105$, respectively (Figure 5).

Leaf growth patterns in leafy vegetables are similar. Sathiyavani et al. (2017) reported that branch elongated will be followed by an increasing leaf number. On the other hand, leaf growth in spinach is also followed by stem growth (Fadilah et al. 2022).

4. CONCLUSION

Based on the research, no-shading (0% shading) is a treatment proven to increase the Brazilian spinach growth and yield.

Meanwhile, guano (F1) is an organic fertilizer that is able to stimulate Brazilian spinach growth and yield more optimally than vermicompost (F2) and liquid organic fertilizer (F3). There is a positive correlation between leaf growth and stem ($R^2 = 0.9918$), branches ($R^2 = 0.7258$) and shoots ($R^2 = 0.9105$).

5. CONFLICT OF INTEREST

The authors have declared no conflict of interest exist.

6. ACKNOWLEDGEMENTS

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