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ADVANCING THE CIRCULAR BIONUTRIENT ECONOMY: ADDRESSING THE SALINITY ISSUE ASSOCIATED WITH URINE AS A FERTILIZER

Proposal to the Laidlaw Undergraduate Leadership and Research Program

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BACKGROUND

The world has a fertilizer problem, a soil health problem, and a sanitation problem, which together threaten climate stability, food security, and global health. The Circular Bionutrient Economy (CBE) strives to address these triplet problems by reversing the linear nutrient flow from rural soils to urban diets and then via mostly untreated sewage into our shared waterways.

The primary nutrients in commercial fertilizers are nitrogen (N), phosphorus (P), and potassium (K), which trigger ecosystem-killing algae blooms downstream from effluent and agricultural runoff. Aside from this direct catastrophe, new research indicates that just the manufacture of nitrogen fertilizers alone could represent greater than 20% of global agriculture's vast greenhouse gas footprint (Menegat et al., 2021). Additionally, phosphorus reserves are diminishing globally, and only a few countries control the majority of potassium mines (Hilton et al., 2021). The conventional approach to nutrient sourcing is non-renewable and prohibitively expensive for many farmers (Houlton et al., 2019; Vitousek et al., 2009).

Urine is of particular interest to the CBE, containing 80-90 percent of the nitrogen and more than half of the phosphorus and potassium in domestic wastewater (Karak & Bhattacharyya, 2011; Randall & Naidoo, 2018; Vinnerås & Jönsson, 2002). When used as a fertilizer, urine has been observed to generate crop yields equal to or greater than commercial fertilizers (e.g., Andersson, 2015; Pradhan et al., 2017; Ranasinghe et al., 2016; Schmidt et al., 2015). Still, for urine to be a viable agricultural input, there are several risks to address: microbiological (pathogens), pharmacology (residual drugs), disgust and privacy, and long-term salinization of soils (Pathy et al., 2021). I hope to understand the salinity risk.

KEY PROJECT OBJECTIVES + IMPACTS

Lab, Greenhouse, and Field Study.

> ℹ *Compare buildup of soluble salts in three urine-based treatments using lab techniques, bioassays, and field samples. Metrics for each include retention of: carbon, nitrogen, carbon to nitrogen ratio, and salts. All urine will be pasteurized for the proposed work.*

- **Direct application.** Direct urine application has been shown to improve plant vigor and productivity in nutrient-deficient soil, but the authors of these studies warn that matching application rates to nutrient needs markedly increases soil salinity (Boh et al., 2013; Karak & Bhattacharyya, 2011; Kassa et al., 2018; Sene et al., 2019).

- **Urine-enriched biochar.** Biochar, pyrolyzed organic matter, is a valuable soil amendment but competes with the desired crop for limited nitrogen. Biochar can be pre-enriched with urine to satisfy its nitrogen affinity and ultimately release the nitrogen to the crops. Additionally, urine-enriched biochar has been shown to outperform urine alone in yield trials, but comparative rates of salinity buildup are lacking in the existing literature (Schmidt et al., 2015; Schmidt et al., 2017; Sutradhar et al., 2021).
- **Urine-treated crop residues.** Where soils are contaminated, farmers can still produce safe crops by building new soil with baled or otherwise bundled residues like wheat straw or maize stover. These high-carbon residues require a source of nitrogen — for which urine is a candidate — to be adequately composted (Van Groenigen et al., 2017).

Scholarship

Analyze techniques for desalination and/or discriminatory nutrient capture from urine and their viability for farmers across geography and economic standing. Synthesize existing literature on accessibility, performance, and adaptability of each method, ultimately proposing novel research and innovation toward appropriate systems for low-capital farmers and commercial handlers.

Community Partnership for Innovation

> *Collaborate locally and globally to identify and address agronomic barriers to a circular bionutrient economy.*

- **The Soil Factory Network (SFN) and constituents: Poverty and Health Integrated Solutions (Kenya), Sanitation First (India), and the Soil Factory (Ithaca, NY).** More than anywhere else in the world, South Asia, West Africa, and East Africa see sufficiently co-located demand for fertilizer and supply of human-derived nutrients (Echevarria et al., 2021). SFN is working to tame untreated fecal waste streams with integrated biochar production and improve accessibility for low-capital farmers. The proposed research complements SFN's work by addressing the salinity risk posed by urine while increasing the nutrient value of excreta-derived fertilizers and soil amendments. The Nelson Lab is a leader in SFN.Urine-enriched biochar.
- **Dilmun Hill Student Organic Farm in Ithaca, NY.** The Nelson Lab's incipient partnership with Dilmun Hill will demonstrate the use of urine-treated crop residues on historically contaminated orchard soil (Lim & McBride, 2015). The proposed research includes Dilmun as a study site and its Steering Committee, of which I am a member, as an approving partner.

POTENTIAL IMPACT OF FINDINGS

The potential impact of understanding salt buildup in different urine-based fertility treatments and synthesizing the technological, biological, and chemical options to detain undesired salts is twofold. First, the findings will inform an agronomic basis for introducing urine. Commercial fertilizers do not carry the same magnitude of toxic salinity risk, so the guidelines should not be the same. Second, the findings will inform innovation by SFN and its partners to develop and study novel and low-capital desalination or nutrient capture methods, a crucial step to making urine a viable and accessible substitute to fossil-fuel-derived fertilizers — a boon to livelihoods around the world.

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