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Assessing the Growth Response of Gimakalmi (*Ipomoea Aquatica*) under Alternative Wetting and Drying (AWD) System as Influenced by Plant Growth Regulator (PGRs) Application in the Rooftop Garden

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ABSTRACT

Growth responses of Gimakalmi (Ipomoea aquatica) was explored under an Alternative Wetting and Drying (AWD) irrigation system supplemented with Plant Growth Regulators (PGRs), specifically gibberellin. The experiment was conducted in a controlled rooftop garden environment at Habiganj Agricultural University, during the Boro season (January-June 2024), to assess the effects of different water supply and PGR treatments on the growth and yield of Gimakalmi.The soil at the experimental site was characterized as silt loam, with a pH of 6.14, 2.25% organic matter, 0.12% total nitrogen, 7.88 mg kg^{-1} of accessible phosphorus (P), 0.14 me 100 g^{-1} of exchangeable potassium (K), and 10.77 mg kg^{-1} of available sulfur (S). The experiment followed a randomized complete block design with four treatments, each replicated three times. The treatments included: T_0- Control, T_1- 100% Recommended Fertilizer Dose (RFD) + PGR, T_2- PGR + AWD water supply, and T_3-100% RFD + PGR + AWD water supply. Chemical fertilizers were applied during final soil preparation. The AWD method was used for irrigation, and PGRs were applied in a single dose. Results indicated that the combination of AWD and appropriate PGR application significantly enhanced the growth of Gimakalmi. At 7 days after sowing (DAS), the control (T_0) treatment recorded the lowest leaf number of 3.83, while the highest leaf number of 7.50 was observed in the T_3 treatment (100% RFD + PGR + AWD). This trend continued at 14 DAS, with the control showing 6 leaves and T_3 showing 12.16 leaves, and at 21 DAS, where T_0 had 7.66 leaves and T_3 had 14.16 leaves. Similarly, plant height was significantly higher in T_3, with the control treatment measuring 3.16 cm (7 DAS), 8.16 cm (14 DAS), and 14.66 cm (21 DAS), while T_3 showed plant heights of 6.83 cm (7 DAS), 24.66 cm (14 DAS), and 28.33 cm (21 DAS).In terms of yield, T_3 outperformed all other treatments. The yield ranged from 5.68 tha^{-1} in the T_0 (control) treatment to 11.51 tha^{-1} in T_3 during the first harvest (21 days after sowing). In the second harvest (36 days after sowing), the yield ranged from 3.96 tha^{-1} in $T_0$to 9.95 tha^{-1} in T_3, and in the third harvest (50 days after sowing), the yield ranged from 4.45 tha^{-1} in T_0 to 11.35 tha^{-1} in T_3.The results clearly show that T_3 (100% RFD + PGR + AWD) significantly enhanced both the growth and yield of Gimakalmi, and the AWD system contributed to improved water-use efficiency, making it a viable solution for sustainable urban agriculture. This research provides valuable insights into optimizing growth conditions for Gimakalmi in rooftop gardens and emphasizes the potential for water conservation, which is crucial for urban farming.

Keywords: *Plant growth regulator (PGRs), Rooftop garden, Gimakalmi (Ipomoea aquatica)*

1.Introduction

As urbanization continues to expand, the availability of arable land in urban areas is rapidly diminishing. This has made the adoption of innovative agricultural practices essential to ensure sustainable food production in limited spaces. One such approach that has gained significant attention is rooftop gardening[1] which allows for the efficient utilization of urban rooftops to cultivate a variety of crops. Among the crops well-suited for these environments, gimakalmi (*Ipomoea aquatica*) stands out for its high nutritional value and remarkable adaptability to diverse growing conditions.

Water spinach is widely recognized for its fast growth, ease of cultivation, and ability to thrive in a range of environments, making it an ideal choice for urban agriculture[2]. However, maximizing its growth and yield in rooftop gardens requires a more nuanced understanding of the factors that influence its development. In particular, the choice of irrigation methods and the application of plant growth regulators (PGRs) play critical roles in determining the success of water spinach cultivation [3]. These factors can significantly impact plant health, growth rate, and overall yield, underscoring the importance of research and experimentation in this area [4].By investigating the effects of different irrigation strategies and PGR applications on the growth of gimakalmi, urban gardeners and researchers can identify the most effective techniques to optimize its productivity. Such efforts not only contribute to sustainable food production in urban spaces but also promote the efficient use of water and other resources. As highlighted by [5], understanding the interplay between these factors is key to unlocking the full potential of rooftop gardening as a solution to urban food security challenges.

The Alternative Wetting and Drying (AWD) system is an innovative irrigation technique that alternates between periods of drying and re-wetting the soil, allowing for substantial water conservation while potentially enhancing plant performance [6]. This method has been widely recognized for its effectiveness in a variety of crops, primarily due to its ability to stimulate root growth and improve the uptake of essential nutrients. However, despite its proven benefits in traditional agricultural settings, the specific impact of the AWD system on gimakalmi (*Ipomoea aquatica*), especially under the distinct environmental conditions of a rooftop garden, remains largely unexplored.

In rooftop gardening scenarios, where space, soil depth, and water availability are often constrained, understanding the role of irrigation techniques such as AWD is particularly critical. This system could hold promise for improving water use efficiency and ensuring consistent growth in crops like gimakalmi, which is valued for its adaptability and nutritional benefits. However, the interaction between the AWD system and other factors, such as plant physiology and rooftop environmental stresses, requires detailed investigation to determine its full potential in urban agriculture.

Additionally, the role of Plant Growth Regulators (PGRs) in enhancing plant productivity cannot be overstated. PGRs are chemical substances that profoundly influence a range of physiological processes in plants, including growth, development, flowering, and stress responses. By modulating these processes, PGRs can help plants adapt to challenging conditions, such as limited soil volume and higher temperatures often encountered in rooftop gardens. Exploring the combined effects of AWD irrigation and PGR applications on gimakalmi could provide valuable insights into optimizing its cultivation in urban settings, paving the way for more sustainable and efficient food production systems.

In constrained environments like rooftop gardens, where challenges such as limited soil depth, restricted root development, and exposure to fluctuating microclimatic conditions are prevalent, the strategic use of Plant Growth Regulators (PGRs) offers a promising solution. These substances can mitigate environmental stress, promote physiological resilience, and enhance overall plant growth, making them an invaluable tool for urban agriculture. Coupled with innovative irrigation methods like the Alternative Wetting and Drying (AWD) system, PGRs have the potential to significantly improve crop performance in such unique growing environments.

This study aims to evaluate the growth response of gimakalmi (Ipomoea aquatica) when cultivated under the AWD irrigation system in a rooftop garden setting, with a specific emphasis on the role of PGR application. Key growth parameters, including plant height, leaf number, biomass production, and water use efficiency, will be systematically assessed to understand the interaction between irrigation practices and PGR influence.The research seeks to uncover practical strategies for optimizing the cultivation of gimakalmi in urban farming systems, contributing to sustainable agricultural practices.

By promoting efficient water use, reducing resource input, and enhancing crop productivity, the findings of this study will provide valuable insights for addressing the challenges of urban food production while ensuring environmental sustainability and resource conservation.

2. Materials and Methods

2.1. Experimental Site and Soil Properties

The experiment was carried out at the rooftop garden of Habiganj Agricultural University, located in Habiganj, during the 2024 boro season, which spanned from February to March. The study utilized 12 soil beds prepared in geo bags, each measuring 3 feet in length, 2 feet in width, and 1 foot in depth. These compact soil beds provided a controlled environment suitable for evaluating the growth and yield of gimakalmi (*Ipomoea aquatica*) under specific irrigation and growth regulator treatments.

Prior to initiating the experiment, a comprehensive soil analysis was conducted to determine the baseline soil properties and ensure optimal growing conditions for the study. To achieve this, twelve composite soil samples were collected systematically from the experimental soil beds. These samples were analyzed using standard laboratory procedures to assess key physical and chemical properties of the soil.

The results of the soil analysis revealed that the soil had a silt loam texture, which is known for its moderate water-holding capacity and good aeration, making it suitable for plant growth. The pH of the soil was determined to be 6.14, indicating a slightly acidic condition, which is within the acceptable range for many crops, including gimakalmi. The soil contained 2.25% organic matter, reflecting a moderate level of fertility that could support healthy plant development. The total nitrogen content was measured at 0.12%, an important factor for vegetative growth. The available phosphorus (P) concentration was 7.88 mg kg^{-1}, which is crucial for root development and energy transfer within the plant. Exchangeable potassium (K), a vital nutrient for overall plant health and stress tolerance, was found at 0.14 me 100 g^{-1}, while the available sulfur (S) content was 10.77 mg kg^{-1}, a nutrient essential for protein synthesis and chlorophyll production.

By establishing these soil characteristics, the experiment was designed with a solid understanding of the initial conditions, allowing for a precise evaluation of the impact of irrigation methods and plant growth regulators on gimakalmi cultivation in a rooftop garden setting. This detailed soil profiling not only ensured the reliability of the study but also provided valuable baseline data for future research in urban agriculture.

2.2. Test Crops and Treatments

Gimakalmi (*Ipomoea aquatica*), a highly adaptable and nutritionally rich leafy vegetable, was selected as the test crop for this experiment due to its suitability for rooftop gardening and its ability to respond to innovative cultivation techniques. The study incorporated four distinct treatment combinations to evaluate the effects of irrigation methods and plant growth regulators (PGRs) on the growth and productivity of the crop. The treatments were as follows:

T0 (Control): This treatment served as the baseline, with no additional inputs or modifications applied, providing a reference point for comparing the effects of the other treatments.

T1 (100% RFD + PGR): This treatment involved the application of 100% of the Recommended Fertilizer Dose (RFD) along with PGR, aimed at assessing the combined impact of optimal fertilization and growth regulator application.

T2 (PGR + AWD Water Supply): In this treatment, PGR was applied alongside the Alternative Wetting and Drying (AWD) irrigation method, designed to evaluate how these two factors interact and influence the growth of gimakalmi under water-saving conditions.

T3 (100% RFD + PGR + AWD Water Supply): This treatment combined all three components—100% RFD, PGR application, and the AWD irrigation method—to explore the synergistic effects of these interventions on plant growth and yield.
These treatment combinations were carefully chosen to investigate the individual and interactive impacts of PGRs, fertilization, and the AWD irrigation system on gimakalmi cultivation. The findings are expected to provide insights into optimizing resource use while enhancing crop productivity in constrained urban gardening environments.

2.3. Organizing Trial Soil Bed (Geo bags) and Seed Sowing

The experiment was conducted using geo bags filled with soil, arranged to create a well-structured and controlled environment for studying the growth of gimakalmi (Ipomoea aquatica). The experimental design followed a Randomized Complete Block Design (RCBD), ensuring reliable results through proper replication and randomization. The experimental area was divided into three blocks, each serving as a replication. Each block consisted of four soil beds, making a total of 12 soil beds for the entire experiment. The treatments were randomly distributed among the unit plots within each block to minimize bias. Each geo bag soil bed measured 3 meters in length, 2 meters in width, and 1 meter in depth, providing ample space for root development and crop growth.
To ensure optimal nutrient availability, nitrogen (N), phosphorus (P), and potassium (K) were applied in the form of urea, triple super phosphate (TSP), and muriate of potash (MoP), respectively, following the guidelines provided in the Fertilizer Recommendation Guide [7]. The recommended application rates were 150 kg N, 50 kg P, and 25 kg K per hectare.
Seeds were sown directly into the soil beds, maintaining a spacing of 5 inches between rows and plants. At each sowing point, 10 seeds were planted to ensure uniform germination and optimal plant density.
The irrigation was managed using the Alternative Wetting and Drying (AWD) method, an efficient water-saving technique that alternates between drying and rewetting the soil. This method was complemented by the application of Plant Growth Regulators (PGRs) in a single dose to enhance plant growth and stress tolerance.
Regular intercultural operations, such as weeding, thinning, and pest management, were carried out as needed to maintain healthy crop growth throughout the experiment.
This setup allowed for a systematic evaluation of the combined effects of AWD irrigation, PGR application, and fertilization on the growth and yield of gimakalmi in a rooftop garden setting. The design and management practices ensured precision and reliability, contributing to the generation of meaningful insights for urban agriculture.

2.4. Harvesting and Data Recording

The crops were harvested once they reached full maturity, ensuring the assessment of their growth and yield potential. Each experimental allotment provided a 6 m^2 harvest space, allowing for the collection of sufficient data from each treatment. Following harvest, the crops were carefully packaged individually to maintain quality and facilitate subsequent analysis.
To evaluate the data statistically, an F-test was employed to assess the significance of the results, helping determine whether there were meaningful differences between the treatments. To further explore these differences, Duncan's New Multiple Range Test (DMRT) was used to identify specific mean differences among the treatments. This statistical approach, as outlined by Gomez and Gomez, ensured a rigorous analysis of the experimental data, providing reliable insights into the effects of the various treatments on gimakalmi growth and productivity.

3. Results and Discussion

3.1.Effect of applying of alternative wetting and drying (AWD) water supply system with plant growth regulator PGRs on leaf number of Gimakalmi (*Ipomoea aquatica*)

The study findings demonstrated that the application of the Alternative Wetting and Drying (AWD) water supply system combined with Plant Growth Regulators (PGRs) had a significant impact on Gimakalmi's (Ipomoea aquatica) growth and yield-contributing traits, such as leaf number (Table 1, Fig. 1).
The leaf number varied significantly across treatments and growth stages. At 7 days after sowing (DAS), the lowest leaf number was observed in the T0 (control) treatment, with an average of 3.83 leaves, while the highest leaf number, 7.50, was recorded in the T3 treatment (100% recommended fertilizer dose [RFD] combined with PGRs and AWD water supply). Similarly, at 14 DAS, the T0 treatment exhibited the lowest leaf number, averaging 6 leaves, whereas the T3 treatment recorded the highest leaf number of 12.16. By 21 DAS, the trend persisted, with T0 showing the lowest leaf number (7.66) and T3 achieving the highest leaf number (14.16). These results highlight the significant influence of the T3 treatment in enhancing leaf production across all growth stages.

Table 1. Effect of applying of alternative wetting and drying (AWD) water supply system with plant growth regulator PGRs on leaf number of Gimakalmi (Ipomoea aquatica)

Treatments	Number of leaves per plantat		
	7 DAS	14 DAS	21 DAS
T0	3.83 ± 0.28^c	6 ± 1^b	7.66 ± 0.57^d
T1	5.16 ± 0.28^b	7.33 ± 0.57^b	10.00 ± 0^c
T2	6.50 ± 0.50^a	8 ± 1^b	11.33 ± 0.57^b
T3	7.50 ± 0.50^a	12.16 ± 0.28^a	14.16 ± 0.28^a
P Value	0.000	0.000	0.000

At the five percent significance level, figures in a column with similar letters do not differ significantly; SE (±) is the standard error of means; p is the probability. Significance level α = 0.05. The treatments are: T0 – Control, T1 – 100% RFD+PGR, T2 – PGR+AWD water supply, T3 – 100% RFD+PGR+AWD water supply

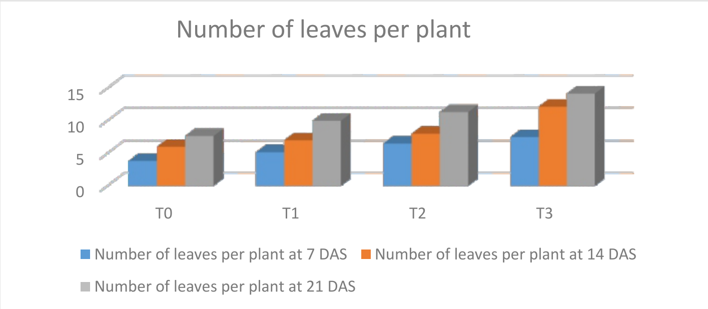

Figure 1. Effect of applying of alternative wetting and drying (AWD) water supply system with plant growth regulator (PGRs on leaf number of Gimakalmi (Ipomoea aquatica)

3.2.Effect of applying of alternative wetting and drying (AWD) water supply system with plant growth regulator (PGRs on plant height of Gimakalmi (*Ipomoea aquatica*)

The application of the Alternative Wetting and Drying (AWD) water supply system combined with Plant Growth Regulators (PGRs) had a significant impact on Gimakalmi's (Ipomoea aquatica) growth and yield-contributing traits, such as plant height (Table 2, Fig. 2).

Plant height showed significant variation among treatments across all growth stages. At 7 days after sowing (DAS), the lowest plant height was recorded in the T0 (control) treatment, with an average of 3.16 cm, while the highest plant height of 6.83 cm was observed in the T3 treatment (100% recommended fertilizer dose [RFD] combined with PGRs and AWD water supply). At 14 DAS, the T0 treatment again exhibited the shortest plants, averaging 8.16 cm, whereas the T3 treatment achieved the tallest plants, with an average height of 24.66 cm. By 21 DAS, the T0 treatment recorded the lowest plant height of 14.66 cm, while the T3 treatment maintained the tallest plants at an average height of 28.33 cm. These findings clearly indicate that the T3 treatment significantly promoted plant height throughout the observed growth stages compared to the control treatment.

Table 2. Effect of applying of alternative wetting and drying (AWD) water supply system with plant growth regulator (PGRs on plant height of Gimakalmi (Ipomoea aquatica)

Treatments	Plant height (cm) at		
	7 DAS	14 DAS	21 DAS
T0	3.16±0.28[c]	8.16±0.28[b]	14.66±0.57[c]
T1	5.16±0.28[b]	13±0.50[b]	19.66±0.57[b]
T2	6.16±0.28[a]	8.50±6.76[b]	21.66±0.57[b]
T3	6.83±0.28[a]	24.66±0.57[a]	28.33±1.52[a]
P Value	0.000	0.001	0.000
At the five percent significance level, figures in a column with similar letters do not differ significantly; SE (±) is the standard error of means; p is the probability. Significance level α = 0.05. The treatments are: T0 – Control, T1 – 100% RFD+PGR, T2 – PGR+AWD water supply, T3 – 100% RFD+PGR+AWD water supply			

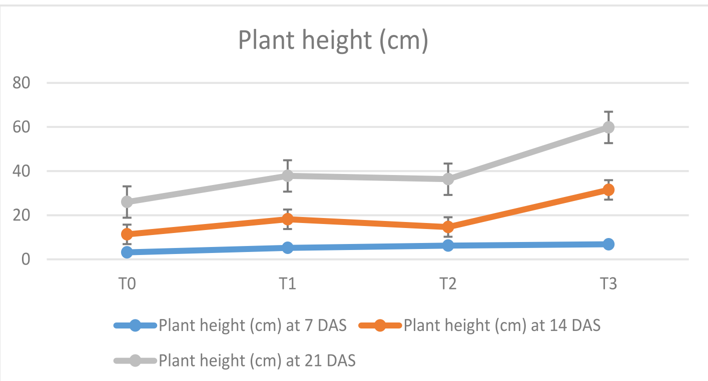

Figure 2. Effect of applying of alternative wetting and drying (AWD) water supply system with plant growth regulator PGRs on plant height of Gimakalmi (Ipomoea aquatica)

3.3.Effect of applying of alternative wetting and drying (AWD) water supply system with plant growth regulator (PGRs) on yield of Gimakalmi (*Ipomoea aquatica*)

The yield of Gimakalmi (Ipomoea aquatica) was significantly influenced by the application of the Alternative Wetting and Drying (AWD) water supply system combined with Plant Growth Regulators (PGRs) (Table 3, 4).

In the first harvest, at 21 days after seed sowing, the yield ranged from 316.67 g in the T0 (Control) treatment to 641.67 g in the T3 treatment (100% RFD + PGR + AWD water supply). In the second harvest, at 36 days after seed sowing, the yield ranged from 221 g in the T0 (Control) treatment to 555 g in the T3 treatment. By the third harvest, at 50 days after seed sowing, the yield ranged from 248.3 g in the T0 (Control) treatment to 632.7 g in the T3 treatment (Table 3, Fig. 3).

These results clearly show the significant effect of the T3 treatment on enhancing yield across all harvest stages compared to the control treatment.

Table 3. Effect of applying of alternative wetting and drying (AWD) water supply system with plant growth regulator (PGRs) on yield of Gimakalmi (Ipomoea aquatica)

Treatments	Yield per bed (g) at		
	21 DAS	36 DAS	50 DAS
T0	316.67±7.64[c]	221±14.93[d]	248.3±23.6[c]
T1	464.3±43.3[b]	325±15[c]	338.7±33.5[bc]
T2	612.33±6.81[a]	423±12.58[b]	440±15[b]
T3	641.67±10.41[a]	555±15[a]	632.7±110.6[a]
P Value	0.000	0.000	0.000
At the five percent significance level, figures in a column with similar letters do not differ significantly; SE (±) is the standard error of means; p is the probability. Significance level α = 0.05. The treatments are: T0 – Control, T1 – 100% RFD+PGR, T2 – PGR+AWD water supply, T3 – 100% RFD+PGR+AWD water supply			

The yield ranged between 5.68 t ha^{-1} (T0- Control) to 11.51 t ha^{-1} (T3- 100% RFD+PGR+AWD water supply) in first harvest at the 21 days after seed sowing. Again the yield was ranged between 3.96 t ha-1 (T0- Control) to 9.95 t ha-1 (T3- 100% RFD+PGR+AWD water supply) in second harvest at the 36 days after seed sowing. The yield was ranged between 4.45 t ha^{-1} (T0- Control) to 11.35 t ha^{-1} (T3- 100% RFD+PGR+AWD water supply) in the third harvest at the 50 days after seed sowing.(Table 4, Fig. 3).

Table 4. Effect of applying of alternative wetting and drying (AWD) water supply system with plant growth regulator (PGRs) on yield of Gimakalmi (Ipomoea aquatica)

Treatments	Yield per ha (ton) at		
	21 DAS	36 DAS	50 DAS
T0	5.68±0.13^{c}	3.96±0.26^{d}	4.45±0.42^{c}
T1	8.33±0.77^{b}	5.83±0.26^{c}	6.07±0.60^{bc}
T2	10.98±0.12^{a}	7.59±0.22^{b}	7.89±0.26^{b}
T3	11.51±0.18^{a}	9.95±0.26^{a}	11.35±1.98^{a}
P Value	0.000	0.000	0.000

At the five percent significance level, figures in a column with similar letters do not differ significantly; SE (±) is the standard error of means; p is the probability. Significance level α = 0.05. The treatments are: T0 – Control, T1 – 100% RFD+PGR, T2 – PGR+AWD water supply, T3 – 100% RFD+PGR+AWD water supply

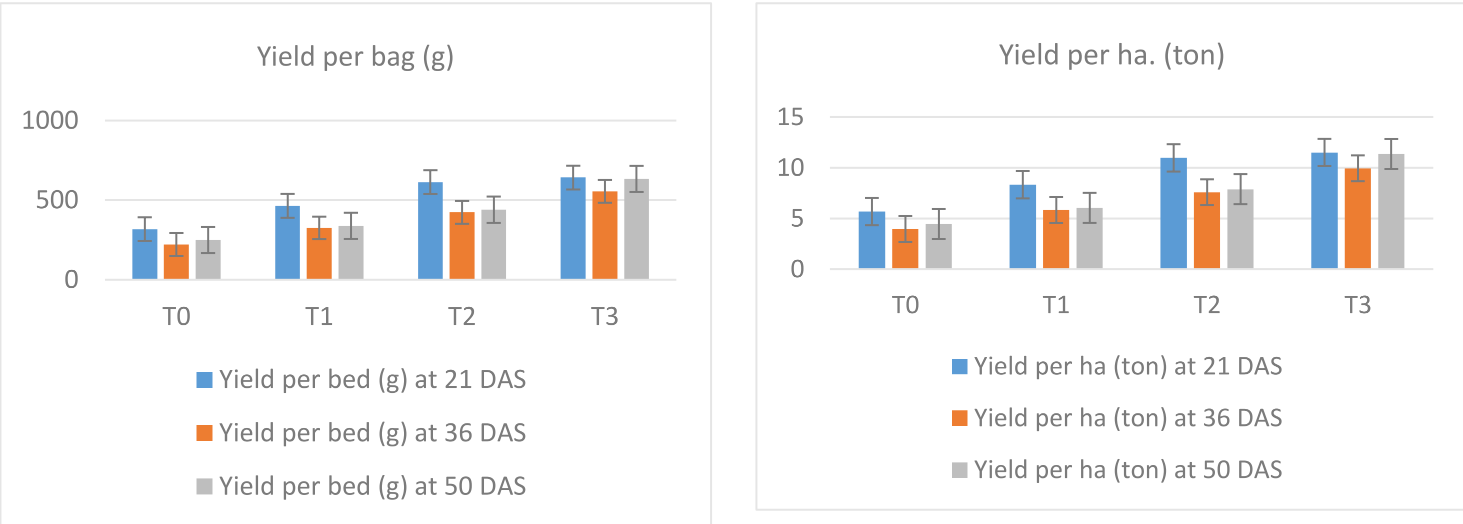

Figure 3. Effect of applying of alternative wetting and drying (AWD) water supply system with plant growth regulator (PGRs) on yield of Gimakalmi (Ipomoea aquatica)

4. Conclusion

This study demonstrates that integrating the Alternative Wetting and Drying (AWD) water management system, full fertilizer application, and Plant Growth Regulators (PGRs) significantly enhances the growth, yield, and water-use efficiency of *Ipomoea aquatica* (gimakalmi) in rooftop gardens. Among the treatments tested, T3 (100% recommended fertilizer dose [RFD] + PGR + AWD) exhibited the highest performance, optimizing both plant growth and yield while efficiently conserving water. T2 (PGR + AWD) also showed promising results, highlighting that PGRs can effectively mitigate water stress and promote plant growth even under water-limited conditions.These findings underscore the potential of combining AWD, PGRs, and full fertilization as a sustainable and efficient approach for urban agriculture, particularly in resource-constrained environments. It is recommended that urban gardeners adopt the T3 treatment to achieve maximum productivity and water conservation, while T2 offers a viable alternative when fertilizer use is restricted. Furthermore, continued research and awareness programs are essential to further explore and promote these practices, expanding their application in urban farming and contributing to more sustainable food production systems.

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