



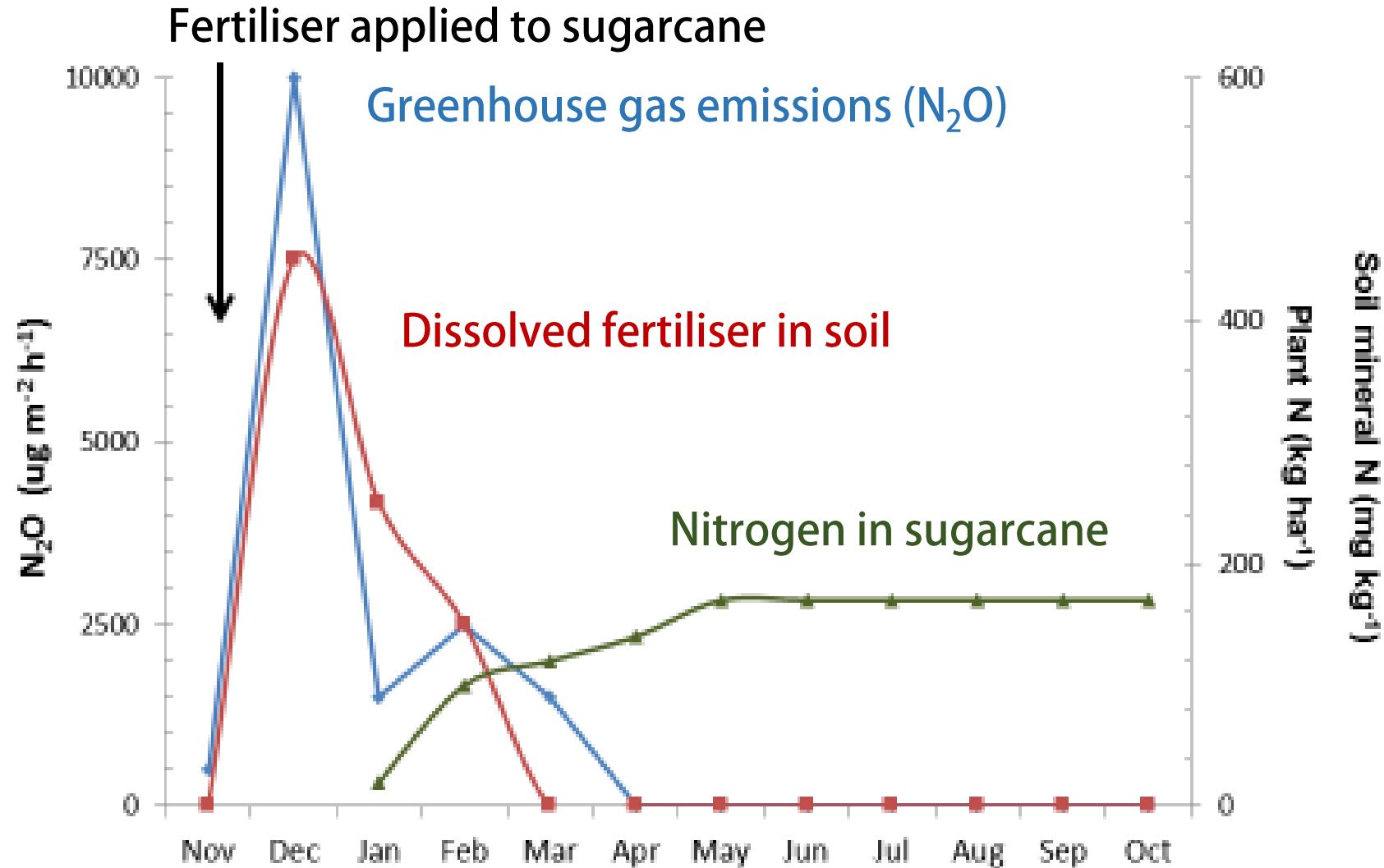
Next generation fertilisers

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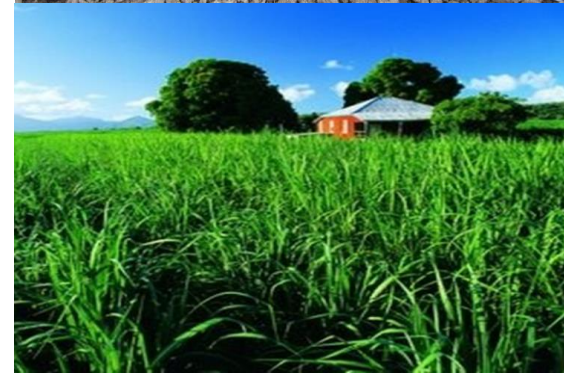


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AUSTRALIA

Inefficiencies of mineral fertilisers: on average 50% of nitrogen fertiliser is used by crops



Adapted from Allen et al. (2010); Kingston et al. (2008)



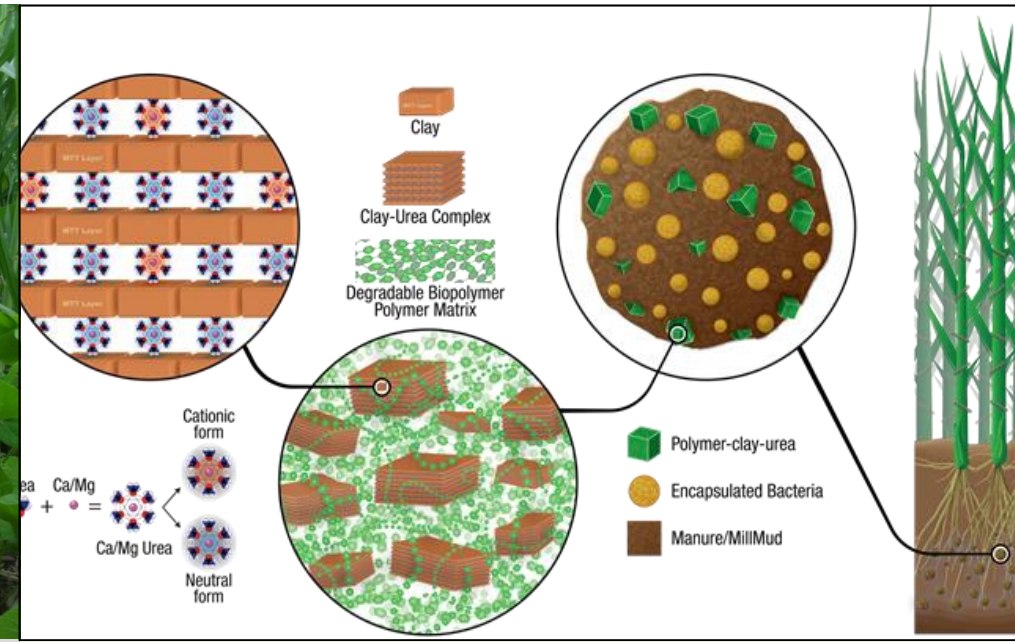
Integrated system for improving nitrogen use efficiency and soil health



NUE cane varieties



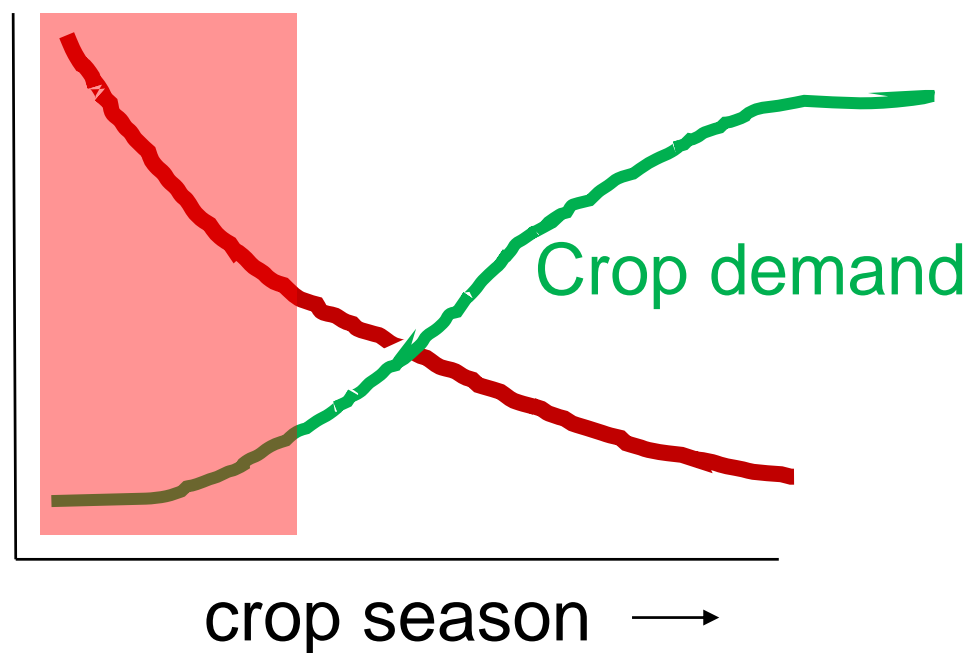
Cropping systems



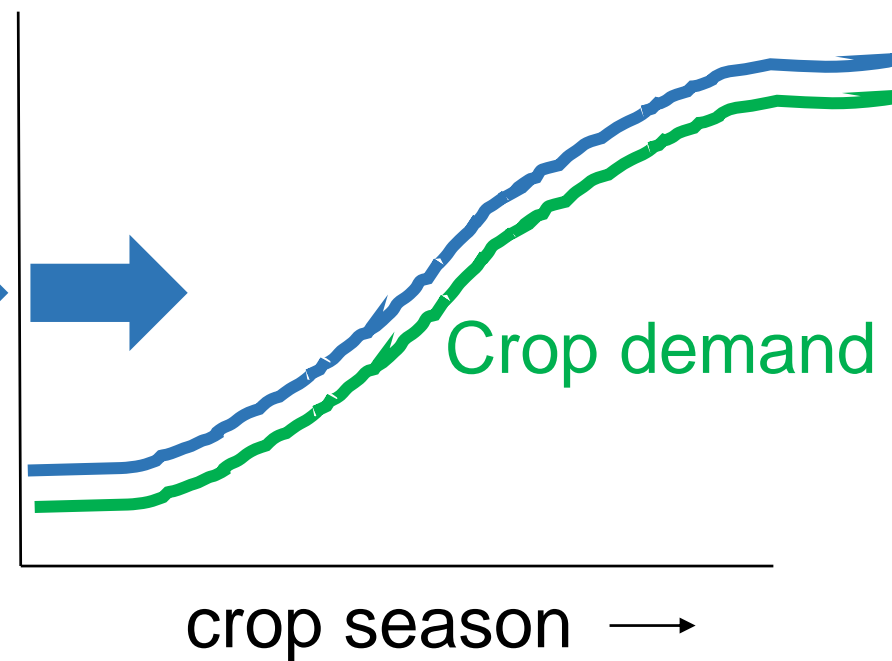
Fertiliser technologies

Synchronising N supply and crop demand

Current fertilisers

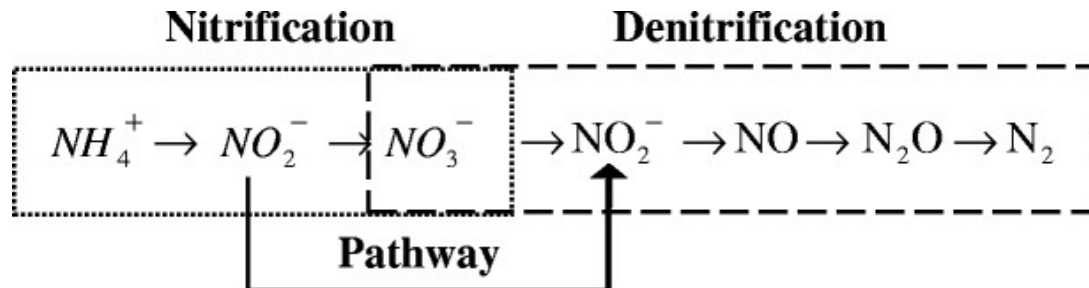


NextGen fertilisers



Current enhanced efficiency fertilisers

Soluble mineral fertilisers
with nitrification inhibitors

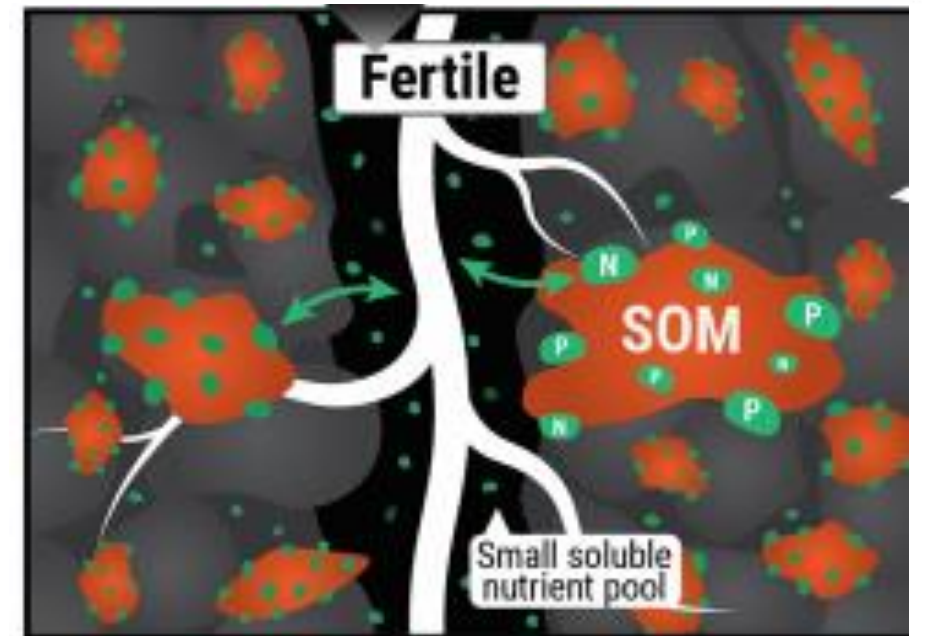


Plastic coated slowed mineral
fertilisers



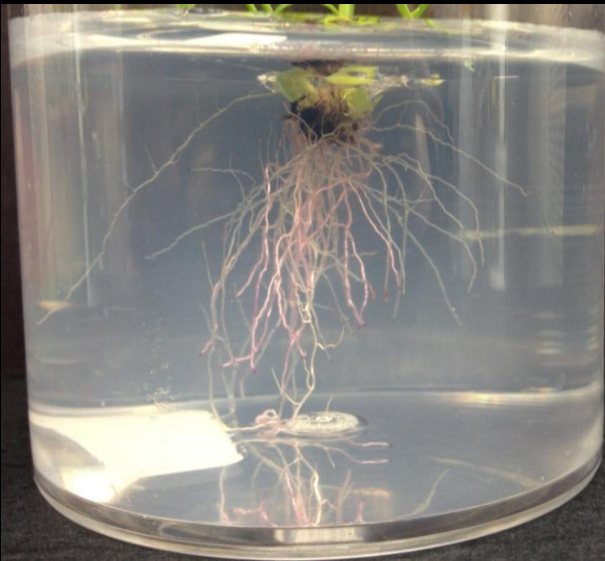
We currently have

- Sub-optimal mineral fertilisers
- Degrading agricultural soils as soil organic carbon (SOM) is lost
- Nutrient-rich wastes that can deliver nutrients and organic carbon



Next-generation fertilisers contain organic nutrients that benefit root vigour

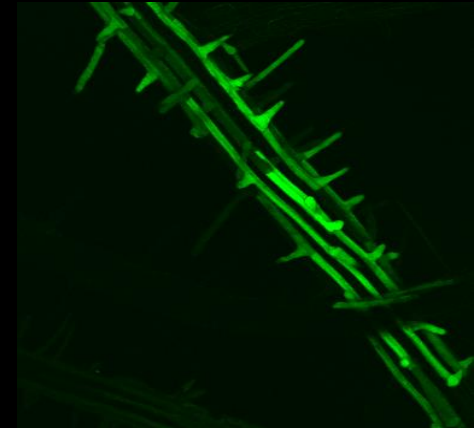
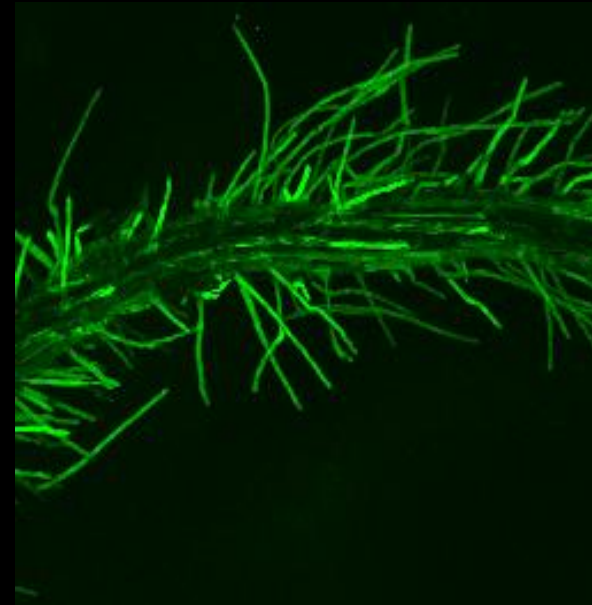
Inorganic
(mineral)
nutrients



Inorganic +
organic
nutrients



Roots take up organic
nitrogen (**protein**)



Paungfoo-Lonhienne et al. 2008
Proceedings of the National Academy of Sciences

Australian agro/industries generate nutrients

Table 4. Estimated N, P and K generated from various industries.

Industry	Nt/yr	Pt/yr	Kt/yr
Sugarcane processing	41,120	14,175	274,150
Cattle feedlots	22,692	7857	27,602
Dairies	620	167	750
Piggeries	3187	4663	2648
Poultry (meat chickens)	26,617	11,978	9981
Poultry (layers)	5125	2579	2428
Meat processing	11,266	8245	2577
Milk processing	2147	1089	721
Seafood processing	370	135	30
Coal mining	0	0	2730
Sewage treatment	32,597	15,203	24,636
Municipal waste (MW)	100,600	15,470	0
Electricity industry	0	6720	11,200
Total	246,342	88,281	359,452

“Waste-derived nutrients can service a substantial fraction of the national nutrient market with 23% of N and P and 100% of K contained in waste streams.”

Organic wastes need to be formulated to avoid inefficiencies

Chicken manure with and without amendments compared to urea in sugarcane cropping

Manure + compost

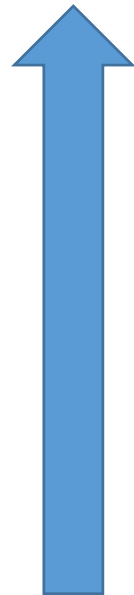
Nitrogen fertiliser (urea)

Manure

Manure + clay

Manure + biochar

No nitrogen fertiliser

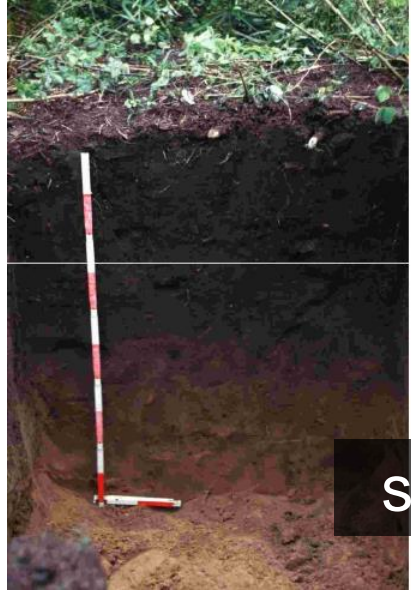


Increasing emission of
Greenhouse gas nitrous oxide

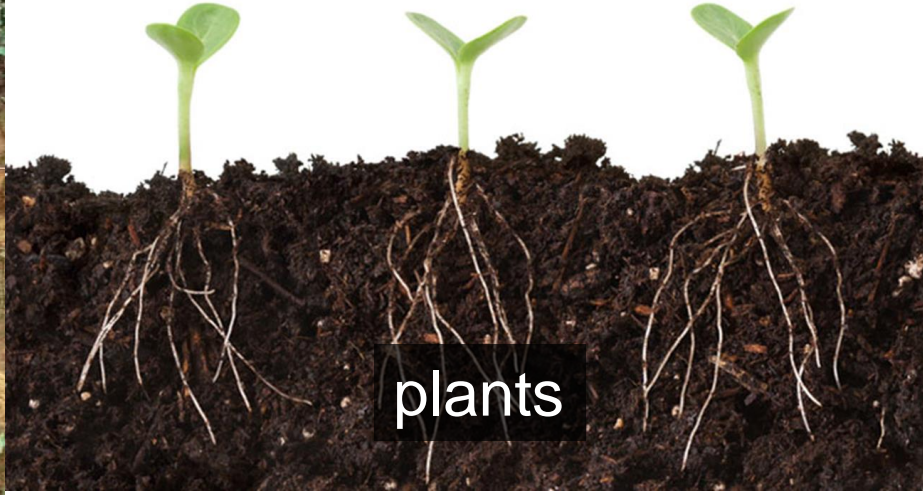
Westermann et al *in preparation*



Wastes + green biotech = next-generation fertilisers



soil



plants



microbes



fertiliser



wastes



sorbers



biochar

Next-generation fertilisers can be based on repurposed wastes and designed to deliver multiple benefits

Nutrients and organic materials

Manures
Mill mud
Compost
Struvite

Sorbers for on-demand release of nutrients

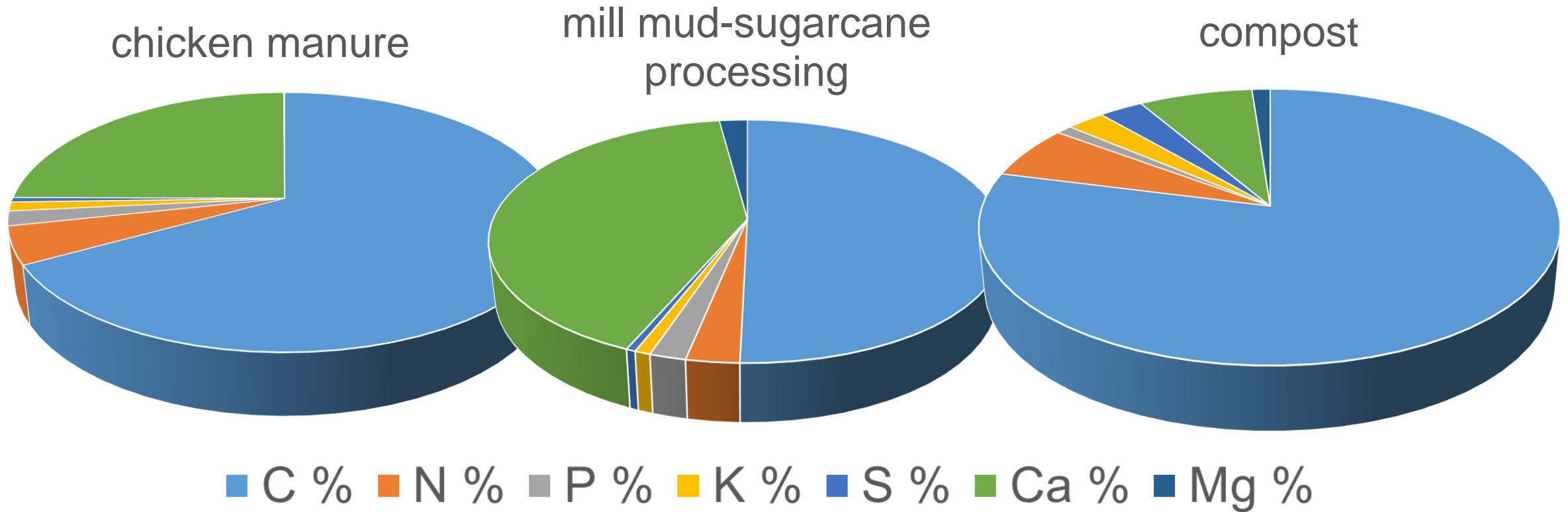
Clays
Biochar
Agricultural residues
Engineered starch
...

Soil biological agents

Plant-growth-promoting microbes
Fungi, bacteria..
Worm eggs
..

Long-term soil fertility and function
Reduced N losses

No waste is perfect: formulate to match plant needs



Screening sorbents/silicates to amend agricultural wastes

Chin et al 2018 Science of the Total Environment

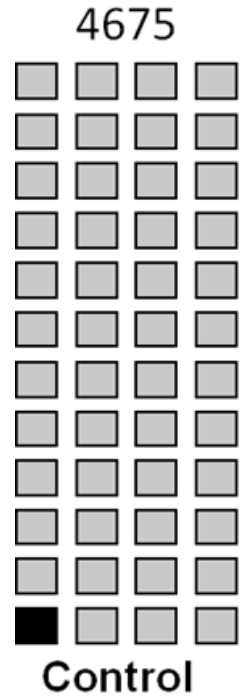
Sorbent	Characteristics	Sorption Capacity $\text{NH}_4^+ \text{ g}^{-1}$	Leaching reduction (%)
Zeolites <ul style="list-style-type: none"> • Clinoptilolite • Chabazite 	Molecular sieve functions	1.0 - 44.30	70-80
Vermiculite	Extremely light and porous	0.36 - 7.00	50
Biochar	High carbon content	0.52 - 37.71	54
Bentonite	High swelling	0.69 - 26.63	57
Palagonite	Large amounts macro/micro nutrients	N/A	23



Aligning N supply from wastes with crop uptake capacity

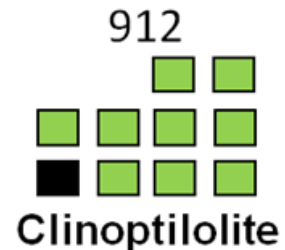
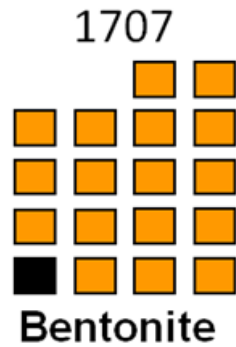
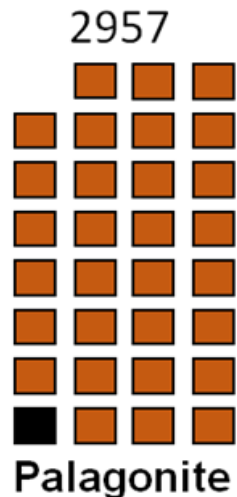
Chin et al 2018 Science of the Total Environment

Sugar mill
mud+
manure



Sugar mill mud + manure

Sorbents

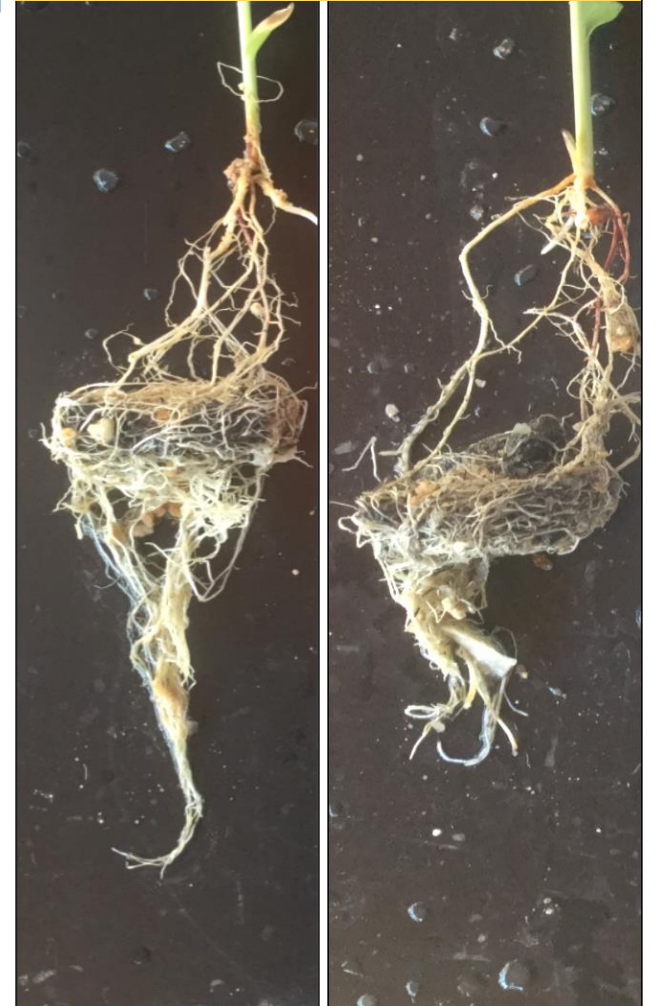


NH_4^+ fluxes in sorbent-amended wastes and I_{max} , the maximum estimated root uptake rate of $\sim 100 \text{ nmol NH}_4^+ \text{ cm}^{-2} \text{ h}^{-1}$ (black square). Each square represents $100 \text{ nmol NH}_4^+ \text{ cm}^{-2} \text{ h}^{-1}$ with total fluxes shown above each column.

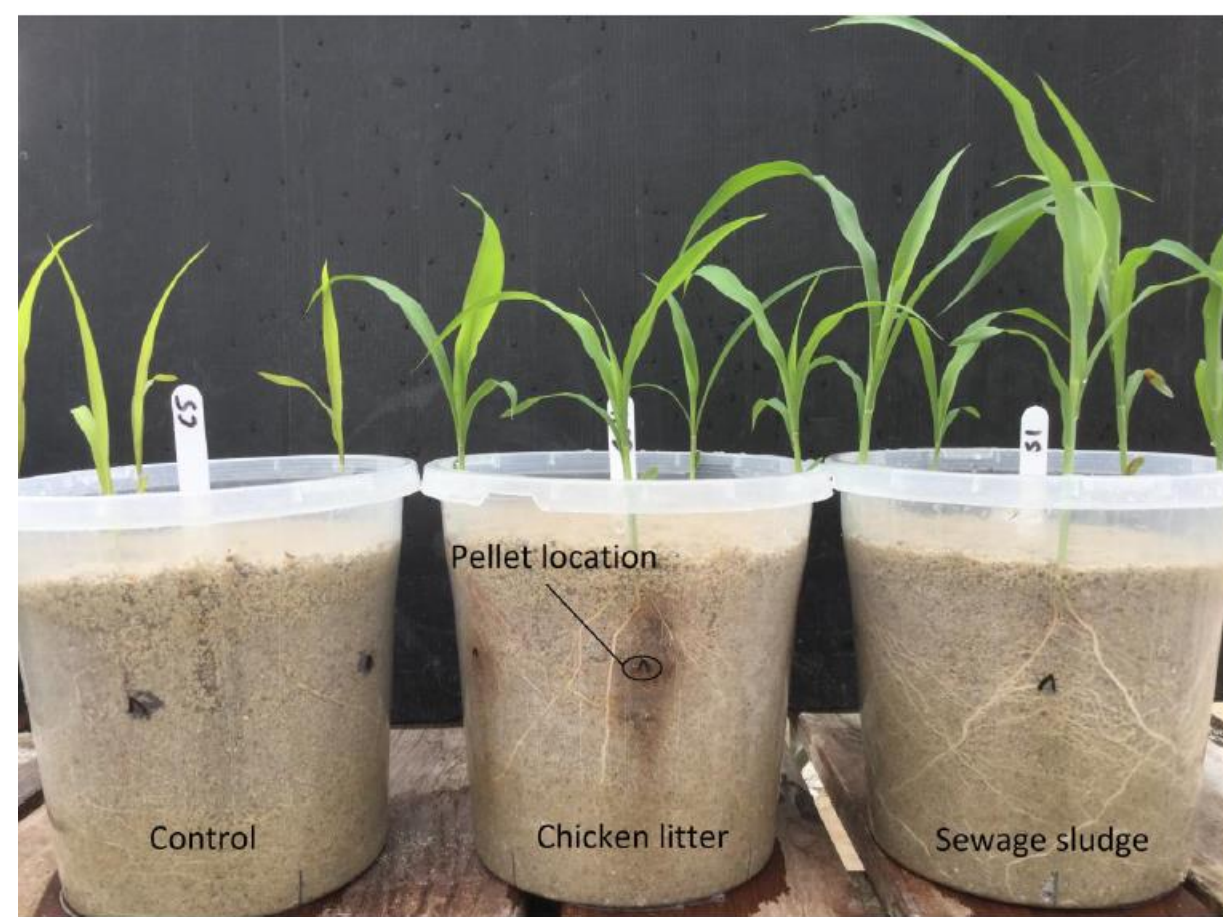
Sugar mill
mud+
manure



Sugar mill mud + manure



Examine root and biomass response to optimise formulations



Determining root interactions with pellets

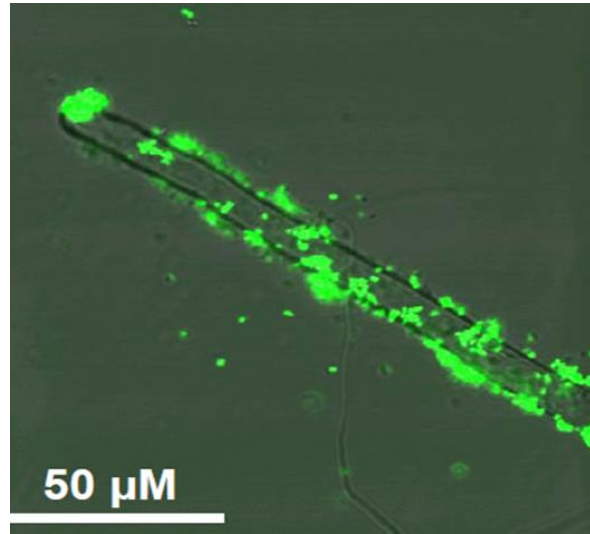
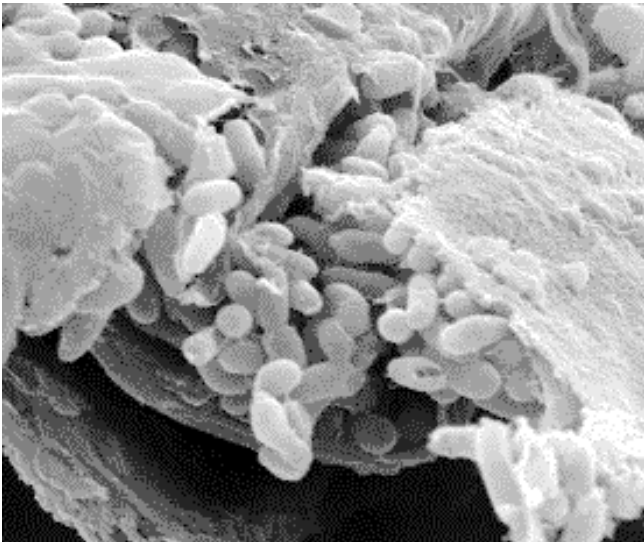


Barren pellet
sawdust-biochar-zeolite

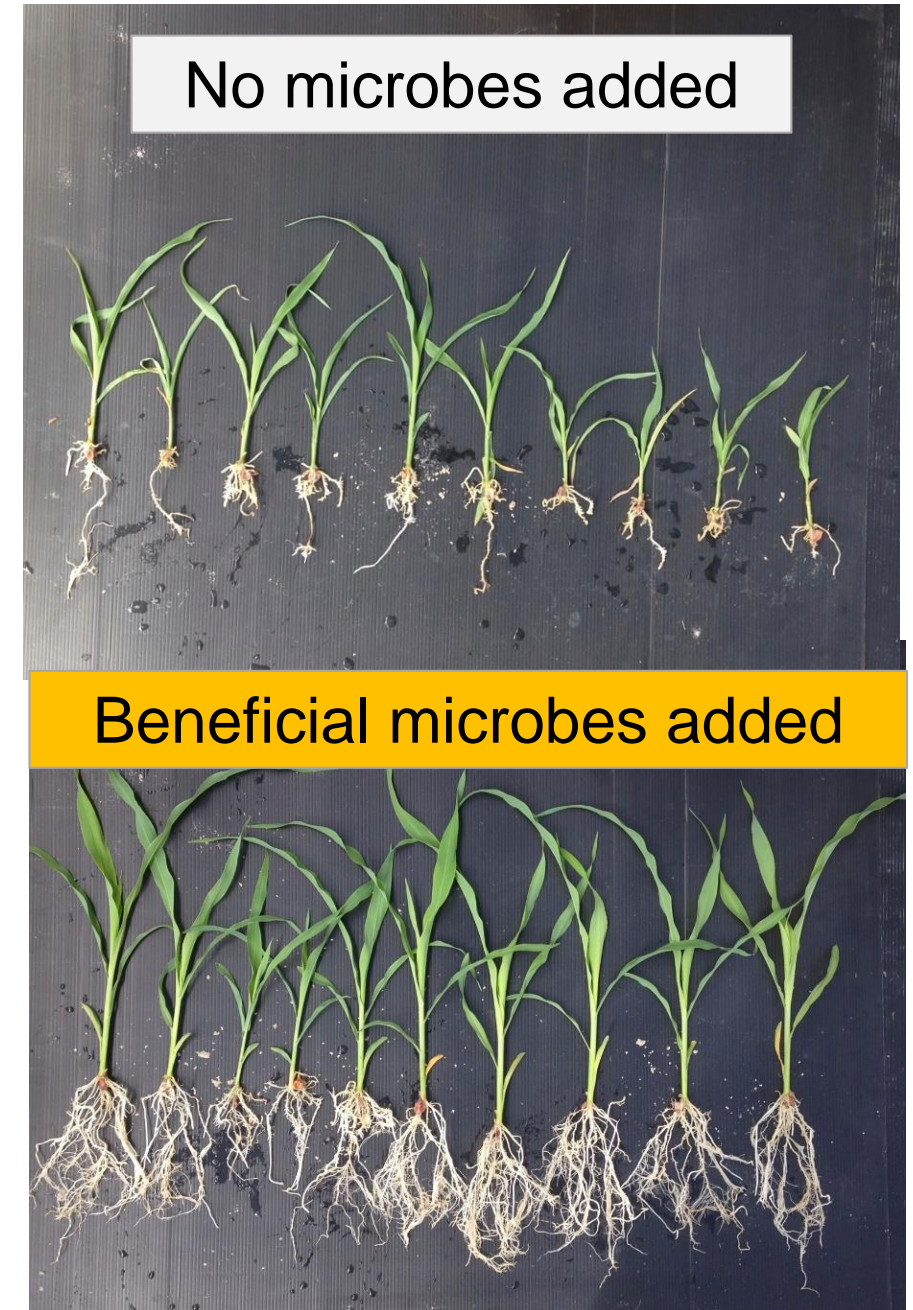


Nutrient loaded pellet
sawdust-biochar-zeolite

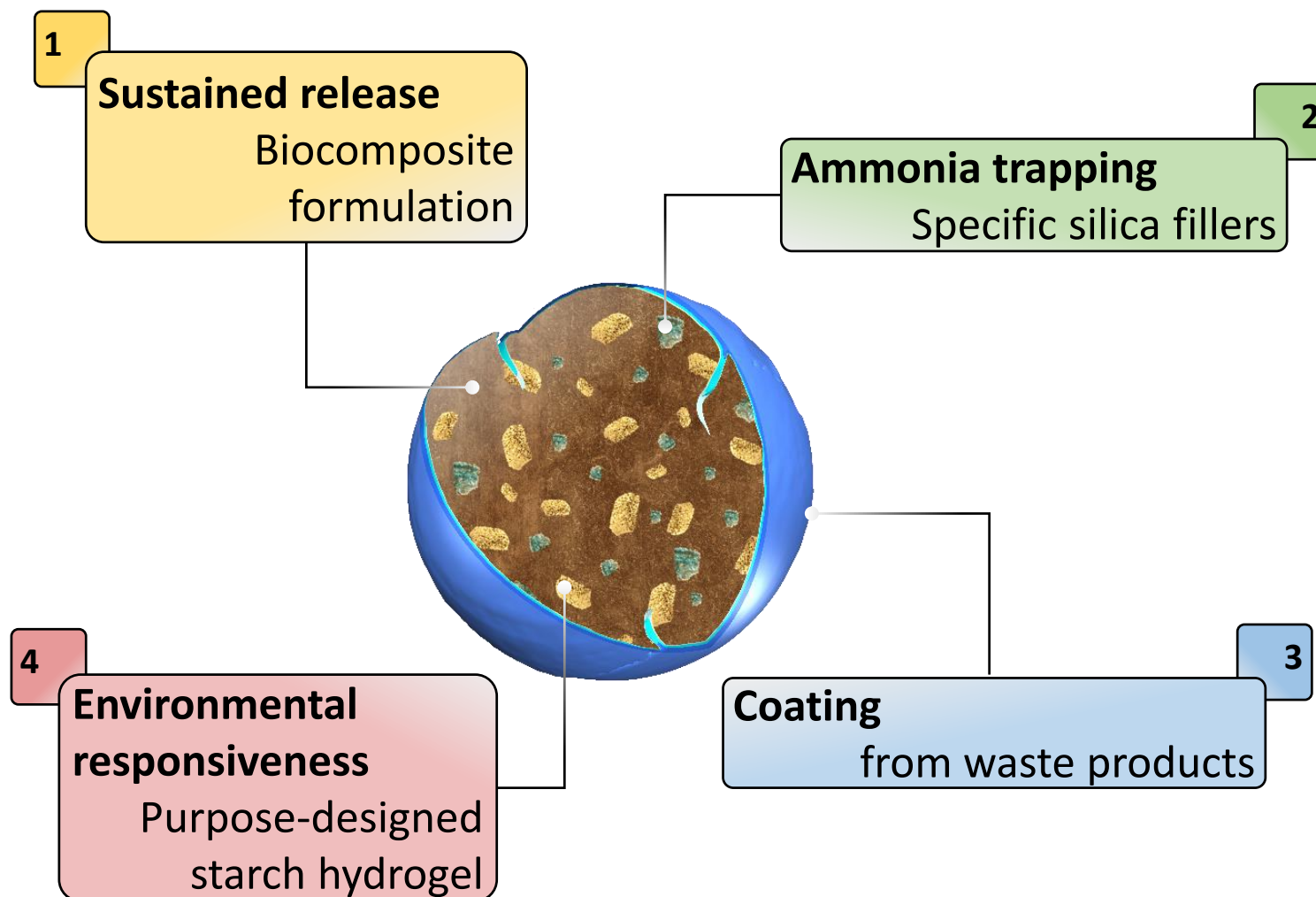
Much evidence that beneficial microbes enhance plant vigour



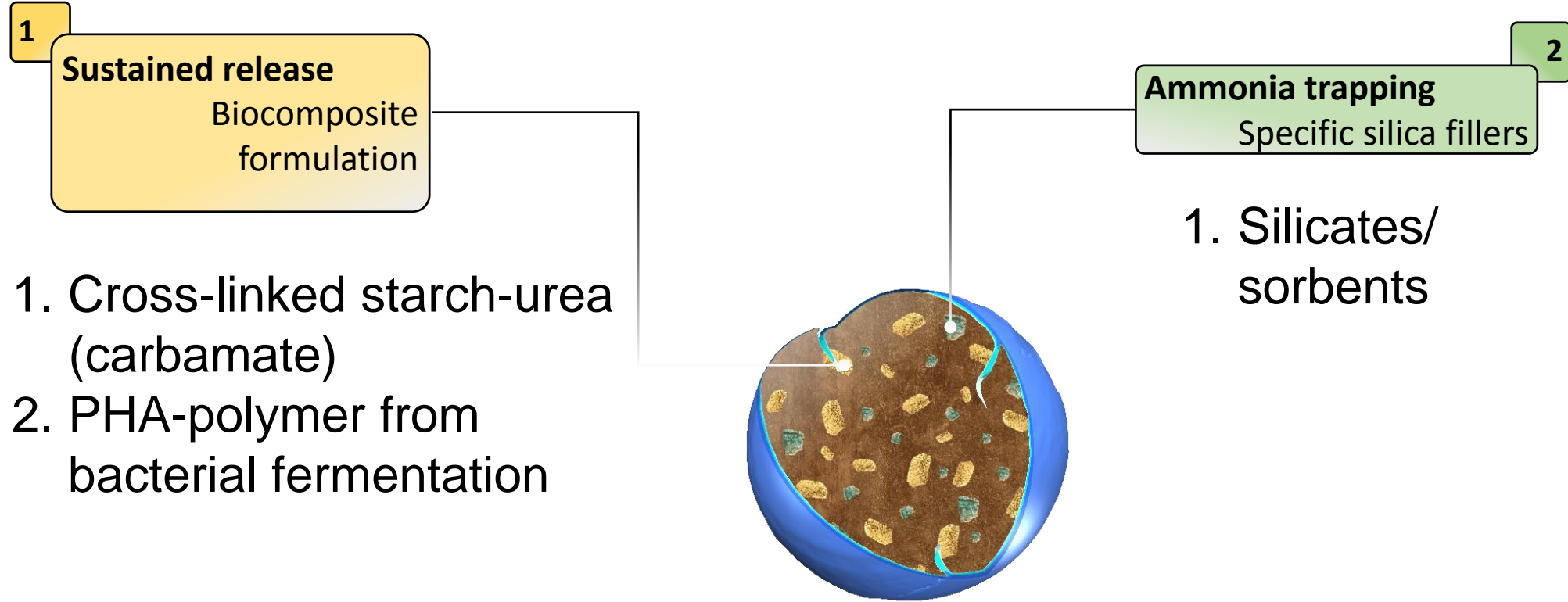
Root surface with bacteria biofilm



Developing multi-functional fertilisers



Current screening trials of formulations



Screening
water, soil
plant



Mechanistic
understanding



Field testing

Processing, agglomeration, binding & extrusion technologies



Thanks

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