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Temporary nutrient depletion in hydroponics: tomato growth response and recovery potential

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Abstract

Finite phosphorus reserves and the energy-intensive production of synthetic nitrogen fertilisers are placing increasing pressure on global nutrient supplies. At the same time, nutrient-rich wastewater discharged into aquatic environments drives eutrophication, highlighting the need for circular resource management. By treating nutrient-rich effluents as a resource rather than a waste, wastewater-based hydroponic systems enable simultaneous nutrient recovery and crop production. However, realising this potential requires understanding the operational boundaries under which plants can function productively.

Nutrient supply in these systems is inherently dynamic, fluctuating due to variable treatment efficiency and system dynamics. Nutrient depletion events may arise from technical faults, inconsistent influent quality, or deliberately through feed-and-deplete strategies, in which renewal is delayed until nutrients are substantially depleted to maximise removal. Beyond nutrient availability itself, vapour pressure deficit (VPD), the evaporative gradient between plant tissue and air, regulates transpiration-driven nutrient fluxes, making it a key environmental driver of plant performance.

To determine the limits of plant productivity under interrupted nutrient supply, tomato plants (*Solanum lycopersicum*) were cultivated in recirculating deep-water culture systems under two VPD levels (0.8 and 2.0 kPa), with solution renewal delayed by 0, 2, 4, or 8 days once nitrogen fell to 5 mg N L^{1}, followed by replenishment and a 7-day recovery period.

After two days, deprivation had only minor effects on biomass, with high VPD showing greater compensatory capacity. From four days onwards, losses increased substantially, reaching 15 % after four days and 31–32 % after eight days, indicating a threshold beyond which recovery remains incomplete. Following replenishment, net CO assimilation recovered rapidly and transiently exceeded control levels, yet lost biomass was not fully regained.

These results establish a practical tolerance window for nutrient supply interruptions in wastewater-based hydroponic systems, providing guidance for operational management strategies that balance treatment efficiency with crop productivity.

Keywords: Deep water culture (DWC), nitrogen deprivation, nutrient recovery, tomato biomass accumulation, vapour pressure deficit (VPD)

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