ABSTRACT

Carbon Quantum Dots (CQDs) have attracted significant attention due to their high fluorescence emission and photoluminescence stability. Nitrogen doping is known to enhance luminescence efficiency and electron transfer, while silica supports vegetative growth. The utilization of geothermal silica waste enables the conversion of low-value local resources into functional materials. This study aims to synthesize, characterize, and evaluate the activity of Si,N-CQDs as a nano-functional fertilizer for pak choi (Brassica rapa var. chinensis). Si,N-CQDs were synthesized via an oil bath method at 140 °C for 150 min using citric acid, urea, and purified geothermal silica waste, with silica masses varied from 10, 15, 20, 25, and 30 mg (SN1–SN5). Characterization included UV-A, photoluminescence spectroscopy, FTIR, PSA, and SEM. Hydroponic application compared Si,N-CQDs, N-CQDs, and a control without CQDs; observed parameters were leaf number, leaf length–width, and chlorophyll content. Si,N-CQDs emitted light blue fluorescence; SN1 exhibited the highest emission intensity, which decreased with higher silica mass. FTIR confirmed Si–O–Si and Si–O–C groups (silica) as well as C=N, C=C, and C=O groups (N-CQDs). SN1 had an average particle size of 6.9 nm with a zeta potential of −27.7 mV. Application on pak choi showed CQDs enhanced growth compared to the control, with SN1 at 0.15–0.20 mg/mL giving the most favorable growth and chlorophyll response. These findings highlight the potential of geothermal waste-derived Si,N-CQDs as dual-function (optical–nutritional) nano-fertilizers for improving crop productivity.

Keywords: *Bok choy, carbon quantum dots*, *hydroponic, oil bath, silica geothermal waste*.