

Chemeca 2025 and Hazards Australasia

28 – 30 September, Adelaide, South Australia

Flow-Made Fertilisers and Their Impact on Radish (*Raphanus sativus*) Biomass Yield and Phosphorus Uptake in Acidic and Calcareous Soils

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ABSTRACT

Phosphorus (P) availability is crucial for plant growth, yet conventional fertilisers suffer from excessive leaching and low nutrient use efficiency. Slow-controlled release P fertilisers, particularly chitosan-based formulations, offer a solution by reducing nutrient loss while ensuring sustained P supply. However, most next-generation fertilisers are produced in batch processes, limiting scalability. This study addresses this challenge by employing continuous flow technologies to develop chitosan-apatite-citrate (CAC) fertilisers for controlled P release and soil remediation. Their performance was evaluated using radish as a demonstrator crop. Growth rate, biomass yield, and P distribution across two model growing seasons were evaluated. The core-shell CAC fertiliser, prepared by imploying crosslinking reaction in a sheath flow of water/oil system (Sheath\_CAC), consistently outperformed other treatments, exhibiting the highest sprouting rate and fastest early growth in both seasons. Compared with the control pots, the Sheath\_CAC promotes the highest dried root yield (increase of 39% in season one, and 60% in season two), surpassing the commercial fertiliser (1% in season one, and 60% in season two); P uptake of radish treated with Sheath\_CAC increased by a maximum of 46.9%. P content in biomass declined due to greater biomass accumulation, total P uptake remained stable, indicating efficient nutrient utilisation. While commercial fertiliser maintained the highest avialable P levels, Sheath\_CAC demonstrated stable, controlled release, minimising leaching risk. These findings highlight Sheath\_CAC as a high-performance fertiliser balancing steady P availability with sustained plant growth. This study underscores the potential of flow-manufactured controlled-release formulations in enhancing nutrient efficiency and reducing phosphorus loss.

KEY WORDS

Flow technologies, slow-release fertiliser, phosphorus uptake, soil remediation

BIOGRAPHY

Nguyen Quang Tu Le received a B.E in Chemical Engineering in 2018 and an M.E in Chemical Engineering in 2020 at Ho Chi Minh City University of Technology – VNU HCM (Vietnam). During his undergraduate years, he developed interests in catalytic processes, colloid chemical approaches to nanotechnology, and nanomaterials for environmental applications. He is currently attending the Joint PhD program of University of Adelaide (Australia) and University of Nottingham (UK), under the supervision of Prof. Volker Hessel. His current research focuses on the potential of microfluidic technology in the preparation of smart-fertiliser for precision agriculture and soil remedidation

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