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Resource Use Efficiency of Vertical Hydroponic Towers in Greenhouse

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INTRODUCTION & AIM

Every year, 70 million people are added to the world's population, which consume 9.8 Mt of food, 1.5 Mha of cropland, of which 331,000 ha are irrigated, which consume 12 Mm^3 of water and 36,400 t of fertilizers. Today's global challenges are driving more efficient food systems, promoting resource-optimizing agri-food systems [1,2]. Vertical farming (VF) offers a promising solution, saving more than 70% of water and up to 50% of fertilizers [3]. Most studies on VF have been conducted in plant factories, whereas, research under greenhouse conditions remains limited. The aim of this research is to determine the efficiency of the use of water and nutrients in a vertical farm within a greenhouse, providing valuable data to support decision-making on the viability of urban food production systems.

SUSTAINABLE DEVELOPMENT GOALS

METHODS

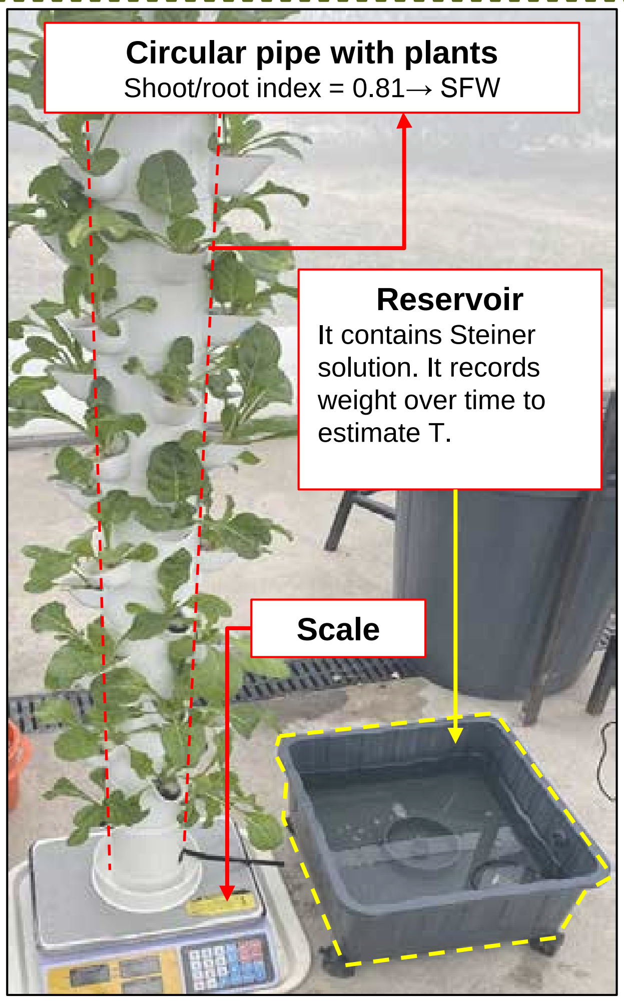

Figure 1. Weighing process to estimate the shoot fresh weight and transpiration of a vertical hydroponic tower.

A trial was carried out (Dec 2024) using chard cv. 'Ford Hook Giant' in a greenhouse of the Faculty of Agronomy and Veterinary, UASLP. The vertical hydroponic towers (1.6 m high) were spaced at 1.2 x 1.5 m each with 45 floors (25 floors·m^{-2}), in a circular pipe over a 20 L tank. A randomized design was used to test three concentrations (0.75; 1.00 and 1.25) of Steiner's Solution (SS), with three replications. Water Use Efficiency (WUE) was calculated from Shoot Fresh Weight (SFW) and Cumulative Transpiration (CT) [4]. The Use Efficiencies of ions (UE: g SFW·g^{-1} or mg^{-1} ion) for [K^+], [Ca^{2+}], [NO_3^-] and [Na^+] (KUE, CaUE, NUE, NaUE) [5] was evaluated. Daily, SFW and CT were measured (±1 g) by weighing the circular pipe and reservoir (Fig. 1). Ion concentrations were analyzed at 32 and 43 DAT using a LAQUA twin 4M kit (HORIBA®). Data were analyzed using ANOVA and Tukey's test ($p< 0.05$) with the IBM® SPSS v.26 program.

RESULTS & DISCUSSION

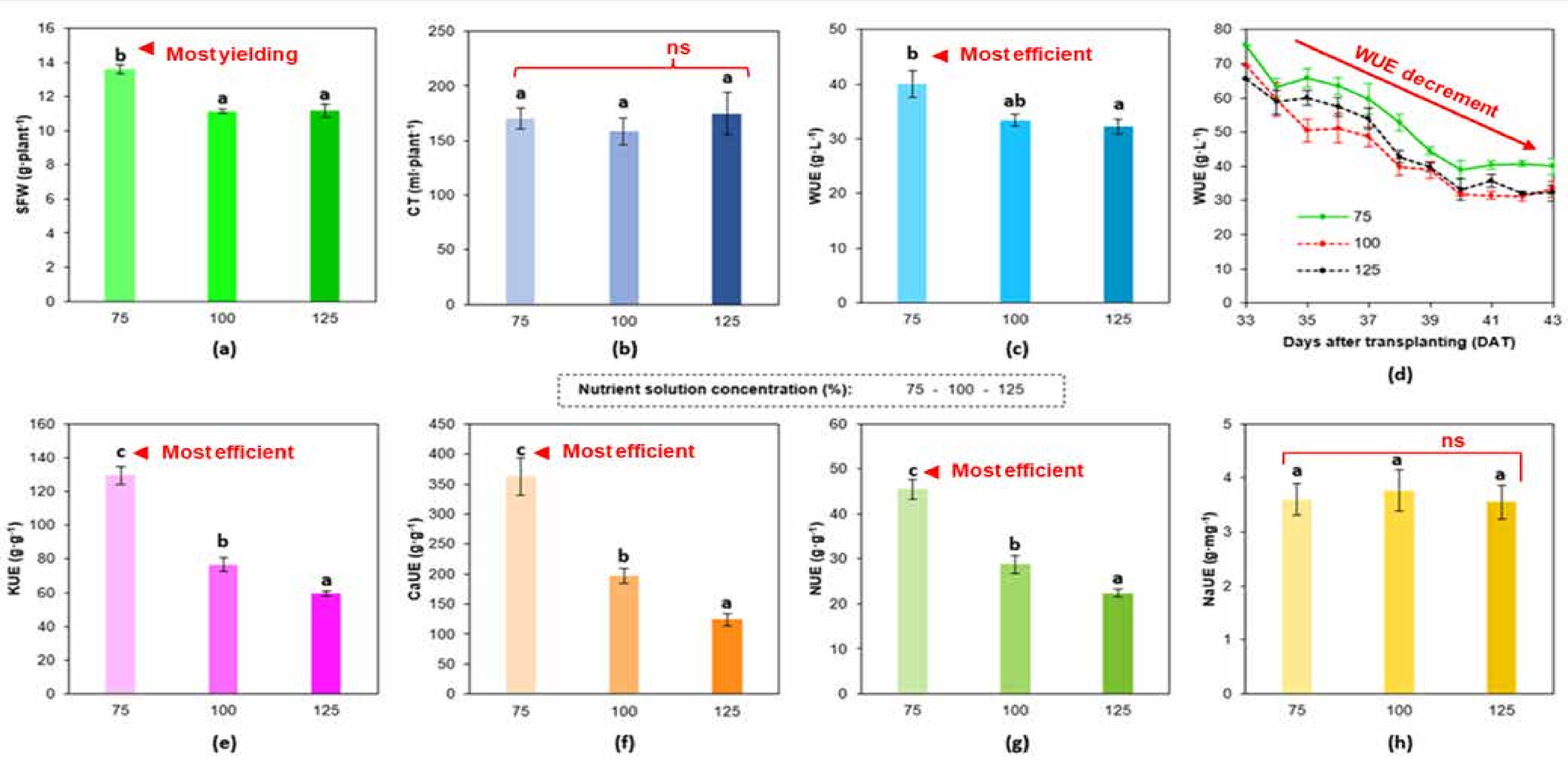

Figure 2. (a) Shoot fresh weight (SFW); **(b)** cumulative transpiration (CT); **(c,d)** water use efficiency (WUE); **(e)** potassium use efficient (KUE); **(f)** calcium use efficiency (CaUE); **(g)** nitrate use efficiency (NUE); **(h)** sodium use efficiency (NaUE). There were significant differences in the bars marked with different letters (Tukey's post hoc test, $p<0.05$). Data were expressed as means ± standard error (n=3). All bar graphs corresponding to data measured at 43 days after transplanting (DAT). Not significant differences (ns).

Compared with 100% treatment, SS at 75% (reducing fertilizer by 25%) increased: marketable yield (22%) and Use Efficiencies; WUE (24%); KUE (69%); CaUE (84%) and NUE (58%). Under 75% SS, chard had a WUE comparable to plant factories grown basil [6], was 3–6 times higher than typical values for leafy greens grown in the open field, and 23–90% higher than greenhouse-grown lettuce, basil, and chicory. Similarly, the NUE at 75% SS was about 70% higher than that reported for soil-grown sugar beet. The KUE was up to 2.5 times higher than those of some cereal crops [7,8]. Fig. 2(d) shows that WUE decreased over time despite continuous increases in SFW and transpiration, indicating that the crop was kept in the early stage of growth (lag phase), during which transpiration rates exceeded biomass accumulation.

CONCLUSION

Vertical hydroponic towers in greenhouses are viable options for urban food production. These systems offer significant water and fertilizer savings compared to soil-based systems or greenhouse crops. The results also highlight the importance of adapting nutrient solutions to crop density and climatic conditions. Less concentrated solutions can increase resource efficiency using closed vertical farming systems

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