**Evaluating organo-mineral fertilisers for climate-positive tea agronomy**

**Year Two 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.

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. 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, 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.

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. 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.

This project seeks to innovate by converting these estate-generated waste into value-added fertiliser products through strategic composting and vermicomposting of these wastes in different ratios with the aim of obtaining a high-quality OMFs organic fertiliser. The organic outputs will be mixed with minimal quantities of mineral fertilisers to make organo-mineral fertilisers. By doing so, it not only addresses the challenge of fertiliser affordability, particularly among smallholder tea farmers, but also promotes waste recycling and resource circularity within the tea value chain.

Beyond fertiliser development, the project also 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

**Project Progress**

The second year of this study was marked by remarkable progress across all key milestones, including experimental execution, rigorous data collection, advanced analysis, and formal reporting to the academic

review team at Cranfield University. The core focus of this period was the conclusion of composting and vermicomposting experiments aimed at developing high-quality organic and organo-mineral fertilisers (OMFs). These trials concluded successfully in late 2025, yielding notable results that validate the technical viability of using locally sourced feedstocks to make high quality organic fertilisers (Figure 1).

A critical success factor in these optimisation experiments was the utilisation of locally sourced, low-cost organic materials. By testing formulations both with and without animal manure, the research demonstrated that regional agricultural waste streams can be efficiently upcycled. The primary feedstocks successfully utilized in the trials included:

- Farm weeds: Collected from local fields to manage invasive biomass.
- Green tea waste: Sourced directly from local cultivation sites.
- Factory tea waste: Organic residues acquired from regional processing plants.
- Boiler ash: A mineral-rich byproduct of tea factory processing.
- Cow dung: Integrated as a traditional nutrient and microbial starter.

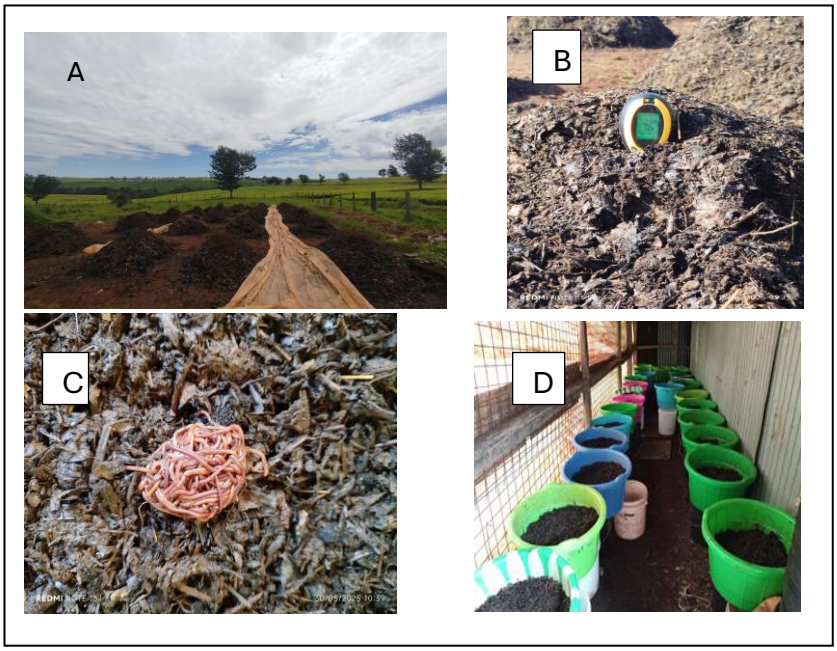


*Figure 1: composting and vercmimpositn set ups where; A-field composting piles, B-observation of temperatures up to 76 °C, C-introducing worms to* feedstocks, D-Vermicomposting bins

Chemical analysis of the resulting organic fertilisers revealed exceptional nutrient profiles, with nitrogen (N) content reaching up to 3.5%. This is a significant milestone, as achieving such high-quality nitrogen levels exclusively from raw, non-fortified feedstocks confirms that local wastes can match or exceed standard local organic soil amendments.

Furthermore, the vermicomposting line achieved an outstanding biological yield, producing a substantial population of red worms (*Eisenia fetida*). This flourishing colony provides a robust, self-sustaining biological resource that is ready to be distributed to target communities for home-scale vermicomposting initiatives.

Backed by solid data, this experimental success provides the scientific foundation and confidence required to roll out community waste-recycling programs.

Building upon these organic foundations, the project achieved a major technological milestone by formulating organo-mineral fertiliser (OMF) (Figure 2) boasting a nitrogen content of up to 9.6%. This balanced formulation addresses a long-standing challenge in Kenyan tea agronomy: the reliance on standard mineral fertilisers, which often degrade long-term soil health.


*Figure 2 from raw wastes to high quality pellets*

To ensure practical farm application, these custom OMF blends were processed into durable pellets. This pelleting process serves several critical functions: it stabilizes the organic matrix, significantly extends shelf life, and simplifies packaging and field transport. Agronomically, the pelleted format transforms the material into a slow-release fertiliser. This ensures a steady, prolonged nutrient supply to the tea bushes over an extended period. In contrast, conventional, fast-dissolving mineral fertilisers are highly susceptible to being swept away by heavy rainfall or leached deep into the lower soil profile where roots cannot reach them.

Simultaneously, data collection from the active field experiments advanced significantly. The field trials, treated with the newly developed organic and organo-mineral formulations, were closely monitored alongside control plots treated with conventional mineral fertilisers. A primary focus of this monitoring was the precise

measurement of greenhouse gas (GHG) emissions. These direct comparative datasets are vital for quantifying the exact atmospheric and environmental footprint of our custom blends relative to synthetic alternatives.

**Potential Benefits of the Project**

As the project transitions from initial design into concrete field application, the theoretical goals established in the first year have materialised into verifiable socio-economic and environmental benefits. By moving closer to a true circular economy, this research directly addresses resource scarcity, high production costs, and ecological degradation within Kenya's tea-growing communities.

Notably, the technical breakthroughs in feedstock processing offer immediate economic relief to smallholder farmers and tea estates. Through this project, my year 3 will be marked by rigorous outreach programs of disseminating the findings to local communities. Plans are underway now to engage with the local community leaders and the chiefs of two locations for local community farmers to participate in trainings which will enable us to translate the research data into practical community training. Through this initiative, farmers will learn to value and upcycle residues like weeds, factory tea waste, household wastes and ash among other wastes and convert them into organic fertilisers. This will allow communities to significantly reduce their annual cash expenditure on expensive, imported synthetic nutrients.

Additionally, the successful multiplication of *Eisenia fetida* is a boost to dissemination process as farmers will be issued with colonies for their home-based projects. This enables household-level waste recycling and decentralized vermicomposting, fostering community resilience, boosting local capacity for nutrient management, and creating self-sustaining circular bio-economies at the village level.

Furthermore, the development of the pelleting technique provides smallholder tea sectors with an accessible pathway for value addition. Engaged farmers will have a chance to be trained on how to acquire a small-scale pelletiser in Kenya, how to use it and thus allow them to transition from handling bulky, wet compost to using stable, transportable, and precise organo-mineral pellets.

From an environmental perspective, the project offers clear advantages for regional ecosystems. By substituting highly soluble mineral inputs with structured OMF pellets, the project mitigates the risk of agricultural runoff, thereby protecting local water resources from eutrophication (nutrient pollution) and preserving aquatic biodiversity.

Furthermore, the integration of stable organic matter actively stimulates beneficial rhizospheric microbial communities, enhancing the soil's structural integrity and water-retention capacity. Most notably, the ongoing collection of field data regarding greenhouse gas emissions provides a transparent, scientifically validated metric of the project's climate-smart credentials. By proving a net reduction in field emissions and soil erosion compared to synthetic regimes, these custom fertilisers offer a scalable strategy for building climate resilience across Kenya's broader agricultural landscapes.

On a personal development, this study's finding will enable me to develop and advance research skills needed to build a career in sustainable agriculture and soil fertility management. It will also strengthen my capacity to work with researchers, industry, extension services, and policymakers to translate the findings into practical organo-mineral fertiliser technologies and management recommendations that can be widely adopted, improving agricultural productivity and environmental sustainability.