

PAPER • OPEN ACCESS

Adaptation of Home Garden-Grown Garut to Light and Organic Fertilizer: Home Garden Initiatives and Practices for Local Food Sustainability

To cite this article: Arry Y Nurhayati *et al* 2025 *IOP Conf. Ser.: Earth Environ. Sci.* **1497** 012001

View the [article online](#) for updates and enhancements.

You may also like

- [Performance of Arrowroot \(*Marantha arundinacea*\) in various light intensities](#)
M B Oktafani, Supriyono, MTh S Budiastuti et al.
- [Effect of various photoperiods towards lollo bionda growth using IoT based lighting control for indoor hydroponic farming system](#)
A M M Shafie, A Azlan, M Z Sariman et al.
- [Sauropus androgynus L. Merr. response to different shades intensities and fertilizer rates](#)
A S Ramadani, J G Kartika and K Suketi

Adaptation of Home Garden-Grown Garut to Light and Organic Fertilizer: Home Garden Initiatives and Practices for Local Food Sustainability

Arry Y Nurhayati^{1*}, Azzizatur Rohmah², Yuda C Hariadi³, M Hasan⁴ and Sigit Soeparjono⁵

^{1,2,3} Physics Department, Faculty of Mathematics and Natural Sciences University of Jember, Indonesia

⁴Mathematics Department, Faculty of Mathematics and Natural Sciences University of Jember, Indonesia

⁵Faculty of Agriculture, University of Jember, Indonesia

*E-mail: arry.fmipa@unej.ac.id

Abstract. Indonesia seeks to increase local food resilience and sustainability in times of uncertainty and crisis such as in pandemics, when there is growing desire to produce food locally escalates. As such, the government has accelerated home garden initiatives and diversification for carbohydrate food sources beyond rice and wheat flour. Garut (*Maranta arundinacea* L.) is an underutilized carbohydrate source grown mostly wild in rural home gardens. Currently, the adaptation of Garut for proper home garden practices is not well understood. In this study, Garut was assessed for light intensity and enrichment with organic fertilizer integration in home garden conditions. Selected plants with uniform growth were treated with variations of light intensities and three variations of organic fertilizer from mixtures of husk, charcoal, rice straw, and cow dung in varying doses. It was found that light intensity had an effect on the total leaf area as well as the dose of fertilizer. In stem diameter growth, light intensity between (37.39 ± 14.73) lux to (13523.036 ± 1184) lux and a fertilizer dose of 150 grams gave optimal results. It is summarized that home garden-grown Garut is adaptable to a variety of light intensities while plant growth was further enhanced with organic fertilizer integration. In addition, the potential of Garut for home garden initiatives and practices is also highlighted in terms of food sustainability.

Keywords: Garut, Home garden, Light intensity, Organic-fertilizer, Sustainability

1. Introduction

The interest in Garut, also known as *Maranta arundinacea* L, has been steadily increasing as evidenced by recent research [1,2,3]. This heightened interest has prompted calls for greater utilization as it is underutilized as a carbohydrate source. Its prospect for high-quality starch and it is competitive with other purposeful flours, offer alternative economical and functional opportunities for healthy food and nutrition. As the need to produce food locally is becoming increasingly apparent, especially in times of global upheaval, government initiatives are needed directly to address this demand. Concurrently, the Indonesian government is supporting local food sustainability by promoting of home garden projects and practices [4]. This commitment also additionally aims to accelerate diversification of carbohydrate food sources [5].



In many different places, both in the wild and under cultivation, Garut has been observed to grow often alongside other plants in agroforestry systems at different altitudes [6,7] However, Garut has been growing in various areas of Jember in home gardens without adequate oversight. To understand the potential benefits of Garut in home gardens, there is a need for proper management of home garden-grown Garut.



Figure 1. Home grown Garut in pots

Home gardens are planned outdoor space used for growing, displaying, and enjoying plants and nature. Home gardens are small areas, typically less than 1 hectare, that surround residential properties and are primarily used by families. During times of crisis local home garden practices help connect producers and consumers by promoting local produce, allowing direct interaction between farmers and consumers [8,9]. This not only strengthens the relationship between producers and consumers but also eliminates the social justice and equity issues that often arise in the wider production and distribution of food. Improving local food resilience during unpredictable and crisis periods, such as pandemics and are closely associated with the UN Sustainable Development Goals (SDGs) [10]. Emphasizing local food production enhances food sovereignty by empowering communities to have greater control over their food sources and fostering a more sustainable and equitable food system.

Home garden grown Garut can present some difficulties with regards to plant selection, growing conditions, fertilizer use, and plant culture methods [11,12]. Managing home garden-grown Garut could lead to better growth performance and easier maintenance. The adaptability of the plant and possibility of growing in home gardens were explored by assessing light intensity and enrichment with organic fertilizer integration. It is well known that using natural materials or products for crop sanitary treatments, organic fertilizers, green and organic additives, and wise irrigation water utilization will lessen adverse environmental effects. Groundwater contamination can arise from the overuse of mineral fertilizers, particularly those containing nitrogen and potassium. Other important issues brought up include pesticide residues and groundwater usage. These adaptability of the plant for home gardens can be understood by planting it in pots or directly in the soil, depending on the size of the home garden.

2. Method

2.1 Sample preparation

Garuts were obtained from local farmers around Sumber Langon, district of Patrang, Jember, East Java Indonesia. The sample plants were grown from the arrowroot under sterilized of sand media. The similarly growth of 45-60 days plant were replanted on the plastic pot which diameter of 20cm x 15 cm, with one plant of arrowroot. Watering was done in around 3-4 days in every week or depend on the condition of the dryness of media. The organic fertilizer was made by mixing of cutting rice straw in about 10-15cm, with charcoal rice husk, Cow manure with composition of 1:1:1 (Figure 2). EM4 was used as activator with addition of sugar for energy source of microorganism. During the process of making organic fertilizer (OF).

The fermentation process took place in around 35 days for a better fermentation process Biochar has been introduced for its capacity in increasing soil fertility and increasing agricultural productivity, and biochar has pushed to mechanism of improving crop growth and nutrient status [13]. By controlling secondary soil salinization, EM may effectively reduce the amount of chemical fertilizer applied, improving the agricultural environment and ensuring the sustainable growth of agriculture [14,15]

2.2 Experimental setting and Measurement

To mimic the home garden, the plants were grown in the plastic with the soil media with the addition of the OF. The seedling plant were adapted to the environmental condition to have similarly grow of plant and placed to the setting area. Four level of intensities were used in this research. Full sun condition, which noted as the I₀, I₁, I₂, and I₃. We used paranet to set a lower intensity, with, i,2 and 3 layers of paranet. The daily of the intensity were measured at time of 7.00, 9.00, 13.00 and 15.00, during the consecutive day for day 1 to day 12, which gave as average of daily intensity and range the intensity for the 12 days. After recultivation, the intensities then measure in the same time with the measurement of other indicator growth, in the same time during the half day.

3. Results and Discussion

3.1 Adaptation of Garut to Intensity



Figure 2. Photograph attributed of part material for organic fertilizer (a) rice straw, (b) charcoal rice husk, (c) cow manure, (d) mixing of material, (e) organic fertilizer

Our first initiation of Garut for home garden were to investigate of the adaptability of Garut on early development, this within 28 days after treatment of the plant. Height of the plant, stem diameter,

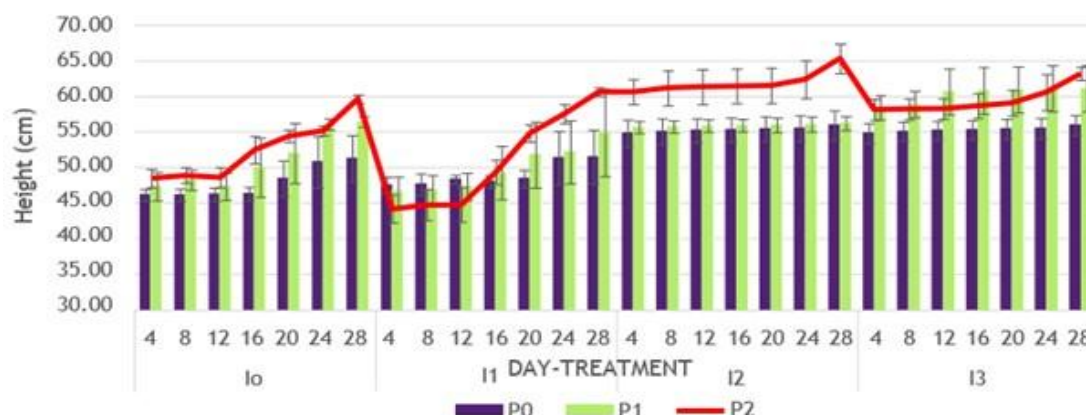


Figure 3. Graph of height with varying level of light and fertilizer of P-1 and P2 (50gr per plant and 150 gr/plant each) and controlled plant P-0 (without addition of organic), during measurement of day 4 to day 28, in every 4 days measurement.

average total leaves area per plant, and appearance of the plant becoming our first concern for their early vegetative growth. On the first graph of the height of plant (Figure 3), during the first two weeks plant has adjusted to their environment of their growth with different respond under different intensity and organic fertilizer dose. It can be seen that under treatment dose of P2 or 150-gram fertilizer per pot, plant growth was enhanced for plant growth under light intensity of I-0, I-1, and I-2. While Garut's height under I-3 have nearly similar value for treatment of P1 and P2 during day 4 to day 24, and increase for day 28.

It can be seen that up to 28 days of early vegetative growth increasing height were observed after day of 16 under treatment of fertilizer of P1 and P2 for plant growth under intensity of I-0 and I-1, compare to controlled plant. Under lower level of I-2 and I-3, the response of increasing growth under fertilizer doses P-2 have been observed increases during day 8, with have dramatically increase at day-28. Increase of height of plant also observed at day-28 for fertilizer doses of P2.

Average total leaves area per plant (Figure 4a) and stem diameter (Figure 4b) both seem have similarly pattern of adaptation to level of light intensity and dose of organic fertilizer. No different of value of total leaves area per plant under lower-level intensity I3 for plant growth under different doses. While there is increasing of both those leaves area and the diameter for plant growth under fertilizer 150gram/plant under intensity leave of I-0 and I-1. The average total leaves area per plant were increases for day 28, under intensity of I-0, with the average total leaves area were in around (173.11 ± 2.84) cm² followed by I-1 of (158.47 ± 4.77) cm², then I-3 of (150.56 ± 4.39) cm² and I-4 of 143.72 ± 4.00 cm² in accordance to ANOVA.

The confirmation of the growth plant data (height, leaves area and stem diameter) was agreed with the appearance of plant in the photograph of Figure 5 for plant growth under the level of intensities and doses of fertilizer. In the photograph showed that plant seemed higher, similarly leaves area and stem diameter. However, plant seemed stronger under intensity of I-0 and I-1. The number of leaves were similar for the plant during this early vegetative time, however, the leaves seemed thinner under low level of intensity. During the early vegetative growth of Garut, we have observed the growth of Garut. We have observed more frequent (in every four days), to have more precise of the plant under the various level of intensity and the adaptation to organic fertilizer.

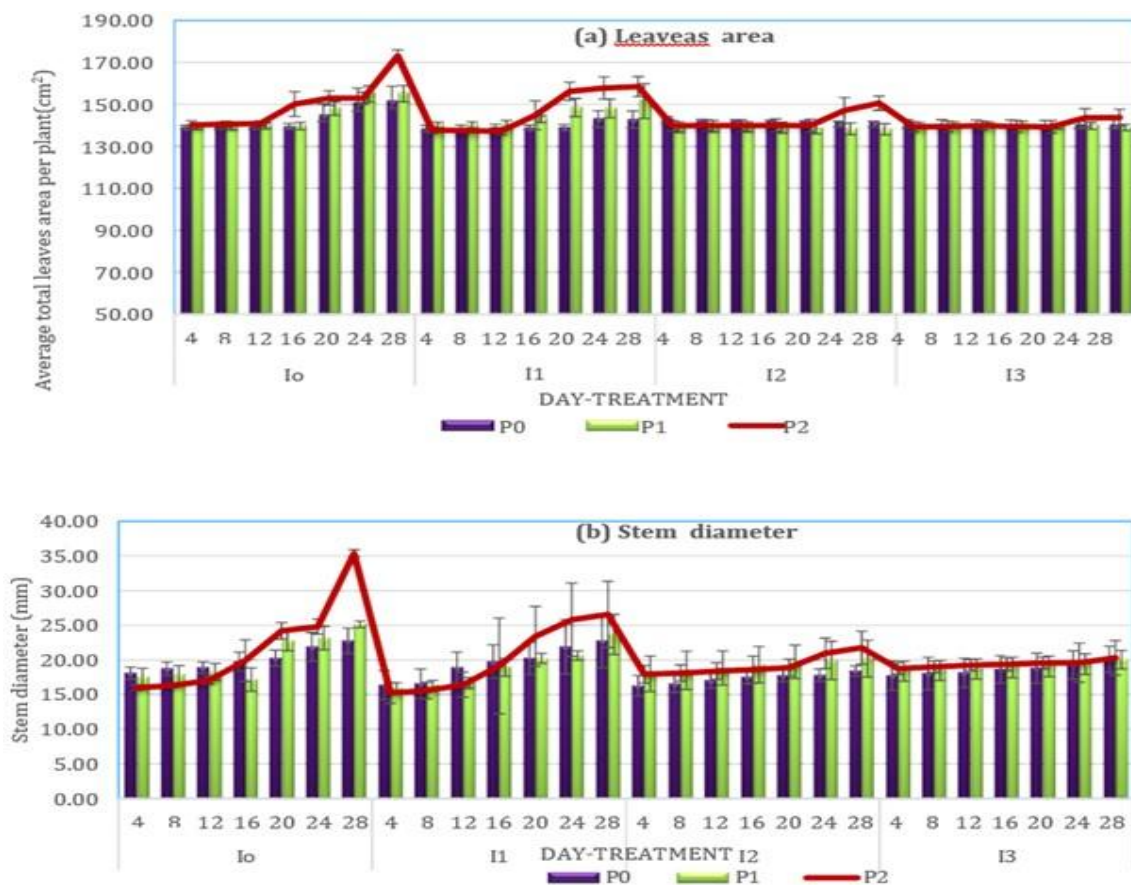


Figure 4. Graph of average total leaves area per plant (a) and stem diameter of Garut plant growth under with varying level of light fertilizer of P-1 and P2 (50gr per plant and 150 gr/plant each) and controlled plant P-0 (without addition of organic), during measurement of day 4 to day 28, in every 4 days measurement.

We summarized of our first initiation that Garut plant has Garut is adaptable to a variety of light intensities, and the organic fertilizer of the level 150gr/plant enhance plant growth. Our found showed that light-intensity had effect on the total leaf area as well as the dose of fertilizer. In stem diameter growth, light- intensity between (37.39 ± 14.73) lux to (13523.036 ± 1184) lux and fertilizer dose of 150 grams gave optimal results. However, Garut have relatively longer period t have adequate tuberous, and also organic fertilizer some kind of slow released fertilizer, also we need for clarification for the day after 28 days for longer the vegetative growth.

3.2 Adaptation of Garut

We need to clarify of the adaptive response of the home garden Garut for more details of the enhancement of organic fertilizer for longer period of vegetative growth. Here we explore for the growth until day of 56 with measurement fortnightly (each 14 days), with starting day of two weeks old plants (day -14), with triplicated of replication.

Plant height and number of leaves have becoming eye catching indicator for visual appearance of plant (Figure 5). Here our measurement of the extension data for Garut has shown that in the Figure 6a for height of plant and Figure 6 b for number of leaves. We have found that the plant growth under P2 have higher of plant in the same growth media. Under lower intensities of I-2 and I-3 plant have height were increase (Figure 6a), however the plant has the lesser number of leaves, i.e. 4 to 5 leaves, compared to 7 to 12 leaves for plants under Intensities I-0 with fertilizer of 150gram/plant (Figure 6b). This showed stagnancy of growth leaves of day 28 (Figure 5) to 56 (Figure 6b).

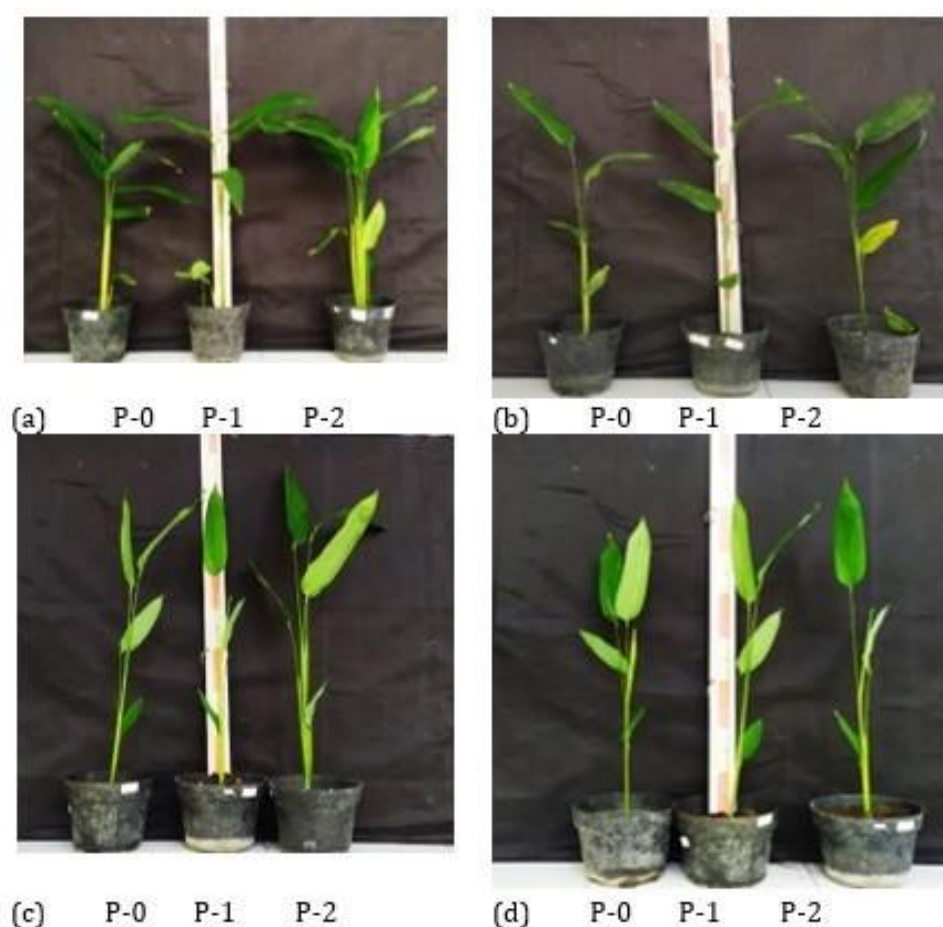


Figure 5. Photograph of plant grown under different level of intensities light of plant grown under composition doses of P-0 (control plant) and doses of organic fertilizer P-1 (50gr/plant) and P-2 (150gr/plant).

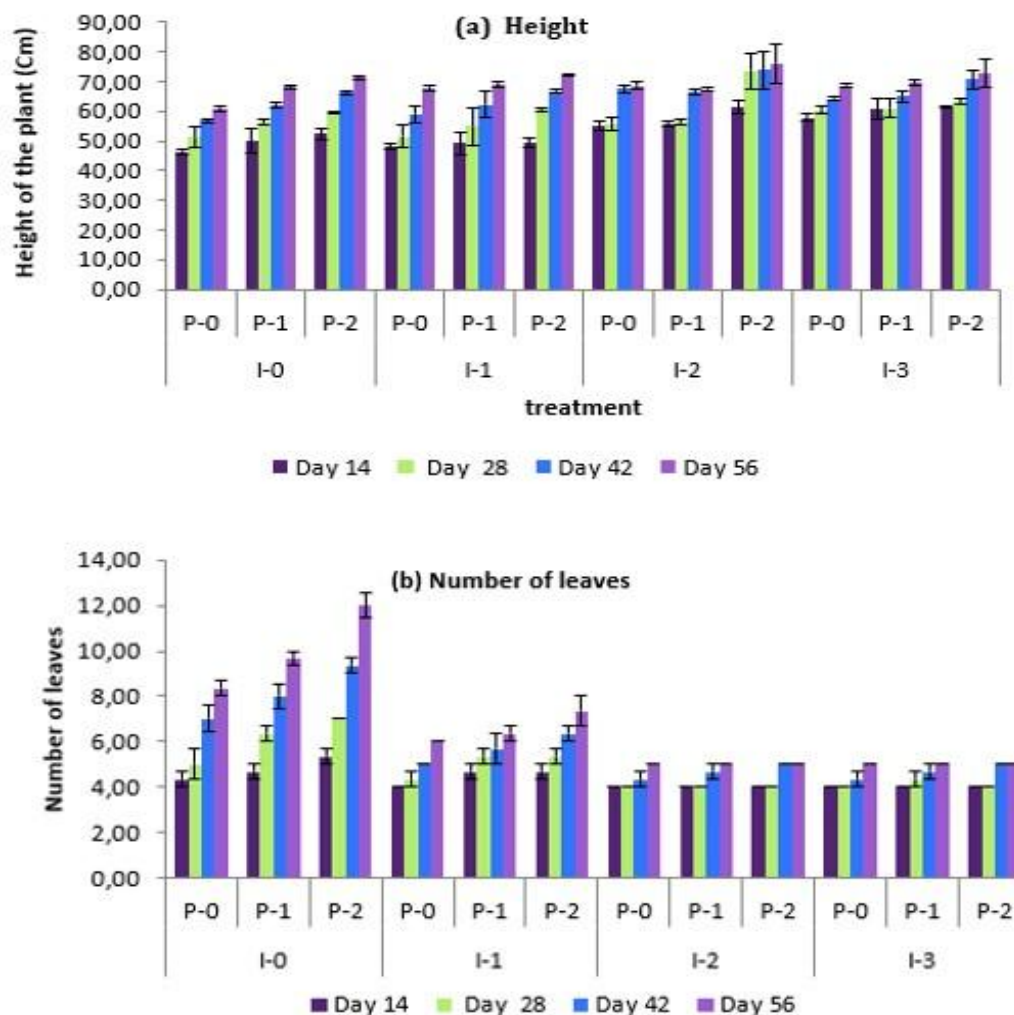


Figure 6. Graph of height (a), and (b) number of leaves of Garut grown in four different level intensities and different level of organic fertilizer during measurement of every 14 days, from day 14 to day 56.

While our results show that little contribution of media with the integration of organic fertilizer to the number of plants for lower intensity such as I-2 and I-3. No increasing of number of leave for intensities I-2 and I-3. No further increases of leaves number for day 42 and 56, for plant growth under lower intensities of I-2 and I-3. Our results showed that little increase of the average total leaves area per plants for Garut growth under intensity of I-2 and I-3, while average total leaves area was enhanced by the fertilizer of doses P2 under intensity of I-0 and I-1 (Figure 7a). Leaves of plants were getting thinner under lower intensities of I-2 and I-3.

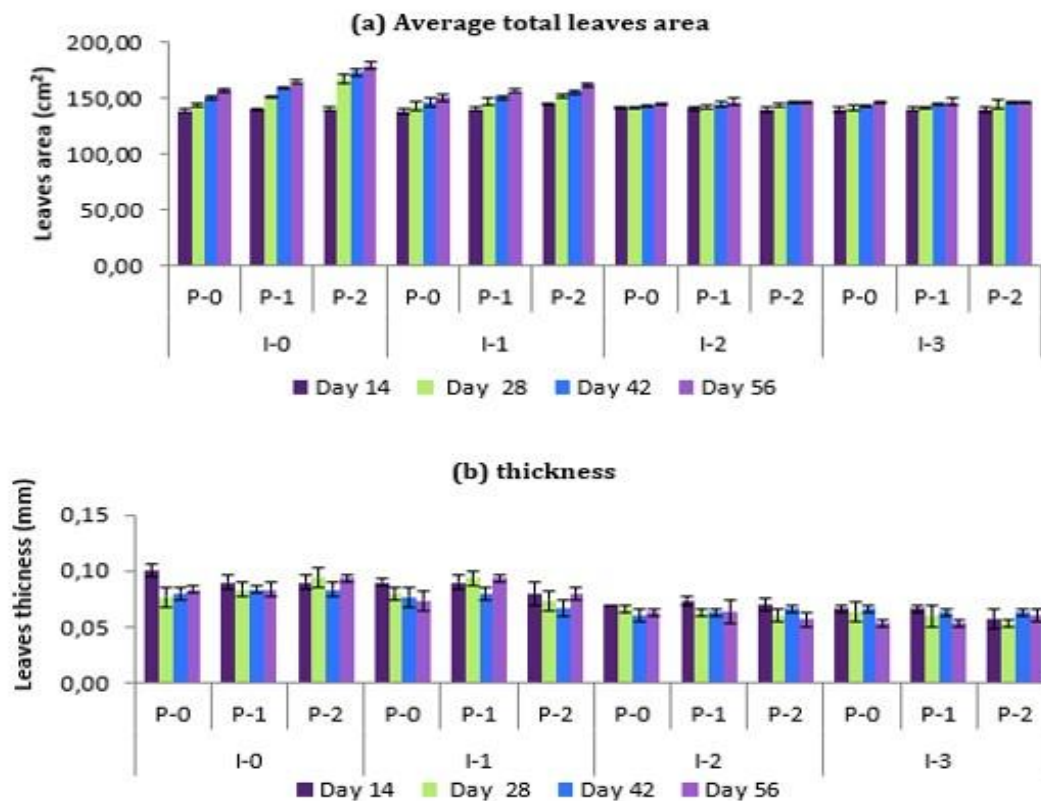


Figure 7. Graph of average total leaves area (a) and thickness of leaves (b) of Garut grown in four different level intensities and different level of organic fertilizer during measurement of every 14 days, from day 14 to day 56.

3.3 Plant Growth – Fresh and Dry weight

Under lower intensities of I-2 and I-3 fresh weight were smaller than the intensity of I-0 and I-1 (Figure 8a) and also for the dry weight of total plant (Figure 8b).

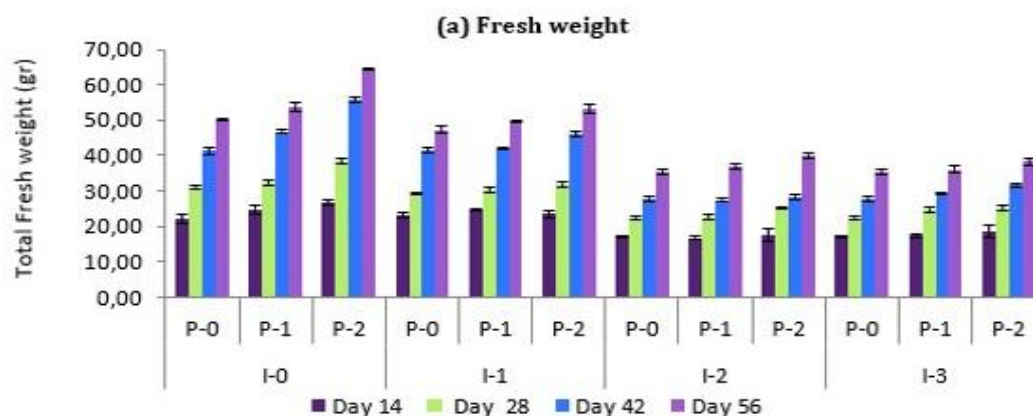


Figure 8a. Graph of Fresh weight of Garut grown in four different level intensities and different level of organic fertilizer during measurement of every 14 days, from day 14 to day 56

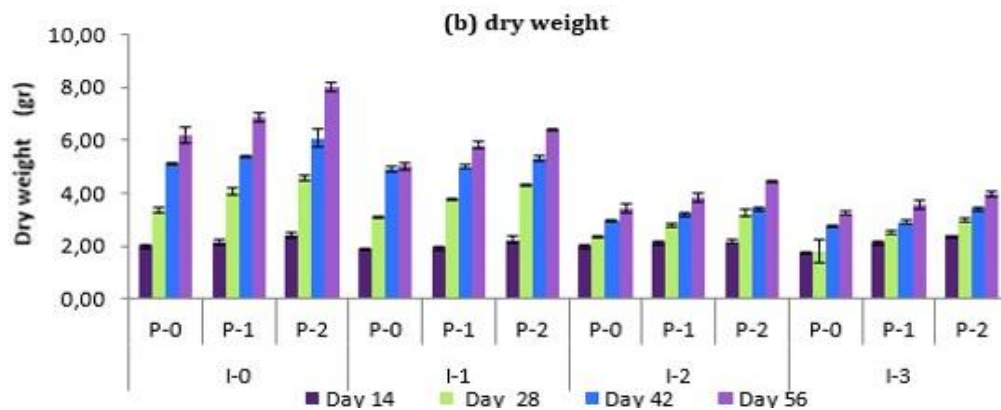


Figure 8b. Graph of dry weight of Garut grown in four different level intensities and different level of organic fertilizer during measurement of every 14 days, from day 14 to day 56.

3.4 Environmental Sustainability -pH and Electrical Conductivity

Application of organic fertilizer to the media, increases electrical conductivity (EC) compared to soil media only (Table 1). From Table 1, can be seen that EC were enhanced by level dose of the organic fertilizer. Applying organic fertilizer for a longer period of time appears to raise the EC. When compared to the controlled plant P-0 soil without any organic fertilizer added, the pH of the soil appeared to drop after applying organic fertilizer (Table 2).

Table 1. Electrical conductivity (EC) for media with enhancement of organic fertilizer

Level Intensities	Doses of Organic Fertilizer	Days	Electrical Conductivity ($\mu\text{S}/\text{Cm}$)			
			14	28	42	56
I-0	P-0		4.09 ± 0.02	5.27 ± 0.04	6.12 ± 0.03	7.45 ± 0.24
	P-1		6.06 ± 1.07	6.70 ± 0.15	7.22 ± 0.32	8.17 ± 0.07
	P-2		6.19 ± 0.33	6.78 ± 0.10	7.99 ± 0.06	8.76 ± 0.08
I-1	P-0		4.25 ± 0.14	5.18 ± 0.03	5.87 ± 0.05	7.14 ± 0.27
	P-1		6.04 ± 1.08	6.38 ± 0.30	8.03 ± 0.08	8.81 ± 0.16
	P-2		6.60 ± 0.08	7.65 ± 0.22	8.99 ± 0.06	9.78 ± 0.05
I-2	P-0		5.13 ± 0.08	6.49 ± 0.16	7.24 ± 0.06	7.82 ± 0.34
	P-1		5.92 ± 1.25	6.57 ± 0.26	7.99 ± 0.01	8.83 ± 0.09
	P-2		6.82 ± 0.5	7.67 ± 0.09	8.91 ± 0.07	9.72 ± 0.16
I-3	P-0		4.73 ± 0.04	5.80 ± 0.05	7.03 ± 0.09	7.06 ± 0.03
	P-1		5.54 ± 1.17	6.73 ± 0.15	7.65 ± 0.03	8.50 ± 0.09
	P-2		5.70 ± 0.11	6.62 ± 0.06	7.69 ± 0.12	8.84 ± 0.03

Table 2. pH for media with enhancement of organic fertilizer for growing Garut under different level of intensities.

Level Intensities	Doses of Organic Fertilizer	Days	pH			
			14	28	42	56
I-0	P-0		6.48 ± 0.19	7.39 ± 0.09	6.95 ± 0.04	7.04 ± 0.08
	P-1		5.89 ± 0.25	5.70 ± 0.15	5.69 ± 0.17	5.51 ± 0.14
	P-2		5.53 ± 0.11	6.15 ± 0.19	5.76 ± 0.08	5.82 ± 0.26
I-1	P-0		6.91 ± 0.06	7.03 ± 0.13	7.05 ± 0.14	7.30 ± 0.20
	P-1		5.99 ± 0.02	5.84 ± 0.08	5.99 ± 0.10	6.02 ± 0.06
	P-2		5.69 ± 0.08	6.08 ± 0.08	5.99 ± 0.06	5.89 ± 0.12
I-2	P-0		6.99 ± 0.07	7.30 ± 0.10	7.01 ± 0.13	7.16 ± 0.06
	P-1		5.92 ± 0.08	5.90 ± 0.12	6.07 ± 0.03	5.89 ± 0.06
	P-2		5.82 ± 0.05	5.85 ± 0.09	5.88 ± 0.06	5.94 ± 0.10
I-3	P-0		7.14 ± 0.04	7.00 ± 0.06	7.17 ± 0.05	6.99 ± 0.10
	P-1		5.54 ± 0.20	5.73 ± 0.15	5.59 ± 0.05	5.50 ± 0.09
	P-2		5.50 ± 0.09	5.62 ± 0.06	5.57 ± 0.06	5.84 ± 0.03

3.5 Home Garden Initiatives and Practices for the Local food Sustainability

The sustainability growth for the research in the home garden were done in the first our research on the growth for the diameter and collecting of the results on the daily of growth for the stem growth during the 28 days of regrowth plant. Following the data growth of Garut, we have seen that the initiative of bringing plant to home garden could be practices by adapting plant with requirement of their growth to support their lives. Here the intensity of range of the I-0 and I-1 could possibly for practicing the home garden Garut. However, it should be noted that some indicator of growth could not be increased by increasing of doses of the organic fertilizer. It implies that requirement of the level intensity for plants was a crucial factor for home garden Garut [16]. Thought that Garut has known as the adaptable of lower intensity, it could be noticed from the result research that intensity as lower as I-2 and I-3 could be burden for further growth of home garden Garut.

Throughout the results we have seen that fertilizer could increase growth, dose as high as 150 gr/pot of organic fertilizer could increase most of the indicator of growth of Garut under sufficiently intensity during the vegetative growth. Healthy grow during vegetative phase will maintain growth for the next phase growth to have a better yield. Organic fertilizer seemed to lower pH compare to Garut growth without any addition of organic fertilizer (Table 2), while Organic fertilizer such as Bokashi has been used for years, and application of EM4 could control secondary soil salinization will improve the agricultural environment and ensure the sustainable growth of agriculture by reducing the amount of chemical fertilizer application [17]. Organic

fertilizer constituents demonstrated unfavorable impact on leaf counts so plants often use the nitrogen components that are present in the soil [18].

Organic fertilizer increasing of leaves area of plant in *Brassicca napus* L also enhance growth, development, and yield performance. Because its ingredients are easily accessible locally, producers are advised to utilize organic fertilizer. The application of organic fertilizer gives rise of sustainable production as well as soil fertility in some plants such as pear-jujube increasing its growth performances [19]. Garut possesses many phytochemicals, exhibit antioxidant and anti-microbial activities [20,21]. The cultivation factor had an impact on the properties of arrowroot flour. The leaves are suitable for the fertilizer as contain of C/N ratio of less than 20 (N=1.28%, K=1.71%), MC less than 30% the residue of leaves could be used as the fertilizer, biopolymer and for industrial application [22]. Like other plants, Garut starch is found in tuber roots and is mostly stored in the endosperm of the amyloplast in grains [23].

4. Conclusion

Garut is noted for its ability to adapt to lower light intensities, yet it is noticed from the result research that intensity as lower as I-2 and I-3 could be burden for further growth of home garden Garut. Organic fertilizer seemed to lower pH compare to Garut growth without any addition of organic fertilizer while increasing EC With the condition of pH and EC. We have shown that the environmental sustainability could initiation for a better management of the home garden Garut. In conclusion, we have adapted of Garut for the purpose of the home garden, we found that the intensity I-0 and I-1 could be applied to the growth of the home garden Garut, and applicable of the organic fertilizer of 150 gr per plant could enhance the vegetative growth. In addition, the potential of Garut for home garden initiatives and practices is also highlighted in terms of food sustainability

5. Conflict of Interest

The authors state no conflict of interest related to the research.

References

- [1] Zhang X D, Zhang Y X and Zhai J 2021. Home garden with eco-healing functions benefiting mental health and biodiversity during and after the COVID-19 pandemic: A scoping review. *Front Public Health*. <https://doi.org/10.3389/fpubh.2021.740187>
- [2] Turnšek M, Gangenes Skar S-L, Piirman M, Thorarinsdottir R I, Bavec M and Junge R 2022. Home gardening and food security concerns during the COVID-19 pandemic. *Horticulturae*. <https://doi.org/10.3390/horticulturae8030189>
- [3] Wu C-F, Trac LVT, Chen S-H, Menakanit A, Le QT, Tu H-M, et al 2022. Enhancing human resilience beyond COVID-19-related stress: Public responses to multi-benefits of home gardening. *Sci Rep*. <https://doi.org/10.1038/s41598-022-05976-2>
- [4] Rohandi A 2021. Karakteristik agroekologi dan potensi tanaman Garut (*Maranta arundinacea* L.) pada berbagai ketinggian lokasi. *Agroecology Characteristics and Potential* **4**(1) 23-37.
- [5] Deswina P, Priadi D 2020. Development of arrowroot as a functional food based on local resources. *IOP Conf Ser Earth Environ Sci*. <https://doi.org/10.1088/1755-1315/425/1/012064>
- [6] Oktafani M B 2018. Performance of arrowroot (*Maranta arundinacea*) in various light intensities. *IOP Conf Ser Earth Environ Sci*. **142** 012048. <https://doi.org/10.1088/1755-1315/142/1/012048>
- [7] Brito-Salentim V H, Nascimento R, Oliveira JN 2021. Arrowroot (*Maranta arundinacea* L.): *Botany, horticulture, and uses*. <https://doi.org/10.1002/9781119750802.ch4>
- [8] Shintu P V, Radhakrishnan V V and Mohanan K V 2015. Pharmacognostic standardization of *Maranta arundinacea* L., an important ethnomedicine. *J Pharmacogn Phytochem* **4**(3) 242-246.
- [9] Xiaohou S, Min T, Ping J and Weiling C 2008. Effect of EM Bokashi application on control of secondary soil salinization. *Water Sci Eng*. [https://doi.org/10.1016/S1674-2370\(15\)30025-1](https://doi.org/10.1016/S1674-2370(15)30025-1)

- [10] Pedersen C S 2018. The UN Sustainable Development Goals (SDGs) are a great gift to business! *Procedia CIRP*. <https://doi.org/10.1016/j.procir.2018.01.003>
- [11] Gandahi A W, Baloch S F, Sarki M S, Gandahi R and Lashari M S 2015. Impact of rice husk biochar and macronutrient fertilizer on fodder maize and soil properties. *Int J Biosci* **7**(4) 12-21 DOI: 10.12692/ijb/7.4.12-21.
- [12] Firoskhan N, Muthuswamy R 2021. Review on *Maranta arundinacea* L. (Marantaceae). *Int J Pharmacogn & Pharm Res.* **3**(1) 01-04.
- [13] Syahputra M G, Antarai A L, Winarto and Lestari E S 2020. Antimicrobial effect of arrowroot (*Maranta arundinacea* L.) methanolic extract against *Staphylococcus aureus* bacterial growth. *J Kedokt Diponegoro* **9**(3) 241-245. DOI: <https://doi.org/10.14710/dmj.v9i3.27499>
- [14] Mahapatra S, Ali H M and Samal K 2022. Assessment of compost maturity stability indices and recent development of composting bins. *Energy Nexus*. <https://doi.org/10.1016/j.nexus.2022.100056>
- [15] Rohandi A, Buidadi, Hardiwinoto S, Harmayani E and Sudrajat D J 2017. Variability in morpho-physiology, tuber yield, and starch content of several arrowroot populations in Garut District. *Agrivita J Agric Sci.***39**(3) 311-323
- [16] Valencia G A, Moraes I C F, Lourenço R V, Habitante A M Q B and Sobral P J A 2014. *Maranta arundinacea* L. starch properties. *Proc 2014 Int Conf Food Prop.* <https://doi.org/10.17503/agrivita.v39i3.1032>
- [17] Solichah E, Deswina P, Sarifudin A, Adriansyah C E and Rahman N 2019. Physicochemical, structural, and morphological properties of some arrowroot (*Maranta arundinacea*) accessions grown in Indonesia. *AIP Proc.* <https://doi.org/10.1063/1.5141300>
- [18] Ieamkheng, S, Santibenchakul S and Sooksawat N 2022. Potential of *Maranta arundinacea* residues for recycling: Analysis of total phenolic, flavonoid, and tannin contents. *Biodiversitas.* **23**(3) 1204-1210
- [19] Tarique J, Sapuan S M, Khalina A, Sherwani S F K, Yusuf J and Ilyas R A 2021. Recent developments in sustainable arrowroot (*Maranta arundinacea* Linn) starch biopolymers, fibers, biopolymer composites, and their potential industrial applications: A review. *J Mater Res Technol* **13** 1191-1219. <https://doi.org/10.1016/j.jmrt.2021.05.047>
- [20] Deluca H D, Mackenzie M D and Gundale M J 2009. Biochar effects on soil nutrient transformations. *Earthscan Publ. London*, 251-270.
- [21] Hossain M Z, Bahar M M, Sarkar B, Donne S W, Ok Y S and Palansooriya K N, et al 2020. Biochar and its importance on nutrient dynamics in soil and plants. *Biochar.* **4** 379-420.
- [22] Beah A A, Norman P E, Scholberg J C, Lantinga E A and Conteh A R 2015. Effect of organic manure on nitrogen mineralization, nitrogen accumulation, nitrogen use efficiency, and apparent nitrogen recovery of cauliflower (*Brassica oleracea* L. var. *Botrytis*). *Int J Plant Soil Sci* **4**(3) 265-272.
- [23] Siavoshi M, Nasiri A and Laware S L 2011. Effect of organic fertilizer on growth and yield components in rice (*Oryza sativa* L.). *J Agric Sci.* **3**(3) 217-224