Physiological responses of Lettuce (*Lactuca sativa*) to electrical conductivity (EC) of human urine-based fertilizer

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Highlights:

- **High EC in urine fertilizer solution can impact the final total weight of the plant, especially the leaves.**
- **High EC in urine-based fertilizer can improve the leaves color aspects, turning it greener, comparing to chemical fertilizer and non-fertilized samples.**
- **The physiological management of plant growth is directly affected by the salinity level of the urine nutriente solution.**

Keywords: Plant-fertilizer relationship; resource-oriented sanitation; toxicity.

INTRODUCTION

Sustainable sanitation presents a practical alternative to conventional sewage systems by addressing their limitations. The separation of excreta is a key technique for efficient treatment, enabling the recycling of nutrients from feces, urine and greywater. This approach promotes water conservation and significantly reduces environmental pollution, contributing to both sanitation and agricultural sustainability (Langergraber & Muellegger, 2005). Furthermore, resource-focused sanitation can be adopted as a cost-effective solution, offering low expenses in implementation, transportation, treatment, and reuse in agriculture.

In this sense, techniques for separating human urine from excreta have been used in various parts of the world, aiming to improve the treatment of wastewater and, also to use the nutrients (nitrogen (N), phosphorus (P) and potassium (K)) as fertilizer in agricultural crops, such as corn, tomato, lettuce, pepper, barley and many others (Botto et al., 2018). It creates a direct link between sanitation and agriculture, allowing for the repurposing of what would otherwise be waste into valuable agricultural inputs, thus closing the nutrient loop and reducing dependency on synthetic fertilizer.

Source-separation systems with nutrients recycling present several advantages compared with conventional systems, such as: environmental protection and preserve natural resources; increasing soil nutrient content and water retention capacity, and increasing plant resistance to pests, insects and parasites (Moreira et al., 2021). By integrating sanitation and agricultural practices, these systems help maintain soil health, reduce soil degradation, and enhance crop resilience, making agricultural systems more sustainable and productive.

However, as Fernandez-Garcia et al. (2004) point out, high salinity can raise EC levels, potentially damaging both soil and crops due to increased toxicity. For this reason, the integration of sustainable sanitation with agriculture can be optimized by addressing challenges such as salinity management, making it a valuable tool for improving both food production and environmental outcomes.

This study linked the physiological effects on the leaves and root zone of lettuce plants and electrical conductivity (EC) under the application of human urine, aiming to achieve better agronomic development of the plants under human urine-based fertilizer application.

METHODOLOGY

The research was carried out in a greenhouse at Dom Bosco Catholic University (UCDB), Campo Grande, Mato Grosso do Sul, Brazil. A total of 140 L of urine was collected and the following parameters were analyzed: pH, EC, Total Phosphorus, Kjeldahl Nitrogen (NTK), ammoniacal nitrogen, nitrite, nitrate; and for the agronomic aspects were: root volume, root length, total weight, root weight, leaf weight and dry weight, monthly until 180 days of storage were completed. Out of these parameters the relationship between physiological responses of the plant and EC by analyzing plant growth and nutrition parameters was the most outstanding.

The statistical design of the cultivation system was 3 treatments (T1: No chemical or urine supplement; T2: Fertilized with chemical supplement; T3: fertilized with urine) and repetitions. The urine application was based on an average Nitrogen concentration, considering a 25% loss due to ammonia volatilization, resulting in 300 ml plant^{-1}, considering 0.2 m of soil depth, subdivided into 4 rates of 75 ml week^{-1}.

The chemical fertilizer was 9 g of NPK (4-14-8) per plant unit. The substrates chosen were commercial organic compost and vermiculite, mixed in a proportion of 50% each. After 30 days of the experiment, the development of the plants was assessed by observing the root length, root weight and leaf weight, then correlated to the electrical conductivity (EC) of the solutions. The results were analyzed in a Pearson correlation coefficient by R software, version 4.3.2.

RESULTS AND CONCLUSIONS

Utilizing Pearson correlation analysis, as depicted in Figure 1, reveals an inverse relation between electrical conductivity and the physiological parameters. Conversely, the intrinsic parameters of lettuce exhibit a proportional association.

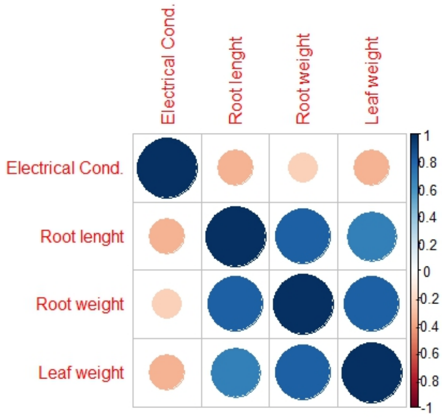

Figure 1: Pearson correlation coefficient

The influence of EC of human urine in each part of the plant is shown, from the lowest to the highest negative influence levels; root weight < root length < leaf weight, correlating the human urine-based fertilizer in liquid form and EC index, corroborating to Grieve et al. (2012) regarding the possibility of EC as a way of measuring soil and solution salinity. The correlation provided a better understanding of the influence of the salt levels not only in the root-zone, often mentioned by various authors, but also in the aerial part of the plant.

The samples that had received urine as fertilizer obtained lighter and smaller leaves, but greener color than the other samples (Fig, 2), representing the high Chlorophyll levels and N effectiveness-absorption from the urine fertilizer. To obtain better results, especially towards weight, it is recommended to use species tolerant to salinity and greater partitioning of the solution throughout the plant cycle, to reduce the salt stress factor, which can limit the growth and production of crops.

Figure 2: Lettuce samples.

Beyond the relationship between the EC index and plant physiology, we had observed the influence of the fertilizer on increasing the soil's Cation Exchange Capacity (CEC), a fundamental parameter for measuring organic matter (Truog, 1946). For instance, on T1, the soil's CEC was 21.90 mmolc.dm^{-3}, for T2, 32.90 mmolc.dm^{-3}, and 35.05 mmolc.dm^{-3} for T3, however, the optimum CEC values are 50-100 mmolc.dm^{-3}, and to reach these optimum values, the soil's pH needs to be increased for at least 6, yet we had obtained pH of 5.4 to 5.8 for all three treatments, addressing the pH levels as one of the causes for the low CEC.

Corroborating with the study developed by Etter et al. (2010) which had found a very good correlation (r^2=0.94), within the EC and the phosphorus content in human urine samples. It could be one of the reasons for the plant development under urine-based fertilizer.

It is also important to emphasize that the low CEC, low-mid values for pH and high levels of EC in urine-based fertilizer can affect the whole plant system, causing the unavailable of nutrients such as: nitrogen, phosphorus, potassium, molybdenum and chlorine due to the Iron/Aluminum relationship in the soil (Hartemink & Barrow, 2023; Malavolta, 1979). In these circumstances, it is recommended to increase the pH of the soil by liming before the fertilizer, to avoid the soil acidification and unavailability of nutrients.

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