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Research Article

Impact of Increased Temperature Conditions on Growth and Yield of Medicinal Plant Heen Araththa (*Alpinia calcarata*)

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Abstract

Alpinia calcarata, commonly known as Heen Araththa, is a medicinal plant with high pharmacological significance in Sri Lankan traditional medicine, which is belonging to *Zingiberaceae* family. This study aimed to assess the growth and yield of Heen Araththa grown in high temperature with organic manure. This pot experiment was conducted at the Open University of Sri Lanka in Nawala, located in the Low Country Wet Zone, using a temperature-controlled plant house and an ambient temperature poly tunnel to simulate high temperature to mimic global warming. The Two-factor factorial Complete Randomized Design (CRD) with three replications was employed, considering two temperature regimes – ambient temperature (27 –32°C, T2) and high temperature (34 –35°C, T4), and three organic manure treatments mixed with 9 kg of Reddish Brown Earth Soil in each pot at the rate of 1kg of compost (100% compost - M1), 1 kg of cow dung (100% cow dung - M2), and 0.5kg of compost and 0.5 kg of cow dung (50:50 mixture of compost and cow dung - M3). Control treatments were only with 10 kg of reddish-brown earth soil without organic manure at high temperature and ambient temperature. Data were analysed using SAS, at a significance level of p=0.05. Growth parameters such as shoot length, number of leaves, number of shoots, and leaf area, along with yield parameters including fresh and dry root weight were measured. Treatment means were compared through ANOVA and Duncan's Multiple Range Test (DMRT). Results indicated that ambient temperature without organic manure (Control treatment) produced the highest shoot length (55.42±11.5 cm), number of leaves (12.52±1.47), leaf area (52.14±32.73 cm^2), fresh root weight (122.67±17.47 g) and dry root weight (39.00±13.53 g). The findings suggest that *A. calcarata* is unlikely to grow and yield optimally under increased temperature conditions. Organic manure application does not consistently enhance growth or yield under increased temperature conditions.

Keywords: Growth, Increased temperature, Medicinal Plant, Organic manure, Yield

1. Introduction

Sri Lanka's forests are home to many rare plant species, making it a major contributor to biodiversity worldwide. The most reliable figures show about 29% of the land is protected, despite occasional claims of a 16.5% forest cover (Sarathchandra *et al*., 2021). Humans have used plants for medicinal purposes for centuries, and one of the oldest and most popular forms of treatment is still herbal medicine (Jesuthasan and Uluwaduge, 2017). Herbal medicines are still becoming increasingly popular around the world because of their natural origin, minimal likelihood of side effects, and cost effectiveness, especially in developing countries where access to modern medicine may be limited (Chaudhary *et al*., 2018). This information has been passed down through the generations by traditional healers and indigenous medicinal systems, significantly contributing to modern pharmacological research (Jesuthasan and Uluwaduge, 2017).

Alpinia calcarata, commonly known as Heen Araththa, is a medicinal plant belonging to the family Zingiberaceae and is highly valued in Sri Lanka. The plant produces rhizomes, or underground stems, which are clearly nodes and internodes and have a strong, aromatic smell. Mature rhizomes range from light to dark brown in colour, and they are branched and dense. The plant's leaf is simple and alternate, measuring 25–32 cm in length and 2.5–5 cm in width. The flowers are pendanculate, bisexual, and irregular. Terminally densed flowers are 8.5 cm long panicles (Rahman and Islam, 2015). In Ayurvedic medicine, the rhizome of this plant is frequently used to cure conditions like indigestion, arthritis, bronchitis, asthma, and inflammation of the throat (Rahman and Islam, 2015). It is well recognized that the rhizomes of *A. calcarata* have antibacterial, anthelmintic, antifungal, antioxidant, aphrodisiac, gastroprotective, antidiabetic, and anticancer properties (Arambewela *et al*., 2010). *Alpinia calcarata*'s rhizomes have been identified by researchers to have a variety of medicinal uses, including the treatment of high blood pressure, diuretics, stomach problems, analgesics, anticandidals, antiplatelets, antispasmodics, antiulcerous hypotensive insecticidal, muscle relaxants, and uterine stimulants (Melanathuru *et al*., 2017). Because of its pharmacological potential and high demand in the field of traditional medicine, the rhizome is the most valuable component (Rahman and Islam, 2015).

However, the cultivation of medicinal plants like *A. calcarata* as well as agricultural production are seriously threatened by rising global temperatures and frequent heat waves. High temperatures have the potential to disrupt photosynthesis, secondary metabolite synthesis, and plant metabolic processes, all of which are essential for medicinal properties (Hasanuzzaman *et al*., 2013). Thus, maintaining these plants' growth and yield under the temperature stress has emerged as a major area of research concern.

As a sustainable soil management technique that improves soil structure, water retention, and nutrient availability while reducing reliance on chemical fertilizers, organic manure is becoming more and more recognized. Additionally, it supports long term soil fertility and microbial activity. Using biological and organic fertilizers can help retain energy, reduce environment pollution, provide nutrients to plants based on their needs, increase biodiversity, improve quality, and increase crop growth and yield (Almasi, 2021). Thus, the negative effects of temperature stress on plant growth and productivity may be reduced by applying organic manure. The combined effects of temperature stress and organic manure on *Alpinia calcarata*, however, have not been thoroughly studied.

It becomes increasingly important to understand the necessity of examining whether applying organic manure will improve the resilience, growth, and yield of Heen Araththa under rising temperature stress. A consistent supply of high-quality medicinal raw materials and sustainable cultivation depend on an understanding of this relationship. These discoveries could help the pharmaceutical sector by ensuring a steady supply of potent herbal resources, as well as farmers by increasing production and income.

2. Materials and Methods

2.1. Experimental site

This study is being carried out in the Open University of Sri Lanka, Nawala, Nugegoda located in the Low Country Wet Zone. This experiment is performed from September 2024. For this experiment, a normal poly tunnel and a temperature regulated plant house are used. The poly tunnel simulates the ambient temperature (T2), while the plant house simulates the increased temperature condition (T1). The polytunnel and plant house are already installed at the Open University of Sri Lanka. The global climate results from the IPCC were used to choose these temperatures (Lee, 2023). The exhaust fans in the polytunnel are activated automatically when the internal temperature rises over the maximum temperature and continue to operate until the temperature drops to the thermostat's maximum setting.

2.2. Experimental Design and Treatments

This experiment is conducted based on Two-factor factorial Complete Randomized Design (CRD) with three replications. Two factors are considered for crop as two temperature levels and three organic manure types. Two temperature levels as temperature stress (T1 as 34-35 °C) and ambient temperature (T2 as 27-32 °C). Three organic input types as,

M1 = Compost + Soil (1:9)

M2 = Cow dung + Soil (1:9)

M3 = Compost + Cow dung + Soil (0.5:0.5:9)

M0 = Soil (No fertilizer)

Treatment combinations are as follows: M0T1, M1T1, M2T1, M3T1 in the plant house and M0T2, M1T2, M2T2, M3T2 in the poly tunnel.

2.3. Irrigation

Plants were irrigated daily until the potting medium reached saturation, indicated by excess water draining from the bottom, ensuring the entire soil profile was thoroughly moistened to field capacity.

2.4. Temperature

Temperature readings were recorded daily at 7:00 a.m. and 5:00 p.m. Each polytunnel and plant house's average temperature was plotted with the dates that corresponded to the temperature recorded by thermometers.

According to this figure, the average temperature of plant house always higher than the temperature of poly tunnel. The plant house was temperature controlled using enclosed conditions, resulting in higher temperatures than the poly tunnel. The temperature difference is approximately 2–4℃. T1 indicates the elevated temperature treatment maintained at 34–35℃ to simulate temperature stress conditions while T2 indicates the ambient temperature. Temperature was recorded during the critical treatment establishment period.

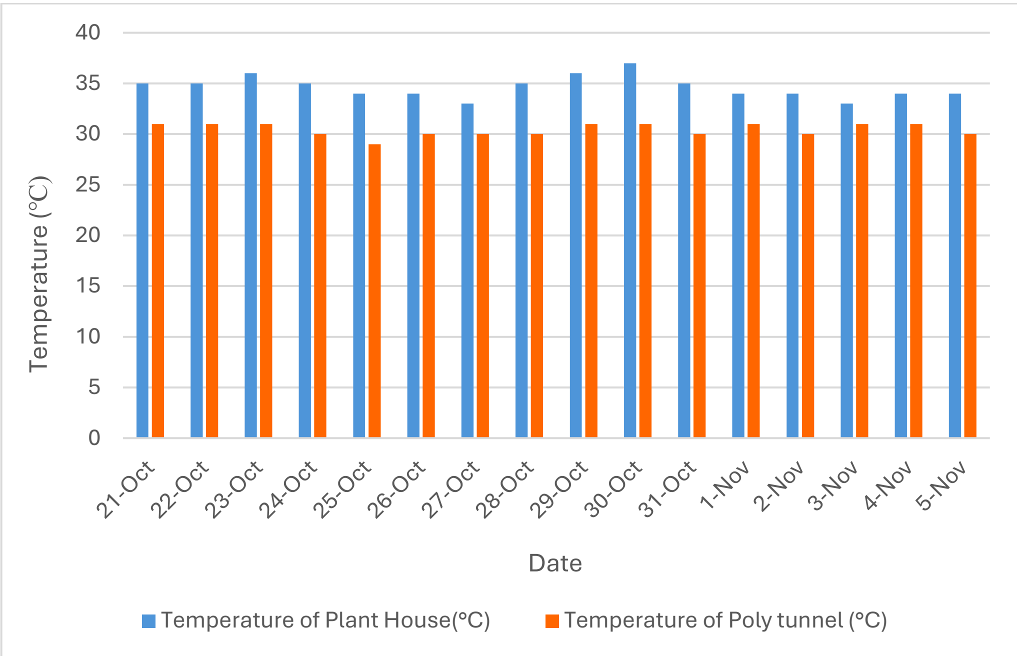

Figure 1. Temperature variation in the plant house and poly tunnel

2.5. Planting Material

Healthy mother plants were selected from crop, and it was vegetatively propagated in a nursery in order to obtain healthy plants for the experiment. Two and half months old plants were selected for the experiment.

2.6. Potting Mixture Preparation and Filling into the Plastic Pots

The potting mixture was prepared using Reddish Brown Earth soil. An equal amount of soil was filled in each pot (8-inch diameter and 10-inch height) approximately 10 kg of soil per one pot.

2.7. Fertilizer Application

Fertilizer was applied in the beginning at 10 ton ha^{-1} rate in 100% manure application, while in the mixed treatment, compost and cow dung were applied equally at a 1:1 ratio.

2.8. Data Collection

Growth parameters were measured in a four-week interval and yield parameters will be evaluated after harvest. Soil parameters were analyzed at the beginning as well as at the end of the study.

2.9. Growth And Yield Parameters

The variables mentioned below are considered as growth and yield parameters. The mean value was calculated by averaging the observations made of these plants.

Growth parameters are shoot height (cm), number of leaves, number of shoots from the rhizome and leaf area (cm^2). Fresh total rhizome weight (g) and dry total rhizome weight (g) are measured as yield parameters.

2.10. Soil Parameters

Soil pH, soil EC, soil N, soil available K, soil available P are measured before and after the study. At the initial stage of the study, similar parameters were measured in cow dung and compost.

2.11. Soil and Organic Manure Analysis

Laboratory procedures were followed for the analysis of soil and organic manure. pH was measured by Soil, organic manure suspension by using pH meter. The electrical conductivity was measured by Soil, organic manure suspension by using EC meter. Available phosphorus was measured by using spectrophotometer. Exchangeable potassium was measured by using flame photometer and total nitrogen was measured by using Kjeldahl method.

2.12. Data Analysis

All measured data were analyzed by using the statistical package 'SAS' (SAS Institute, Inc., Cary, NC, USA) was used to display the means and SE of the dataset. Significance or otherwise of the differences between treatments were tested by Analysis of Variance (ANOVA). To evaluate the significance between all possible pairs of treatment means, mean separation was performed with Duncan's Multiple Range Test (DMRT).

3. Results and Discussion

3.1. Growth Parameters

3.1.1. Shoot Length

The results show that both temperature and fertilizer treatment significantly affect the shoot length. Moreover, the interaction between fertilizer treatment and temperature was significant ($p < 0.0001$), suggesting that the effect of fertilizers varied under different temperature conditions. The highest shoot length was observed in the no fertilizer treatment under ambient temperature, with a mean value of 55.42 ± 11.5 cm (Table 1 and 2). The 100% cow dung treatment under ambient temperature differed significantly from the no-fertilizer treatment, while the 50% compost with 50% cow dung treatment showed no significant difference from it. The lowest shoot length occurred in the 100% compost treatment under temperature stress, with a mean of 26.19 ± 3.54 cm (Table 2). The no fertilizer treatment under ambient conditions was significantly different from the 100% compost treatment under temperature stress. Similarly, previous studies have shown that environmental and substrate factors influence shoot and root growth. For instance, seedlings grown on fresh straw had longer shoots and shorter roots than those on bare soil (Kasperbauer, 1999). Temperature also influences plant morphology and reproductive growth through "thermomorphogenesis" which means morphological changes induced by elevated, non-stressful temperatures (McClung *et al.*, 2016).

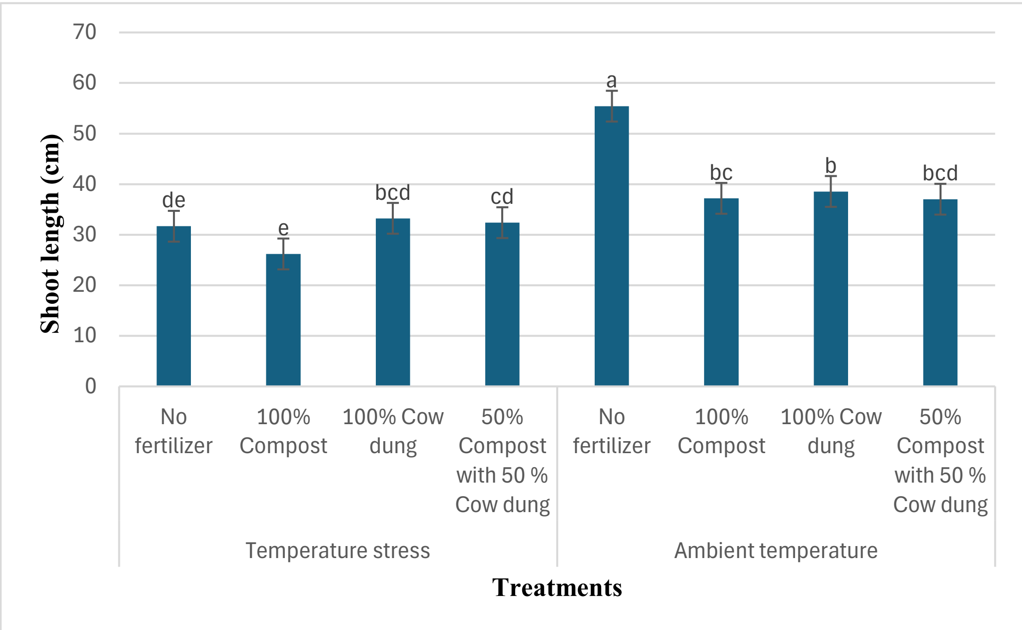

Figure 2. Effect of different organic fertilizer treatments on shoot length of Heen Araththa under temperature stress and ambient temperature conditions

Table 1. Analysis of variance results of probability values with the effect of organic manure, temperature and organic manure: temperature interaction effect on growth parameters

	Shoot length (cm)	**Number of shoots**	**Number of leaves**	**Average leaf area (cm^2)**
Organic manure (OM)	****	**	***	***
Temperature	****	*	****	Ns
OM : Temperature	****	****	****	*

Note: Ns denotes not significant at any level, ****, ***, **, * denote the significant at 0.0001, 0.001, 0.01 and 0.05.

3.1.2. Number of Shoots

The results indicate that both fertilizer treatment and temperature significantly affect the number of shoots in *A. calcarata*, with a highly significant interaction between the two factors ($p < 0.0001$). The interaction effect indicates that treatment responses differed under different temperature conditions. The highest number of shoots (14.24 ± 4.62) was recorded under 100% compost treatment at temperature stress conditions (Table 1 and 2), which was significantly different from the lowest value (7.48 ± 1.81) observed in the no-fertilizer treatment under the same temperature stress. Temperature plays a crucial role in the growth and metabolic processes of medicinal plants, influencing their phenological development when water and nutrient availability are not limited. Higher temperatures within the normal range generally promote faster plant growth (Wang *et al*., 2024). The superior performance of plants treated with 15 t ha^{-1} food waste compost may be attributed to the compost's rich nutrient and hormone content, which improves soil porosity, aeration, and water retention, thereby promoting vigorous growth. The findings align with previous studies showing that organic fertilizers, especially compost, enhance plant growth (Kebede *et al*., 2023). Similarly, a previous research reported that biofertilizers like Lumbrical (produced by the Californian earthworm *Lumbricus rubellus*) increased vegetative growth by improving nutrient availability and photosynthetic activity (Berova *et al*., 2010).

Table 2. Growth parameters of Heen Araththa under different organic fertilizer treatments subjected to temperature-stress and ambient-temperature conditions. Values represent mean ± SD. Means within a column followed by the same letter are not significantly different at $p \leq 0.05$.

Treatment combination (OM : Temperature)	Growth parameter			
	Shoot length (cm)	**Number of shoots**	**Number of leaves**	**Average leaf area (cm²)**
No fertilizer with Temperature stress (M0T1)	$31.67^{de}\pm6.7$	$7.48^{d}\pm1.81$	$9.67^{c}\pm1.98$	$45.5^{ab}\pm11.95$
100% Compost with Temperature stress (M1T1)	$26.19^{e}\pm3.54$	$14.24^{a}\pm4.62$	$7.81^{d}\pm1.12$	$46.82^{ab}\pm17.55$
100% Cow dung with Temperature stress (M2T1)	$33.24^{bcd}\pm8.27$	$10.14^{c}\pm4.05$	$9.71^{c}\pm1.59$	$45.75^{ab}\pm24.26$
50% Compost + 50% Cow dung with Temperature stress (M3T1)	$32.38^{cd}\pm6.84$	$12.48^{ab}\pm3.8$	$9.57^{c}\pm2.06$	$24.73^{c}\pm8.18$
No fertilizer with Ambient temperature (M0T2)	$55.42^{a}\pm11.5$	$11.05^{bc}\pm2.38$	$12.52^{a}\pm1.47$	$52.14^{a}\pm32.73$
100% Compost with Ambient temperature (M1T2)	$37.19^{bc}\pm9.35$	$9.14^{cd}\pm3.21$	$11.29^{b}\pm1.68$	$40.6^{b}\pm12.05$
100% Cow dung with Ambient temperature (M2T2)	$38.55^{b}\pm10.5$	$9.76^{c}\pm3.77$	$9.95^{c}\pm1.4$	$44.76^{ab}\pm14.69$
50% Compost + 50% Cow dung with Ambient temperature (M3T2)	$37.02^{bcd}\pm12.08$	$9.57^{cd} \pm 3.93$	$10.33^{bc}\pm2.33$	$40.46^{b}\pm16.41$

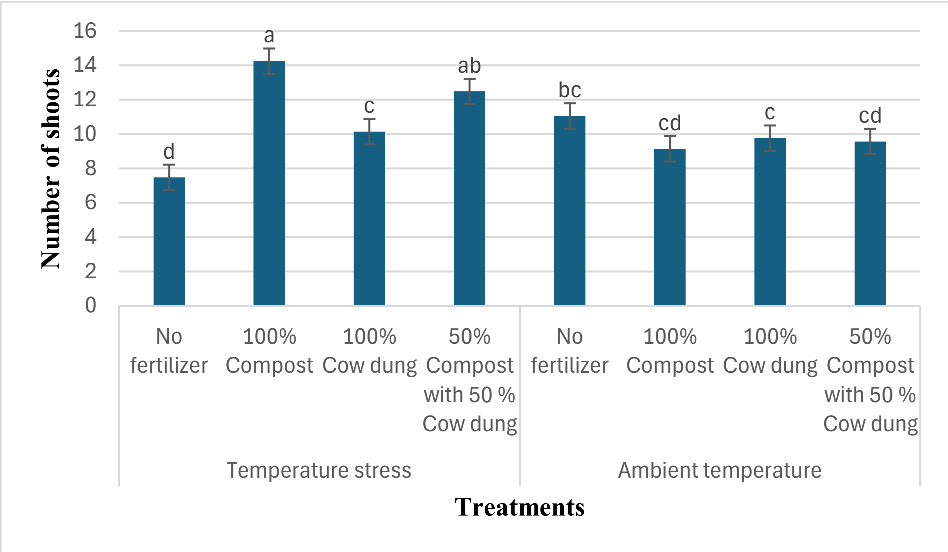

Figure 3. Effect of different organic fertilizer treatments on number of shoots of Heen Araththa under temperature stress and ambient temperature conditions

3.1.3. Number of leaves

The results indicate that both treatment and temperature have statistically significant effects on the number of leaves, with a strong interaction between the two factors (p-value < 0.0001). This interaction suggests that the influence of fertilizer treatments varies depending on temperature conditions. The highest mean number of leaves (12.52±1.47) was observed in the no fertilizer treatment under ambient temperature (Table 1 and 2), which was significantly different from the 100% compost treatment under temperature stress, where the lowest number of leaves (7.81±1.12) was recorded. However, there was no significant difference between the 100% cow dung treatment under ambient temperature and 50% compost with 50% cow dung treatment under ambient temperature. Previous studies also support the influence of temperature on leaf development, where the 35/27℃ treatment resulted in the highest number of leaves, followed by 40/32℃ and 30/22℃, suggesting that leaf development is less sensitive to higher temperatures and is optimal at around 32.5℃ (Walne and Reddy, 2022). Additionally, soil type influences leaf production, with most soils promoting leaf increase except for Clayey loam (Jimoh *et al*., 2020).

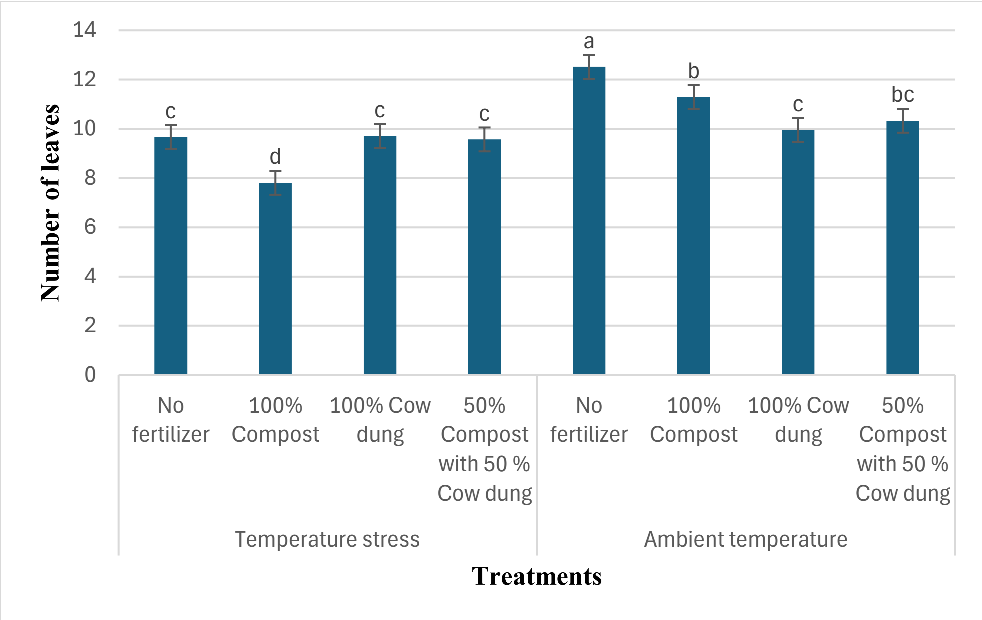

Figure 4. Effect of different organic fertilizer treatments on number of leaves of Heen Araththa under temperature stress and ambient temperature conditions

3.1.4. Leaf Area

The treatments had a significant effect on leaf area (p = 0.0008). Leaf area was significantly influenced by the interaction between organic manure treatments and temperature conditions. The highest mean leaf area was observed in the no-fertilizer treatment under ambient temperature (M0T2), recorded as 52.14 ± 32.73 cm^2 (Table 1 and 2). This was significantly different from the 50% compost with 50% cow dung treatment under temperature stress, which had the lowest average leaf area of 24.73 ± 8.18 cm^2. However, M0T2 was not significantly different from M0T1, M1T1, or M2T1, indicating that even under temperature stress, Heen Araththa performs relatively well with or without organic manure.

Previous studies reported that the largest leaf area growth occurred under a 35/27℃ regime, while the lowest was under 20/12℃ (Walne and Reddy, 2022). Temperature affects both shoot development and leaf photosynthesis, while light intensity mainly impacts photosynthetic rate (Shin *et al*., 2001). Plants growing in nutrient-rich soils had larger leaves compared to those in skeletal soils, with distinct leaf morphology noted in lithic leptosol populations (Jovanović *et al*., 2023).

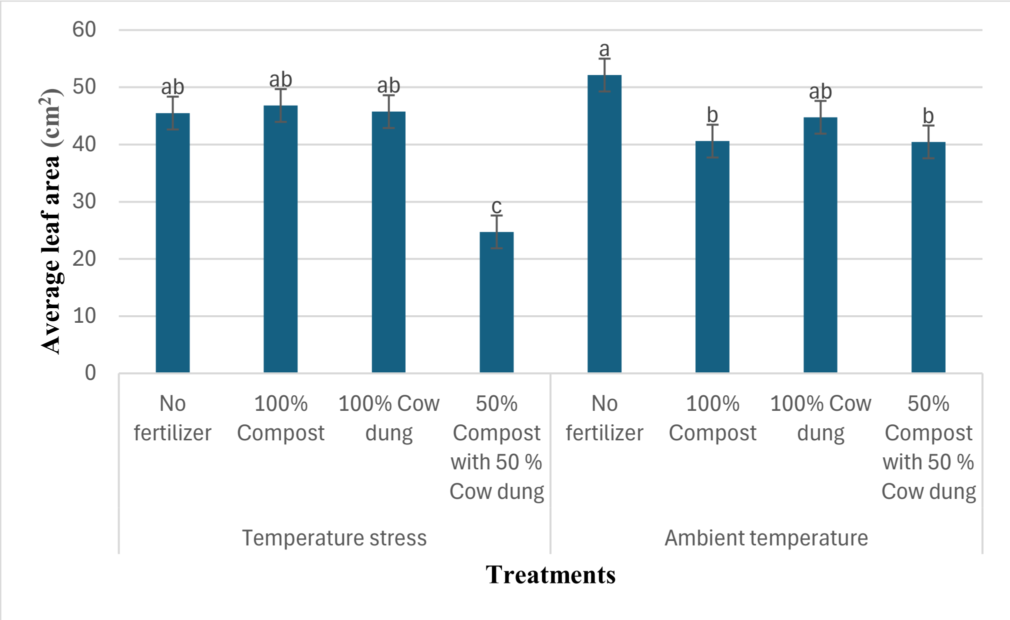

Figure 5. Effect of different organic fertilizer treatments on average leaf area (cm^2) of Heen Araththa under temperature stress and ambient temperature conditions

3.2. Yield Parameters

3.2.1. Fresh Root Weight

The results show that both fertilizer treatment and temperature significantly affect the fresh root weight, and the interaction between fertilizer treatment and temperature was significant ($p = 0.0094$), indicating that the influence of treatments varied with temperature. The highest fresh root weight (122.67 ± 17.47 g) was observed in the no-fertilizer treatment under ambient temperature (Table 3), which was significantly different from the 100% compost treatment under the same temperature condition. The lowest value (62.00 ± 5.57 g) was recorded for the 100% compost treatment under ambient temperature, while no significant differences were found among other interactions.

Previous studies have shown that lower soil bulk density improves crop yield by promoting root growth, whereas high bulk density (1.5–1.9 g/cm^3) restricts it due to reduced porosity and aeration (Gulser *et al*., 2010). In tropical regions, high temperatures and intense radiation are major constraints to plant growth and yield, causing leaf scorching, tissue damage, and reduced productivity (Wahid *et al*., 2007). Optimal temperatures enhance vegetative growth, including roots, shoots, and leaves, but excessive heat suppresses it. Generally, vegetative growth occurs at higher optimal temperatures than reproductive development in most plant species (Hatfield and Prueger, 2015).

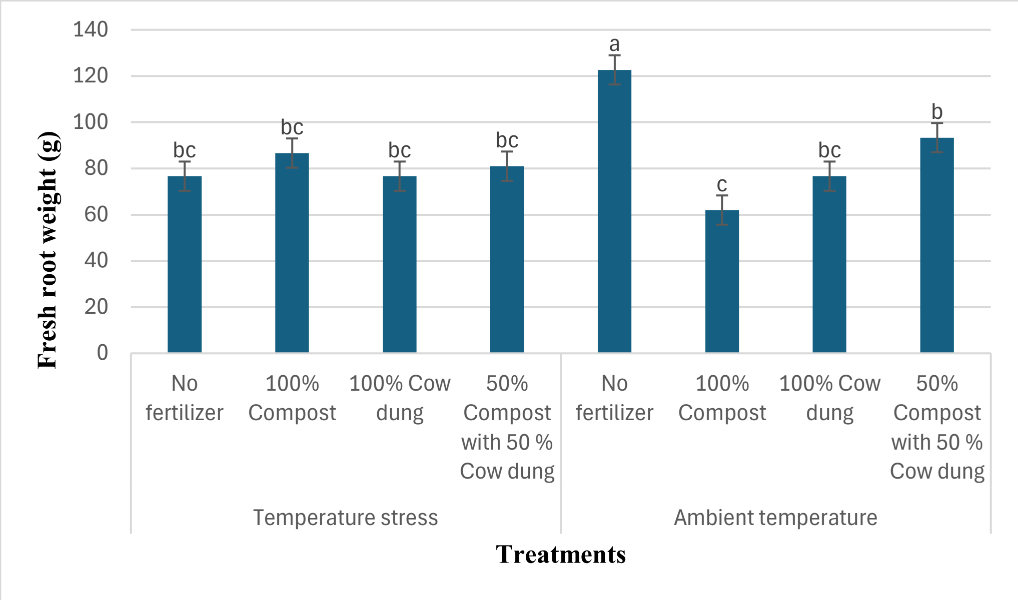

Figure 6. Effect of different organic fertilizer treatments on fresh root weight (g) of Heen Araththa under temperature stress and ambient temperature conditions

3.2.2. Dry Root Weight

The dry root weight remained relatively stable across temperature levels. The interaction between treatment and temperature was not significant but approached the 0.05 threshold, implying a possible trend that may emerge with larger samples. The highest dry root weight (39.00 ± 13.52 g) was observed in the no fertilizer treatment under ambient temperature (Table 3), while the lowest (11.33 ± 3.06 g) occurred in the 100% compost treatment under the same condition. Only these two differed significantly from each other.

Previous studies indicate that moist soils with lower impedance facilitate root penetration, while dense, dry soils hinder it. Some pioneer species develop aerenchyma to enhance aeration and survive under poor oxygen conditions. Reduced ped size improves soil structure and root growth (Logsdon, 2013). Temperature changes affect plant metabolic functions and structural components, influencing overall productivity, including root and shoot growth, nutrient and water uptake, and physiological processes like respiration and photosynthesis (Walne and Reddy, 2022). Further, concentrations of secondary metabolites too vary according to temperature changes in medicinal plants (Attanayake *et al*., 2025).

Table 3. Yield parameters of Heen Araththa under different organic fertilizer treatments subjected to temperature-stress and ambient-temperature conditions. Values represent mean ± SD. Means within a column followed by the same letter are not significantly different at $p \leq 0.05$.

Treatment combination (OM : Temperature)	Yield parameters	
	Fresh root weight (g)	**Dry root weight (g)**
No fertilizer with Temperature stress (M0T1)	76.67^{bc}±9.29	26.00^{ab}±5.57
100% Compost with Temperature stress (M1T1)	86.67^{bc}±34.96	25.00^{abc}±15.59
100% Cow dung with Temperature stress (M2T1)	76.67^{bc}±6.03	18.67^{bc}±2.52
50% Compost + 50% Cow dung with Temperature stress (M3T1)	81.00^{bc}±14.52	21.67^{bc}±5.03
No fertilizer with Ambient temperature (M0T2)	122.67^{a}±17.47	39.00^{a}±13.53
100% Compost with Ambient temperature (M1T2)	62.00^{c}±5.57	11.33^{c}±3.06
100% Cow dung with Ambient temperature (M2T2)	76.67^{bc}±0.58	19.00^{bc}±4.58
50% Compost + 50% Cow dung with Ambient temperature (M3T2)	93.33^{b}±5.86	21.33^{bc}±3.21

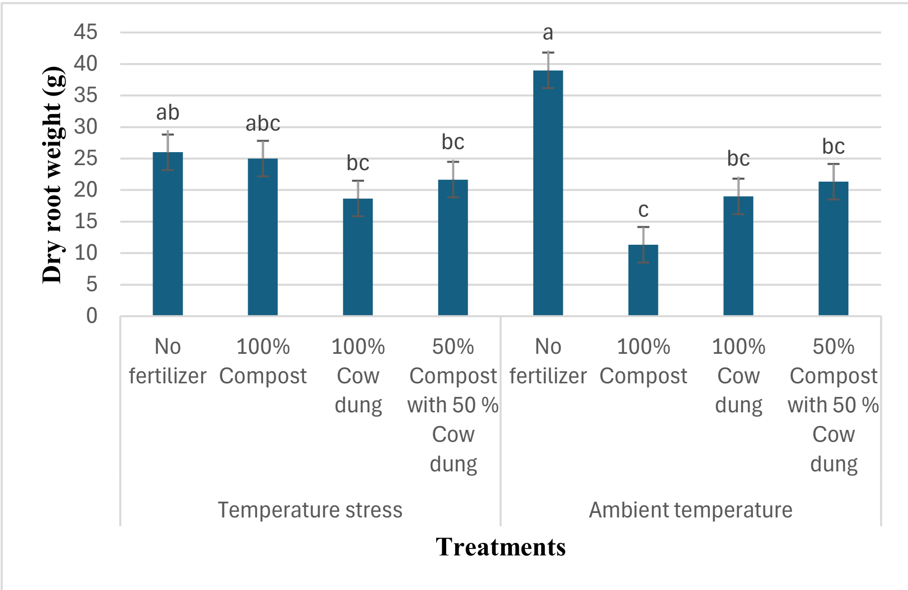

Figure 7. Effect of different organic fertilizer treatments on dry root weight (g) of Heen Araththa under temperature stress and ambient temperature conditions

3.3. Soil and Organic Manure Analysis

The potting mixture, composed of reddish-brown earth (RBE) soil, had a pH of 5.25, an electrical conductivity of 1.48 dS m^{-1}, 0.76% total nitrogen, 0.008% available phosphorus, and 0.001% exchangeable potassium. Both compost and cow dung exhibited good levels of available phosphorus and exchangeable potassium, with cow dung showing a higher total nitrogen content compared to compost.

Table 4. Initial analytical data of soil and organic manure

Soil/Organic Manure	pH	Electrical Conductivity (dS m^{-1})	Nitrogen %	Available phosphorous %	Exchangeable potassium %
Soil	5.25	1.48	0.76	0.88	1.06
Compost	6.35	0.39	0.6	0.08	0.77
Cow dung	8.28	0.973	1.25	0.33	1.68

Table 5. Final analytical data of soil and organic manures measured at the end of the experimental period.

Treatment combination	pH	Electrical Conductivity (dS m^{-1})	Available phosphorous %	Available potassium %
No fertilizer with Temperature stress (M0T1)	5.9	0.072	0.003	0.034
100% Compost with Temperature stress (M1T1)	6.0	0.289	0.01	0.075
100% Cow dung with Temperature stress (M2T1)	6.2	0.337	0.008	0.079
50% Compost + 50% Cow dung with Temperature stress (M3T1)	5.9	0.170	0.007	0.062
No fertilizer with Ambient temperature (M0T2)	6.3	0.068	0.003	0.060
100% Compost with Ambient temperature (M1T2)	5.8	0.157	0.007	0.062
100% Cow dung with Ambient temperature (M2T2)	6.2	0.113	0.002	0.047
50% Compost + 50% Cow dung with Ambient temperature (M3T2)	6.0	0.134	0.005	0.047

4. Conclusions

The study emphasizes how organic manure and temperature treatments have a major impact on various growth parameters for the medicinal plant Heen Araththa. When exposed to no fertilizer treatment under ambient temperature, the results showed a significant increase in shoot length, number of leaves, and leaf area. Additionally, the number of shoots showed significant enhancement with 100% compost treatment under the temperature stress. Considering the interaction effect of organic manure and temperature, the highest growth rate was observed in no fertilizer treatment under ambient temperature.

Furthermore, the fresh and dry weight of roots exhibited significant increase under ambient temperature with no fertilizer treatment. These findings suggest that, increased temperature will have detrimental effects on growth and yield of Heen Araththa. Further application of different organic manures too has no effect on growth and yield of Heen Araththa.

Author Contributions

Conceptualization, C.S.De.S. and H.K.L.K.G.; methodology, C.S.De.S. and H.K.L.K.G.; software, K.P.K.R.N.K. and A.M.S.U.M.A.; validation, K.P.K.R.N.K.and A.M.S.U.M.A.; formal analysis, K.P.K.R.N.K. and A.M.S.U.M.A.; investigation, K.P.K.R.N.K. and A.M.S.U.M.A.; resources, C.S.De.S. and H.K.L.K.G.; writing—original draft preparation, K.P.K.R.N.K.; writing—review and editing, C.S.De.S. and H.K.L.K.G.; supervision, C.S.De.S. and H.K.L.K.G.; project administration, C.S.De.S. and H.K.L.K.G. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest: The authors declare no conflict of interest.

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