Uptake, Translocation and accumulation:

CQDs' stable and unique fluorescence signal offers a promising method for tracking them in plants. Several studies have used fluorescence imaging (J. Chen et al., 2016), confocal laser scanning microscopy (CLSM), transmission electron microscopy (TEM) (Li et al., 2020), or Raman spectroscopic measurements (Tripathi & Sarkar, 2015) to show CQD uptake in plants.

For example, (Li et al., 2020) used mung bean as a model plant to show the uptake, translocation and accumulation of CQDs. Hydroponics ensured the availability and uptake of CQDs by the plant. Germination of the seed and growth of the seedling was observed after 5 days of cultivation at 25°C. The mung bean plant's increased absorption of CQDs was demonstrated by its clear concentration-dependent reddish-orange fluorescence under 365 nm UV light. A CLSM was employed to image the root, stem, cotyledon and leaves to locate the CQDs in the mung bean seedlings after 5 days of incubation. The fluorescence signals of the CQDs were found to be mainly located in the vascular system in the parts of the root, stem and leaves. TEM imaging of the cross sections of the seedlings showed the agglomeration in the form of large clusters in the intercellular spaces. It can be concluded that CQDs enter the seed coating through the intercellular space and accumulate in the cotyledons to speed up seed germination. The CQDs were adsorbed on the root surface and penetrated the root vascular bundles after the root emerged. The CQDs were then found in the veins of the leaves after being transferred from the roots to the stems and leaves via the vascular system.

(Lin et al., 2009) used rice plants to demonstrate the generational uptake, translocation, and transmission of carbon nanomaterials at different stages of growth and development. Newly harvested rice seeds were primed in a petri dish with C70–NOM and MWNT–Natural organic matter. After germination at 25 ±1 8°C for 2 weeks, the seedlings were transplanted to soil in big pots and grown in a greenhouse to maturity. To investigate generational transmission of nanomaterials, mature seeds from the control plants and C70-treated plants were harvested 6 months after germination, and 60 seeds of similar size for each plant were chosen and harvested. Tissues of rice plants at various developmental stages were sampled, thoroughly washed using distilled water, cut, sectioned to make thin layers, and imaged on glass slides using a bright field microscope. Black dots (nanomaterials) were frequently found in seeds and roots and less frequently in stems and leaves. Black aggregates were mostly located near the vascular system of the stems, indicating their simultaneous transport with the uptake of water and nutrients. Later, dots were spotted in the form of aggregates in the veins of leaves, indicating their accumulation. To confirm that the aggregates were composed of C70 or C70 derivatives, Fourier transform (FT)-Raman and IR spectra were acquired at room temperature.

(R. Chen et al., 2010) used Allium cepa to exemplify the uptake of carbon nanomaterials. Different doses of fullerene C-70, suspended in natural organic matter (NOM), and fullerol C-60(OH)20, a water-soluble fullerene derivative, were used as the source of nanomaterials. Laminar Allium cepa cells were prepared, and HT-29 cell lines were cultured to 60% confluence. They were then incubated separately with C-70–NOM and C-60(OH)20 at doses ranging from 10 to 110 mg L-1 for 9 h. The cells were examined using TEM, and orange spots were frequently observed in the plant cell walls and less frequently near underlying plasma membranes. The osmosis assay revealed that C70 aggregates were mostly adsorbed on or trapped within the hydrophobic cellulose matrices of the plant cell walls, suggesting an apoplastic pathway of uptake and translocation. These nanoparticles were confined between the cell wall and the plasma membrane under capillary and van der Waals forces (accumulation).

(Gong & Dong, 2021) used wheat as a model plant to explain the transfer, transportation, and accumulation of Cerium-doped CQDs. Disinfected wheat seeds were germinated in darkness at 30°C for 48 hours and under illumination for 72 hours. Growing seeds were placed in petri dishes with Hoagland nutrient solution in an incubator at 25°C. When the seedlings grew to 2 cm, Ce, CDs, and CDs:Ce solutions with different concentration gradients were applied to the wheat seedlings. Leaves at the same position of all seedlings and root systems were tested after 15 days. Ce contents in roots, stems, and leaves of wheat plants absorbed from CDs:Ce were tested via ICP-MS to assess the transfer, transportation, and accumulation of CDs:Ce in wheat seedlings. CDs:Ce absorption of wheat plants under the optimal concentration (0.025 mg/mL) was tested with CLSM and fluorescence microscopes. It was illustrated that CDs:Ce were absorbed by root hairs of wheat and then transported through the vascular system of stems and leaves via fibrovascular tissues. The root system is the primary site of biological accumulation of CDs:Ce, but most of the accumulation was observed in the veins and stomata of the leaves.