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Circular Bioponics for African Indigenous Vegetables Using Waste-Derived and Mineral Fertilisers

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Background & Rationale

- African indigenous vegetables (AIVs) are vital for nutrition and livelihoods in sub-Saharan Africa
- Production is constrained by high mineral-fertiliser costs and unsustainable input practices
- Circular bioponics recycles nutrients from organic waste - insect frass, animal manure, aquaculture sludge
- Offers a climate-resilient alternative to synthetic inputs while sustaining yields

Objective

- Evaluate black soldier fly (BSF) frass, chicken manure, and fish sludge - relative to mineral NPK - on the growth of three African indigenous vegetables in a circular bioponic system

Materials & Methods

- 4 × 3 factorial RCBD - three field replicates, two production cycles
- INCiTiS-FOOD Living Laboratory, Egerton University (0.23° S, 35.35° E; 2,238 m a.s.l.)

Fertiliser source (4)	Vegetable species (3)
M1 BSF frass	V1 African nightshade
M2 Chicken manure	V2 Cowpea
M3 Fish sludge	V3 Amaranth
M4 NPK (control)	

- Measured: plant height, branching, leaf number & area, SPAD index, above-ground biomass
- Two-way ANOVA (fertiliser source × species); means separated by Tukey's HSD (P ≤ 0.05)

Study Crops

African nightshade

Solanum villosum

Amaranth

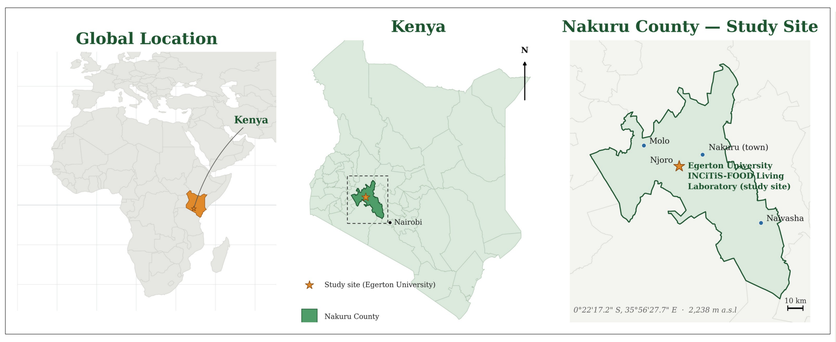
Amaranthus dubius

Cowpea

Vigna unguiculata

Waste inputs: BSF frass INSECTPRO and chicken manure Molo-chicken farm ; fish sludge from the bioponic recirculating aquaculture loop; NPK 17:17:17 as the mineral control.

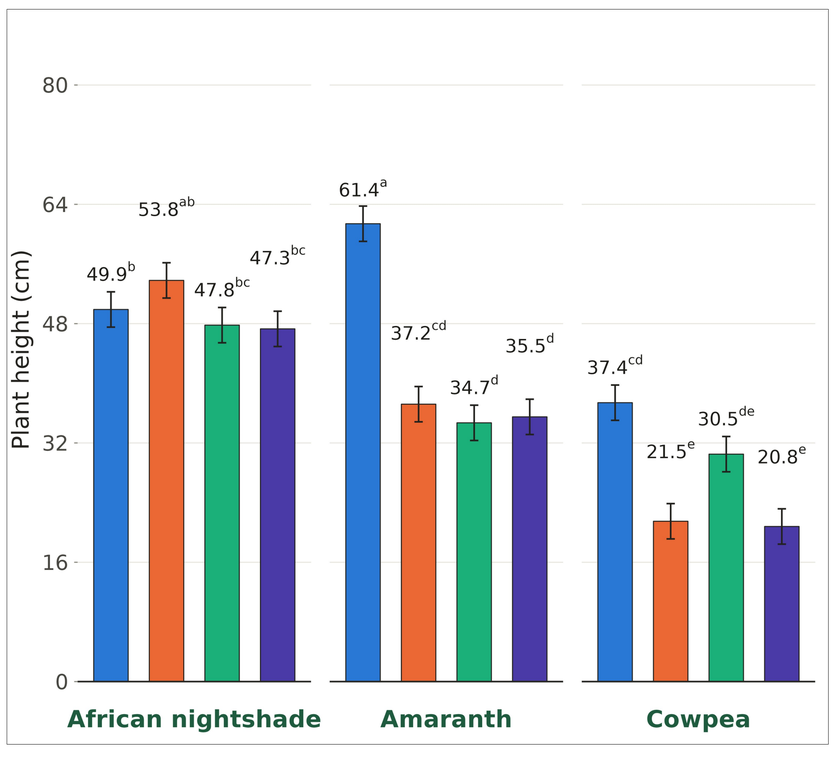
Study Site



Study site: INCiTiS-FOOD Living Laboratory, Egerton University, Njoro, Nakuru County, Kenya (0°22'11" S, 35°55'58" E; 2,238 m a.s.l.).

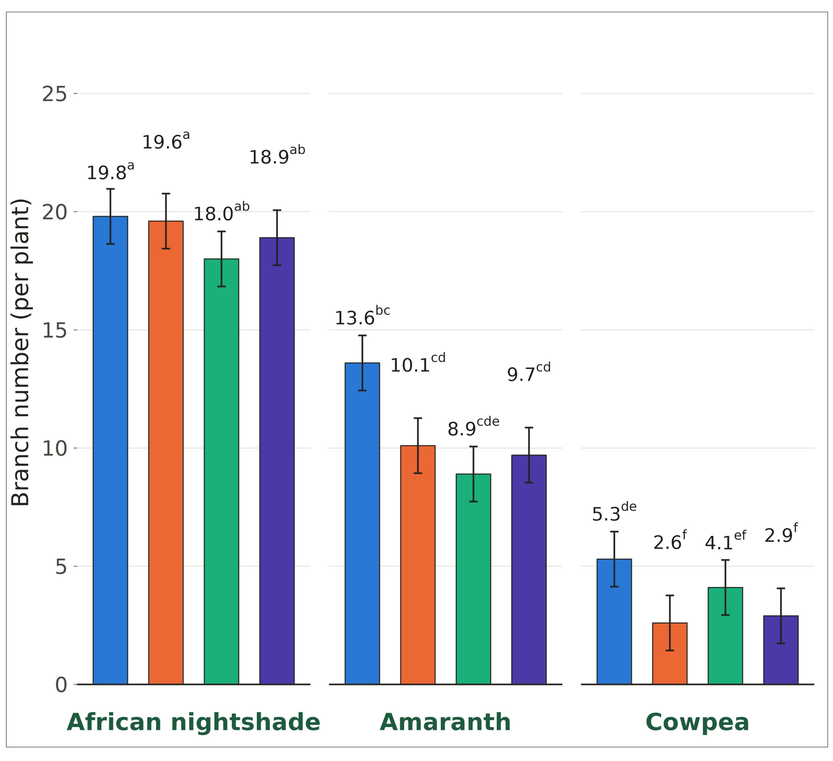
Results

Plant height at 6 weeks after treatment initiation (WATI)



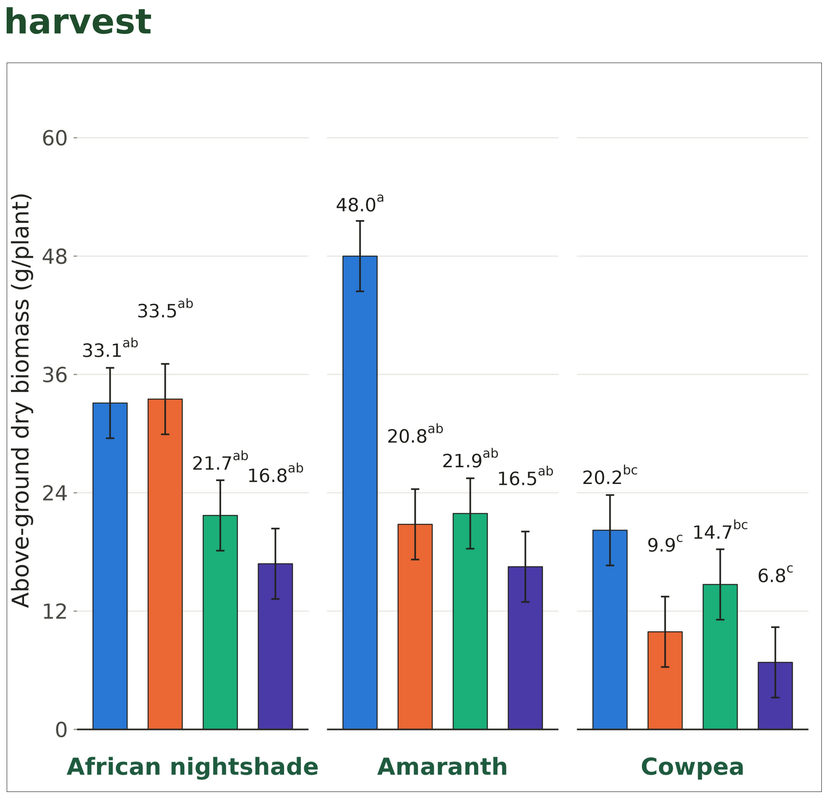
Fish sludge produced the tallest African nightshade (53.8 cm); NPK drove the strongest early amaranth growth. Cowpea was sown one week before the other species, so WATI aligns each species to its own treatment start. Letters = Tukey's HSD groups (P ≤ 0.05) within species.

Branch number at 6 weeks after treatment initiation (WATI)



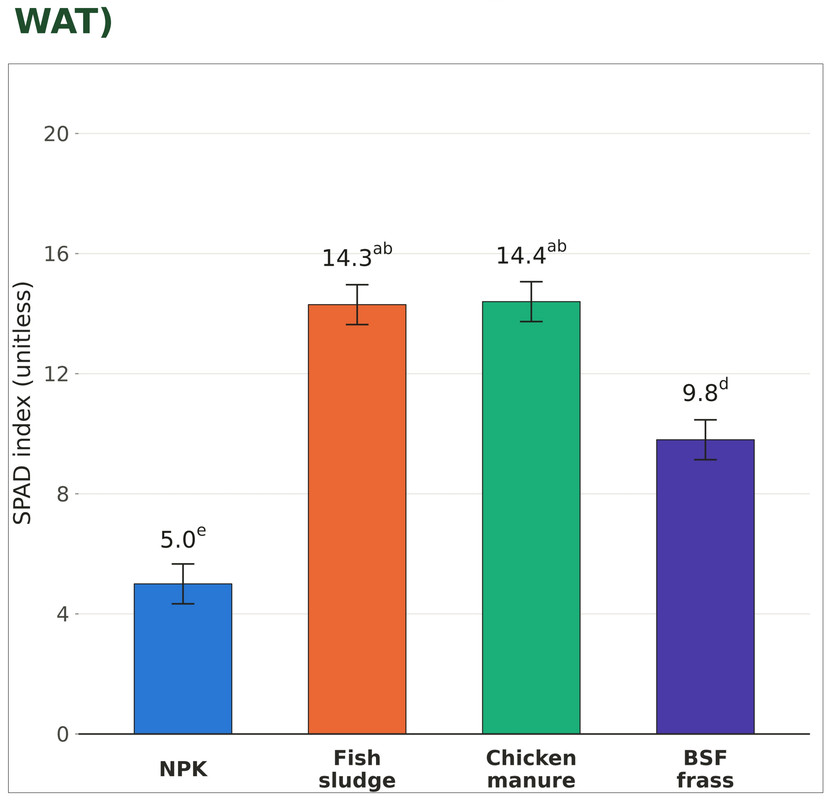
Fish sludge matched NPK for branching in African nightshade (19.6 vs 19.8 branches/plant; same HSD group). Cowpea was sown one week before the other species, so WATI aligns each species to its own treatment start. Letters = Tukey's HSD groups (P ≤ 0.05) within species.

Above-ground dry biomass at final harvest



Fish sludge matched NPK dry biomass in African nightshade (33.5 vs 33.1 g/plant), showing organic inputs can rival mineral fertiliser. Letters = Tukey's HSD groups (P ≤ 0.05), BDW only.

SPAD index in African nightshade (4 WAT)



Organic fertilisers decoupled SPAD status from structural growth: chicken manure and fish sludge nearly tripled SPAD values relative to NPK (HSD = 2.33). Letters = Tukey's HSD groups (P ≤ 0.05).

Key Findings

1. Fertilizer source significantly affected all measured growth parameters (P < 0.05) across all three species, confirming pronounced crop-specific nutrient responses.
2. Fish sludge and BSF frass achieved biomass levels comparable to NPK during mid-growth, demonstrating effective nutrient release within the biophonic system.
3. Cowpea consistently showed lower biomass accumulation, but organic treatments sustained growth performance, indicating potential as fertilizer substitutes.
4. Organic treatments frequently produced SPAD values equal to or exceeding NPK, particularly during mid-vegetative growth.

Conclusion

Integrating waste-derived fertilisers into circular bioponic systems enhances nutrient recycling, reduces reliance on synthetic inputs, and maintains AIV productivity - supporting climate-resilient intensification and sustainable agroecosystem development in sub-Saharan Africa.

Keywords

African indigenous vegetables · bioponics · circular agriculture · climate-resilient agriculture · nutrient cycling · sub-Saharan Africa · waste valorisation

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