Evaluating organo-mineral fertilisers for climate-positive tea agronomy

First Year Student Progress Report

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By

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Background and Rationale

Tea (Camellia sinensis) is the most consumed beverage worldwide, enjoyed by millions in the form of green, black, and oolong tea. Its global popularity is driven not only by its distinctive taste and high caffeine content but also by its potential health benefits, including antioxidant properties that may inhibit the growth of cancer cells. These benefits are largely attributed to polyphenol catechins, compounds found in young tea leaves and buds; the parts of the plant that are typically harvested for tea production.

The repeated harvesting of these nutrient-rich parts removes essential elements from the plant, making it highly dependent on soil-derived nutrients to sustain growth and maintain productivity. As a result, tea cultivation requires a steady supply of both macronutrients, such as nitrogen, phosphorus, potassium, magnesium, and micronutrients, such as calcium and copper. These nutrients are vital for root development, chlorophyll production, and the regeneration of new leaves after harvesting. Without adequate nutrient supply, tea yields and quality decline significantly. To address these nutritional needs, farmers commonly apply synthetic, inorganic, fertilisers. In Kenya, commercial tea production heavily relies on repeated cycles of fertiliser application to sustain high productivity. Numerous studies have shown that the application of nutrients such as nitrogen, phosphorus, and potassium boosts both the quality and quantity of tea harvested, enhancing attributes like leaf density, chlorophyll content, and resistance to stress.

However, despite their effectiveness, the long-term sustainability of inorganic fertilisers is increasingly in question. Overuse of chemical fertilisers has led to environmental concerns such as reduced soil fertility, increased leaching of harmful substances into water systems, and emissions of greenhouse gases like nitrous oxide. In addition, the heavy reliance on imported fertilisers, up to over 600,000 metric tons annually in Kenya alone, has become a major financial burden for both large-scale producers and smallholder farmers. Fertiliser prices have surged dramatically in recent years, pushing the cost of a 50 kg bag of NPK fertiliser to unsustainable levels for many growers.

Tea production is currently responsible for up to 73% of greenhouse gas emissions from the crop stage to the farm gate. This is mainly due to the production of synthetic nitrogen (N) fertilizer and the emissions released when it is used in the field. Even further along the supply chain,

through processing, packaging, and transport to the supermarket shelf, tea crop production still accounts for 73% of the total emissions. This clearly shows that reducing nitrogen-related emissions is essential for reaching net-zero targets.

Browns East Africa Plantations (BEAP), formerly Lipton which is the world's largest tea producer has tea plantations in Kenya, Tanzania and Rwanda with tea production and breeding operations. However, these plantations are under pressure from climate change, due to prolonged and more frequent droughts. Tea production also relies on synthetic nitrogen fertilisers that have a large carbon footprint, contributing to greenhouse gas emissions. Lipton has formed a strategic vision to make its tea plantations climate positive so they will contribute to carbon sequestration and increased biodiversity. This will contribute to regenerative agriculture. The major challenges to this vision are to reduce synthetic nitrogen use, and to keep the crop productive and resilient in times of drought.

Considering these challenges, there is a growing interest in identifying sustainable, cost-effective alternatives to synthetic fertilisers. Organic fertilisers, derived from plant and animal waste, have been shown to improve soil health by enhancing physical structure, boosting microbial activity, and replenishing organic matter. Another promising approach is the use of organo-mineral fertilisers (OMFs), which blend organic materials with smaller amounts of mineral nutrients. OMFs aim to strike a balance between the immediate nutrient availability supplied by synthetic fertilisers and the long-term soil health benefits of organic amendments.

Recent research and innovation have demonstrated the potential of OMFs in agriculture. Studies have explored the use of biosolids, composted livestock manure, and even carbon-captured materials to formulate OMFs with comparable efficacy to traditional fertilisers. These solutions not only reduce dependency on imported chemicals but also support circular economy principles by recycling organic waste into valuable farm inputs.

In the tea growing regions of Kenya, such as Kericho County, experiments with locally sourced materials by Tea Research Institute of Kenya, like composted sheep manure enriched with NPK, have yielded promising results. These blends improved soil structure, increased soil organic matter, and enhanced tea yields, outperforming conventional fertilisers. In particular, enriched manure applied at optimal rates produced higher yields and better photosynthetic performance, underscoring the potential of OMFs to support sustainable tea production.

Given these findings, the integration of organic and organo-mineral fertilisers into tea farming presents a viable pathway toward reducing the environmental footprint of tea production while also improving economic resilience for farmers. By utilising locally available feedstocks and reducing reliance on costly chemical imports, these alternatives offer a scalable, environmentally friendly solution to meet the nutritional demands of tea plants and promote long-term soil health.

Notably, tea estates generate substantial amounts of organic and inorganic waste throughout the production process, offering a largely untapped resource for sustainable fertiliser development.

These wastes include post-processing tea residues from factories, rejected fresh tea leaves, prolific weed biomass from plantations, and boiler ash produced during tea drying. Together, these materials provide a consistent and locally available supply of organic feedstocks that can be harnessed to produce nutrient-rich composts or used directly in the formulation of organo-mineral fertiliser (OMF) blends.

This project seeks to innovate by converting these estate-generated wastes into value-added fertiliser products through strategic composting and vermicomposting of these wastes in different ratios with the aim of obtaining a high-quality organic fertilisers. The organic outputs will be mixed with minimal quantities of mineral fertilisers to make organomineral fertilisers. By doing so, it not only addresses the challenge of fertiliser affordability, particularly among smallholder tea producer, but also promotes waste recycling and resource circularity within the tea value chain. The formulation of OMFs using tea-specific waste streams supports the development of context-appropriate fertilisers that align with local environmental conditions and crop requirements.

Beyond fertiliser development, the project aims to evaluate the agronomic performance of these OMFs under field conditions, as well as their environmental impacts, including potential reductions in greenhouse gas emissions and nutrient losses. By leveraging waste from within the tea system itself, this initiative presents a closed-loop solution that transforms production by-products into inputs, reducing external dependencies and fostering greater sustainability. Ultimately, the project will support smallholder empowerment, enhance climate resilience, and reduce the ecological footprint of tea production.

Overall aims and objectives

To develop and evaluate organo-mineral fertilizers (OMFs) for sustainable tea agronomy by optimizing production, enhancing soil microbiota, and assessing nutrient dynamics and environmental impacts.

Specific Objectives

1. To optimise composting and vermicomposting process for the efficient valorisation of locally sourced feedstocks into high quality organic fertilisers for making organomineral fertilisers
2. To characterise organomineral fertilisers and evaluate their efficacy in enhancing the diversity and abundance of rhizospheric microbial communities in tea
3. To assess the nutrient mineralisation patterns of organomineral fertilisers between successive applications
4. To assess the effect of field organomineral fertiliser application on greenhouse gas emissions and the diversity and abundance of rhizospheric bacterial and fungal communities in tea
5. To determine the effect of OMF on diffuse pollution through erosion studies

Methods

Review of composting, vermicomposting and organomineral fertiliser formulations

Literature search dominated my first year as I sought to find the research gaps to fill and understand the concept of organic fertiliser making and OMF formulation. Literature search was performed using Scopus, thanks to Cranfield university which has subscribed to a huge database of up-to-date academic research papers. For a successful search, I used specific keywords related to my study including OMFS, organic fertiliser formulation using local wastes, composting, and vermicomposting. The results from the search indicated that there is limited research that has been done in Kenya particularly using tea wastes, tea leaves, weeds, and boiler ash in making organic and organomineral fertilisers, providing an opportunity to fill the gap. Furthermore, the literature search indicated that OMF formulation has not been done in Kenya and thus the need to do it at this point and experiment to understand its nutrient supply and greenhouse gas emissions.

Objective 1: Optimization of composting and vermicomposting

Composting and vermicomposting experiments were set up co-currently in the month of April 2025. They are currently being monitored for temperatures, moisture, and microbial shifts. Data on temperature shifts are collected weekly to monitor microbial activity and the breakdown of feedstocks into organic fertilisers. A good compost that will result in high quality organic fertiliser is expected to achieve the thermophilic phase which we have achieved. This is an early indicator that we are heading in the right direction as guided by literature. The experiment is expected to run for the next 120 days from the beginning. Analysis for quality will be conducted at the end including checking for carbon to nitrogen ratio, full range chemical analysis and phyto-toxity. Below are pictures from composting and vermicomposting set ups.

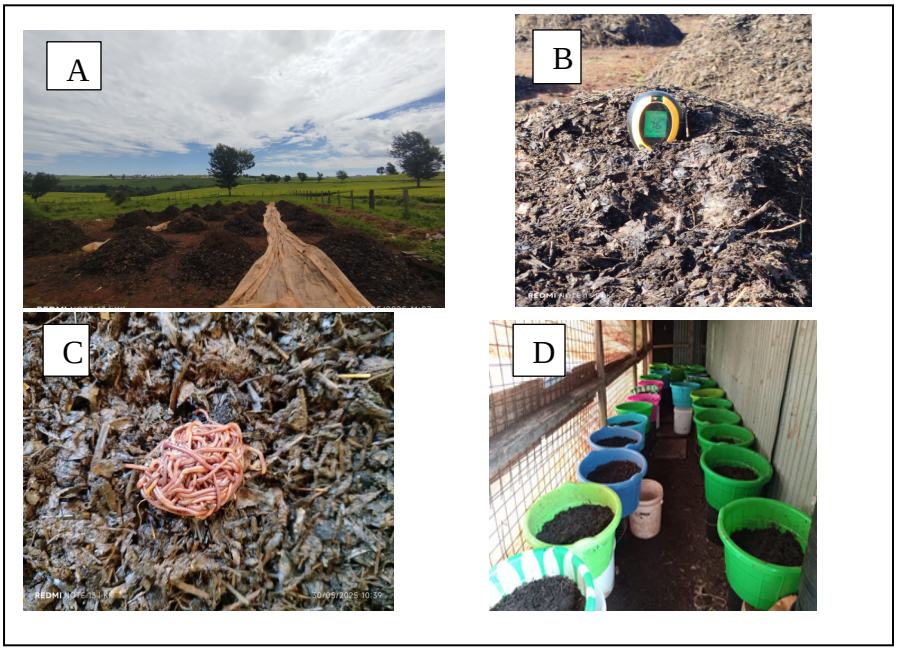

Figure 1: showing composting and vermicomposting set ups where; A-field composting piles, B-observation of temperatures up to 76 °C, C-introducing worms to feedstocks, D-Vermicomposting bins

Potential Benefits of the Project

This project is at its first year. It aims to develop and evaluate organo-mineral fertilisers (OMFs) specifically designed to promote sustainable tea agronomy by optimising the use of locally sourced organic feedstocks combined with reduced mineral fertiliser inputs. By improving composting and vermicomposting processes, the project will produce high-quality organic fertilisers that serve as the backbone for effective OMF blends. This innovation addresses critical resource scarcity and environmental challenges linked to conventional fertiliser use in Kenya's tea sector.

Beyond the technical development of fertilisers, a key benefit of this project lies in empowering local smallholder farmers and tea estate workers with practical knowledge and skills related to composting, vermicomposting, and sustainable fertiliser management. Through targeted training and community engagement, farmers will learn how to efficiently valorise organic waste materials generated on their farms, such as tea processing residues, farm weeds, and animal manures, transforming these wastes into valuable fertiliser inputs. This knowledge transfer will enhance local capacity for on-farm nutrient recycling, reduce reliance on expensive imported fertilisers, and promote environmentally friendly farming practices.

The project will also facilitate improved understanding of how OMFs enhance soil health by stimulating the diversity and abundance of beneficial rhizospheric microbial communities that drive nutrient cycling and plant growth. Insights into nutrient mineralisation patterns over time will help farmers optimize fertiliser applications to maximize tea yields sustainably.

Moreover, the research will evaluate the environmental impact of OMF use in tea plantations, including their potential to reduce greenhouse gas emissions and limit nutrient runoff and soil erosion, thus protecting local water resources and biodiversity. By integrating organic amendments with mineral inputs, OMFs provide a balanced nutrient supply that improves soil structure and resilience, fostering climate-smart agriculture.

Ultimately, this project will contribute to the socio-economic well-being of tea-growing communities by reducing production costs, increasing farm productivity, and promoting sustainable land management. Empowered with new skills and sustainable fertilisation technologies, local farmers will be better equipped to improve livelihoods, enhance food security, and build resilience against climate variability. This initiative represents a vital step toward more inclusive, environmentally sound, and profitable tea production systems in Kenya.