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Circular bioponics for African indigenous vegetables using waste-derived and mineral fertilisers

Monica A. Omondi[1], Arnold Mathew Opiyo[1], Benard Karanja[1], Ranka Junge[2]

[1] *Egerton University, Dept. of Crops, Horticulture and Soils, Kenya*
[2] *Zurich University of Applied Sciences (ZHAW), Inst. of Natural Resource Sciences, Switzerland*

Abstract

To develop climate-resilient food production systems, it is imperative to adopt innovative strategies that incorporate nutrient recycling and minimise the reliance on synthetic fertilisers. African indigenous vegetables (AIVs) are crucial for nutrition and livelihoods in sub-Saharan Africa; however, their cultivation is hindered by high input costs and unsustainable fertiliser practices. This study assessed a circular bioponic system that integrates waste-derived fertilisers, black soldier fly (BSF) frass, chicken manure, and fish sludge with mineral NPK fertiliser for the cultivation of African nightshade (*Solanum villosum*), amaranth (*Amaranthus dubius*), and cowpea (*Vigna unguiculata*) crops.

Plant performance was evaluated based on parameters such as plant height, leaf characteristics, chlorophyll content, branching, and biomass. The type of fertiliser applied significantly affected all measured parameters ($p < 0.05$), indicating pronounced crop-specific nutrient response. NPK fertilisation facilitated rapid early growth, with amaranth achieving the highest biomass at 240.52 g plant^{-1}. Fish sludge enhanced structural growth in African nightshade, resulting in a plant height of 53.8 cm, whereas chicken manure increased branch number in African nightshade to 18 branches per plant and improved chlorophyll content in cowpea by up to 59 % compared to NPK alone. Waste-derived fertilisers, particularly fish sludge and BSF frass, achieved biomass levels comparable to NPK during the mid-growth stage, demonstrating effective nutrient release within the bioponic system. Although cowpeas generally exhibited lower biomass accumulation, organic treatments maintained sustained growth performance, indicating their potential as partial or complete substitutes for mineral fertilisers. This study illustrates that the integration of organic waste streams into circular bioponic systems can enhance nutrient recycling, diminish reliance on synthetic inputs, and maintain the productivity of vegetables. This methodology supports climate-resilient intensification of African Indigenous Vegetable production and contributes to the sustainable development of agroecosystems in sub-Saharan Africa.

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

Contact Address: Monica A. Omondi, Egerton University, Dept. of Crops, Horticulture and Soils, Njoro, Nakuru, Kenya, e-mail: omondimonica@ymail.com