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Assessment of Biofertilizer and Silicon Nanoparticle Treatments on Plant Growth, Nutrient Uptake, and Salinity Stress Tolerance in Tomato

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Abstract--- Tomato (Solanum lycopersicum L.) is a vital vegetable that is particularly susceptible to high soil salinity levels, which adversely impact the development of the plant, uptake of nutrients, photosynthesis, and its productivity. Increasing frequency of salinized soils calls for a sustainable farming strategy to enhance performance of crops while minimizing the use of excessive amounts of chemical fertilizers. In this study, the objective is to test the effect of biofertilizer and silicon nanoparticle application separately and together on tomato growth and nutrient uptake under salinity stress. The uniqueness of the proposed research will be in testing the synergistic effect of microbial biofertilization and silicon nanotechnology technology in relation to plant physiological and nutrient responses to salinity. The experimental design will be the use of pots with various treatment combinations that include: control, biofertilizer alone, silicon nanoparticles alone, salinity stress alone, and biofertilizer-silicon nanoparticle treatment combinations. Parameters of growth including height of the plant, root length, leaf area, fresh weight, and dry biomass will be determined. Nutrient absorption will be analyzed in terms of nitrogen, phosphorous, and potassium levels, whereas the presence of chlorophyll, relative water content, proline, and antioxidant enzymes will be investigated to determine stress tolerance capacity. Observations obtained will be statistically analyzed via analysis of variance and appropriate post-hoc test. It is anticipated that this study will show that treatments together increase the nutrient levels, maintain physiological balance, and minimize negative impacts of salt stress. This research may provide an ecologically sustainable approach for growing tomatoes in saline-affected soils.

Keywords--- Biofertilizer, Silicon Nanoparticles, Tomato, Salinity Stress, Nutrient Uptake, Plant Growth, Antioxidant Activity, Sustainable Agriculture.

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I. Introduction

Tomato (Solanum lycopersicum L.) is one of the most extensively grown horticultural crops due to its nutritional value, commercial worthiness, and high consumption. Tomatoes contain vitamins, minerals, antioxidants, and other health-promoting constituents that help maintain good human health (Alam et al., 2025; Sane et al., 2025). Tomato cultivation is becoming more difficult due to environmental stresses, especially soil salinity. Soil salinity arises due to natural soil processes, ineffective watering, improper fertilization, and build-up of soluble salts in farmlands. High salt content causes osmotic and ionic imbalance and limits the plant's ability to absorb water and disrupts many physiological activities of the plant (Akhtar et al., 2022; Guardiola-Márquez et al., 2023).

Salinity stress has an adverse effect on nutrient uptake by promoting sodium accumulation and disrupting the uptake of essential nutrients like potassium, calcium, and nitrogen. High amounts of sodium in the plant can affect membrane structures, inhibit enzyme actions, inhibit chlorophyll formation, and cause an increase in the production of reactive oxygen species. Tomato plants suffer from oxidative stress, lower photosynthetic capacity, and lower biomass accumulation (Ashraf et al., 2022). Traditional methods involving soil modifications, better irrigation practices, and chemical fertilizers can offer some relief; however, their efficacy is dependent upon the environmental factors. Therefore, biological methods are needed to enhance tomato tolerance towards salinity stress. Biofertilizers provide an eco-friendly way of increasing the fertility of the soil

and nutrients in plants through the use of beneficial microorganisms. Beneficial plant growth promoting rhizobacteria, phosphate solubilizing bacteria and fungi can help with nutrient release and root formation (Alharbi et al., 2022). Microorganisms may assist in making nitrogen available to the plants, increasing phosphate solubility and stimulating plant growth via metabolite production (Kaleem et al., 2025).

The use of silicon nanoparticles is receiving much interest as an agricultural input, given the ability of this input to modulate plant physiological and biochemical processes (Karnwal et al., 2023; Mahmoud et al., 2022; Hosseinpour et al., 2020). Application of silicon might help to enhance water relationships, increase the strength of plant tissues, control ion balance and antioxidant defence mechanisms (Shoukat et al., 2024). Nanoparticle applications can offer certain benefits due to small particle sizes and improved interactions with plants; however, their efficiency is dependent on particle size, concentration, and method of application (El-Shal et al., 2022).

Use of biofertilizers in conjunction with silicon nanoparticles would lead to complementary action of both these factors in terms of improving the uptake of nutrients and increasing physiological resistance to stresses. Nevertheless, the complex effects of microorganism treatment, nanoparticle application and the state of soil under saline conditions require further systematic study. Thus, the aim of this work is to assess the effects of both independent treatments and of their combination on the tomato growth, nutrient uptake and salinity tolerance.

Problem Statement

Salinity of the soil poses as a major constraint in agriculture and affects tomato yield through interference with water uptake, nutrients uptake, ionic balance, and physiology. Increase in the levels of sodium impairs uptake of both potassium and calcium, causing limited root growth, low chlorophyll content, increased oxidative stress, and poor biomass production. While conventional fertilizers have proven ineffective in overcoming these problems and may cause environmental problems if misused, biofertilizers enhance nutrients mobilization and silicon has been shown to improve plant response to stress. However, there is a need for more studies on the combined use of biofertilizers and silicon for tomatoes. The lack of information about the interactions between the two makes it hard to know how to utilize them effectively for tomato improvement. There is a need to undertake a comprehensive study on the effects of using either or both of these on tomato performance through physiological and nutritional measures.

Section Overview

The organization of this research paper follows a sequence of sections that allow for the systematic investigation of biofertilizer and silicon nanoparticle use in growing tomatoes. First, the introduction describes the background of the research, problem statement, and its objectives. Then the literature review section focuses on the analysis of current practices of biofertilizer use, silicon nanoparticles application, and plant adaptation to salinity. After that, the identified gaps in the literature are discussed. The methodology section introduces the design of the experiment, including the combination of treatments, measured parameters, and statistical analysis used. Finally, the proposed architecture is provided.

II. Literature Review

High salinity has received considerable attention as one of the environmental stresses impacting the yield of horticultural crops. The presence of high amounts of soluble salts causes osmotic and ionic disorders affecting plant water relations, nutrient uptake, and metabolism. Tomato plants grown in a saline environment generally suffer from slow seedling emergence, poor root and leaf growth, low levels of chlorophyll and biomass. Accumulation of sodium and chloride ions can affect the balance of potassium and calcium ions leading to oxidative stress in plants. This indicates the need for devising sustainable ways of ensuring crop productivity in salt affected soils.

The use of biofertilizers represents an important biological method for promoting nutrient uptake and enhancing soil fertility. Rhizosphere microbes play a role in nutrient cycles, nitrogen fixation, phosphate solubilization, and synthesis of growth substances. Plant growth promoting bacteria help in stimulating root growth, increasing nutrient availability, and influencing plant hormone actions. Some microbial strains can promote stress tolerance through the production of exopolysaccharides, osmo protectants, and enzymes involved in stress regulation. Such activities may improve nutrient uptake and minimize negative effects of saline environment. Performance of biofertilizers depends on the type of microbes, soil characteristics, application methods, and environmental conditions.

A combination of biofertilizer treatment with silicon-based materials is likely to be a useful technique in crop production. Biofertilizers are known to increase the availability of nutrients and biological activity associated with roots; silicon nanoparticles might be used for protecting plants physiologically and regulating ions However, the interaction between the microbial activity, the presence of nanoparticles, the uptake of nutrients, and the reaction of the plants to such a stressful situation appears to be complicated. The difference in soil properties and the conditions of the experiment can affect the efficacy of the treatment as well.

Thus, an integrated experimental analysis needs to be performed to estimate the efficiency of the individual and joint treatments at controlled salt concentrations. The combination of morphological, nutritional, physiological, and biochemical analysis may contribute to a better understanding of the treatment efficacy.

Research Gap

Earlier research has considered biofertilizers and silicon nanoparticles as two separate means of promoting plant growth and stress resistance due to abiotic stress factors. Nonetheless, it is important to conduct further research in order to establish the impact of the combination of the two means on tomato plants in various conditions of salinity. First of all, there is a lack of research that analyzes the effect of microbial nutrient solubilization, silicon nanoparticles' concentration, uptake of nitrogen-phosphorus-potassium and physiological stress indicators at once. Moreover, differences in treatment regimes, properties of the used nanoparticles and the level of salinity pose additional problems. Finally, the development of the most effective means can only be achieved through the consideration of multiple aspects of plants' reaction simultaneously.

III. Methodology

Measurement of Plant Growth Parameters

Plant growth will be assessed during specified observation periods. Plant height will be determined by measuring from the topsoil surface to the growing point, whereas the root length will be calculated post the extraction of the plant. The leaf area will be assessed through the suitable leaf area assessment method. Fresh and dry biomass will be measured in order to evaluate plant growth performance.

Parameters include:

- Plant height (cm).
- Root length (cm).
- Number of leaves.
- Leaf area (cm^2).
- Shoot fresh weight (g).
- Root fresh weight (g).
- Shoot and root dry weight (g).

The dry biomass will be quantified after drying plant samples in the oven for a certain constant temperature.

Assessment of Nutrient Uptake

Plant tissue samples will be harvested, washed, dried, and analyzed for nutrients. Nitrogen content will be quantified by employing a proper analytical method involving digestion. Phosphorus will be quantified by adopting an appropriate colorimetric approach, and potassium will be quantified by performing flame photometry or an equivalent analytical method.

Nutrient accumulation will be calculated as follows:

Nutrient Uptake=Nutrient Concentration × Dry Biomass

This parameter will aid in distinguishing between nutrient concentration and nutrient accumulation in plants. Soils will also be characterized with respect to pH, EC, and nutrients.

Soil pH, EC and nutrients will be quantified to characterize changes in growth environment.

Evaluation of Physiological and Biochemical Responses

Physiological analysis will be done to determine the effects of salt stress and treatment on tomatoes.

The following parameters will be analyzed:

1. Chlorophyll levels to determine stability of photosynthetic pigments.
2. Relative water content for the determination of plant hydration status.

3. Concentration of proline for the determination of osmotic regulation.
4. Malondialdehyde (MDA) for the estimation of lipid peroxidation.
5. SOD, CAT and POD activity for the evaluation of antioxidative defense.
6. Concentration of sodium and potassium for ionic homeostasis.

Such analysis will provide an insight into physiological mechanisms related to salinity tolerance.

Proposed Architecture

The proposed structure provides the full sequence of the experiment for the evaluation of the combined effect of biofertilizers and nanoparticles on plant growth. First, tomato plants and soil will be prepared according to the standard procedure. Next, experimental groups will be formed based on biofertilizer treatment, nanoparticle treatment, and salinity condition. Samples will be taken from the plants at certain time points for assessment of growth parameters, uptake of nutrients, and other physiological parameters. Then, the results will be analyzed statistically to detect any treatment interactions and comparative performance.

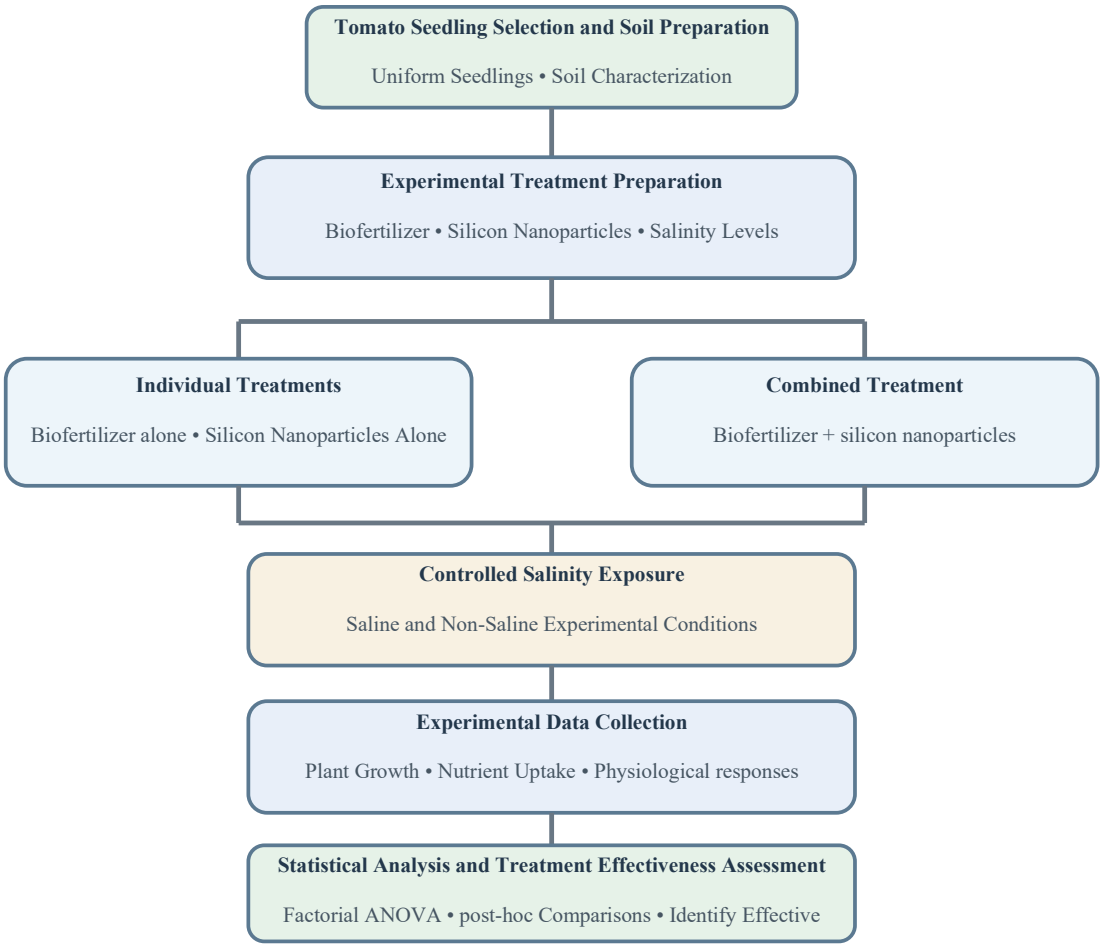


Figure 1: Proposed Experimental Methodology Architecture

The experimental approach has been demonstrated in figure 1, which starts with selection of tomato seedlings and preparation of soil, followed by application of treatment individually and together. The salinity level can be controlled to assess the response of plants. Subsequent morphological, physiological, and nutritional analysis will allow comparison of treatments and possible advantages of their combination.

IV. Role of Biofertilizer and Silicon Nanoparticles in Improving Tomato Growth and Nutrient Uptake

The use of biofertilizers and silicon nanoparticles is a combination of two technologies to improve the growth and nutrient acquisition of tomatoes under stress conditions. While biofertilizers work through the beneficial activity of rhizospheric microorganisms, silicon nanoparticles may positively affect the construction

of a plant, water relations, and physiology. The use of both techniques together can enable tomatoes to grow even under saline conditions. Nitrogen-fixing bacteria increase the nitrogen supply by transforming atmospheric nitrogen into a usable form of the element. Phosphate solubilizing microorganisms secrete organic acids that dissolve insoluble phosphates, thus helping in root formation, energy transfer, and metabolism processes. Plant growth promoting microorganisms can produce indole-3-acetic acid, which stimulates root branching and growth. The larger area covered by roots will enable better water and nutrients intake. These roles may supplement microbial nutrient mobilization as biofertilizers facilitate better nutrient availability around roots while silicon helps plants cope with disturbance induced by salts. Treatment efficiency should be evaluated taking into account not only nutrient concentrations but also total nutrient accumulation. Nutrient concentration may prove to be a misleading parameter when the plant biomass varies among treatments. For that reason, it is necessary to measure nitrogen, phosphorus, and potassium in addition to dry weight. Nitrogen is needed for synthesis of chlorophyll and proteins; phosphorus is involved in energy transfer and root growth; potassium manages osmotic regulation, stomata functioning and enzyme activity. In the case of salinity, excess sodium may limit potassium accumulation, hence, the ratio of these elements is a good indicator of ionic balance. Nevertheless, additional benefits cannot be expected automatically. The level of nanoparticle concentration, nanoparticle properties, the strain of microbes, soil parameters, and treatment delivery technique may matter. An overexposure to nanoparticles may have negative impact on microorganism survival or root growth; hence, compatibility and dose response test is needed. It is necessary to compare plant height, root length, leaf surface area, biomass, and nutrient accumulation in control, individual, and combined treatments.

Physiological Mechanisms of Salinity Stress Tolerance in Tomato Plants

Salinity-induced stress in tomatoes results from the occurrence of osmotic, ionic, and oxidative stress, limiting growth and metabolic activities in the plants. There is a need to study the physiological effects of biofertilizer and silicon nanoparticle on the plants in order to assess the potential ability of these substances to increase stress tolerance in the plants. The first effect of salinity is the decrease in the soil water potential, leading to difficulty in water absorption by the plants. This leads to low leaf expansion, closure of stomata, and low photosynthesis activities. The continued presence of salt in the environment causes increased sodium and chloride concentration, causing imbalance of potassium and calcium. The high sodium may also affect the membranes of cells and enzymatic processes. Some physiological adaptations that may occur due to use of biofertilizer involve microbial properties. Some microorganisms have the ability to produce extracellular polysaccharides affecting soil aggregation and root conditions. Microbial strains also have the ability to produce ACC deaminase regulating stress-related ethylene production and promoting root growth. Moreover, there are other physiological functions such as nutrient acquisition and plant antioxidant responses that may be facilitated by beneficial microorganisms.

High concentration of ROS can cause harm to cell membrane, proteins, pigments and nucleic acids. There are antioxidant enzymes that play a role in controlling oxidative stress and stabilizing cells. Proline accumulation is an important indicator of plant response to salinity since it aids in osmotic adjustment and cell protection. The relative water content and proline accumulation are used to demonstrate the response of plants to saline environment. Chlorophyll accumulation will give an idea about the stability of the photosynthetic pigments whereas malondialdehyde (MDA) accumulation will be the marker of lipid peroxidation. Keeping high levels of chlorophyll accumulation and reducing the oxidative stress can facilitate biomass accumulation. This analysis of these physiological and biochemical indicators can help in understanding the effect of combination treatments on salinity tolerance of tomatoes.

V. Experimental Comparison Table

Table 1 presents the proposed experimental treatments and their expected biological responses under saline and non-saline conditions. It compares individual and combined applications based on plant growth, nutrient uptake, and stress tolerance. The expected benefits represent research hypotheses and require experimental validation rather than confirmed findings.

Table 1: Proposed Comparison of Biofertilizer and Silicon Nanoparticle Treatment Groups

Treatment	Growth Response	Nutrient Uptake	Stress Tolerance
T1 – Control	Baseline Growth	Baseline	Normal Conditions
T2 – Biofertilizer	Microbial Growth Promotion	Improved Availability	Potential Improvement
T3 – Silicon Nanoparticles	Physiological Support	Possible Improvement	Potential Improvement
T4 – Combined	Possible Synergistic Response	Potentially Improved	Potentially Improved
T5 – Salinity	Growth Reduction	Nutrient Imbalance	High Stress
T6 – Biofertilizer + Salinity	Potential Growth Recovery	Improved Mobilization	Partial Protection
T7 – Silicon + Salinity	Potential Growth Recovery	Improved Ionic Regulation	Partial Protection
T8 – Combined + Salinity	Expected Better Recovery	Expected Improved Uptake	Expected Improved Tolerance

VI. Graphical Evaluation

The use of the multiple line chart is appropriate in the study as it will enable the comparison of the growth change of tomatoes at different times in the varying treatments and levels of salinity. The height of the plants is used as the response variable.

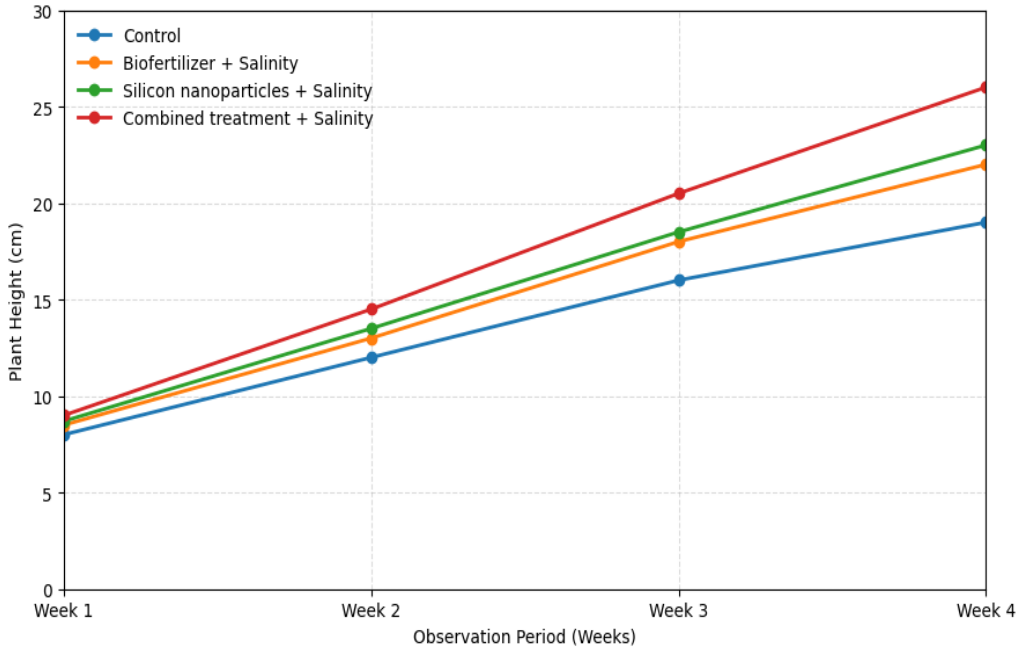


Figure 2: Comparative Plant Height Response Under Biofertilizer and Silicon Nanoparticle Treatments

The figure 2 shows the change in height of the plants concerning time for all the four different stages of the experiment for all the different treatments and the control in the saline conditions. It can be seen from the graph that the combined treatment of biofertilizer and silicon nanoparticles gives better growth trend than the other treatments and controls. This graph would be useful for comparing the results of treatments during the entire experiment period. The data present in the graph is hypothetical and should be replaced with real data.

VII. Discussion

The suggested experiment offers a complete method of assessing the impact of biofertilizers and silicon nanoparticles on tomato growth under salt stress conditions. Biofertilizers can promote better nitrogen fixation, phosphorus solubilization, and positive root interactions, while silicon nanoparticles can increase plant physiological stability due to better water relations, membrane protection, and antioxidant activity. Application of both types of additives in combination might also have some advantages for plants subjected to salt stress. The study of physiological parameters like chlorophyll content, relative water content, proline

content, and antioxidant enzymes' activities will help to reveal the mechanisms of stress tolerance. Much attention should be paid to interaction of treatments as their combined application may not always lead to additive effects. Plant responses might depend on microbe compatibility, nanoparticles concentration, and salt stress level. Therefore, appropriate statistical analyses are required to reveal statistically significant differences between the treatments. In case of improved growth and nutrients uptake at combined treatments, this method can be considered as a useful tool for sustainable tomato production in saline soils.

Challenges and Limitations

Some potential limitations associated with the above experiment need to be taken into account when interpreting experimental results. The first limitation is the tendency of nanoparticles to aggregate, which may affect the uniformity of application and treatment effectiveness. Second, there is the possibility that some concentrations of silicon nanoparticles will be harmful to beneficial microorganisms; therefore, compatibility testing should be done. Third, differences in soil electric conductivity and nutrient content may lead to variations in the response of plants. Finally, laboratory analyses for nutrient content, enzyme activity, and physiological parameters must follow standard methods of analysis. Lack of experimental time may limit the evaluation of soil properties and the fruit yield at the end of the experiment. Pot experiments cannot entirely simulate field conditions of agricultural production.

Future Recommendations

Research should target optimization of the amount of silicon nanoparticles required in order to find proper dosages that enhance tomato plant growth without toxicity. Various types of biofertilizers containing nitrogen fixing and phosphate solubilizing microorganisms should be tested to know whether they are compatible with silicon nanoparticles. Experiments that involve varied salt concentrations are suggested to be conducted so as to study the performance of various treatments under different stress levels. Fruit yield, quality, nutritive value and post-harvest properties need to be studied further so as to establish the agricultural advantages of using the combination treatments. Research on stress-related genes, antioxidant responses and ion transport pathways is important for gaining more knowledge regarding plant stress response mechanisms. Field experiments that will confirm results from laboratory tests under natural environmental conditions are required. In addition, future research needs to consider the accumulation of nanoparticles, activity of microorganisms in the soil and any other possible environmental impacts. Lastly, cost evaluations must be done to establish economic viability of the treatments.

VIII. Conclusion

This study intends to assess the impact of biofertilizer and silicon nanoparticle treatments on the growth, nutrient acquisition, and salinity tolerance capacity of tomatoes (Solanum lycopersicum L.). The increase in soil salinity poses serious difficulties to tomato cultivation because it influences the processes of water intake, nutrient availability, ion equilibrium, and physiology. Thus, it is crucial to apply sustainable practices to ensure improved nutrition of plants and stress resistance. The uniqueness of this study can be seen in assessing the impact of the combined treatment with biofertilizer and silicon nanoparticles under soil salinity conditions. This is in contrast to studies solely analysing the growth parameters. The research methodology suggested here will involve an experiment with pots in which eight combinations of treatments will be considered. Parameters, such as plant height, root length, leaf area, biomass, nitrogen, phosphorus, potassium, chlorophyll concentration, relative water content, proline concentration, and the activities of antioxidant enzymes will be measured. The factorial analysis of variance and relevant post-hoc test will be used to determine significant effects of the treatments. Based on the expectations, biofertilizer and silicon nanoparticles can enhance tomato development, uptake of nutrients, the K/Na ratio and stability of physiology in saline conditions. Increased activities of antioxidants and decreased membrane damage can additionally help to develop stress resistance. Still, these conclusions need to be verified experimentally since the effectiveness of the treatments may differ depending on microorganisms, concentrations of nanoparticles, and saline conditions. It is necessary to carry out future studies of these approaches in greenhouse and field conditions, as well as to determine the concentrations and economic efficiency of the treatment.

References

[1] Karnwal, A., Dohroo, A., & Malik, T. (2023). Unveiling the potential of bioinoculants and nanoparticles in sustainable agriculture for enhanced plant growth and food security. *BioMed research international*, *2023*(1), 6911851. https://doi.org/10.1155/2023/6911851

[2] Alam, P., Yalcin, M., Faizan, M., & Albalawi, T. (2025). Response of tomato to silicon dioxide nanoparticles under salinity: Impact on photosynthesis, antioxidant enzymes activity, stress biomarkers and osmoregulatory substances. *Plant Nano Biology*, *13*, 100171. https://doi.org/10.1016/j.plana.2025.100171

[3] Ashraf, M., Shahzad, S. M., Abid, M., Mehmood, K., Aziz, A., Sarwar, A., ... & Mehran, M. (2022). Ionic homeostasis and growth characteristics of tomato (Solanum lycopersicum L.) grown with municipal wastewater by supplying silicon, farmyard manure and plant growth promoting rhizobacteria. *Silicon*, *14*(18), 12855-12867. https://doi.org/10.3390/plants14233632

[4] Akhtar, N., Ilyas, N., Meraj, T. A., Pour-Aboughadareh, A., Sayyed, R. Z., Mashwani, Z. U. R., & Poczai, P. (2022). Improvement of plant responses by nanobiofertilizer: a step towards sustainable agriculture. *Nanomaterials*, *12*(6), 965. https://doi.org/10.3390/nano12060965

[5] Mahmoud, A. W. M., Esmail, S. E., El-Attar, A. B., Othman, E. Z., & El-Bahbohy, R. M. (2022). Prospective practice for compound stress tolerance in thyme plants using nanoparticles and biochar for photosynthesis and biochemical ingredient stability. *Agronomy*, *12*(5), 1069. https://doi.org/10.3390/agronomy12051069

[6] Alharbi, K., Hafez, E., Omara, A. E. D., Awadalla, A., & Nehela, Y. (2022). Plant growth promoting rhizobacteria and silica nanoparticles stimulate sugar beet resilience to irrigation with saline water in salt-affected soils. *Plants*, *11*(22), 3117. https://doi.org/10.3390/plants11223117

[7] Kaleem, M., Shah, A. A., Usman, S., Xu, W., & Alfarhan, A. H. (2025). Foliar application of calcium phosphate nanoparticles improves photosynthetic efficiency, nutrient uptake, and antioxidant capacity in Coriandrum sativum L. under salinity stress. *ACS omega*, *10*(40), 46393. https://doi.org/10.1021/acsomega.5c00987

[8] Shoukat, A., Saqib, Z. A., Akhtar, J., Aslam, Z., Pitann, B., Hossain, M. S., & Mühling, K. H. (2024). Zinc and silicon nano-fertilizers influence ionomic and metabolite profiles in maize to overcome salt stress. *Plants*, *13*(9), 1224. https://doi.org/10.3390/plants13091224

[9] Guardiola-Márquez, C. E., López-Mena, E. R., Segura-Jiménez, M. E., Gutierrez-Marmolejo, I., Flores-Matzumiya, M. A., Mora-Godínez, S., ... & Jacobo-Velázquez, D. A. (2023). Development and evaluation of zinc and iron nanoparticles functionalized with plant growth-promoting rhizobacteria (PGPR) and microalgae for their application as bio-nanofertilizers. *Plants*, *12*(20), 3657. https://doi.org/10.3390/plants12203657

[10] Hosseinpour, A., Haliloglu, K., Tolga Cinisli, K., Ozkan, G., Ozturk, H. I., Pour-Aboughadareh, A., & Poczai, P. (2020). Application of zinc oxide nanoparticles and plant growth promoting bacteria reduces genetic impairment under salt stress in tomato (Solanum lycopersicum L.'Linda'). *Agriculture*, *10*(11), 521. https://doi.org/10.3390/agriculture10110521

[11] Sane, A. K., Ngom, M., Ba, O., Kane, A., & Sy, M. O. (2025). Salinity stress in plants and enhancing tomato tolerance: Insights from chemical and bio-organic fertilization, priming, and breeding approaches. *Agronomy Journal*, *117*(6), e70252. https://doi.org/10.1002/agj2.70252

[12] El-Shal, R. M., El-Naggar, A. H., El-Beshbeshy, T. R., Mahmoud, E. K., El-Kader, N. I. A., Missaui, A. M., ... & El-Sharkawy, M. S. (2022). Effect of nano-fertilizers on alfalfa plants grown under different salt stresses in hydroponic system. *Agriculture*, *12*(8), 1113. https://doi.org/10.3390/agriculture12081113