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Growth and yield of vegetable cowpea (*Vigna unguiculata*) grown in bucket lysimeters for crop coefficient determination

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Abstract
As rainfall patterns become unpredictable and water resources increasingly become strained due to climate change, efficient irrigation scheduling becomes critical to maximize yields while conserving scarce water resources. This requires precise knowledge of overall water consumption by the crop which is often obtained through weighing lysimeters. However, standard lysimeters are expensive, therefore not readily available for use. This creates need to develop low-cost lysimeters to make them available at an affordable price and thus contribute to improvement of management of water resources. A simplified lysimeter was therefore made using two buckets. One bucket full of soil with perforations at the bottom to allow water to drain was inserted inside a slightly larger bucket. Excess drainage from inner bucket was collected inside the larger outer bucket. The lysimeters were installed flush with the soil surface and surrounded with rows of plants. Plants in lysimeters and surrounding were allowed to grow optimally. A comparison between plants growing within the lysimeter and those outside was done to determine the effect of the lysimeter on cowpea plant growth and yield. Growth was determined in terms of plant height, number of leaves and number of branches which were used to calculate relative growth rate parameters. Fresh weight and dry weights of above ground biomass for both lysimeter and non-lysimeter plants were determined by weighing before and after oven-drying the harvested samples All growth parameters did not differ significantly between lysimeter plants and non-lysimeter plants. While relative change in height was 3.62 for lysimeter plants, and for non-lysimeter plants. Relative change in number of leaves was 0.907 for both lysimeter and non-lysimeter plants. Relative change in number of branches was 7.148 for lysimeter plants, 9.75 for non-lysimeter plants. The fresh weights were 40g for lysimeter plants and 60g for non-lysimeter plants while dry weight was 6g for lysimeter plants and 8g for non-lysimeter plants. The results show that bucket lysimeter has no significant effect on plant growth and therefore may be used to prove an easy set up for estimating water use.

Keywords:
Climate change, Crop water requirements, irrigation, water resources management

Introduction
Agriculture in Sub-Saharan Africa faces increasing pressure from climate change, which manifests through erratic rainfall and rising temperatures. These fluctuations intensify water scarcity, reducing its reliability for irrigation supplies for agriculture and thereby threatening food

security (Hussain et al., 2024). Kenya's vegetable production sector is a key contributor to improved food nutrition, security, income, and livelihoods (FAO, 2022). Smallholder farmers dominate vegetable production in Kenya's arid and semi-arid lands (ASALs), which cover over 85% of the national territory and host nearly 40% of the population (Government of Kenya, 2026). This vast coverage highlights how water scarcity in ASALs directly threatens sustainable vegetable production and food security. Due to climate variability, rainfall patterns have become unpredictable forcing famers to practice irrigated agriculture, over-relying on natural water resources which are increasingly being strained (Kogo et al., 2020). Efficient irrigation scheduling is critical in maximizing yields while conserving scarce water resources. Yet smallholder vegetable farmers in Kenya's ASALs face persistent challenges in managing irrigation. Addressing this challenge requires precise irrigation scheduling, guided by accurate stage-specific crop coefficient (Kc) values that reflect crop water demand across growth stages of individual crop species.

Cowpea (*Vigna unguiculata*), a nutritious leavy vegetable member of the Fabaceae family is widely cultivated in Africa and Asia. The crop is recognized for its dual contribution to food security and soil fertility through nitrogen fixation. Studies have shown that its resilience under deficit irrigation and comparatively lower evapotranspiration rates makes it a promising candidate for climate-resilient agro-ecosystems (Elzopy et al., 2025; Kim et al., 2025). However, localized stage-specific Kc values for vegetable-type cowpea are unavailable, constraining efficient irrigation planning in water-scarce contexts.

Traditionally, lysimeter experiments have been the gold standard for measuring crop water use, yet commercial lysimeters are prohibitively expensive and inaccessible to many research institutions and farmers (Pereira et al., 2025). Locally improvised bucket lysimeters offer a pocket-friendly alternative, enabling reliable estimation of evapotranspiration and Kc values without compromising accuracy. Studies confirm that well-constructed bucket lysimeters produce results comparable to commercial systems such as those of FAO, making them suitable for resource-constrained environments (Chavarria Parraga et al., 2020; Ketter et al., 2023). Their affordability and ease of construction allow wider adoption in developing regions, where optimizing irrigation scheduling is critical for sustainable resource management and rural development (Benard et al., 2025). By demonstrating the reliability of locally improvised bucket lysimeters, this research contributes to efficient irrigation scheduling for smallholder farmers and aligns with the 2026 conference theme of advancing multi-functional agro-ecosystems that promote climate-resilient futures."

Material and Methods

A field experiment covering one crop cycle was conducted at the institution farm of Jomo Kenyatta University of Agriculture and Technology (JKUAT), Kenya. Vegetable cowpea seeds (Simlaw, Kenya) were used for the field trial carried out from 7 November 2025 to 18 December 2025. The trial was carried out to determine the growth of vegetable-type cowpea using simplified lysimeters constructed from nested buckets for estimating crop evapotranspiration (ETc). Each lysimeter had two buckets: an inner narrower bucket, perforated at the bottom and filled with field soil and an outer non-perforated slightly wider bucket, to collect drainage water. The lysimeters were installed flush with the soil surface and surrounded with three rows of plants at a spacing of 0.3 meters inter-row and 0.2 meters intra-row on a raised bed measuring one meter wide and 20 meters long resulting in 303 plants per bed. The plants in lysimeters and surrounding were allowed to grow optimally. The lysimeter plant was replicated nine times, resulting in a total of 9 observational units. The units were laid on a raised bed measuring 1meter wide by 20 meters long. Lysimeters were positioning and sequence collection, resulting in a total of 18 non-lysimeter plants. Sequence and time of data collection within the bed was random to

minimize micro-environmental and spatial bias. Data was collected weekly in the late afternoon (1530 to 1630 hours), starting and ending at 10 and 39 days after planting respectively. A comparison between plants growing within the lysimeter and those outside was done to determine the effect of the lysimeter on cowpea plant growth. Growth was determined in terms of plant height in centimeters, number of leaves and number of branches which were used to calculate relative growth rate. The measurements of the three growth parameters were recorded weekly for a period of five weeks. Relative change in growth was calculated by using the means of initial and final measurements of each parameter. The vegetable cowpea was harvested on the 39^{th} day after planting, after a closed canopy had formed but just before the flowering stage began. Fresh biomass in grams was determined by immediately weighing harvested above-ground plant material comprising of stems and leaves. Dry biomass was determined after oven-drying the samples for yield. Computations were done to determine the effect of the lysimeter on vegetable cowpea plant growth and yield.

Results and Discussion

The growth parameters did not differ significantly between the lysimeter plants and non-lysimeter plants (Table 1). While the relative change in height was 3.62 for both lysimeter non-lysimeter plants. Similarly, relative change in number of leaves was 0.907 for both lysimeter non-lysimeter plants. Relative change in number of branches was 7.15 for lysimeter plants and 9.75 for non-lysimeter plants. The Fresh weights were 40g for lysimeter plants and 60g for non-lysimeter plants while dry weight was 6g for lysimeter and 8g for non-lysimeter There was no significant difference observed in the growth and yield between lysimeter and non-lysimeter plants. The results show that the bucket lysimeter has no significant effect on plant growth and yield, and therefore provides an easy set up for estimating water use.

Table 1: Growth and yield parameters for lysimeter and non-lysimeter plants

Variable	**Non lysimeter plant**	**Lysimeter plant**	**p**
Relative change in height (cm)	3.62 a	3.62 a	0.987
Relative change in Number of leaves	0.907 a	0.907 a	0.653
Relative change in Number of branches	9.75 a	7.15 a	0.118
Fresh weight (g)	60 a	40 a	0.069
Dry weight (g)	8 a	6 a	0.191

Means followed by the same letter within the row are not significantly different

Conclusions and Outlook

Growth and yield of vegetable cowpea is not significantly affected by simple bucket lysimeters. Further experiment will be carried out using the bucket lysimeters since no adverse effects were noted from the trial. The experiments will be used to generate crop coefficients which will be used for irrigation scheduling for vegetable cowpea in the Kenya's arid and semi-arid lands. The work will contribute to enhancement of food and nutrition security as well as climate resilience.

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