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Nanomaterials for crop protection

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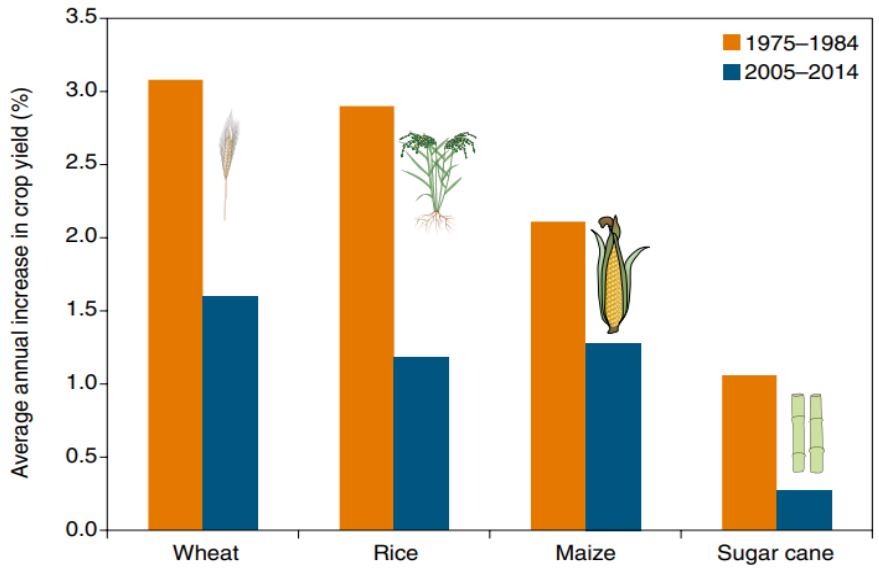
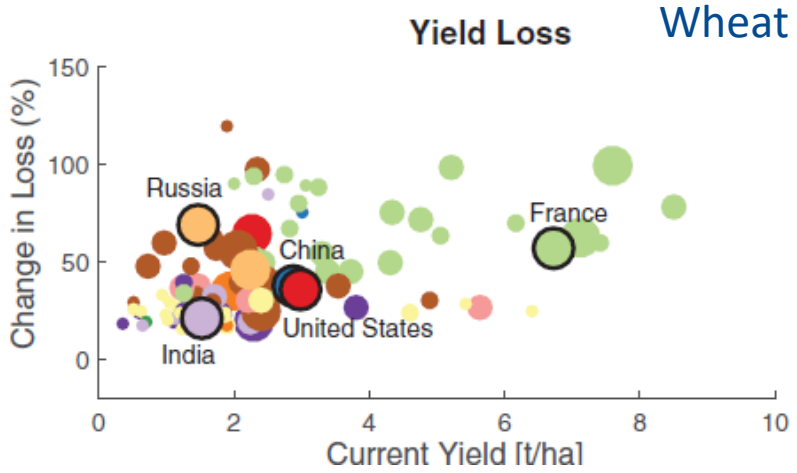
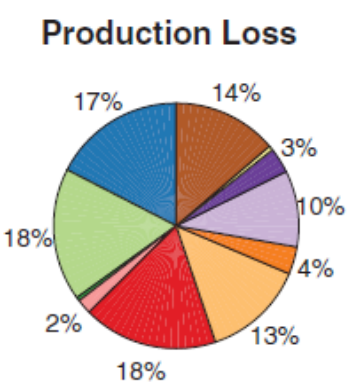
Why focus on nano-agriculture?

- Annual increase in agricultural productivity **declined**
- Agricultural systems in most countries have plateaued at 20–80% of yield potential
- Agrochemical delivery is inefficient:75-99% fertilizers or pesticides never reach targets
- Negative pressure from arable soil loss, climate change and environmental pollution





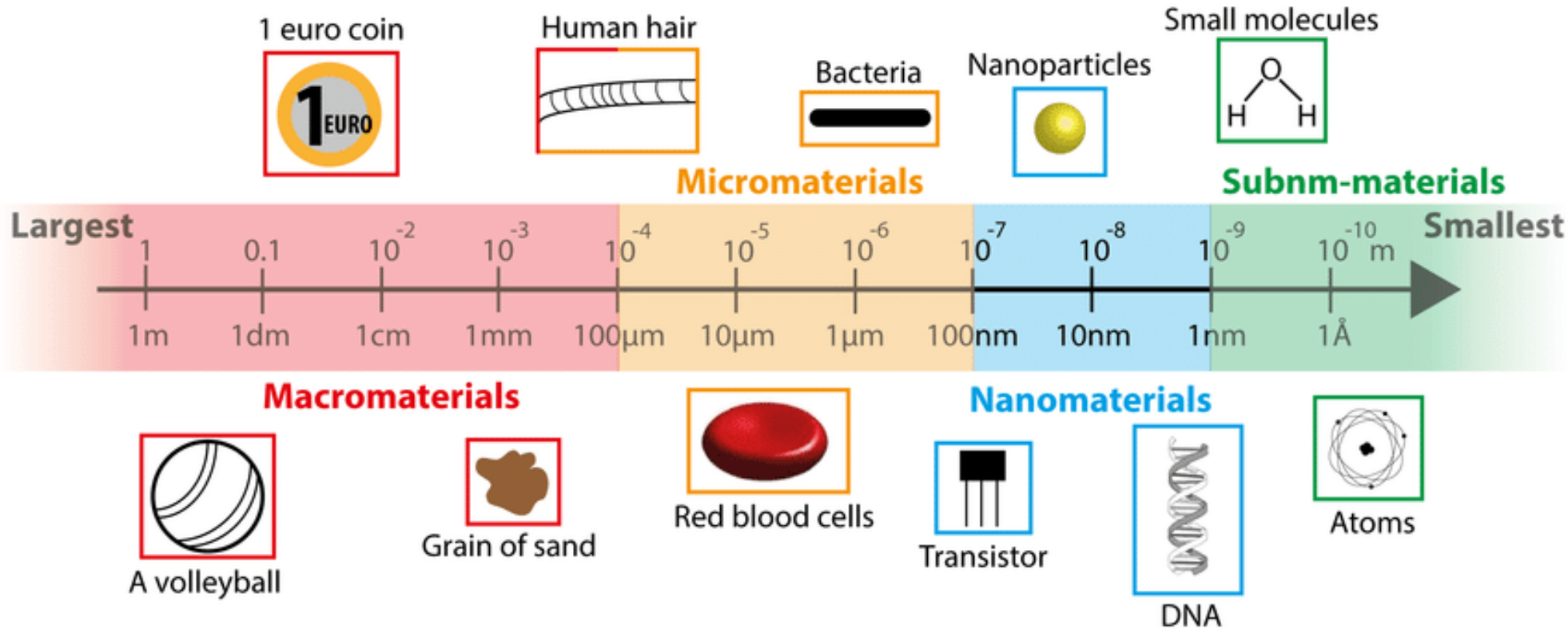


Kah et al., Nature Nanotechnology, 2019, 14, 532-540;
Deutsch et al., Science, 2018, 361, 916-919

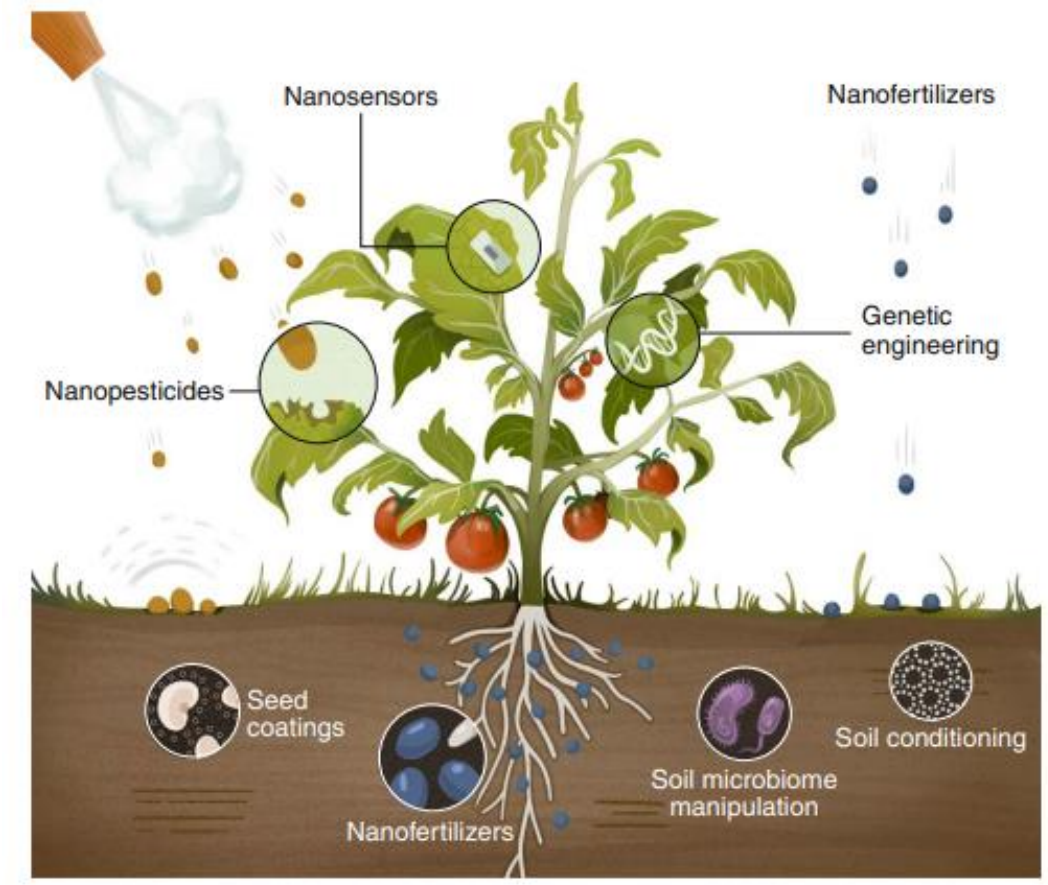
Nano-agriculture offer solutions

Materials have at least one dimension between 1 and 100 nanometers

ISO, 2008; European Commission, 2011



Nano-agriculture offer some solutions

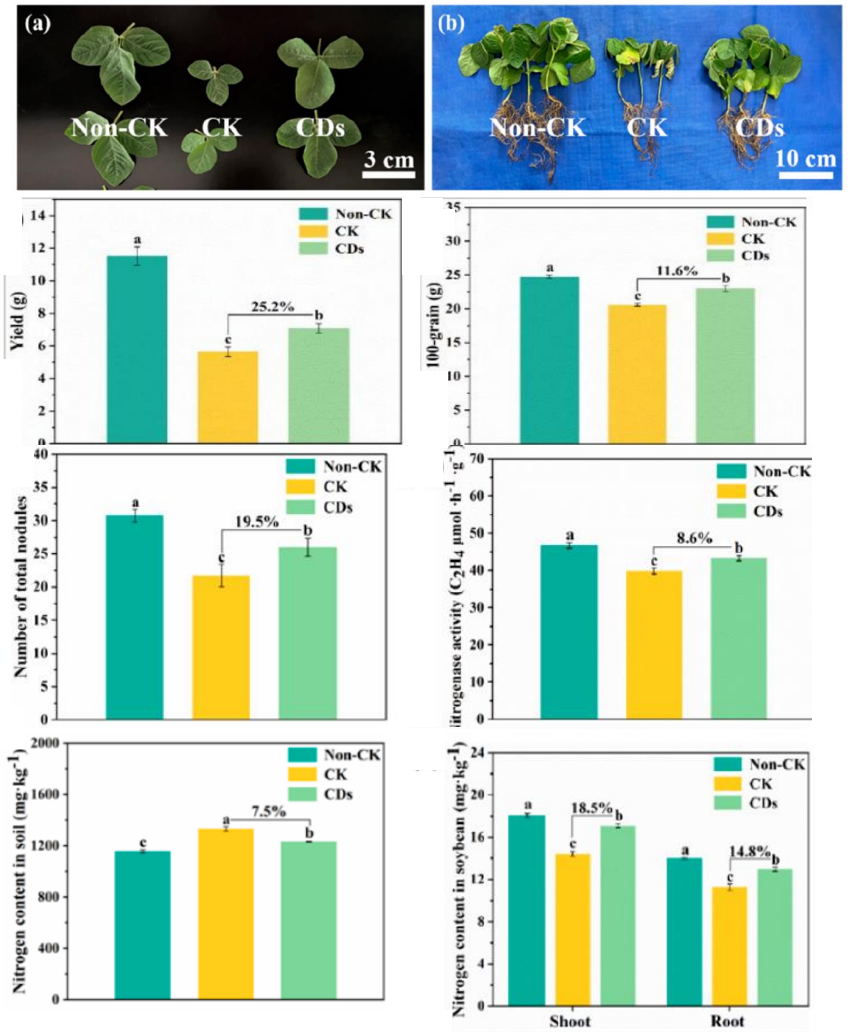


Potential application of nanotechnology in plant agriculture

- Increase nutrient utilization efficiency
- Mitigate the impacts of climate change
- Improve the efficiency of pest management

Hoffman et al., Nature Food, 2020, 1, 416-425

Nanomaterials alleviates drought-induced damage



Carbon dots increase soybean yield per plant and the 100-grain weight by 25.2% and 11.6%

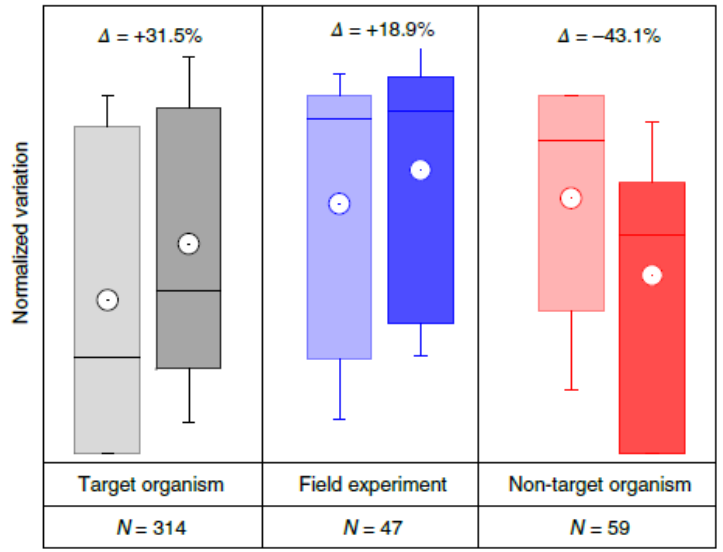
- Promote N uptake by modulating rhizosphere exudates and microbial communities
- Improve N-fixing ability of nodules
- Increase N transport and water uptake
- Improve the nutritional quality of soybeans under drought stress

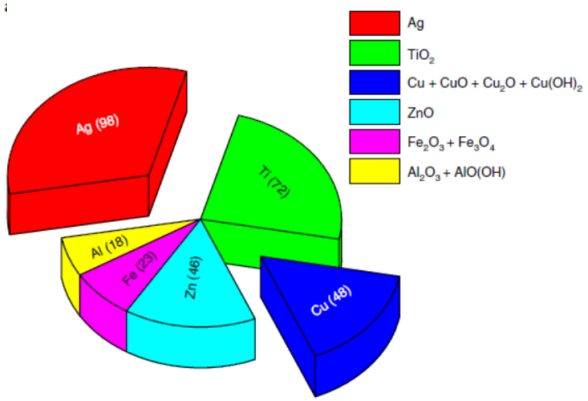
~211 US$ ha^{-1} for CDs vs. ~399.2 US$ ha^{-1}

Non-CK: non-drought stress
CK: control, drought stress
CDs: carbon dots (5 mg/kg)

Cao et al., ACS nano, 2022, 16, 12415-12424

Nanopesticides to improve the efficiency of pest management





A meta-analysis of nanopesticides compared to their conventional analogs (36,658 Google Patents, 500 papers between 2015-2021)

High efficiency

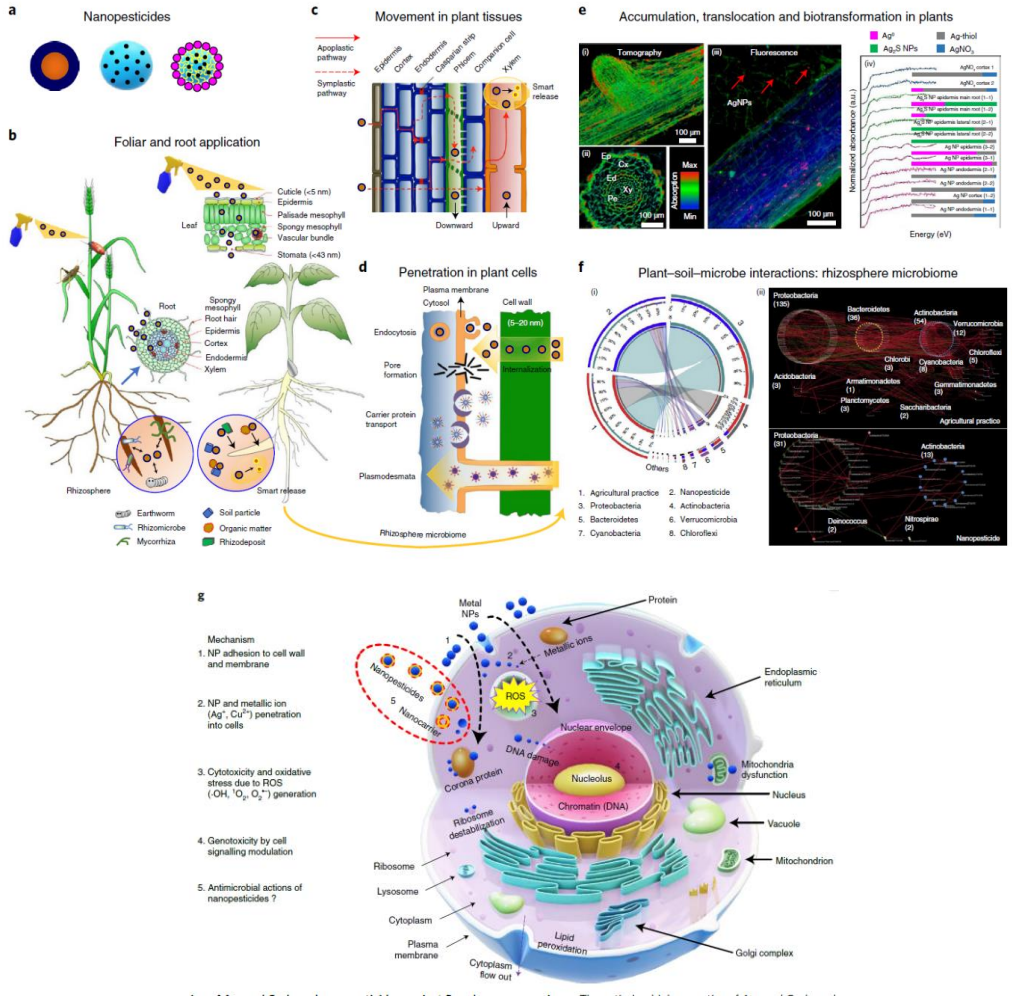
The efficiency of nanopesticides against target is **31.5%** higher, including an 19.9% increased efficiency in field trials

Environmental friendly

The toxicity toward nontarget is **43.1%** lower

Wang et al., Nature Nanotechnology, 2022, 10.1038/s41565-022-01082-8

Nanopesticides to improve the efficiency of pest management



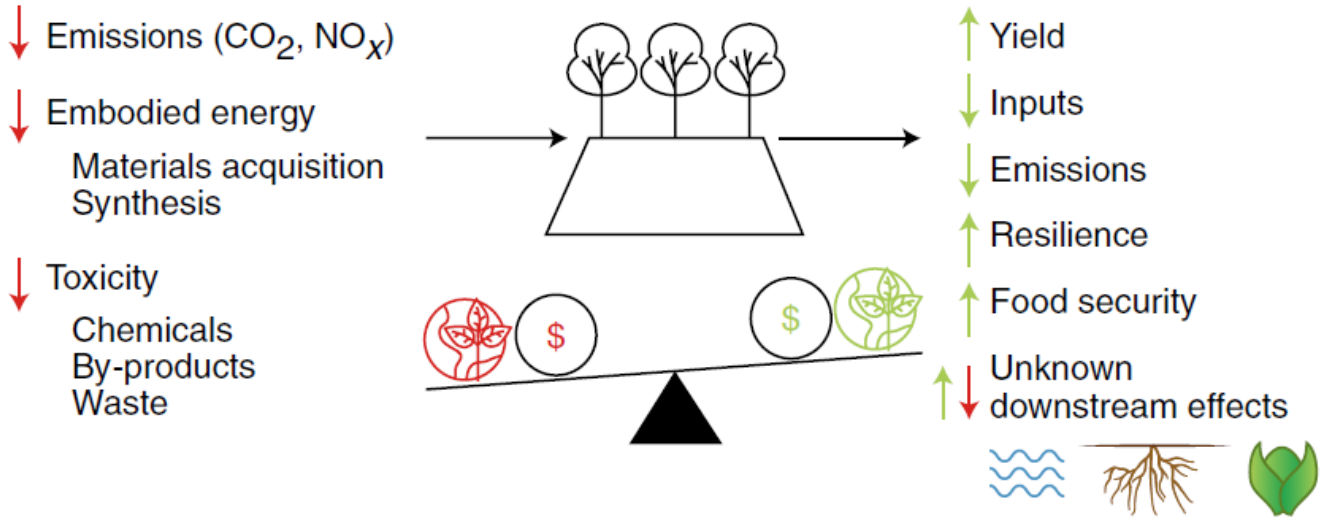
- The premature loss of active ingredients (AI) prior to reaching target is reduced by 41.4%, paired with a 22.1% lower leaching potential of AI in soils

- Other benefits:
  - ✓ Enhanced foliar adhesion
  - ✓ Improved crop yield and nutrition
  - ✓ Mitigate abiotic stresses such as drought

Wang et al., Nature Nanotechnology, 2022, 10.1038/s41565-022-01082-8

Conclusions

- Nanotechnology has the potential for sustainable agriculture
- Nanomaterials can be used to mitigate the effects of climate change and to improve the efficiency of pest management
- System trade-offs: unintended negative impacts



Lowry et al., Nature Nanotechnology, 2019, 14:517-522

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