Coffee Wastewater for Acidifying Animal Bonemeal: Impacts on Crop Growth and Phosphorus Nutrition in P Deficient Soils in Ethiopia

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Background

- Establishing reliable phosphorus (P) supply is critical for assuring sustainable food security.
- Not only are the world's supplies of minable P running out in ~ 250 years, but the quality of existing rock-phosphate reserves is decreasing – leading to increased cost of production.
- Africa has the lowest per hectare fertilizer use rates due to high cost for low-income farmers and often experiences reduced crop yields.
- Ethiopia is home to the largest population of livestock in Africa, representing massive potential for developing a new, sustainable, affordable P-fertilizer from animal bones.
- Ethiopia is also the largest producer of coffee in Africa; the large quantities of acidic coffee wastewater (pH ~ 4) produced during wet-processing of coffee could be used to acidify bones.

Hypothesis

- Phosphorus availability and plant biomass will increase more in response to application of fine-ground bonemeal (< 2 mm) treated with coffee wastewater as compared to coarse-ground bonemeal (> 2 mm) with or without coffee wastewater treatment.

Objective

- The objective of this study was to evaluate the interactive effects of bonemeal and coffee wastewater on phosphorus availability and plant biomass in soils with contrasting pH and texture.

Greenhouse Study Design

Study Site

- Hawassa University, Ethiopia. For this greenhouse study soil samples (0-15 cm) were collected from two agricultural fields located in Wolaita and Ziway (Table 1).

Treatments

- Two soil types (clay and sandy loam), two bonemeal materials [fine (< 2 mm)- and coarse (>2mm)-ground bonemeal], three shaking times (0 h, 24 h, and 72 h) in coffee wastewater (1:200 w/v), and two crops (maize and haricot bean); 3 replicates of each treatment combination in CRD (n = 72) (Fig. 1).
- DAP and unfertilized control were included (n = 24).

Fig. 1: A lab technician shaking bonemeal with coffee wastewater (left) and an illustration of the pot experiment in a greenhouse (right) at Hawassa University.

- DAP and bonemeal were applied at same P rate: 46 kg P_2O_5 ha^{-1}.
- Bonemeal has pH: 7.28, total P: 73413.6 mg kg^{-1}, and available P: 179.3 mg kg^{-1}.
- Coffee wastewater has pH: 4.36, total P: 10.17 mg kg^{-1}, and available P: 4.82 mg kg^{-1}.
- Data collected: plant biomass (90 days later), plant and soil (total and $NaHCO_3$ available) phosphorus.

Table 1: Physical and chemical properties of the two soils used in the greenhouse study.

Location	Parameter											
	Particle size distribution (%)			pH	Total P	Avail. P ($NaHCO_3$)	TOC	Total N	Cu	Fe	Mn	Zn
	Sand	Silt	Clay		----(mg kg^{-1})----		------(%)------		----------(mg kg^{-1})----------			
Wolaita	17.2	25.9	56.1	6.27	6081.2	25.3	1.9	0.19	0.34	26.61	22.97	0.85
Ziway	54.9	32.1	12.8	7.95	4643.7	48.2	2.02	0.12	0.44	4.94	7.72	0.73

Results and Conclusions

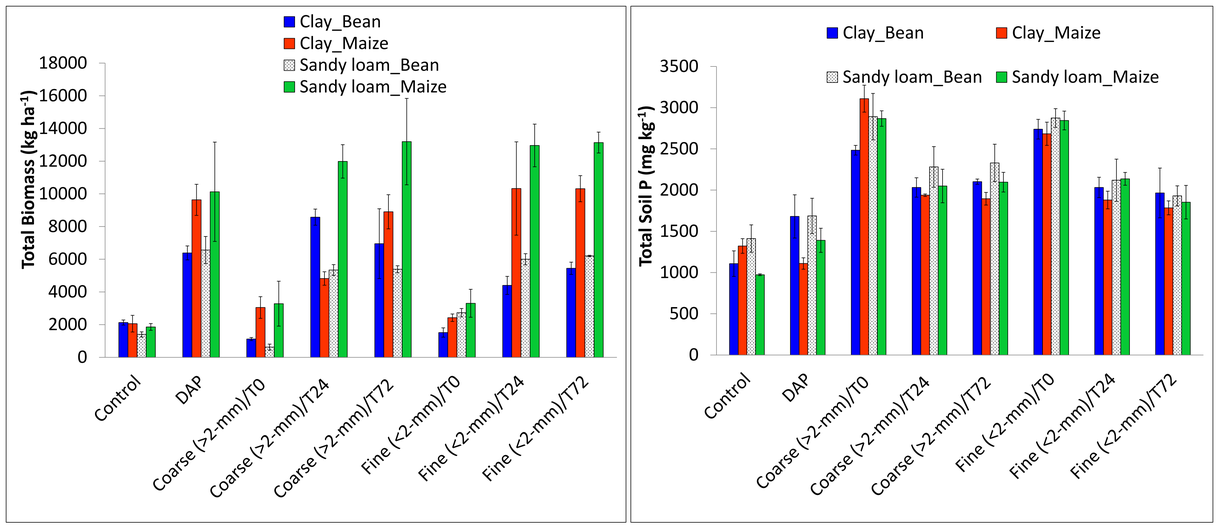

Fig. 2: Plant biomass (top left), total soil P (top right), P uptake (bottom left), and available soil P (bottom right) as affected by DAP and bonemeal with and without coffee wastewater treatment.

- Maize and haricot bean biomass did not differ between bonemeal without coffee wastewater treatment and the control, regardless of bonemeal size and soil type.
- Haricot bean biomass was comparable between DAP and bonemeal treated with coffee wastewater in clayey soil (pH 6.27) but not in the sandy soil (pH 7.95), regardless of bonemeal size and shaking time.
- Maize biomass was similar between DAP and bonemeal treated with coffee wastewater in both soils, irrespective of bonemeal size and shaking time.
- Total P was generally higher in soils amended with bonemeal than found under DAP-amended or control soil.
- Patterns of soil available P across treatments generally resembled the trends seen for plant biomass, and available P was positively correlated with total P uptake (R = 0.497, $p < 0.0001$).
- **These results suggest that either fine (< 2 mm) or coarse (> 2 mm) ground bonemeal treated with coffee wastewater for at least 24 h before application offers great potential as affordable P-fertilizer for low-income farmers when used on slightly acidic clayey soil.**