The Oscar Publishing Services
American Journal Of Agriculture And Horticulture Innovations

VOLUME Vol.05 Issue05 2025
PAGE NO. 1-5

Enhancing Urea Metabolism and Stress Tolerance in Tomato Through Foliar Nickel Application

Simon Johnson
Department of Plant Sciences, University of California, Davis, USA

Rio Martinez
Department of Horticultural Science, University of Madrid, Spain

Received: 03 March 2025; **Accepted:** 02 April 2025; **Published:** 01 May 2025

Abstract: Nickel (Ni) is recognized as an essential micronutrient pivotal for urea metabolism and stress mitigation in plants. This study synthesizes research findings to examine the role of foliar Ni application in improving urea conversion efficiency and enhancing abiotic stress resilience in tomato (Solanum lycopersicum). Highlighting biochemical, physiological, and agronomic perspectives, the article elaborates how Ni influences urease activation, antioxidant defense systems, and stress alleviation mechanisms. Results from previous studies demonstrate the critical contribution of Ni in managing nutrient assimilation, fruit quality, and disease resistance, suggesting a promising agricultural strategy to ensure tomato productivity under environmental challenges.

Keywords: Nickel (Ni) nutrition, urease activity, urea metabolism, tomato (Solanum lycopersicum), abiotic stress tolerance, nitrogen use efficiency (NUE), foliar fertilization, antioxidant defense, blossom-end rot, climate change resilience.

Introduction: Tomato (Solanum lycopersicum), a globally significant horticultural crop, is highly susceptible to abiotic stresses, including salinity, drought, and nutrient imbalance [11, 19, 28, 31]. Climate change further exacerbates these stress conditions, necessitating innovative agronomic strategies to sustain tomato yield and quality [12, 44].

Nickel (Ni) has been increasingly acknowledged as a crucial micronutrient essential for the functioning of urease, the enzyme responsible for hydrolyzing urea into usable nitrogen forms for plant metabolism [6, 24, 32]. Urea-based fertilization, although widely adopted for its high nitrogen content, can suffer from inefficient conversion without sufficient Ni availability, leading to reduced nitrogen-use efficiency and environmental nitrogen losses [1, 35, 46].

Several studies emphasize that foliar Ni application not only enhances urease activity but also bolsters antioxidant mechanisms, thus providing dual benefits of improved nutrient utilization and abiotic stress mitigation [2, 14, 23]. In tomatoes, Ni has also been linked to improved calcium accumulation, reduced blossom-end rot incidence, and overall enhancement of fruit development [20, 21, 22].

Given these multifaceted roles, the present review systematically explores the impacts of foliar Ni application on urea conversion and stress mitigation in tomatoes, drawing upon findings across agronomy, plant physiology, and molecular biology domains.

Tomato (Solanum lycopersicum) is one of the most widely cultivated and economically significant crops globally, providing essential nutrients and vitamins to millions of people. However, its growth and productivity are often constrained by various environmental factors, including abiotic stresses such as drought, high temperature, and soil nutrient imbalances. Among these, nitrogen (N) is a critical macronutrient that influences tomato growth, development, and fruit yield. Urea, a widely used nitrogen fertilizer, plays a pivotal role in meeting the nitrogen demands of crops. However, the efficiency of urea utilization in plants can be suboptimal, often leading to nitrogen losses in the environment through processes such as volatilization and leaching. This inefficiency not only compromises crop yield but also exacerbates environmental pollution, making nitrogen management a crucial aspect of sustainable agriculture.

Recent studies have explored the potential of micronutrients in improving nitrogen metabolism in plants, particularly in enhancing the efficiency of urea conversion. Among these micronutrients, nickel (Ni) has gained significant attention due to its essential role in various plant physiological processes, including nitrogen metabolism. Nickel is a co-factor for the enzyme urease, which catalyzes the hydrolysis of urea into ammonia and carbon dioxide. Adequate nickel availability is crucial for optimal urease activity, which in turn enhances nitrogen use efficiency (NUE) and minimizes nitrogen losses in the soil. Despite its importance, nickel deficiency is often overlooked in agricultural practices, especially in regions with low nickel content in the soil.

The application of nickel as a foliar fertilizer has emerged as a promising strategy for mitigating nickel deficiency in plants and improving urea conversion efficiency. Foliar application allows for the direct absorption of nickel by the leaves, ensuring a more rapid response compared to soil application. Studies have shown that foliar nickel application can enhance urease activity, promote better nitrogen assimilation, and improve overall plant growth and productivity. Furthermore, nickel's role in plant stress tolerance has also been well-documented. It has been found to boost antioxidant defense systems and reduce the negative impacts of various abiotic stresses, including oxidative stress induced by drought and salinity.

Tomato plants, in particular, exhibit increased susceptibility to various forms of abiotic stress, including drought, salinity, and nutrient deficiencies. These stresses often lead to reduced yield, poor fruit quality, and increased susceptibility to diseases such as blossom-end rot. Nickel, through its involvement in antioxidant metabolism and stress signaling pathways, has shown potential in mitigating these stresses, thereby improving plant resilience. Moreover, the interplay between nickel and calcium in tomatoes has been an area of particular interest. Blossom-end rot, a common disorder in tomatoes, has been associated with calcium deficiency, but recent studies suggest that nickel can help reduce its incidence, even under conditions of calcium deficiency.

The importance of optimizing nutrient management strategies, particularly for micronutrients like nickel, is becoming increasingly evident in the face of climate change and its associated impacts on crop production. As global temperatures rise and water availability becomes more uncertain, the ability to enhance crop resilience and nutrient efficiency through micronutrient supplementation could be a critical tool for ensuring food security. Therefore, understanding the role of foliar nickel application in improving urea conversion, mitigating abiotic stress, and enhancing overall tomato productivity is of paramount importance for sustainable agricultural practices in the coming decades.

This review aims to explore the role of foliar nickel application in tomato cultivation, focusing on its effects on urea conversion, nitrogen metabolism, and abiotic stress mitigation. By synthesizing current research findings, this article provides a comprehensive overview of the physiological mechanisms underlying nickel's action in plants and its potential as a tool for enhancing tomato growth under challenging environmental conditions.

METHODS

Literature Search Strategy

A comprehensive literature search was conducted in scientific databases including Web of Science, Scopus, and Google Scholar, targeting peer-reviewed articles published between 1987 and 2024. Keywords such as "nickel nutrition," "urea hydrolysis," "abiotic stress in tomato," "urease activity," and "foliar micronutrient application" were utilized.

Selection Criteria

Studies selected for inclusion specifically addressed:

- Effects of Ni supplementation (particularly via foliar application) on tomatoes or related crops.
- Observations related to urea metabolism, antioxidant enzyme activity, and stress resistance.
- Experimental designs including field trials, greenhouse experiments, and hydroponic systems.

Data Extraction

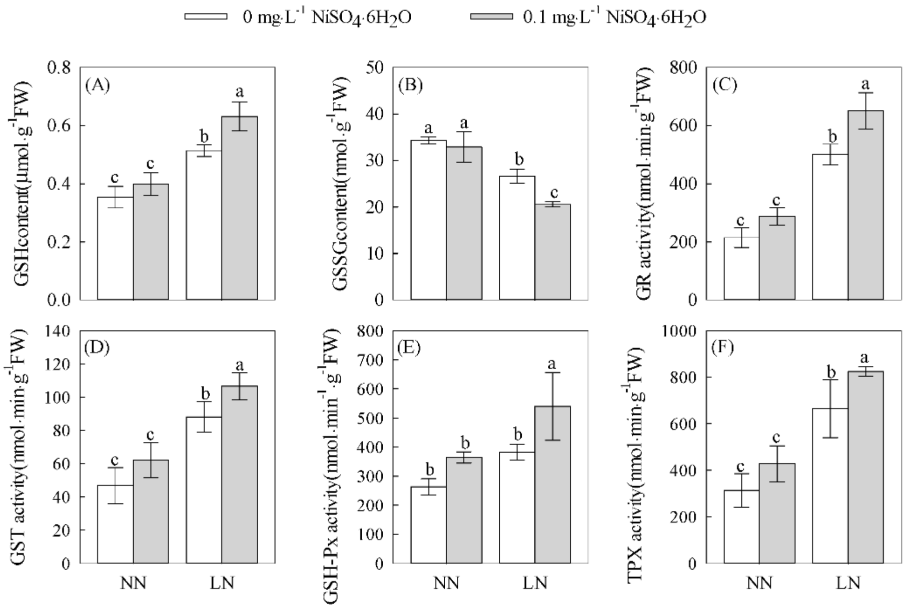
Key findings, methods, and conclusions were systematically extracted and cross-referenced. Attention was given to studies linking biochemical, physiological, and agronomic outcomes with Ni applications.

RESULTS

1. Importance of Nickel in Plant Urea Metabolism

Nickel is a cofactor for urease, which catalyzes the hydrolysis of urea into ammonium ions, critical for nitrogen assimilation in plants [6, 36, 32]. Deficiency in Ni can lead to urea accumulation, resulting in cellular toxicity and impaired growth [6, 38].

Tan et al. (2000) demonstrated that tomatoes supplied with urea as the sole nitrogen source showed significantly improved growth when supplemented with Ni, underlining the element's necessity for effective nitrogen utilization [45]. Similarly, Myrach et al. (2017) reported that the urease activation complex depends on Ni delivery via accessory proteins [36].



2. Foliar Application: A Targeted Approach

Foliar application of Ni offers a precise method to correct micronutrient deficiencies and enhance physiological processes without relying solely on soil nutrient availability [16, 42]. Studies on soybeans (Barcelos et al., 2018) and barley (Kumar et al., 2018) have shown that foliar Ni treatments significantly increased urease activity and improved overall nutrient status [2, 25].

Macedo et al. (2022) found that foliar Ni application in tomatoes boosted calcium accumulation in fruits, helping mitigate blossom-end rot, a major quality issue [21].

3. Role of Nickel in Abiotic Stress Mitigation

Abiotic stresses such as drought, salinity, and heat disrupt plant metabolism, primarily by inducing oxidative stress [11, 13, 15]. Ni plays a vital role in activating antioxidant enzymes, thus reducing oxidative damage under stress conditions [14, 18].

Garai et al. (2020) highlighted the role of glyoxalase systems in stress recovery, where Ni-dependent enzymes help detoxify harmful metabolites [13]. Nickel-mediated enhancement of the antioxidant defense system has also been linked to improved tolerance to salt and drought stresses in tomato plants [19, 28, 29].

4. Influence on Fruit Development and Quality

Nickel application has profound effects on fruit development processes. Macedo et al. (2021) reported that Ni supplementation altered calcium distribution patterns in tomato fruits, promoting uniform ripening and better structural integrity [22]. Moreover, proper Ni nutrition reduces the incidence of physiological disorders like blossom-end rot by enhancing calcium and nitrogen metabolism [20, 21, 50].

According to Sovarel et al. (2016), foliar fertilizers containing micronutrients, including Ni, significantly improved tomato yield and fruit quality traits such as sugar content, firmness, and color [43].

DISCUSSION

Synergistic Role of Nickel in Nutrient Assimilation and Stress Response

Nickel enhances nitrogen-use efficiency not only by activating urease but also by facilitating a broader range of physiological responses vital under stress conditions [24, 32, 36]. The antioxidant properties conferred by Ni supplementation help protect plant cells against ROS accumulation, a common consequence of abiotic stresses [14, 18, 29].

The strong interplay between urease activation, antioxidant defense, and calcium metabolism underscores the multi-dimensional benefits of foliar Ni applications.

Practical Implications for Tomato Cultivation

Applying Ni through foliar sprays can be a practical intervention for improving urea-based fertilization strategies, particularly under stress-prone environments [42, 43, 49]. Given the projected increase in climate-related stress events [12, 44, 47], foliar Ni supplementation could serve as an essential component of resilient tomato production systems.

Moreover, managing soil and tissue Ni levels could prevent hidden deficiencies, a concept increasingly emphasized in recent soil fertility studies [46].

Future Research Directions

Further investigations are warranted to:

- Optimize foliar Ni dosage and application timing specific to tomato growth stages.
- Explore molecular mechanisms underpinning Ni-regulated gene expression during stress responses [31, 41].
- Assess long-term environmental impacts of increased Ni usage in agricultural systems.

CONCLUSION

Foliar application of nickel emerges as a promising strategy to enhance urea conversion, optimize nitrogen metabolism, and strengthen abiotic stress resilience in tomato cultivation. By simultaneously improving nutrient efficiency and physiological robustness, Ni supplementation aligns with sustainable agricultural goals aimed at ensuring crop productivity amidst climatic and environmental challenges.

REFERENCES

Apodaca, L. (2023). Nitrogen statistics and information | U.S. Geological Survey. https://doi.org/10.9767/jcerp.20099

Barcelos, J. P., Reis, H., Godoy, C., Gratão, P., Furlani Junior, E., Putti, F., Campos, M., & Reis, A. (2018). Impact of foliar nickel application on urease activity, antioxidant metabolism and control of powdery mildew (Microsphaera diffusa) in soybean plants. Plant Pathology, 67(7), 1502–1513. https://doi.org/10.1111/ppa.12871

Batth, R., Jain, M., Kumar, A., Nagar, P., Kumari, S., & Mustafiz, A. (2020). Zn^{2+} dependent glyoxalase I plays the major role in methylglyoxal detoxification and salinity stress tolerance in plants. PLoS ONE, 15(5), e0233493. https://doi.org/10.1371/journal.pone.0233493

Bhalerao, S. A., Sharma, A. S., & Poojari, A. C. (2015). Toxicity of nickel in plants. International Journal of Pure and Applied Bioscience, 3(2), 345–355.

Brown, P. H., Welch, R. M., Cary, E. E., & Checkai, R. T. (1987). Micronutrients: Beneficial effects of nickel on plant growth. Journal of Plant Nutrition, 10(9–16), 2125–2135.

Chaudhry, S., & Sidhu, G. P. S. (2022). Climate change regulated abiotic stress mechanisms in plants: A comprehensive review. Plant Cell Reports, 41(1), 1–31.

Dhaliwal, S. S., Sharma, V., & Shukla, A. K. (2022). Impact of micronutrients in mitigation of abiotic stresses in soils and plants—A progressive step toward crop security and nutritional quality. Advances in Agronomy, 173, 1–78. https://doi.org/10.1016/bs.agron.2022.02.001

Fabiano, C. C., Tezotto, T., Favarin, J. L., Polacco, J. C., & Mazzafera, P. (2015). Essentiality of nickel in plants: A role in plant stresses. Frontiers in Plant Science, 6, 754. https://doi.org/10.3389/fpls.2015.00754

Garai, S., Bhowal, B., Pareek, A., Singla-Pareek, S. L., Kaur, C., & Sopory, S. K. (2020). Expression dynamics of glyoxalase genes under high temperature stress in plants. Plant Physiology Reports, 25, 533–548. https://doi.org/10.1007/s40502-020-00545-1

Gerszberg, A., & Hnatuszko-Konka, K. (2017). Tomato tolerance to abiotic stress: A review of most often engineered target sequences. Plant Growth Regulation, 83(2), 175–198. https://doi.org/10.1007/s10725-017-0251-x

Liang, G., Liu, J., Zhang, J., & Guo, J. (2020). Effects of drought stress on photosynthetic and physiological parameters of tomato. Journal of the American Society for Horticultural Science, 145(1), 12–17.

Li, H., Liu, H., Gong, X., Li, S., Pang, J., Chen, Z., & Sun, J. (2021). Optimizing irrigation and nitrogen management strategy to trade off yield, crop water productivity, nitrogen use efficiency and fruit quality of greenhouse grown tomato. Agricultural Water Management, 245, 106570. https://doi.org/10.1016/j.agwat.2020.106570

Macedo, F. G., De Melo, W. J., Delarica, D. D. L., Cruz, R. B., Santos, E. F., De Melo, G. M. P., & Cecílio Filho, A. B. (2022). Nickel increases productivity, Ca accumulation and reduces blossom-end rot in tomato. Archives of Agronomy and Soil Science, 68(11), 1543–1553.

Macedo, F. G., Montanha, G. S., Pereira de Carvalho, H. W., & De Melo, W. J. (2021). Nickel influences urease activity and calcium distribution in tomato fruits. ACS Agricultural Science & Technology, 1(1), 29–34. https://doi.org/10.1021/acsagscitech.0c00003

Myrach, T., Zhu, A., & Witte, C. P. (2017). The assembly of the plant urease activation complex and the essential role of the urease accessory protein G (UreG) in delivery of nickel to urease. Journal of Biological Chemistry, 292(35), 14556.

Pachauri, R., & Meyer, L. (2014). AR5 Synthesis Report: Climate Change 2014—IPCC.

Parvin, K., Hasanuzzaman, M., Bhuyan, M., Nahar, K., Mohsin, S. M., & Fujita, M. (2019). Comparative physiological and biochemical changes in tomato (Solanum lycopersicum L.) under salt stress and recovery: Role of antioxidant defense and glyoxalase systems. Antioxidants, 8(9), 350.

Quinet, M., Angosto, T., Yuste-Lisbona, F. J., et al. (2019). Tomato fruit development and metabolism. Frontiers in Plant Science, 10, 1554. https://doi.org/10.3389/fpls.2019.01554

Robinson, W. A. (2021). Climate change and extreme weather: A review focusing on the continental United

States. Journal of the Air & Waste Management Association, 71(10), 1186–1209. https://doi.org/10.1080/10962247.2021.1942319

Sovarel, G., Costache, M., & Croitoru, M. (2016). The influence of some foliar fertilizers on tomato yield and fruit quality. Bulletin UASVM Horticulture, 73(1), 1–3. https://doi.org/10.15835/buasvmcn-hort:11495

Tan, X. W., Ikeda, H., & Oda, M. (2000). Effects of nickel concentration in the nutrient solution on the nitrogen assimilation and growth of tomato seedlings in hydroponic culture supplied with urea or nitrate as the sole nitrogen source. Scientia Horticulturae, 84(3–4), 265–273. https://doi.org/10.1016/S0304-4238(99)00107-7

Tijjani, S. B., Giri, S., & Woznicki, S. A. (2022). Quantifying the potential impacts of climate change on irrigation demand, crop yields, and green water scarcity in the New Jersey Coastal Plain. Science of the Total Environment, 838, 156538. https://doi.org/10.1016/j.scitotenv.2022.156538

Topcu, Y., Nambeesan, S. U., & van der Knaap, E. (2022). Blossom-end rot: A century-old problem in tomato (Solanum lycopersicum L.) and other vegetables. Molecular Horticulture. https://doi.org/10.1186/s43897-021-00022-9

Zhao, R., Liu, J., Xu, N., He, T., Meng, J., & Liu, Z. (2022). Urea hydrolysis in different farmland soils as affected by long-term biochar application. Frontiers in Environmental Science, 10, 950482. https://doi.org/10.3389/fenvs.2022.950482