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Effects of Sodium Nitroprusside on the Growth and Development of Melothria scabra

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Abstract. This study examined the ideal concentration and application method of sodium nitroprusside for improving vegetative growth of melothria scabra (thumb watermelon) with the objective of providing a theoretical basis and technical guidance for reducing the cultivation period of watermelon and improving planting efficiency. **[Methods]** Uniform seedlings of Melothria scabra were selected and assigned for the experiment. Seven treatment groups were established:root irrigation at three sodium nitroprusside concentrations (1 mg/L, 2 mg/L, and 4 mg/L); foliar spraying at the same three concentrations; and a control group treated with water. The treatments were made every 5 days, a total of 4 times, with 10 mL of solution applied at each application per plant. Plant height, stem diameter, and leaf number were measured at regular intervals to assess the effects of the different treatments. **[Results]** All the sodium nitroprusside levels substantially contributed to the growth of Melothria scabra seedlings compared to the control. Root irrigation was consistently superior to foliar spraying in improving plant height, stem thickness, and leaf production. Among the treatments, root irrigation using 2 mg/L sodium nitroprusside showed the highest improvement, with plants attaining an average height of 79 cm, a mean stem diameter of 0.52 cm, and an average of 18 leaves. **[Conclusion]** The application of sodium nitroprusside would significantly increase the vegetative growth of Melothria scabra. Comprehensive evaluation of growth indicators indicates that root irrigation with a 2 mg/L solution of sodium nitroprusside is the most effective approach to improve plant vigor, providing technical support to reduce the growth cycle and increase crop productivity.

Keywords: Melothria scabra (thumb watermelon); Plant development; Plant growth regulators; Root irrigation; Foliar spraying.

1. Introduction

Melothria scabra Naudin, or Mexican miniature watermelon and thumb watermelon, is an annual climbing vine in the family of Cucurbitaceae native to Mexico and Central America. Its fruits have utility as a food source and decorative product, being rich in bioactive compounds such as vitamin C and cucurbitacinc C. These nutritional and functional properties render the fruit the fruit with significant appeal, both in the context of fresh consumption and with respect to its potential application in health-promoting products. Due to its adaptability and endurance during storage and transportation, Kava has become increasingly popular in the past few years as a specialty crop. However, one key constraint to its extensive development is the rather extended time span for fruit maturation, often 65-80 days from fruit set to harvest[1]. Under open-field conditions, this long cycle enhances susceptibility to disease, particularly under rainy seasons, and also increases production costs associated with crop protection and field management. Moreover, the extended growth period may limit the efficiency of land use, preventing farmers from rotating or intercropping with other short-season crops. In areas that have limited growing seasons, such as northern areas, the long maturing season has become a major issue for its successful introduction and commercialization. Therefore, the development of effective strategies to reduce the length of both the vegetative and the reproductive growth stages is critical in attaining efficient and high quality production.

Plant growth regulators are bioactive substances with a key role in plant development regulation. Exogenous use of plant growth regulators allows for the precise manipulation of endogenous hormone levels to affect vegetative growth, fruit set, yield, and overall crop quality[2]. Among these compounds sodium nitroprusside has gained broader interest in recent years. It's considered a very efficient, non-toxic, and residue-free cell activator. It quickly moves into plant cells and induces protoplasmic streaming and increases cell activity, thus aiding developmental processes as diverse as

root initiation, seed germination, vegetative growth, and reproductive development. Previous studies had shown that sodium nitroprusside can be used to speed up fruit development, reduce the fruit-set time, and enhance photosynthetic efficiency and stress tolerance of different crops[3]. From an agronomic perspective, the application of appropriate amounts of sodium nitroprusside usually leads to enhanced chlorophyll retention, increased stomatal conductance, and more efficient nutrient utilization. All these traits play a significant role in promoting higher biomass accumulation and enhancing the stability of crop yields. Nevertheless, the impacts of sodium nitroprusside are contingent upon its concentration, the timing of application, and the plant species involved. Notably, low doses of sodium nitroprusside tend to stimulate plant growth and enhance stress resilience. However, when treatments involve excessive amounts or are applied inappropriately, there is a risk of disrupting cellular homeostasis. Consequently, optimizing the application protocols of sodium nitroprusside for specific crops at particular growth stages is of the utmost importance, as it enables us to maximize the benefits brought by sodium nitroprusside while effectively avoiding any unintended adverse side effects.

Despite the wide use of plant growth regulators, little is known about the specific effect of sodium nitroprusside on Melothria scabra. In particular, the best method of application (root irrigation versus foliar spray) and concentration for stimulating vegetative growth are thus characterized. To characterize that gap, the present work systematically assessed the impact of various concentrations of sodium nitroprusside applied by root irrigation and foliar spraying on the vegetative growth of Melothria scabra seedlings. By comparing growth parameters across treatments, this study not only identifies the most effective application strategy but also provides insights into the broader physiological roles of sodium nitroprusside in early-stage plant development. The results strive to serve as the theoretical foundation and technical guideline for early maturation and improving the yield for this new specialty crop.

2. Materials and methods

2.1 Experimental materials and growth conditions

The seeds of Melothria scabra were first germinated and then developed into seedlings. Healthy, pest-free seedlings that were fully enlarged at the cotyledons, with a uniform height (5.0 ± 0.5 cm), were selected for the experiment. On January 15, 2025, the seedlings were planted in black plastic pots (5 cm diameter x 15 cm height). The cultivation substrate consisted of a 1:1 volumetric mixture of nutrient soil and peat moss to ensure optimal aeration and drainage. On January 16, 2025, all pots were moved into a greenhouse and managed under uniform conditions of light, temperature, and humidity. Standard cultivation practices, including watering, pest control, and pruning, were maintained throughout the experiment.

2.2 Experimental design

The experiment was conducted using a completely randomized design with 7 treatments and 3 replications, for a total of 21 experimental units. The treatments were as follows: Root Irrigation: 1 mg/L, 2 mg/L, and 4 mg/L sodium nitroprusside solutions. Foliar Spray: 1 mg/L, 2 mg/L, and 4 mg/L sodium nitroprusside solutions. Control: Application of plain water via both root irrigation and foliar spray, synchronized with the treatment groups.

Sodium nitroprusside (98% purity, commercial grade) was dissolved in distilled water to prepare the specified concentrations. For root irrigation, the solution was gently poured along the inner wall of the pot to avoid disturbing the root system. For foliar application, a manual sprayer was used to uniformly moisten both the adaxial and abaxial surfaces of the leaves until glistening but not dripping. The initial treatment was applied on January 18, 2025, followed by subsequent applications every 5 days for a total of four times. Each plant received 10 mL of solution per application.

2.3 Measurements and methods

The growth status of the Melothria scabra seedlings was observed and recorded regularly. Growth indicators were measured on the day of the first treatment (January 18, 2025) and subsequently at 10, 20, 30, 40, 50, and 60 days post-application. For plant height, the vertical distance from the substrate surface to the apical growing point was measured with a ruler to the nearest 0.1 cm. For stem diameter, the diameter of the stem at 1 cm above the substrate surface was measured with a vernier caliper to the nearest 0.01 cm. For leaf number, the quantity of fully expanded, healthy leaves on each plant was counted (cotyledons were excluded).

2.4 Data analysis

Data were processed and organized using Excel 2019, and results were expressed as the mean ± standard deviation (Mean ± SD). A one-way analysis of variance (ANOVA) was conducted using SPSS 27.0, followed by Duncan's new multiple range test for post-hoc comparisons. A probability level of $P < 0.05$ was considered statistically significant.

3. Results and Analysis

3.1 Effects of sodium nitroprusside on the plant height of Melothria scabra

As illustrated in Figure 1, all sodium nitroprusside treatments significantly promoted the height of Melothria scabra plants compared to the water-treated control, with this effect becoming more pronounced over time. Seedlings in the control group grew slowly, reaching only about 20 cm by March 19. In contrast, plants in all treatment groups were substantially taller and entered a phase of rapid growth after February 7, demonstrating the activating effect of sodium nitroprusside on vegetative growth. Overall, root irrigation was superior to foliar spraying for increasing plant height. The growth curves for the root-irrigated plants were consistently above those for the sprayed plants, and their growth rate was faster. By March 19, the 2 mg/L root irrigation treatment produced the tallest plants (nearly 80 cm), which was significantly greater than the height achieved with the same concentration applied as a foliar spray (70 cm). This suggests that root uptake of sodium nitroprusside allows for more direct and efficient regulation of above-ground growth. The 2 mg/L concentration was identified as the optimal root irrigation treatment, as it resulted in significantly greater plant height at all measurement points compared to the 1 mg/L and 4 mg/L concentrations and displayed the most stable growth pattern. Among the foliar spray treatments, the 4 mg/L concentration yielded the greatest height, though it was still less effective than any of the root irrigation treatments. The 1 mg/L spray was the least effective treatment, indicating that the efficacy of foliar applications is limited by leaf absorption efficiency. All treated plants exhibited a sharp increase in height between February 7 and February 17, identifying this as a critical period for vegetative growth in Melothria scabra that is effectively enhanced by sodium nitroprusside.

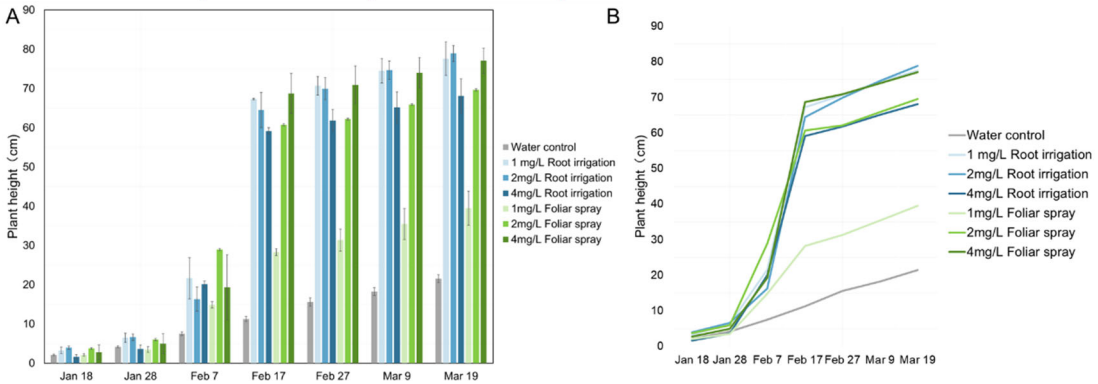

Figure 1: Effects of sodium nitroprusside application at different concentrations and methods on the plant height of Melothria scabra

3.2 Effects of sodium nitroprusside on the stem diameter of Melothria scabra

All sodium nitroprusside treatments effectively promoted the thickening of the stems (Figure 2). Compared to the control, all treated groups showed significantly higher rates of increase in stem diameter and a larger final diameter. The stems of control plants thickened slowly, reaching only about 0.3 cm by March 19, whereas treated plants entered a rapid thickening phase after January 28. Consistent with the results for plant height, root irrigation was generally more effective than foliar spraying in promoting stem diameter. The growth curves for root-irrigated plants were consistently higher and showed greater stability. By the end of the experiment, the 2 mg/L root irrigation treatment produced the thickest stems (0.52 cm), which was significantly greater than that from the same concentration applied as a foliar spray (0.31 cm). This finding suggests that root uptake more directly stimulates the development of vascular bundles and mechanical tissues within the stem. The 2 mg/L root irrigation treatment was optimal, producing significantly thicker stems than the 1 mg/L and 4 mg/L treatments at all measurement points and demonstrating the most stable rate of increase. A critical period for stem thickening was observed between January 28 and February 17, during which all treated plants showed a sharp increase in diameter, indicating that sodium nitroprusside application can effectively accelerate stem strengthening during this key developmental stage.

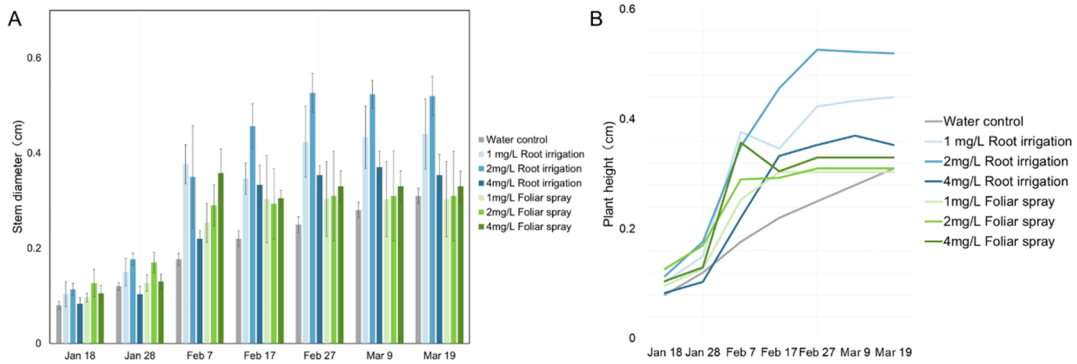

Figure 2: Effects of sodium nitroprusside application at different concentrations and methods on the stem diameter of Melothria scabra

3.3 Effects of sodium nitroprusside on the leaf number of Melothria scabra

As shown in Figure 3, all sodium nitroprusside treatments effectively increased the number of leaves. Treated plants exhibited significantly higher rates of leaf production and greater final leaf counts than the control group. Control plants produced only about 13 leaves by March 19, while treated plants entered a period of rapid leaf development after January 28. In the early stages (before February 7), root irrigation initiated leaf production more rapidly than foliar spraying. The 2 mg/L root irrigation treatment resulted in the highest final leaf count (nearly 20) and demonstrated high stability. Interestingly, the leaf counts in the foliar spray groups began to catch up to the root-irrigated groups in the later stages of the experiment (after February 27). The final leaf number under the 4 mg/L spray treatment was not significantly different from the root irrigation groups, suggesting a delayed but sustained effect from foliar application. Within the root irrigation treatments, the 2 mg/L concentration consistently produced significantly more leaves than the 1 mg/L and 4 mg/L concentrations. A sharp increase in leaf number was observed in all treated plants between January 28 and February 17, highlighting this period as a critical window for leaf initiation and expansion that is effectively stimulated by sodium nitroprusside.

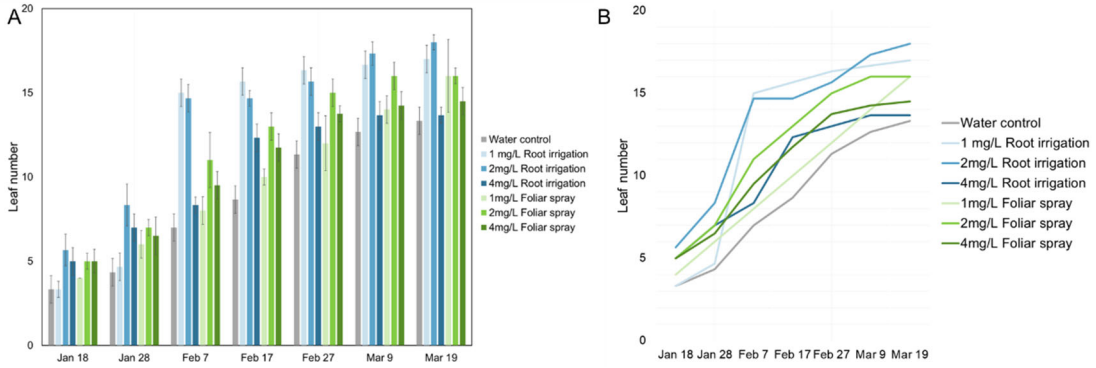

Figure 3: Effects of sodium nitroprusside application at different concentrations and methods on the leaf number of Melothria scabra

4. Discussion

This study systematically evaluated the impact of sodium nitroprusside on the vegetative growth of Melothria scabra and clearly demonstrates that early application made exogenously strongly accelerates the early development. These results fill an important research void and offer a new technical method to overcome the serious production limitation of the extended cultivation time in Melothria scabra.

The results that all sodium nitroprusside treatments significantly improved plant height, stem diameter, and leaf number reveals its broad-spectrum growth-promoting activity in this plant species. The reason for this underlying mechanism can be explained by its acting as a cellular activator: Sodium nitroprusside readily penetrates plant tissues, enters the protoplasmic streaming, and increases the action of important metabolic enzymes such as ATPases that accelerate the entire cellular metabolism[4]. At the level of morphology, this cellular activation stimulates both rapid cellular division and elongation in the meristematic tissues, resulting in more intense stem elongation and thickening, as well as the differentiation of leaf primordia and expansion of leaf blades. These findings are similar to other cucurbits like the cucumber and watermelon, indicating that growth-promoting mechanism of SNP is broadly conserved across the species[5].

A particularly important result of this study is the superior effectiveness of root irrigation over foliar spraying in improving systemic growth characteristics such as plant height and stem diameter. This difference is related to the unique pathways of uptake and transport in plants. Roots are the main organ for absorption of water and nutrients, central to hormone biosynthesis and signaling[6]. When sodium nitroprusside is applied via root irrigation, it is efficiently absorbed and transported through the xylem with the transpiration stream, enabling rapid and sustained delivery to aerial tissues, particularly the shoot apices where active growth occurs[7]. By contrast, foliar absorption of water-soluble compounds such as sodium nitroprusside is constrained by the hydrophobic cuticular barrier. Although limited uptake can occur through stomata or microcracks, subsequent redistribution relies mainly on phloem transport, which is slower, energy-dependent, and more restricted in capacity compared with xylem-mediated translocation[8,9]. Consequently, foliar application tends to exert more localized and delayed effects on growth, explaining its lower efficacy relative to root irrigation observed in this study.

This research identified 2 mg/L as the optimal concentration for root irrigation, with the 4 mg/L concentration being less effective. This non-linear, dose-dependent response, often described as hormesis or a "low-promotion, high-inhibition" effect, is characteristic of plant growth regulators[10]. The 1 mg/L concentration, while beneficial, may have been below the threshold required to fully saturate cellular receptors and activate signaling pathways. The 2 mg/L concentration appears to fall within the optimal range, maximally stimulating metabolic activity and synergistic interactions with endogenous hormones. However, at 4 mg/L, the effect may have shifted from promotion to inducing mild stress. For a soil drench, an excessively high concentration can increase the osmotic potential of

the rhizosphere, imposing transient osmotic stress on delicate root hairs and partially inhibiting their absorptive function. This would force the plant to divert energy toward stress mitigation rather than growth, thereby reducing the overall promotional effect.

Although this study focused on the vegetative stage, its agronomic significance lies in establishing a strong foundation for increased yield and a shorter total production cycle. In vine crops like Melothria scabra, the plant's capacity to support fruit development is directly dependent on the total amount of photoassimilates produced by its vegetative organs (leaves and stems). Weak vegetative growth results in an insufficient supply of nutrients to developing flowers and fruits, leading to high rates of abscission or the production of small, low-quality fruit. By using 2 mg/L sodium nitroprusside via root irrigation, this study demonstrated significant increases in plant height, stem diameter, and leaf number. This enhanced vegetative framework not only builds the necessary reserves for subsequent reproductive growth but also allows the plant to reach an effective leaf area index more quickly, thereby enabling an earlier and more vigorous transition into the fruiting stage.

The novelty of this research lies in its first-time application of sodium nitroprusside to Melothria scabra and its systematic comparison of different application methods and concentrations. These findings aim to bridge fundamental plant physiology with practical agronomic applications, thereby supporting the cultivation of Melothria scabra in diverse agricultural systems. While the results confirm its strong potential for accelerating vegetative growth, this study was confined to the seedling stage. Future research should focus on its effects on subsequent developmental stages, including flowering time, fruit set rate, fruit development period, and final yield and quality parameters such as vitamin C content.

5. Conclusion

This study systematically demonstrated that the exogenous application of sodium nitroprusside significantly promotes the growth of Melothria scabra seedlings, enhancing plant height, stem diameter, and leaf number. This acceleration of the vegetative phase provides a solid foundation for shortening the overall cultivation cycle. Root irrigation was identified as a more efficient application method than foliar spraying, conferring a clear and sustained advantage in key systemic growth traits. Integrating all findings, the optimal treatment strategy for promoting the vegetative growth of Melothria scabra is root irrigation with a 2 mg/L solution of sodium nitroprusside. This protocol supports balanced plant development, thereby ensuring a robust framework for subsequent reproductive growth and yield formation.

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