

# Nano-Sized Delivery For Agricultural Chemicals

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# Outline

- I. Potential benefits to agricultural chemicals
- II. Nano-particle (NP) cellular uptake
  - Can NP be taken up by model cell systems?
- III. Hydroponic nano-delivery study
  - Can NPs enter root and move upward in xylem?
  - How does NP size or surface functionality affect plant health?
  - Can fungicide loaded NPs provide disease protection?
- IV. Nano-capsule pesticide formulation
  - Can pesticide be delivered via nano-sized formulations?
  - Can nano-sizing improve efficacy?
- V. Summary

# I. Agrochemical Application

## Application



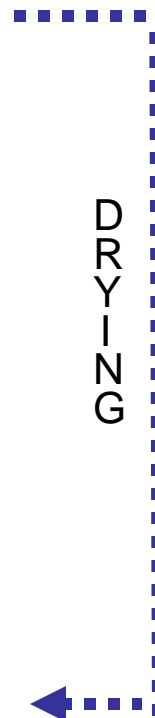
SPRAYING



## Reaching the Target



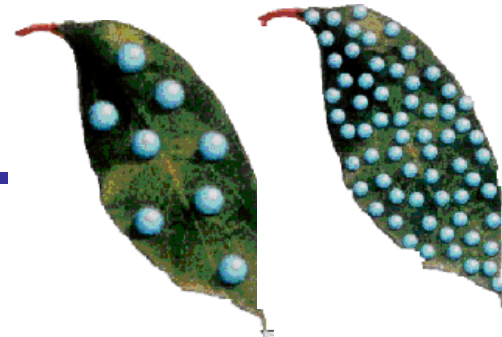
DRYING



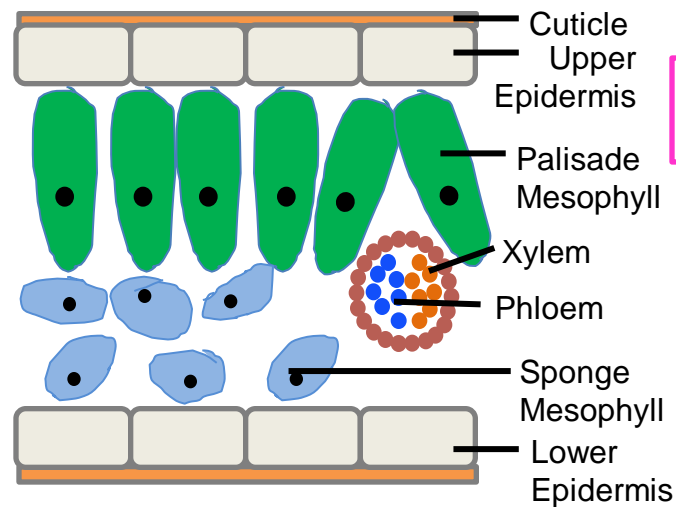
Improving Efficiency



## Deposit Formation



PENETRATION  
& UPTAKE



Leaf Cross Section

# Agrochemical Formulations Containing Solid

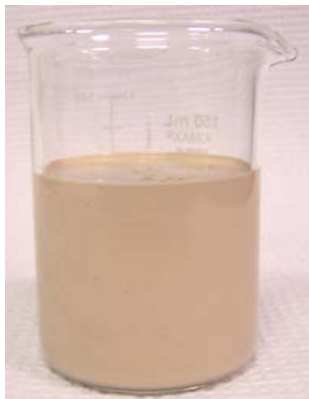
Liquid Forms

Suspension Concentrates (SC)

Capsule Suspensions (CS)

Oil Dispersions (OD)

Suspo Emulsions (SE)



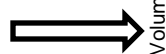
Solid Forms

Wettable Powders (WP)

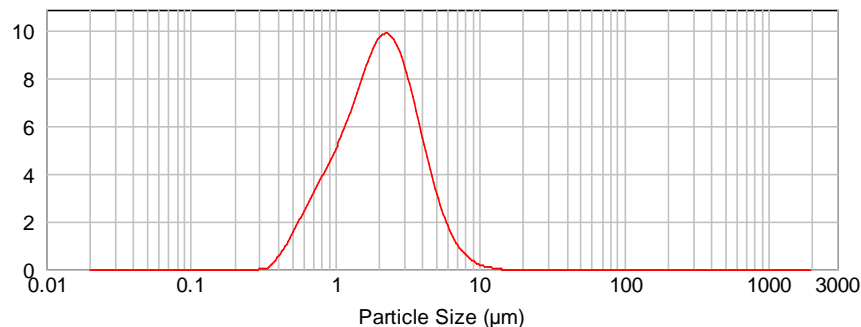
Water Dispersible Granules (WDG or WG)



Solid particles are within conventional size range (microns)

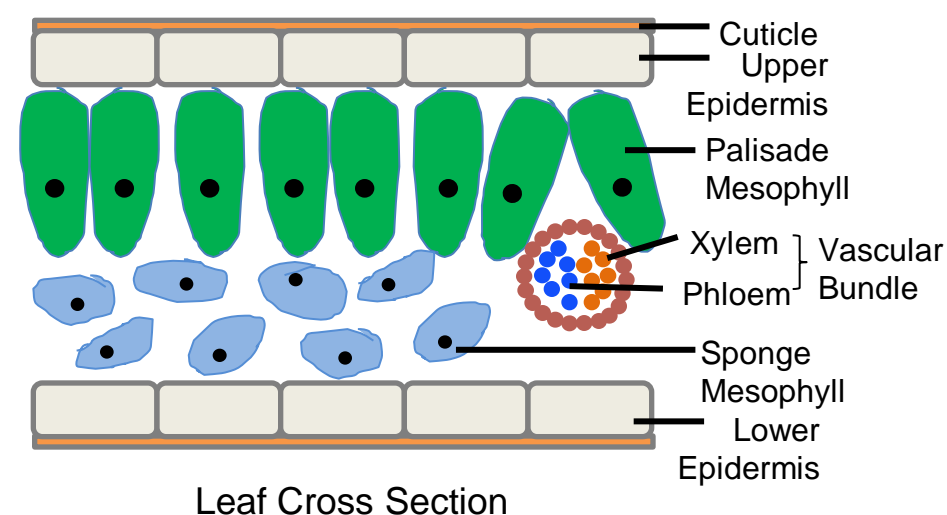


Volume (%)



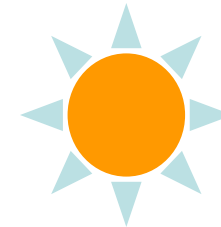
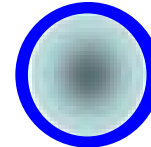
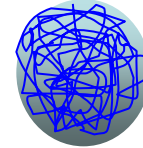
# Nano-Technology vs. Agriculture

- Can nano-sizing delivery systems improve pesticide efficiency?
  - Broadly applicable delivery system, small in size (50-300nm), possibly with designed surface functionality, to deliver active ingredients more efficiently/effectively than those in the conventional size range (microns).
- How could nano-sized formulations improve efficiency?
  - Enhance penetration, uptake, and systemicity through biological systems (root, stem, foliar, insect guts, etc.)
  - Enhance bio-availability (solubility, soil mobility)
  - Improve or overcome undesirable phys-chem properties of AIs
  - Control release



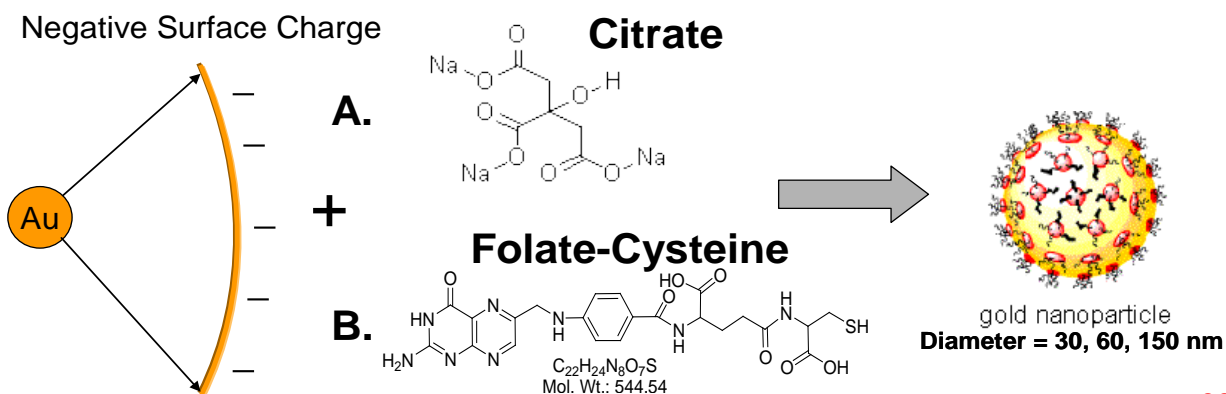
# Types Of Pesticide Loaded Nano-Particles

- Homogeneous
- Matrix
- Capsule
- Gold or silica surface coupling

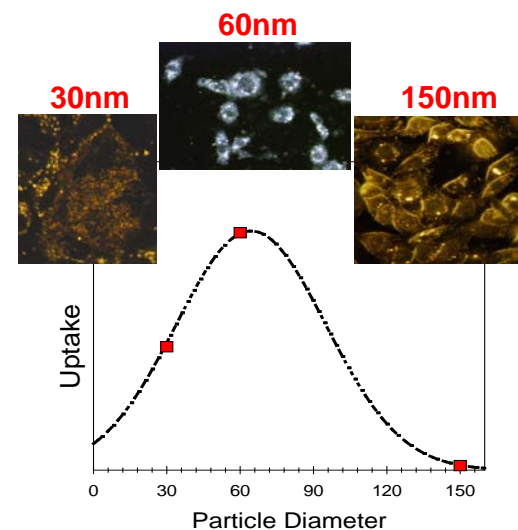


## II. Nano-Particle Cellular Uptake

- The uptake of NP is surface-ligand dependent and an active process
  - Folate for Chinese Hamster Ovarian (CHO) cells, Citrate for tobacco NT1 cells.



- Optimal size of functionalized particle was estimated at 60 nm, qualitatively determined by analysis of dark field images after a fix-time uptake procedure. (20 min incubation at 37°C, 5% CO<sub>2</sub>)



# Nano-Particle Cellular Uptake

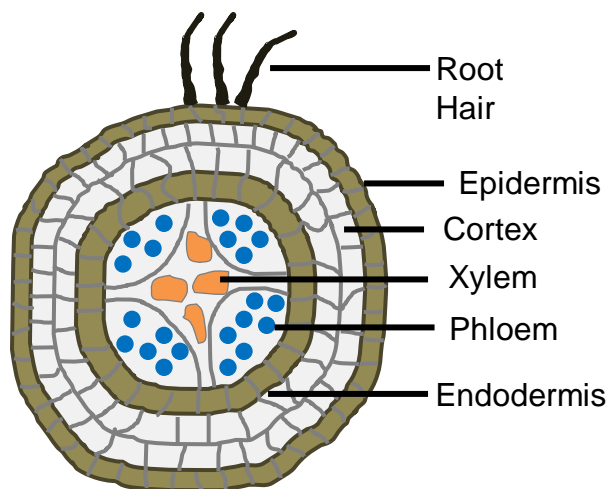
- Preliminary assay of citrate-Au NP on tobacco leaf tissue demonstrated that the particle could penetrate quickly through epidermal cells into palisade cells.



# III. Hydroponic Rice/Wheat Test System



Rice Paddy



Root Cross Section



# Q1: Can NPs Enter Root And Move Upward In Xylem?

## Testing Protocol

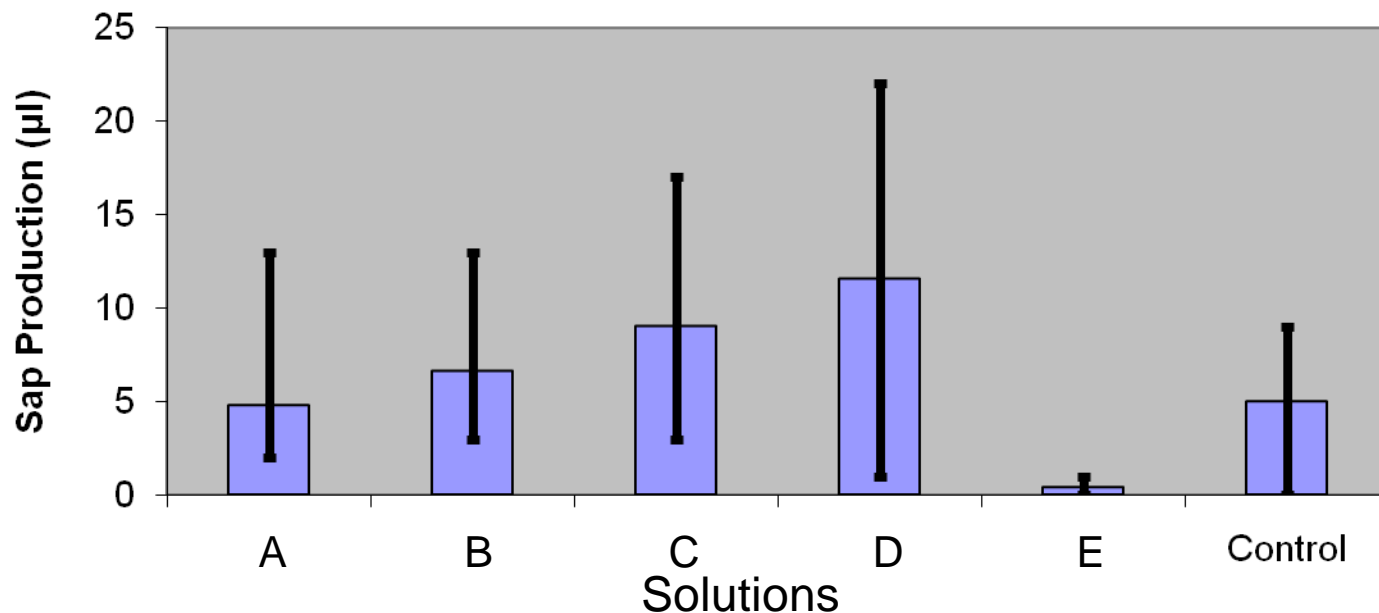
- NP (internally dyed with fluorescein) solution was injected into the hydroponic solution (1600 ppm NP concentration)
- Sap was collected every 15 minutes
- Fluorescence detection in the produced sap



*sap for collection*



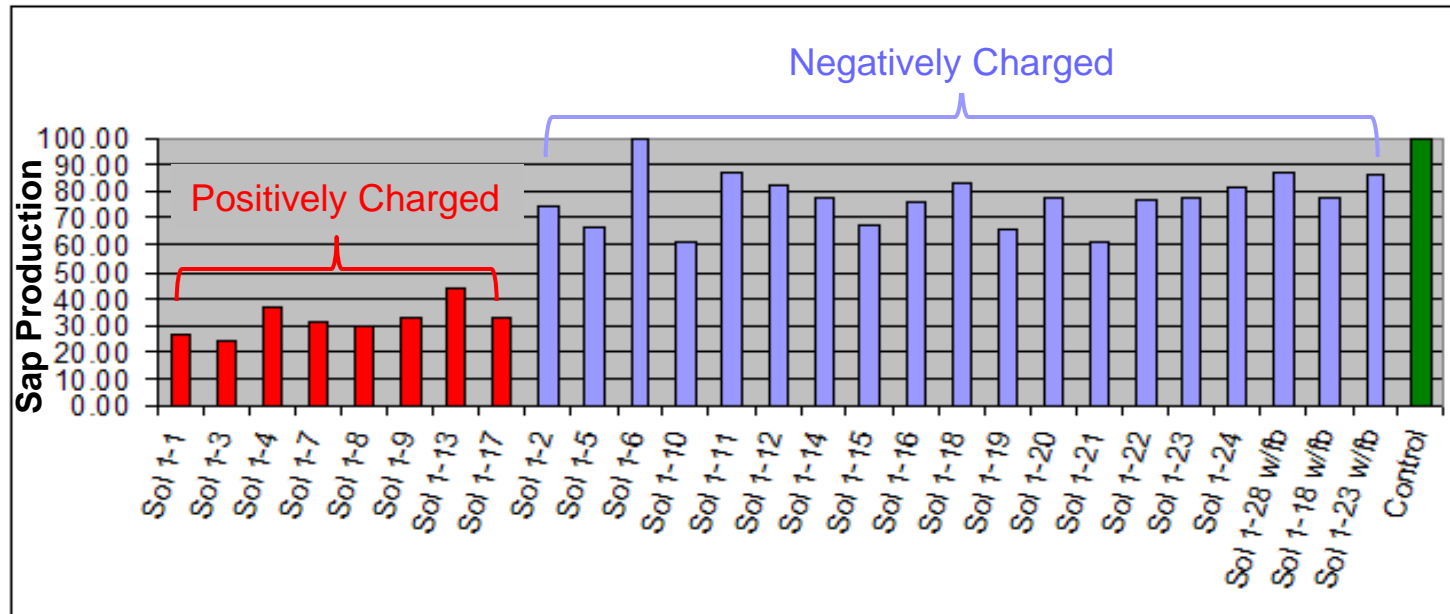
# Q1: Can NPs Enter Root And Move Upward In Xylem?



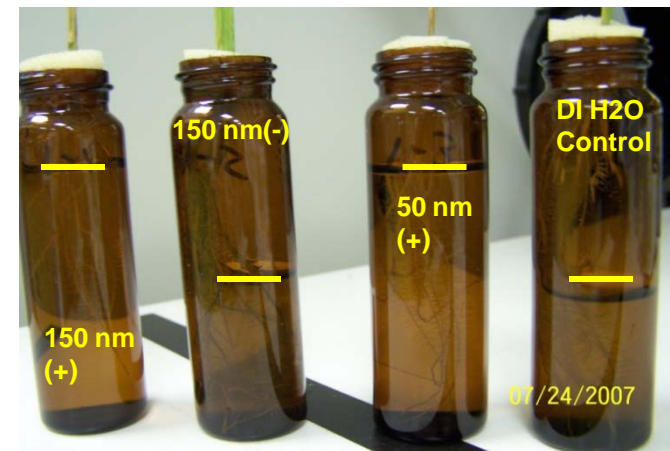
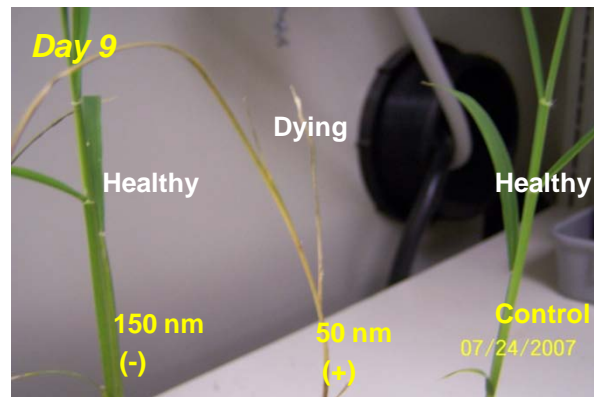
Fluorescence in produced sap (threshold 8ppm)	Y	Y	Y	Y	N	N
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NP transport through the root barrier and the vascular system was confirmed by fluorescence of the produced sap.

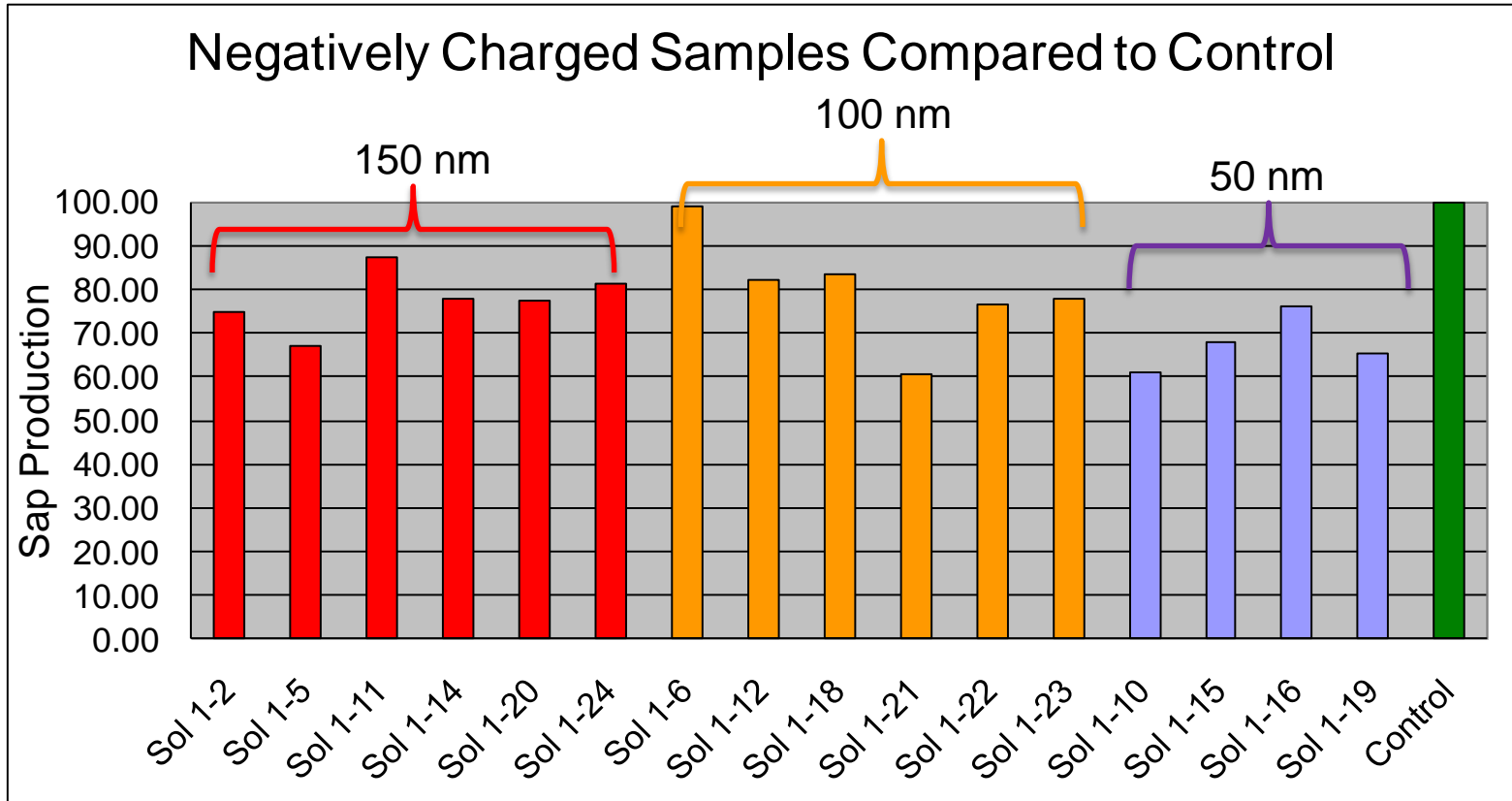
# Q2: Effects Of Nano-Particle Surface Functionality On Plant Health?



At the chosen NP concentration (1600 ppm), positively charged particles clearly hinder root uptake of hydroponic solutions.



# Q2: Effects Of Nano-Particle Size On Plant Health?



The size of nano-particles was not a major factor on plant health.

# Q3: Can Fungicide Loaded NPs Provide Disease Protection?

## Bioassay Test

- Vials were spiked with nano-particle solutions then inoculated with brown rust disease of wheat.
- Assessments were done 6 days after inoculation.
- NP loaded with fungicide show disease protection.



NP w/o fungicide



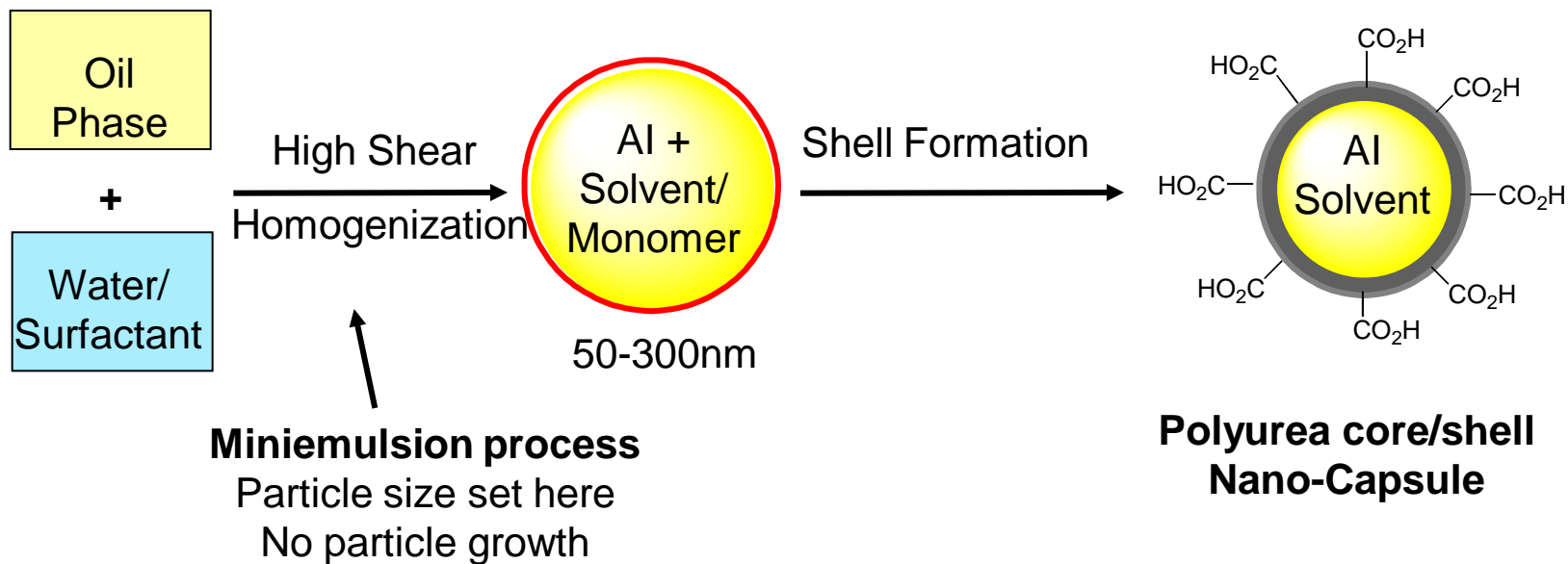
NP w/ Fungicide



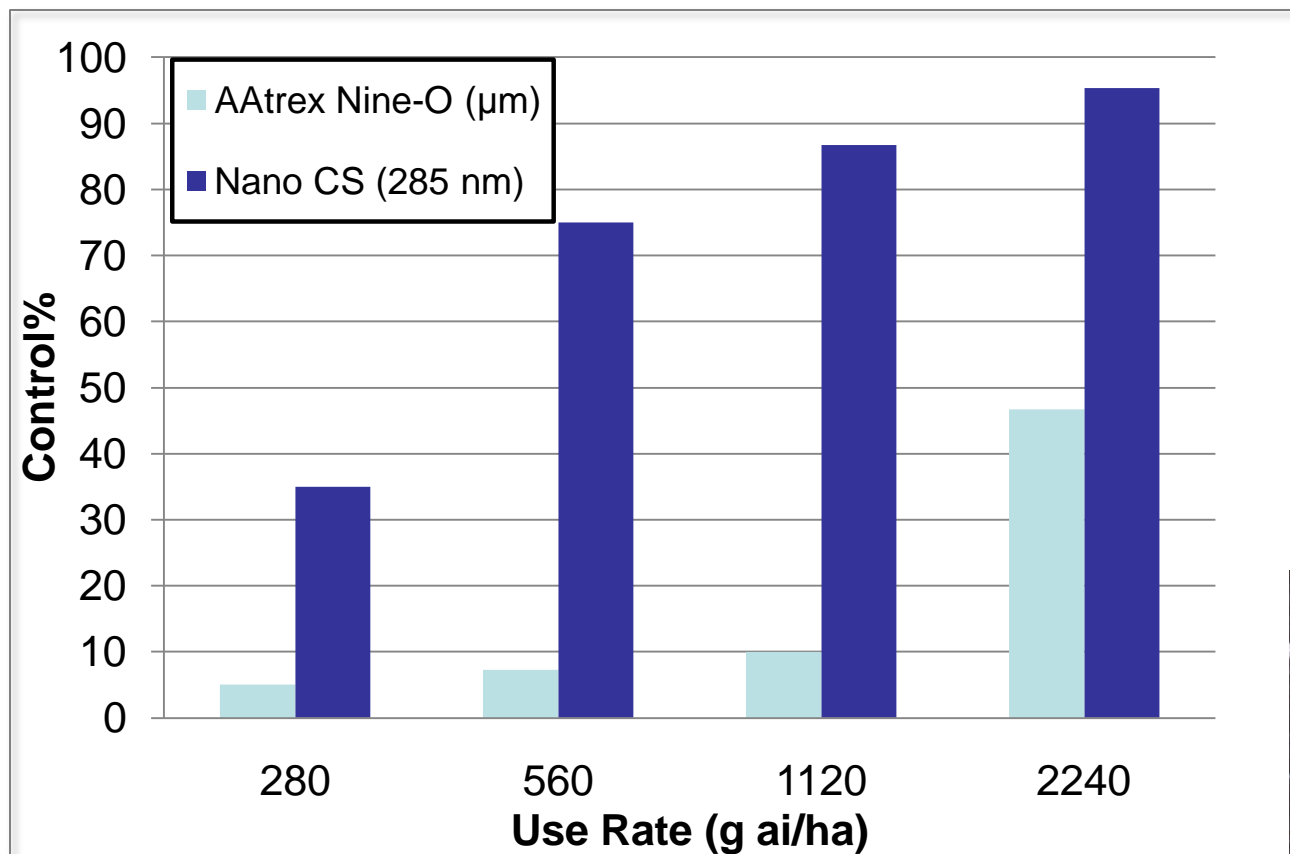
Fungicide wettable powder, foliar applied

# IV. Pesticide Formulation

- Pesticide active ingredient (AI) candidates for NP Model systems:
  - Low water solubility (<1000 ppm)
  - Performance limited due to restricted penetration/uptake
  - Target for 25-50% efficacy enhancement
  - Soluble in common organic solvent
- Nano-delivery systems:



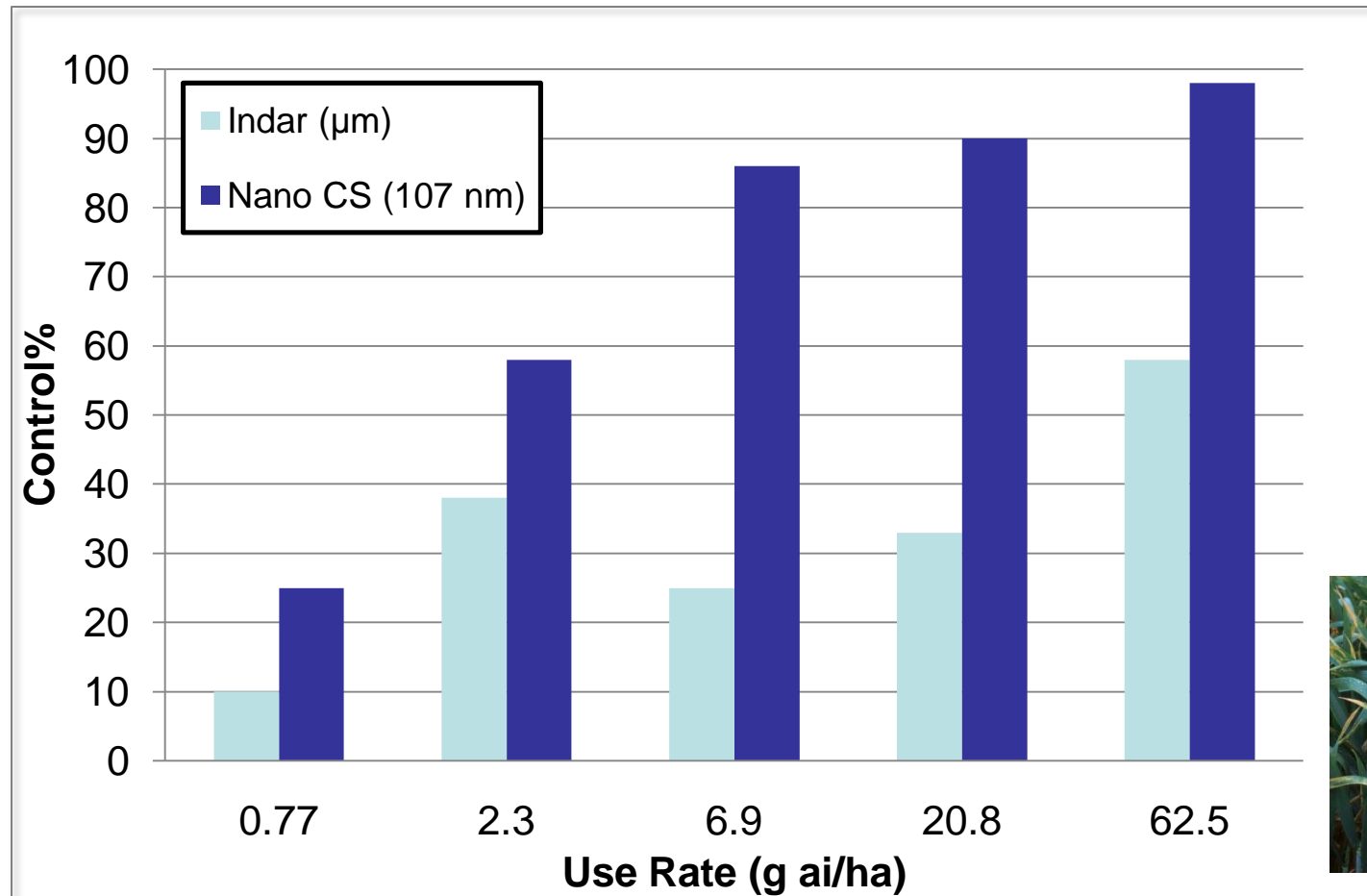
# Herbicide: Atrazine Control On Sicklepod (*Cassia obtusifolia*)



Nano capsule formulation provided superior weed control to conventional sized formulation.

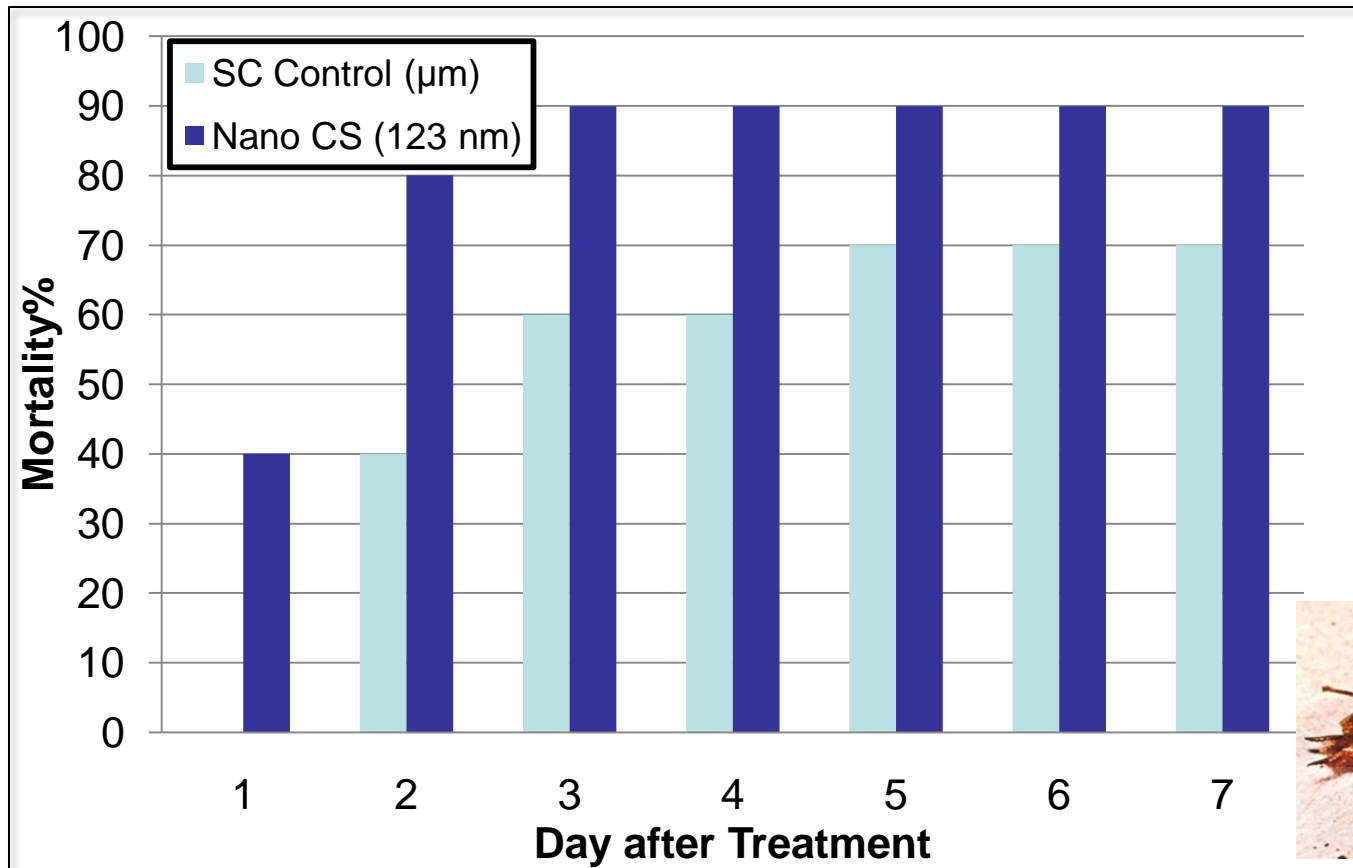


# Fungicide: Fenbuconazole Curative Effect On Wheat Leaf Blotch (*Septoria tritici*)



Nano capsule formulation provided improved disease control compared to conventional sized formulation.

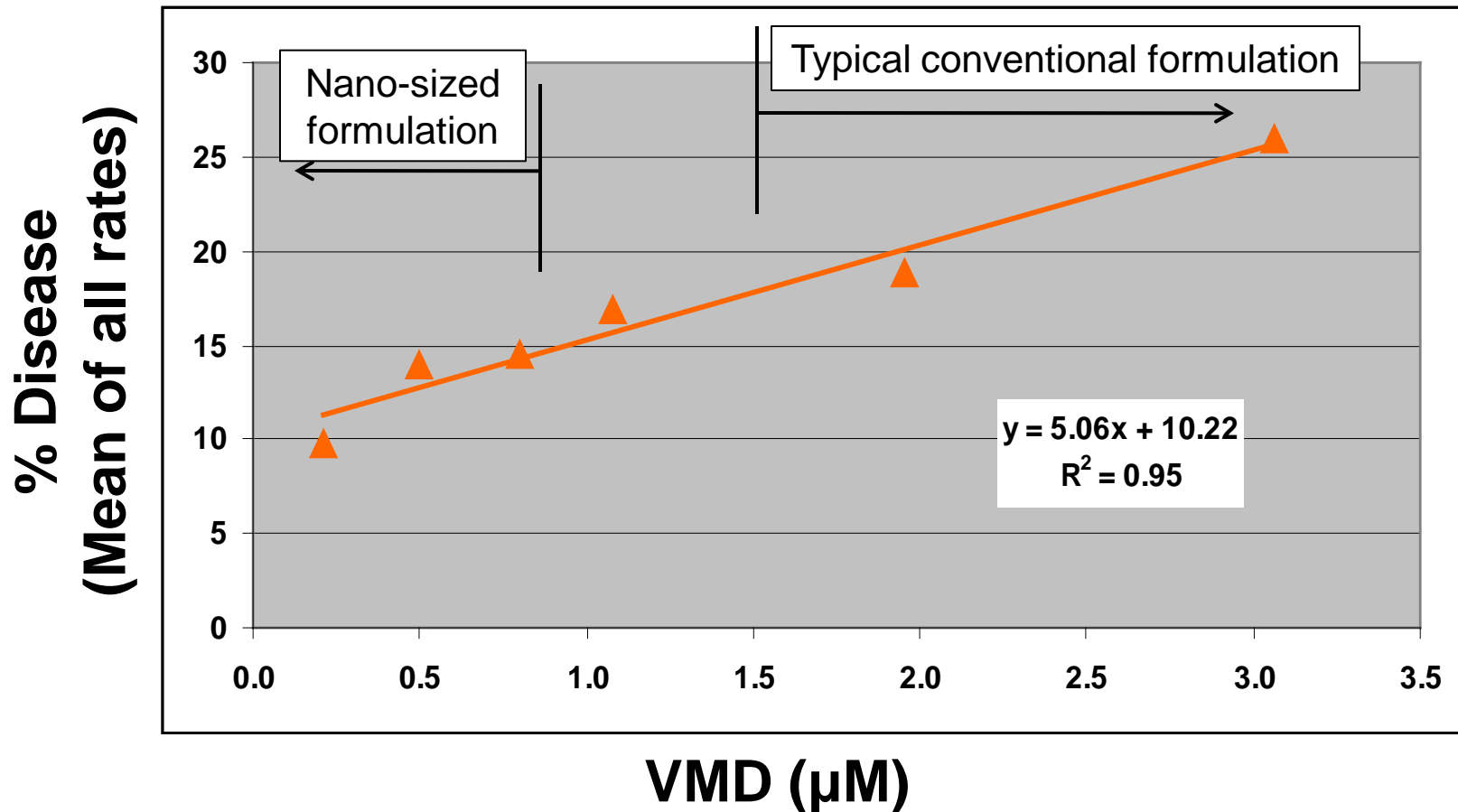
# Insecticide: Indoxacarb Topical Control On German Cockroach (*Blatella germanica*)



Use rate: 0.1%

Nano capsule formulation increased cockroach mortality compared to conventional sized formulation.

# Size Dependence Of Fenbuconazole Efficacy In Green House



# V. Summary

1. Demonstrated the penetration, uptake, and mobility of NP in model cell systems.
2. Proved that NPs transport through root and xylem.
3. Confirmed the adverse effect from positively charged NPs and size independence on plant health.
4. Demonstrated fungicide loaded NP showing disease protection.
5. Formulated nano-sized pesticide capsules.
6. Demonstrated enhanced efficacy in green house test with a herbicide, fungicide, and insecticide.
7. Confirmed size dependence over 200-3000 nm.
8. Continuing efforts of nano-sized delivery for agricultural chemicals.