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Climate Change and the Possibility of Tea Production in the Egyptian Soils

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CLIMATE change is one of the most important global issues that impacts all our life sides. Growing crops and their productivity also are influenced by changing in the climate and climatic elements. Growing tea in non-traditional regions like Egypt could be considered a challenge due to the specific climatic and soil requirements for growing and production. However, with careful planning and experimentation, it might be possible to establish tea cultivation in such conditions. So, a lysimeter trial was conducted as an exploratory experiment aiming to assess tea cultivation performance in both sandy and clayey soil. Additionally, a separate field trial was carried out to evaluate tea growth in clayey soil along with applied organic fertilizer (chicken manure). The findings revealed that, under the lysimeter trial, tea plants exhibited robust growth on both sandy and clayey soil. Various parameters, including plant height, fresh and dry weights, leaf area, chlorophyll content, and leaf N, P, K levels, indicated superior performance on sandy soil compared to clayey soil. In the field trial, notable superiority was observed in plants grown on the organic medium containing chicken manure over those plants grown on clayey soil without such supplementation. These outcomes suggest that climate changes could potentially transform Egypt into a favorable region for tea cultivation. More studies are needed to establish a complete program of cultivation of tea including the water and nutrient requirements.

Keywords: Clayey soil, Sandy soil, Chicken manure, Tea quality, Organic fertilizer, Lysimeter.

1. Introduction

Tea (*Camellia sinensis* L.) is an important cash crop all over the world, cultivated in 58 countries, and mainly include China, India, Indonesia, Sri Lanka, and Kenya **(Han et al. 2018).** The global tea cultivated area was 4.9 million ha, whereas the annual production was 5.96 million tons in 2018 **(Parida et al. 2023).** This crop also has an economic potential, where contributes in the exportation sector (about 60 % in Sri Lanka from the total export earnings). The global retail value of tea market is expected to increase from 50 to 73 billion USD from 2017 to 2024, respectively **(Jayasinghe and Kumar 2021).** Tea plants generally thrive in subtropical to tropical climates with well-defined seasons **(Ren et al. 2023).**

The tea plant thrives in subtropical to tropical climates with optimal temperatures ranging from 20-30°C (68-86°F), tolerating minimum temperatures of 10-13°C (50-55°F). Adequate and well-distributed rainfall between 1500 to 2500 mm annually is crucial for optimal growth, as tea plants are sensitive to drought stress. High relative humidity levels, ideally between 70% and 90%, are beneficial for cultivation. Extreme heat can induce stress and impact tea leaf quality. Additionally, the availability of carbon dioxide plays a role in photosynthesis, a fundamental process for tea plant growth, but direct effects and requirements may vary based on other environmental factors. Overall, maintaining the right balance of

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moisture, temperature, and carbon dioxide is essential for the successful cultivation of high-quality tea **(Ahmed et al. 2018).** Tea cultivation, traditionally associated with regions featuring specific climatic and soil conditions, has encountered formidable challenges in adapting to the Egyptian agricultural landscape. The unique requirements of tea plants, encompassing factors such as temperature, humidity, and soil composition, have posed significant hurdles to successful cultivation in Egypt. Despite multiple attempts to introduce tea farming to the country, previous efforts have faced limitations, with full-scale success remaining elusive **(Atwa *et al.* 2005).** Various experiments and trials conducted in the past to acclimate tea to Egyptian conditions have encountered obstacles, resulting in less-than-optimal outcomes. The divergence in climate and soil characteristics between Egypt and traditional tea-growing regions has thwarted endeavors to establish a thriving tea industry. However, with the emerging dynamics of climate change and advancements in agricultural management practices, there is renewed optimism for the prospect of tea cultivation flourishing in Egyptian conditions **(Zheng *et al.* 2019).**

It is well known that, climate change, triggered by global warming, is considered as a major challenge across the universe. In this context, this changing climate has unforeseen influence on crop production, including that of tea **(Jayasinghe and Kumar 2021).** Tea is considered a rain-fed mono-cropping system, and its cultivation depends mainly on climatic conditions for optimal growth **(Han et al. 2018).** Several studies reported on the impact of climate change on tea crop productivity with focus on the yield and quality **(Mittal et al. 2021),** the cultivation **(Han et al. 2018)**, impacts on tea secondary metabolites **(Ahmed et al. 2019),** on the Kenyan tea industry **(Muoki et al. 2020),** plant growth and leaf quality **(Zhang et al. 2020)**, and the response to elevated CO_2 **(Ahammed et al. 2020)**. More recent publications on tea production under climate change in different countries like Turkey **(İzmirli and Gül 2023)**, China **(Zhao et al. 2022),** and India **(Modak et al. 2023)**. The changing climate presents an opportunity for the reassessment of tea cultivation in Egypt. As temperature and precipitation patterns evolve, it becomes imperative to explore the potential of tea plants to adapt and thrive under these new conditions. Additionally, advancements in agricultural science and sustainable management practices offer avenues for overcoming historical challenges.

This study endeavors to delve into the challenges that have historically hindered the successful cultivation of tea in Egypt. By scrutinizing past attempts and identifying the specific barriers faced, the study aims to provide insights into how climate changes, coupled with effective agricultural management, may pave the way for tea cultivation to become a strategic crop in an independent Egypt. The objective of current study is to uncover the potential avenues for overcoming historical limitation and establishing a viable and sustainable tea industry in the region. Through a comprehensive analysis, this research seeks to contribute valuable knowledge to the broader agricultural landscape of Egypt and underscore the potential economic and agricultural significance of successful tea cultivation in the country.

2. Materials and Methods

2.1 Experimental location

Lysimeter and field trials were conducted at the experimental farm located in El-Dakahlia Governorate, Egypt, affiliated with Mansoura University (31°03′٠٠″N 31°22′٥٩″E). During the growing season, the temperatures were from 20 °C to 39 °C (from February to October).

2.2 Studied soil characteristics

Two soil types were scrutinized for both trials, and their characteristics are outlined in **Table 1.** The soil analysis involved collecting two surface samples: the first one, obtained from the experimental site, was indicative of clayey soil, while the second sample was sourced from Kalabshoo District, El-Dakahlia Governorate, Egypt, to signify sandy soil. Particle size distribution analysis followed the method outlined by **Gee and Bauder (1986).** The textural class was identified using the soil texture triangle. Organic matter content was determined utilizing the Walkley and Black method, as detailed by **Dewis and Freitas (1970).** Soil pH was measured in a soil suspension (1:2.5 ratio) using a pH meter (BLE-9909, China), while electrical conductivity (EC) was determined in a saturated soil paste extract employing an EC meter (BLE-9909, China) **(Hesse, 1971).** Available soil nitrogen (N), phosphorus (P), and potassium (K) were assessed using the Kjeldahl method, spectrophotometric method (PD-303S, Japan), and flame photometer (PFP7, Jenway company, Türkiye), respectively, following the procedures outlined by **Tandon (2005).**

2.3 Chicken manure used

Chicken manure was obtained from a private poultry farm and the applied amount was 25 m^3 fed^{-1} for the field trial one month before planting. The attributes of the chicken manure employed in the field experiment are outlined in **Table 2**, with fertilizer analysis conducted in accordance with the guidelines specified by **Tandon (2005).**

2.4 Plant materials

A cutting of tea (Hypride Charleston type, variety Eui) was dedicated by a private nursery for propagation and saving the necessary cuttings for this study. Different stages for the cuttings and other plant materials can be presented in the **Figure 1.**

2.5 Experimental set up

2.5.1 Lysimeter trial

This trial was conducted using a total of 20 lysimeters**,** comprising two soil types (sandy and clayey) with 10 replicates for each treatment. Each lysimeter had an area of 0.6 square meters (0.78 meters in length × 0.75 meters in width, with a depth of 0.78 meters). The lysimeters were divided into two groups, first group was filled with sandy soil and the other group filled with clayey soil. Tea plant cuttings were planted on 28 February 2023 and harvested by October 2023. To provide essential nutrients, a fertilization solution was prepared by dissolving 20 g of Kristalon, a commercial compound with a composition of 19:19:19 (N:P:K), in one liter of tap water. The NPK fertilizer was administered as a soil application at a consistent rate monthly throughout the duration of the experiment (for 8 months). The initial dose was applied 10 days after transplantation, followed by subsequent doses at monthly intervals. Concerning the irrigation program, the irrigation was performed twice and once per week for lysimeter and field trials, respectively.

2.5.2 Field trial

This trial involved the utilization of a total of 20 ridges, as illustrated in **Figure 1.** Each ridge measured 6.0 meters in length and 0.75 meters in width. The distance between plants was 20cm. Out of the 20 ridges, ten only were treated with chicken manure at a rate of 25 m^3 fed^{-1}, while the remaining ten ridges did not receive any organic manure. Tea plant cuttings were planted on 28 February 2023. No additional fertilization was carried out throughout the course of this experiment.

2.6 Plant measurements

Eight months after planting, samples of tea plants were meticulously uprooted for the purpose of assessing various parameters. These parameters included plant height (cm), fresh and dry weights (g $plant^{-1}$), leaf area (cm^2 $plant^{-1}$), chlorophyll content, and levels of leaves nitrogen (N), phosphorus (P), and potassium (K) in both lysimeter and field trials. Chlorophyll content was quantified using the SPAD method (SPAD-502, Soil-Plant Analysis Development Section, Minolta Camera, Osaka, Japan). The determination of leaf nitrogen, phosphorus, and potassium levels was conducted through the Kjeldahl method, spectrophotometric method, and flame photometric method, respectively, following the procedures outlined by **Walinga *et al.* (2013).**

Table 1. Characteristics of clayey and sandy soils.

Soil attributes	Values	
	Clayey soil	**Sandy soil**
Sand, %	25.00	90.5
Silt, %	25.50	2.7
Clay, %	49.50	6.8
Soil texture	Clayey	Sandy
Field capacity, %	36.0	16.0
Saturation, %	72.0	32.0
Organic matter, g kg^{-1}	13.5	2.90
pH	7.90	8.00
EC, dS m^{-1}	2.99	1.34
Available N, mg kg^{-1}	53.6	23.2
Available P, mg kg^{-1}	11.4	3.5
Available K, mg kg^{-1}	224.9	112.5

Table 2. Characteristics of chicken manure used.

Characteristics	Values
Potassium (K_2O), %	1.06
Phosphorus (P_2O5), %	0.52
Organic matter, %	47.30
Organic carbon, %	27.50
Total nitrogen, %	2.58
C:N ratio	10.60
EC, dS m^{-1} (1:10)	3.60
pH (1:10)	6.34

1. Selecting the tea variety for propagation

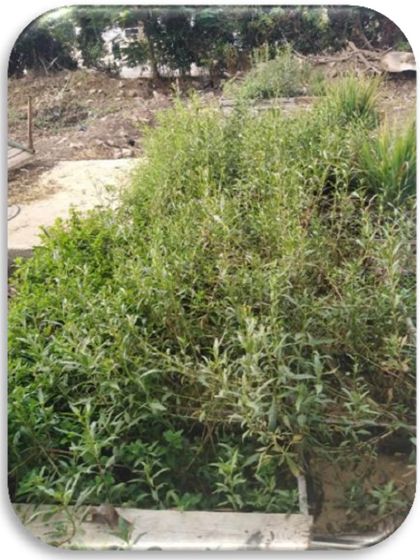
2. Producing the needed cuttings in the nursery

3. Cultivation the cuttings in the field

4. Growing the tea cuttings in the field

5. Preparing the lysimeters for tea cultivation

6. Cultivation of tea cuttings in the lysimeters



7. Growing the tea lants in the lysimeters

8. Flowering the tea plants in the field

9. The harvested leaves of tea plants

10. The ready tea for dinking after boiling in water

Fig. 1. Different stages for the tea cultivation in the current study.

3. Results

3.1 Lysimeter trial

Figures 2 and 3 show the performance of tea plants under both sandy and clayey soils. Various parameters, including plant height (cm), fresh and dry weights (g plant^{-1}), leaf area (cm^2 plant^{-1}), chlorophyll content (SPAD reading), and leaf N, P, K levels (%), were used to evaluate tea plant responses. The results consistently reveal a superior performance of tea plants in sandy soil compared to clayey soil. In other words, the mean values of plant height (cm), fresh and dry weights (g plant^{-1}), leaf area (cm^2 plant^{-1}), chlorophyll content (SPAD reading), and leaf N, P, and K (%) for tea plants grown on sandy conditions were more higher than those of plants grown on clay conditions.

3.2 Field trial

Figures 4 and 5 show the performance of tea plants grown on clayey soil in the presence or absence of chicken manure. Various parameters, including plant height (cm), fresh and dry weights (g plant^{-1}), leaf area (cm^2 plant^{-1}), chlorophyll content (SPAD reading), and leaf N, P, K levels (%), were used to evaluate tea plant responses. The results consistently reveal a superior performance of tea plants in the presence of chicken manure. In other words, the mean values of plant height (cm), fresh and dry weights (g plant^{-1}), leaf area (cm^2 plant^{-1}), chlorophyll content (SPAD reading), and leaf N, P, and K (%) for tea plants grown on soil treated with chicken manure were more higher than those of plants grown on untreated soil.

4. Discussion

The current study investigated the impact of soil texture (i.e., sandy and clayey class in a lysimeter trial) and organic fertilizer (i.e., chicken manure in a field trial) on the growing, and productivity of tea crop under the Egyptian conditions (temperature ranges from 27 to 45 °C during the going period from February to October 2023). Are the notable high temperatures during summer and humidity enough to grow and produce tea in Egypt? Is soil texture and/or organic fertilizer a crucial factor for growing and producing tea? Are there new non-traditional regions for tea cultivation all over the world beside Egypt? To answer the following questions, this section will cover them through the following parts.

The tea plant is an evergreen shrub or small tree characterized by glossy, dark green leaves with serrated edges. The plant is capable of reaching a height of up to 9 meters if left unpruned, but it is typically cultivated and maintained at a more manageable height for ease of harvesting **(Carr, 1972).** The tea plant's most distinctive feature is its ability to produce various types of tea, including black, green, oolong, and white tea, depending on the processing method applied to the leaves. It thrives in sub-tropical to tropical climates and requires well-drained acidic soil for optimal growth (**Xia *et al.* 2020**). The plant's delicate flowers are inconspicuous, and it bears small fruits containing seeds that can be used for propagation, and the propagation using cuttings is successful as well **(Soundy et al. 2008).** Tea plant is known for its caffeine content and the rich array of bioactive compounds that contribute to the diverse flavors and health benefits associated with different types of tea **(Xia *et al.* 2020).**

Due to changing in the climate, notable high temperatures during summer and humidity in Egypt can be noticed, which allow growing and producing tea under the Egyptian conditions, as proved in the current study. Scientific reasons for the superiority of tea plants under sandy soil as compared to clayey conditions may be due to the sandy soils generally offer better drainage, preventing waterlogged conditions that can be detrimental to tea plant roots (**Castán et al. 2016).** Sandy soils promote good aeration, allowing the roots to access oxygen, which is crucial for tea plant growth. Sandy soils tend to warm up more quickly, providing a favorable temperature for tea plant growth, especially in cooler climates. The loose structure of sandy soils facilitates root penetration and exploration, allowing tea plants to access nutrients more efficiently. While sandy soils may have lower water retention, they often have higher nutrient availability, which can contribute to enhanced plant growth **(Huang and Hartemink, 2020).** Sandy soils may reduce the risk of certain root diseases associated with waterlogged conditions, contributing to the overall health of tea plants. These scientific factors collectively contribute to the superior performance of tea plants in sandy soils, as reflected in the observed growth parameters **(Sharaf El-Din *et al.* 2022).**

Under field conditions, the superiority of tea plants grown in the presence of chicken manure can be attributed to several scientific factors. Chicken manure is a rich source of essential nutrients, including N, P, and K, as well as other micronutrients. These nutrients contribute to improved soil fertility and provide the necessary elements for robust plant growth. Chicken manure enhances the organic matter content of the soil. Increased organic matter improves soil structure, water retention, and nutrient-holding capacity, creating a more favorable environment for tea plant roots. Chicken manure contains beneficial microorganisms that promote soil health **(Zhang et al. 2021).** The organic matter in chicken manure enhances the soil's water retention capacity, ensuring a more consistent and available water supply for tea plants. This is particularly beneficial in regions with irregular rainfall patterns. Chicken manure can influence soil pH positively, creating conditions that are conducive to tea plant growth. Tea plants generally thrive in slightly acidic to neutral soils, and chicken manure can help maintain an optimal pH range **(Ye et al. 2022)**. The microbial activity in chicken manure may contribute to suppressing certain soil-borne diseases, protecting tea plants from potential infections and promoting overall plant health. The observed increase in chlorophyll content (SPAD reading) indicates improved photosynthetic activity in tea plants treated with chicken manure. Enhanced chlorophyll levels contribute to better energy capture and utilization for plant growth. Chicken manure provides a balanced mix of nutrients, promoting a harmonious nutrient ratio that meets the specific needs of tea plants. This balance is crucial for optimal growth and development. In summary, the scientific reasons for the superiority of tea plants grown in the presence of chicken manure lie in the nutrient-rich composition of the manure, its positive effects on soil structure and microbial activity, and its ability to create an environment that supports the overall health and productivity of tea plants **(Mažeika *et al.* 2021).**

Soil is important and limiting factor for tea cultivation and production as reported by many studies such as impact of magnesium fertilization (**Yang et al. 2023**), reclaimed soil (**Agbeshie et al. 2021**), soil fertility (**Ren et al. 2023**), and polluted soil (**Ju et al. 2024)**. As mentioned above, soil texture is a crucial factor in tea cultivation and more studies are needed to investigate different possible soil types including soil textures and other soil conditions such as waterlogged, calcareous, alkaline and saline soils under the Egyptian conditions. Concerning the organic fertilizer, this study proved that chicken manure is a crucial factor for growing and producing tea. More studies are required for establish the proper program of both fertilization and irrigation for this promising crop in Egypt.

There are many new non-traditional regions for tea cultivation all over the world beside Egypt like Turkey, as reported by **İzmirli and Gül (2023)**, and it is expected to change the traditional zones for tea cultivation in the next decade. This study might open many questions for the expected non-traditional regions for tea cultivation and production like Egypt because the economic value of this crop. These questions are mainly related to the relationship between tea cultivation and climate change. These questions should focus on the suggested current and future climate change scenarios (**Jayasinghe and Kumar 2021**), tailored climate projections for the vulnerability of tea production (**Mittal et al. 2021),** the adaptation of tea cultivation to climate change (**Zhao et al. 2022**), and the expected changes in tea land use patterns (**Jayasinghe and Kumar 2023**). The most important question that still needed concerning the possibility of tea cultivation in Egypt; is climate change supporting the cultivation of tea in Egypt?

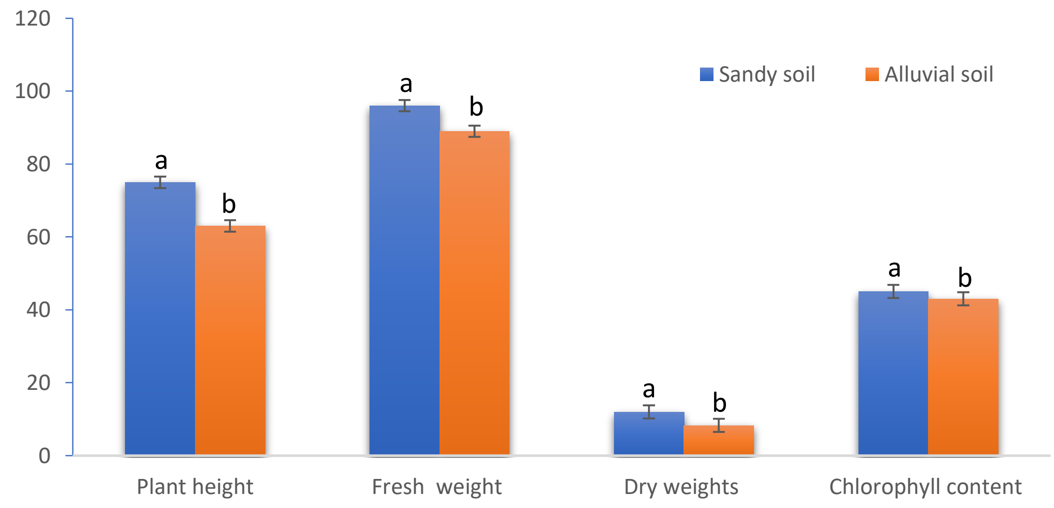


Fig. 2. Effect of soil type on tea plant response [plant height (cm), fresh and dry weights (g plant^{-1}), chlorophyll content (SPAD reading)] under lysimeter trial.

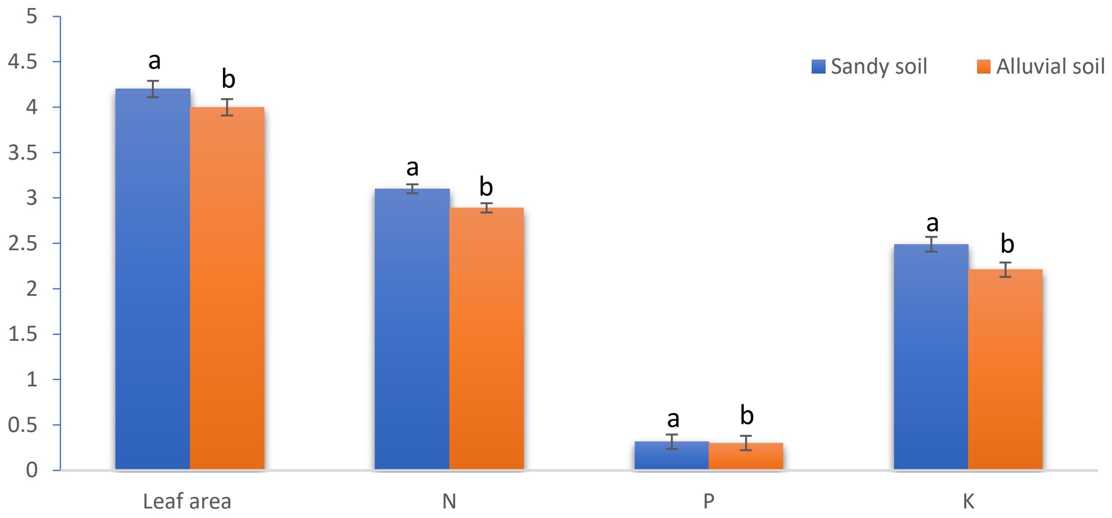


Fig. 3. Effect of soil type on tea plant response [Leaf area (cm^2 $plant^{-1}$) and leaf N, P, K levels (%)] under lysimeter trial.

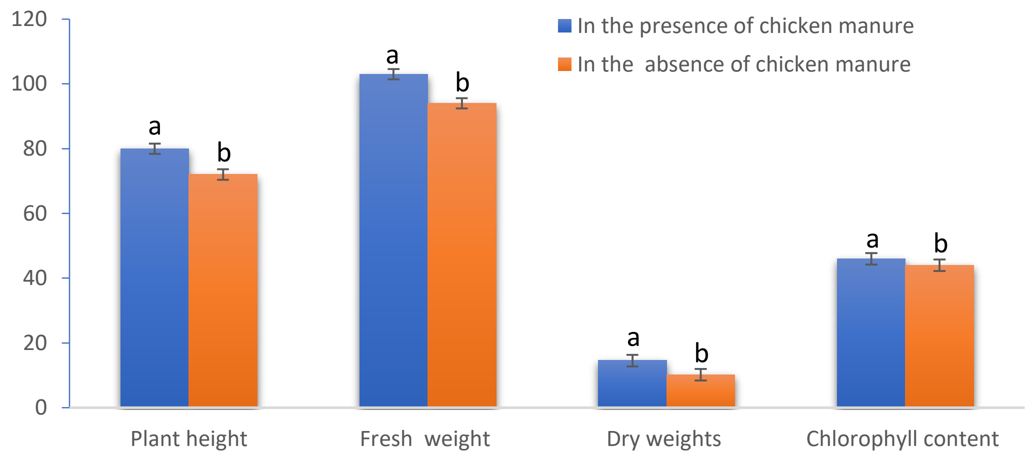


Fig. 4. Effect of chicken manure on tea plant response [Plant height (cm), fresh and dry weights (g $plant^{-1}$), chlorophyll content (SPAD reading)] under field trial.

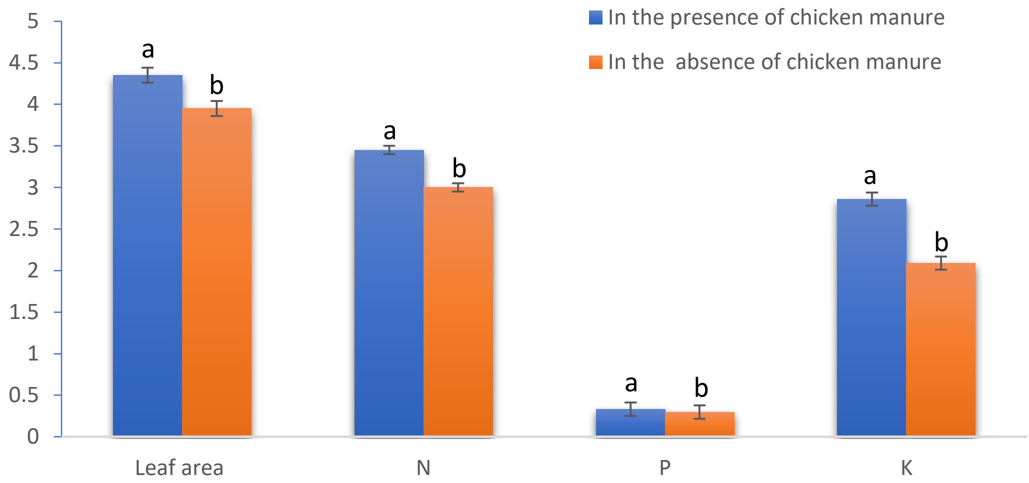


Fig. 5. Effect chicken manure on tea plant response [Leaf area (cm^2 $plant^{-1}$) and leaf N, P, K levels (%)] under field trial.

5. Conclusion and recommendations

In conclusion, the lysimeter trial and field trial conducted to evaluate the possibility of tea cultivation in non-traditional regions like Egypt provided valuable insights. The lysimeter trial demonstrated that tea plants can exhibit robust growth in both sandy and clayey soil, with a particularly superior performance noted in sandy soil across various key parameters. The field trial further underscored the positive impact of an organic medium enriched with chicken manure on tea plant growth, outperforming plants grown in clayey soil without such supplementation. These findings suggest that, despite the inherent challenges, tea cultivation in Egypt holds promise, especially with strategic soil and nutrient management. The adaptability of tea plants to varying soil conditions and the favorable response to organic enrichment open avenues for potential expansion of tea cultivation in the region. This study might present the following recommendations:

1. Implement targeted soil management practices, such as pH adjustments and organic enrichment, to optimize conditions for tea cultivation. This includes assessing and amending soil characteristics to ensure an ideal environment for tea plants.
2. Consider the incorporation of organic fertilizers, such as chicken manure, to enhance soil fertility and provide essential nutrients for tea plants. Regular soil testing and nutrient analysis can guide effective nutrient management strategies.
3. Continue conducting trials and experiments to refine cultivation practices tailored to the local conditions. This includes testing different varieties of tea plants and monitoring their performance under Egyptian climatic and soil conditions.
4. Adaptation strategies may be necessary to address evolving climatic conditions and ensure the sustainability of tea farming in the region.

By incorporating these recommendations, there is a prospect for enhancing the viability and sustainability of tea cultivation in Egypt, potentially transforming it into a successful venture within non-traditional tea-growing regions.

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