Plant Nanobionics for Photosynthetic Augmentation

KONSTANTINOS TELEMACHUS KOTOULAS [A], ANDREW BURROWS [B], GARETH CAVE [C, A], MING XIE [A]
Department of Chemical Engineering, [B] Department of Chemistry, University of Bath, Bath, BA2 7AY, [C] Department of Chemistry, Nottingham Trent University, Nottingham, NG11 8NS, United Kingdom

Photosynthesis: Vital to crop productivity

Socioeconomical concerns

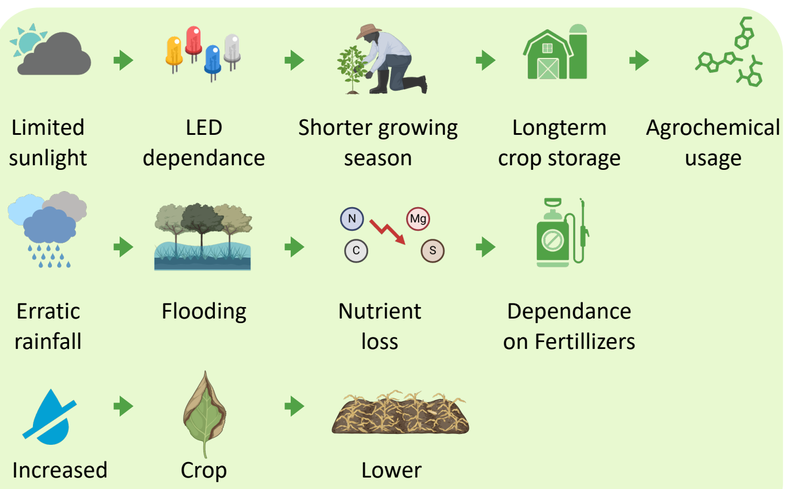
◉UK Population
Polulation increase of 8 million by 2050

◉Food demand
23 kilotons/ day of vegetables by 2050

◉UK imports
2024 food security report: 47% of UK vegetables are imported

◉Food waste
30% of total fruit and vegetables are wasted

Environmental constraints



Limitations of photosynthesis

◉Full solar light spectrum utilisation beyond blue and red light for photosynthesis.

◉Uneven distribution of light on leaf chlorophyll.

◉Light damage to plant leaf from reactive oxygen species (ROS).

◉The maximum quantum efficiency is 4-6% for converting solar energy into biomass.

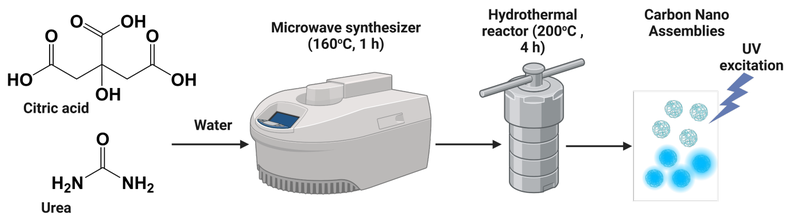
Plant Nanobionics

Key features

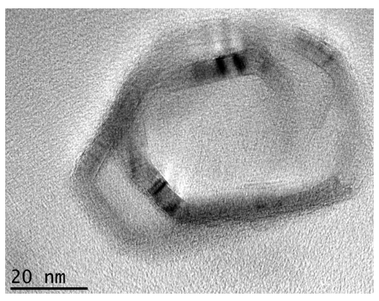
◉**Nanobionics engineering of plant function for light-harvesting to boost photosynthesis.**

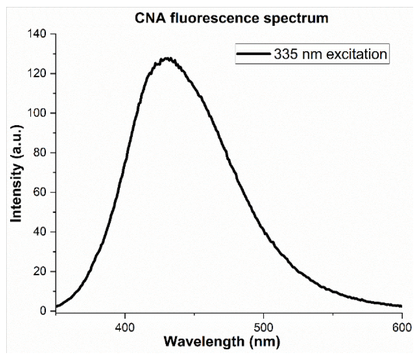
◉Our approach is **carbon nano assemblies** (CNAs) derived from cheap and sustainable precursors (e.g., citric acid and urea).

Synthesis and Characterisation

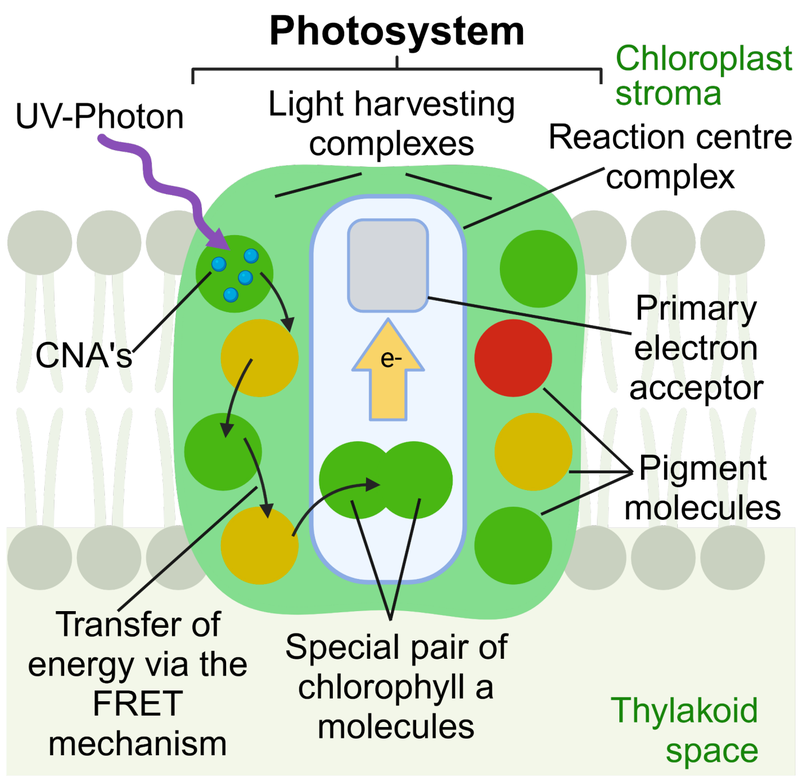


Our CNAs enhance light capture by enabling plants to utilize previously unharvested UV-radiation and fluoresce into photosynthetically active wavelengths (blue and red).



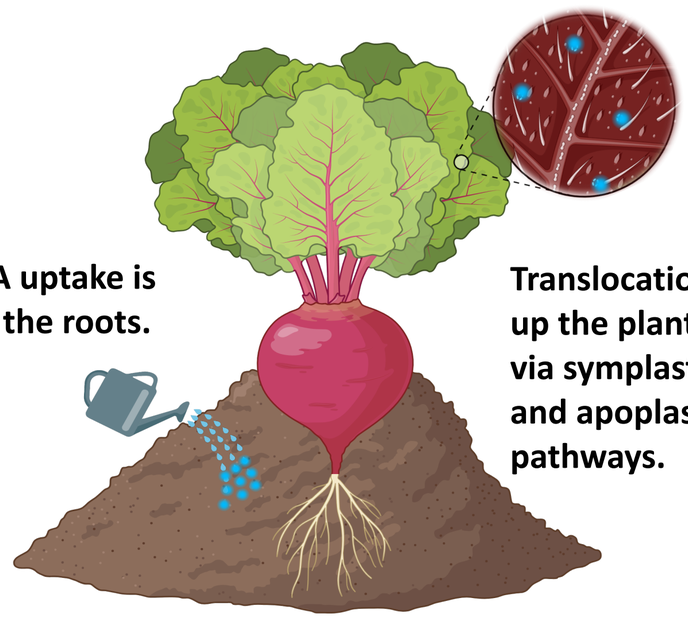


Nanobionic mechanism



Förster Resonance Energy Transfer (FRET):
The excited molecule transfers its energy via vibrations to a nearby molecule.

Plant trial



CNA uptake is via the roots.

Translocation up the plant is via symplastic and apoplastic pathways.

◉Plant nanobionics enabled by CNA broadens available wavelengths from the solar spectrum, maximizing photosynthesis and crop yield, and growing seasons, reducing energy consumption.

◉Increases water content in crops and additional functions of the plant for climate resistance.

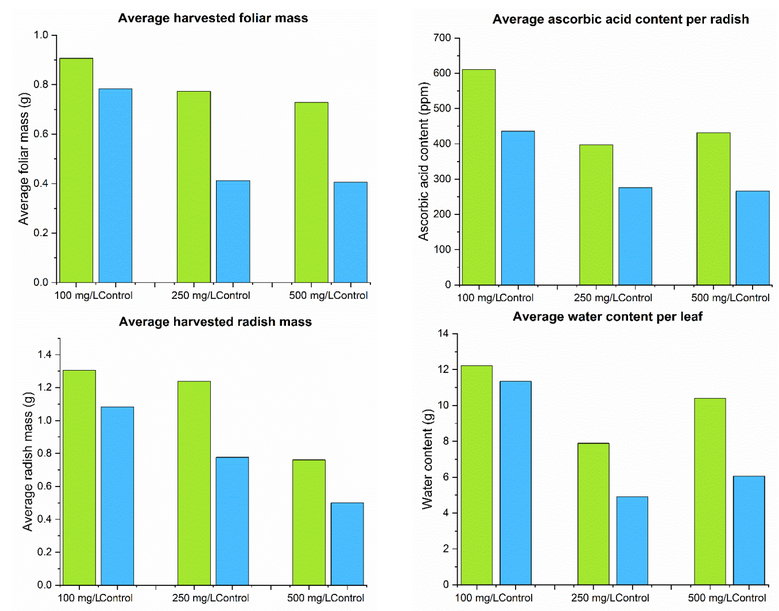
CNA boosts plant photosynthesis

Trials Conditions

108 crops (Raphanus sativus) treated weekly with CNA concentrations (**100, 250, 500 mg/L**).

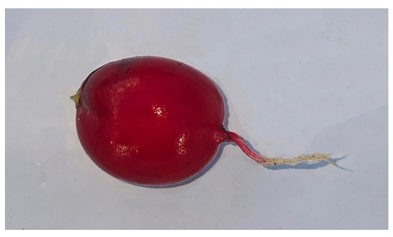
Plant growth

Growing conditions	Foliar growth (cm^2)	Chlorophyll concentration (mg/L)	Carotenoid concentration (mg/L)
Control	248.36 ± 46.90	1.78 ± 0.44	0.27 ± 0.09
100 mg/L	286.26 ± 56.46	1.67 ± 0.53	0.25 ± 0.05
Control	111.36 ± 21.32	1.44 ± 0.34	0.26 ± 0.13
250 mg/L	204.70 ± 27.17	1.37 ± 0.32	0.19 ± 0.06
Control	132.13 ± 32.53	2.10 ± 0.48	0.29 ± 0.09
500 mg/L	244.91 ± 52.87	1.87 ± 0.67	0.23 ± 0.03



Plant profile

Control



CNA Treated

◉Treated crops displayed greater yields, vitamin concentrations and drought tolerance.

◉Despite lower pigment levels, treated crops grew faster, illustrating the mechanism of nanobionics

Optimal CNA concentration of 250 mg/L

◉**88%** higher foliar dry mass, **60%** higher radish dry mass

◉**61%** greater foliar water content and **40%** greater total ascorbic acid per radish

Conclusion

Plant nanobionic with CNA engineering manifests significant increases in growth, yield, and water content, compensating for reduced pigments and offering drought stress resistance.

Further work

◉Exploring metal doping (e.g., cerium) to create multifunctional agents combining light harvesting, ROS scavenging, and antibacterial properties.

◉Our research also extends to developing practical light-harvesting solutions, such as fluorescent biodegradable films for plant incubators and greenhouse coatings.

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