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Transgenerational impact on nutrients and enzymatic activity of beans grown in soil with coated/uncoated ZnO nanomaterials

Sustainable Nanotechnology Organization
Research | Education | Responsibility

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Los Angeles, CA
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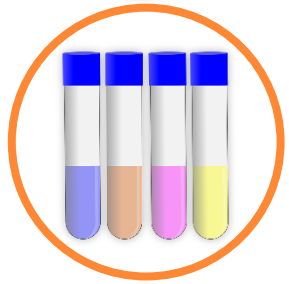
Background

Project overview

Production

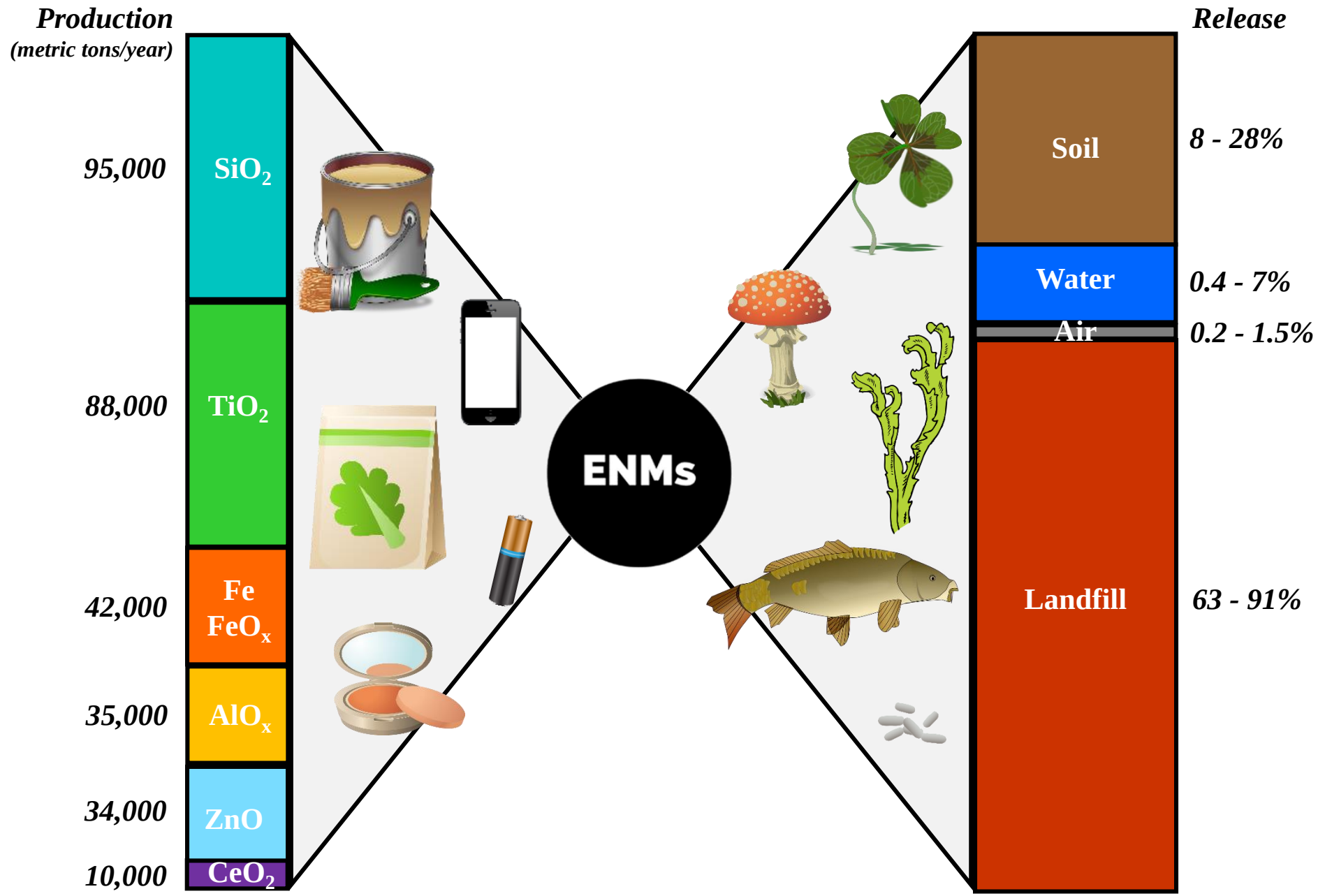
Nutrient composition of pods and seeds



Enzymatic activity of the second generation of seeds

Outline

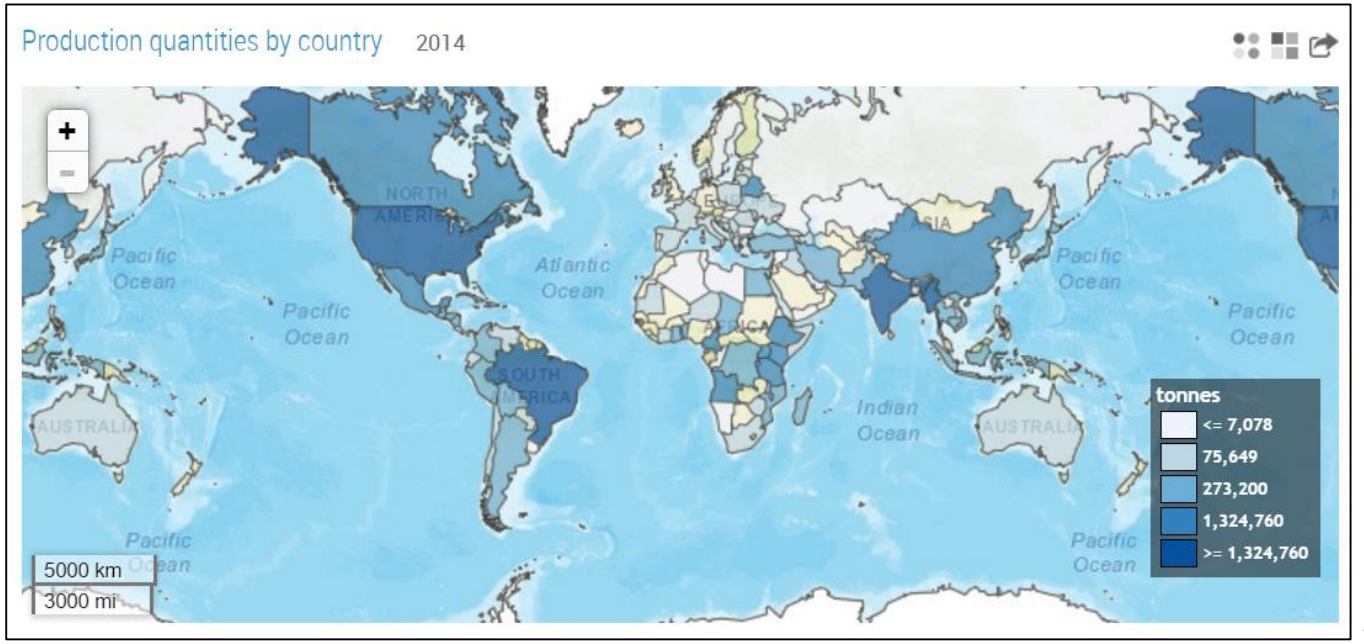
Keller, A. A. et al. (2013) J Nanopart Res 15, 1-17
Retrieved on 09/28/2017 from: www.nanotechproject.org/cpi/products



Medina-Velo, I. A. et al. (2017) MRS Bulletin 42(5), 379

Beans

- Most consumed legume in the world
- High protein and low cost
- More than 26 million tons/year produced
- Cultivated in large range of environments



FAOSTAT (2014)

Agriculture
Supplement

Medicine
Medical plasters
Dental cement

Automotive
Rubber material

Cosmetics
Sunscreens

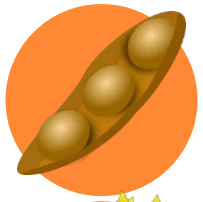
Paints
Mildew controller
Corrosion inhibitor

Construction
Glass and ceramic

ZnO nanomaterials

34,000 tons produced yearly | 2.4% of overall ZnO production

Keller, A. A. et al. (2013) J Nanopart Res 15, 1-17; SCCS of the European Commission (2012); Piccinno, F. et al. (2012) J Nanopart Res 14, 1-11

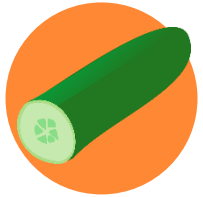


Altered nutritional values[1]
Reduced biomass production and root elongation[1]

Decreased biomass
Inhibited soil enzymes[2]

Reduced production of cobs
Decreased photosynthesis[3]

Increased fruit yield
Enlarged root and stems[4]
ZnO NPs showed comparable Zn toxicity to bulk and Zn salt[5]



Higher Zn in tissues from coated/uncoated ZnO NPs than bulk
<100 ppm -positive effects and 1000 ppm –phytotoxic[6]

Increased grain yield by ZnO NPs and $ZnSO_4$ at low NPK
Increased grain Zn by NPs and ions[7]

[1] *Peralta-Videa, J.R. et al. (2014) Plant Physiol Biochem 80, 128-135;*
[2] *Priester, J.H. et al. (2012) Proc Natl Acad Sci 109, E2451-EE2456;*
[3] *Zhao, L. et al. (2015) Environ Sci Technol 49, 2921-2928;*
[4] *Raliya, R. et al. (2015) Metallomics 7, 1584-1594;*
[5] *Garcia-Gomez, C. et al. (2017) Sci Total Environ 589, 11-24*
[6] *Moghaddasi, S. et al. (2017) Ecotox Environ Safe 144,543-551*
[7] *Dimpka, C. et al. (2017) J Agric Food Chem 65, 8552-8559*

ZnO ENMs

~ UV attenuation

~ Antimicrobial properties

~ Water/oil affinity

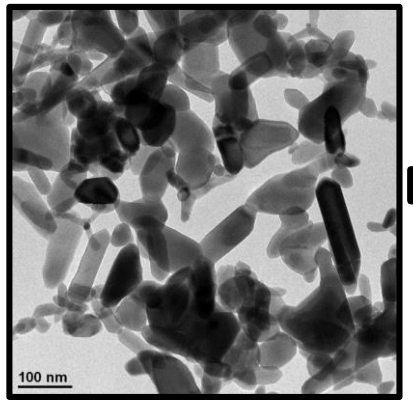
BASF (2000)

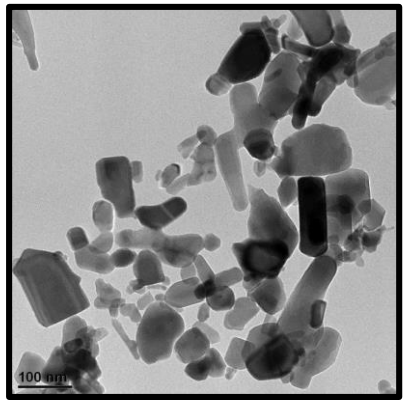
Z-COTE®
Uncoated
Amphiphilic
Water formulations

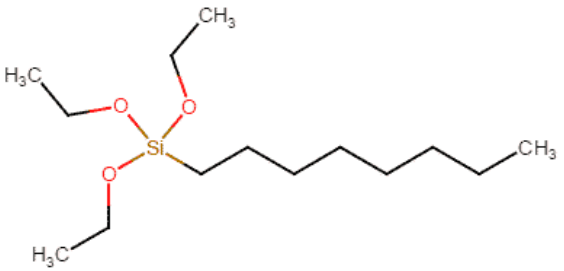
BASF
The Chemical Company

Z-COTE® HP1
Coated with
triethoxycaprylylsilane
-binder and emulsifier-
Hydrophobic
Oil phase formulations

Z-COTE®		Z-COTE HP1®
10-300 nm	Primary size	10-300 nm
Hexagonal	Phase and structure	Hexagonal
Elongated shape	Shape/Morphology	Elongated shape
16.6 m^2/g	Surface area	13.1 m^2/g
286 ± 2 nm	Size in DI water (50 µg/mL)	276 ± 7 nm
21.8 ± 0.8 mV	Zeta potential in DI water	-23.6 ± 0.9 mV
99.1 ± 0.2 %	Purity	98.2 ± 0.6 %







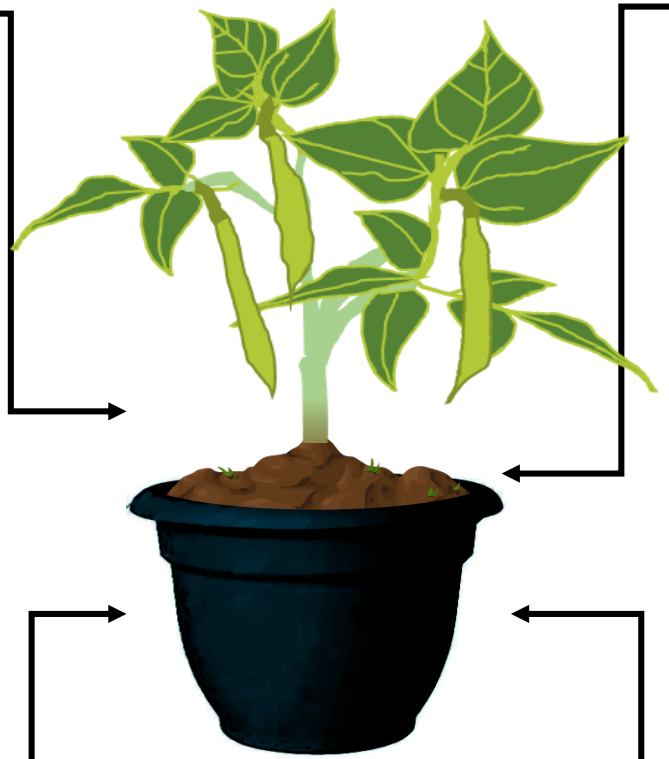
Medina-Velo et al. (2017) J Hazard Mater, 332: 214–222

4 compounds

- Z-COTE
- Z-COTE-HP1
- Bulk ZnO
- $ZnCl_2$

5 concentrations

- 0 mg/kg (Control)
- 62.5 mg/kg
- 125 mg/kg
- 250 mg/kg
- 500 mg/kg



Plant

Red Hawk kidney bean

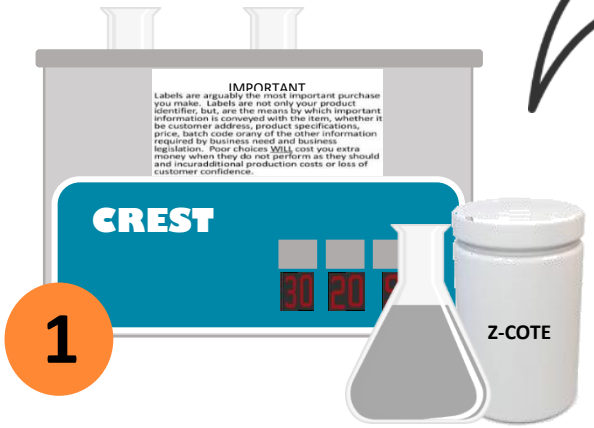
Soil

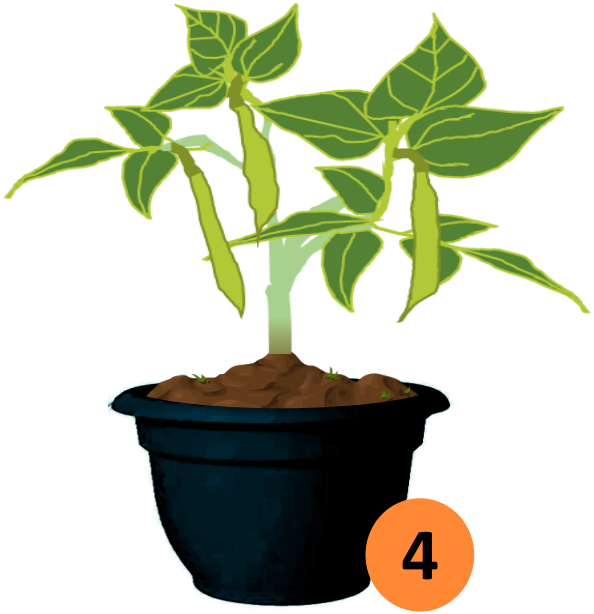
50% natural soil
+
50% potting mix

Harvest time

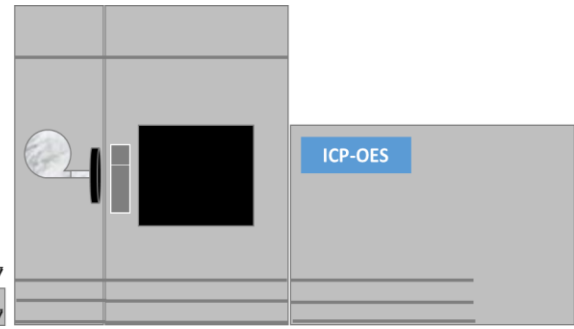
- 45 days (young pods)
- 100 days (first generation)
- 100 + 100 days (second generation-no NMs)

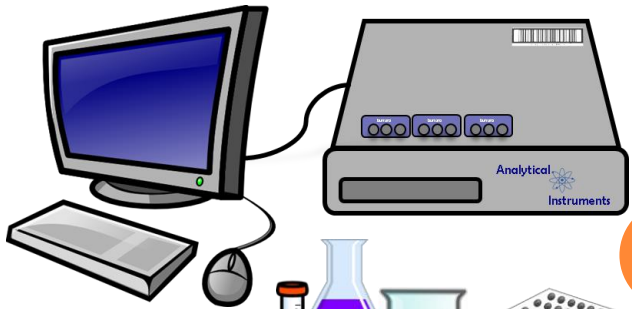
Plant exposure

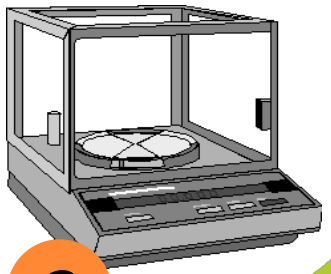


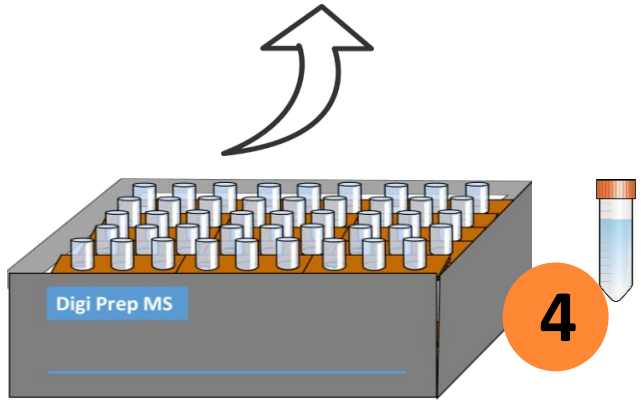


Seeds analyses



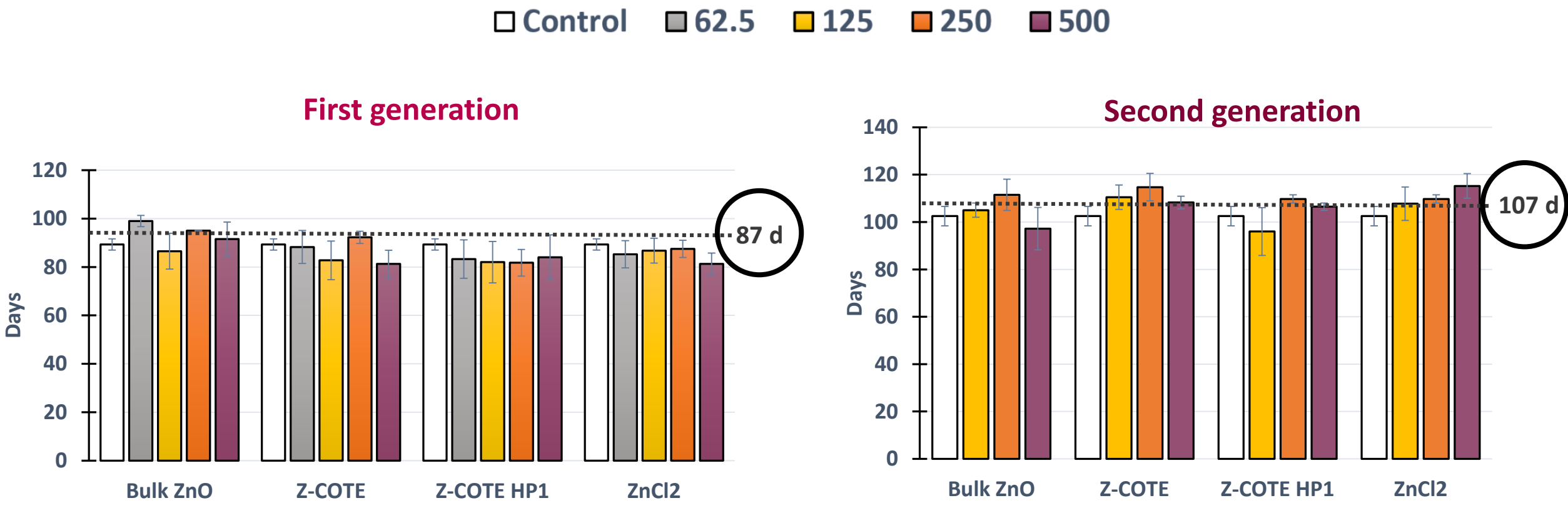






Days to harvest maturity

· Plants from second generation took 20 days more to reach harvest maturity



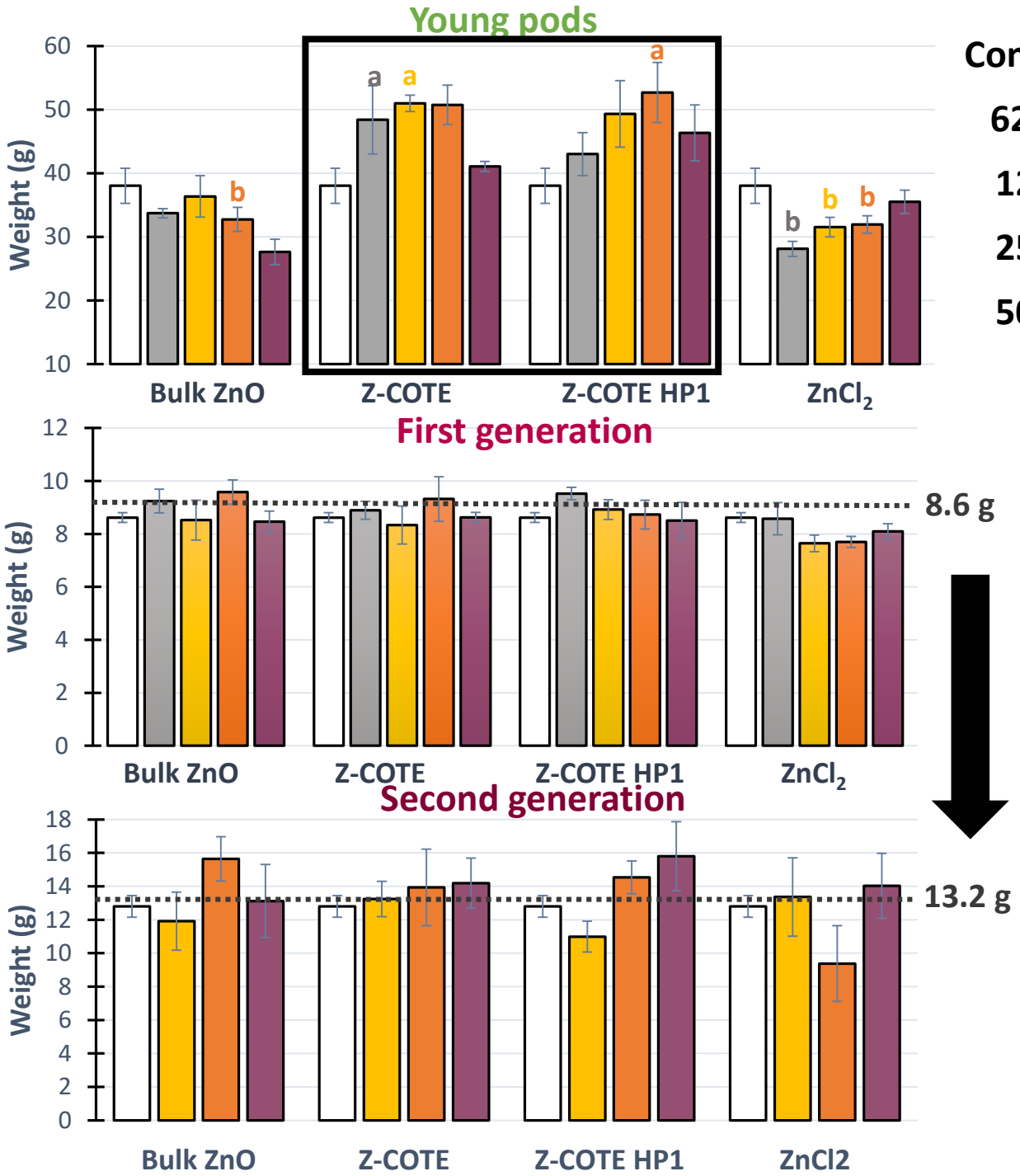
Medina-Velo et al. (2017) Environ Sci Nano (in press); Medina-Velo et al. (manuscript in preparation)

Pod production

· In young pods, the exposure to ZnO NMs increased pod production in comparison to bulk and ionic compounds

Pod production was not compromised

· Pod production increased by 53% in the second generation



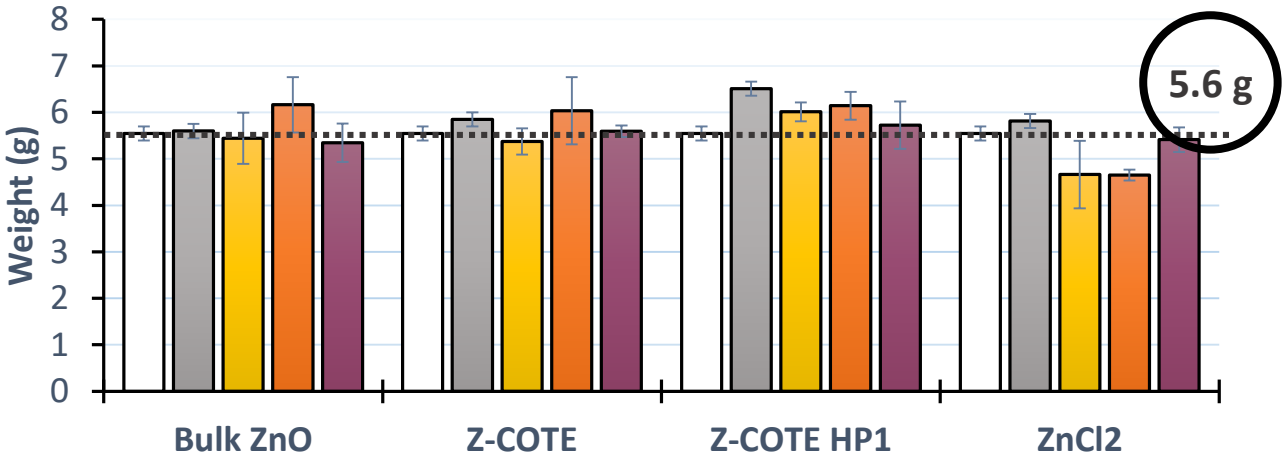
Medina-Velo et al. (2017) Environ Sci Nano (in press);
Medina-Velo et al. (manuscript in preparation)

Seed production

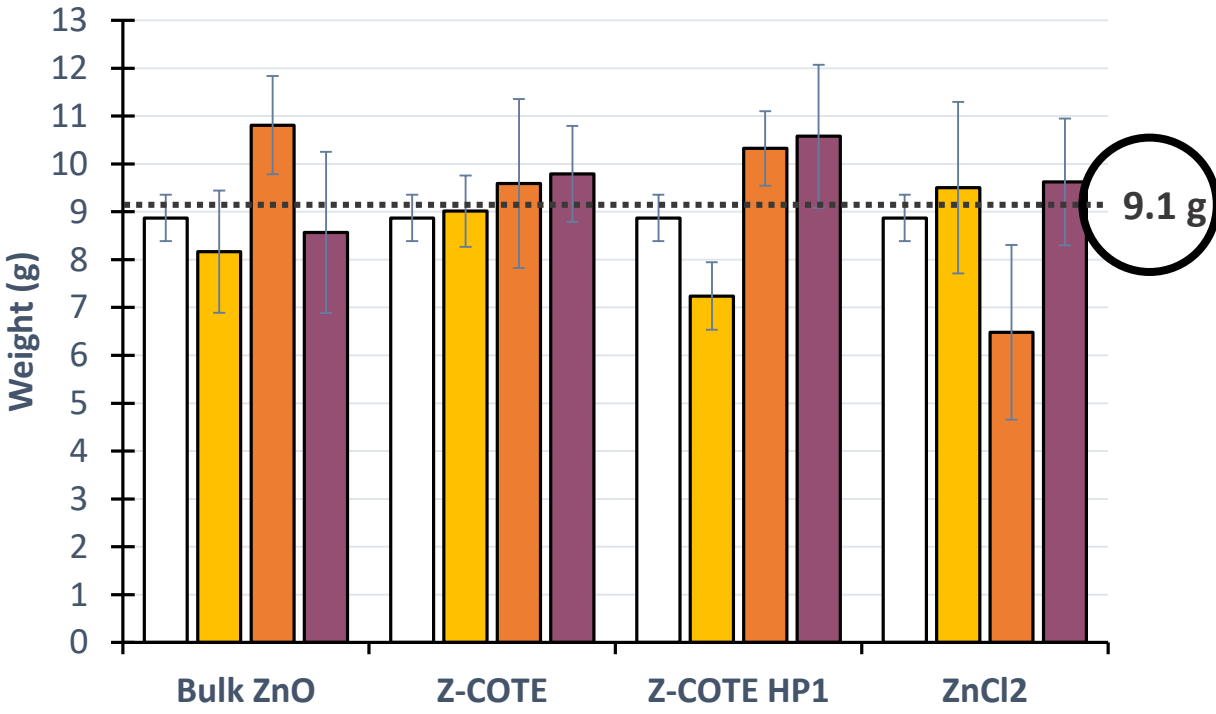
- Seed production was not compromised in comparison to controls
- Second generation plants produced more seeds

Control 62.5 125 250 500

First generation



Second generation



Medina-Velo et al. (2017) Environ Sci Nano (in press); Medina-Velo et al. (manuscript in preparation)

Zn accumulation

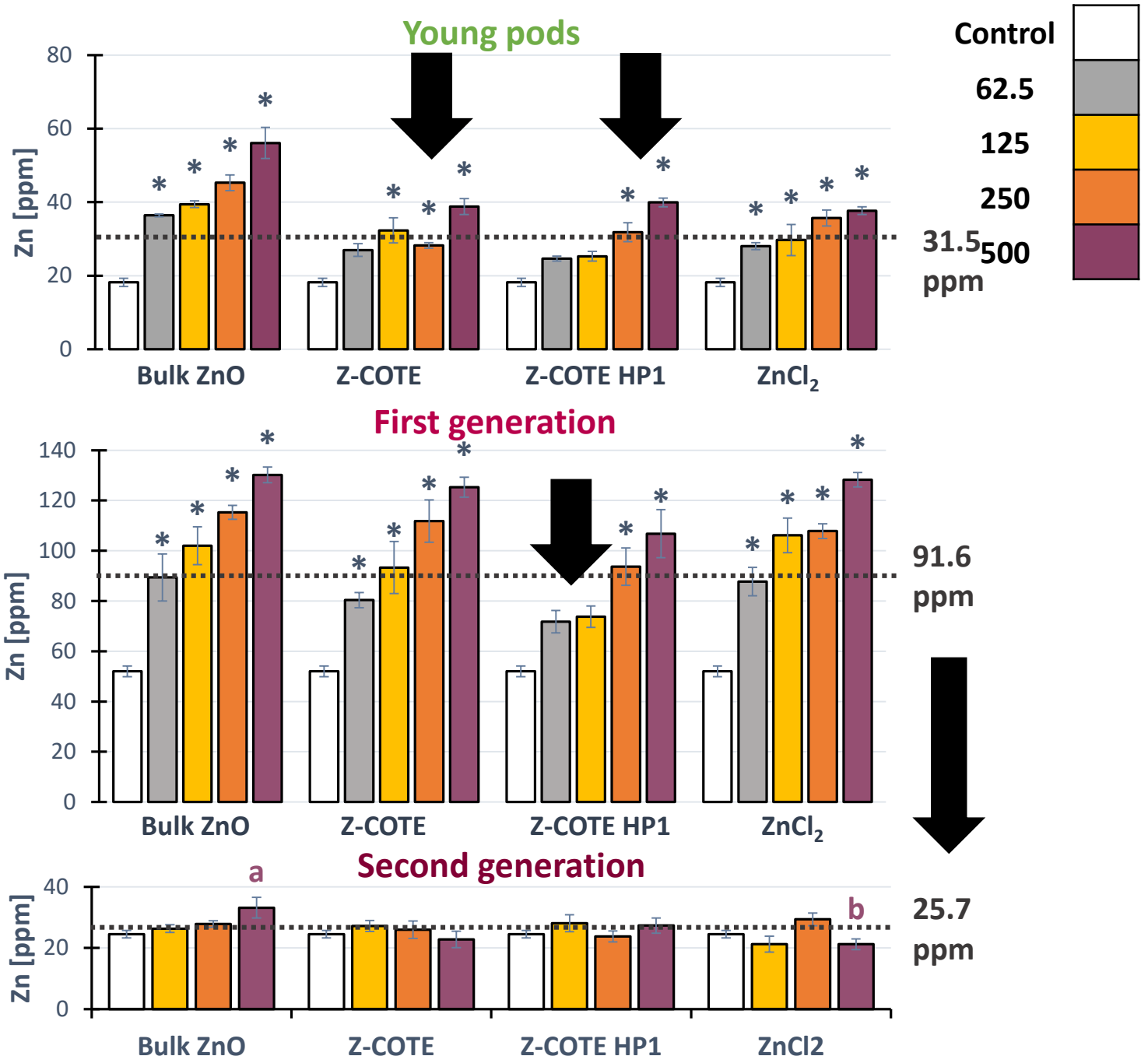
· In young pods, significant Zn accumulation by ZnO NMs only at high concentrations

· In seeds of first generation the lowest concentrations of Z-COTE HP1 did not increase Zn

Concentration-dependent Zn accumulation

· Lower seed Zn in second generation

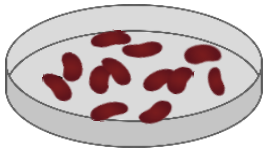
Medina-Velo et al. (2017) Environ Sci Nano (in press);
Medina-Velo et al. (manuscript in preparation)



Mineral composition

Young pods

Mn	↑ 65% - Bulk · 500 ↑ 60% - $ZnCl_2$ · 500
K	↓ 22% - Z-COTE · 500



First generation

K	↑ 15% - $ZnCl_2$ · 500
Ni	↓ 37% - Bulk · 500 ↓ 44% - Z-COTE · all ↓ 51% Z-COTE HP1 · 125 and up

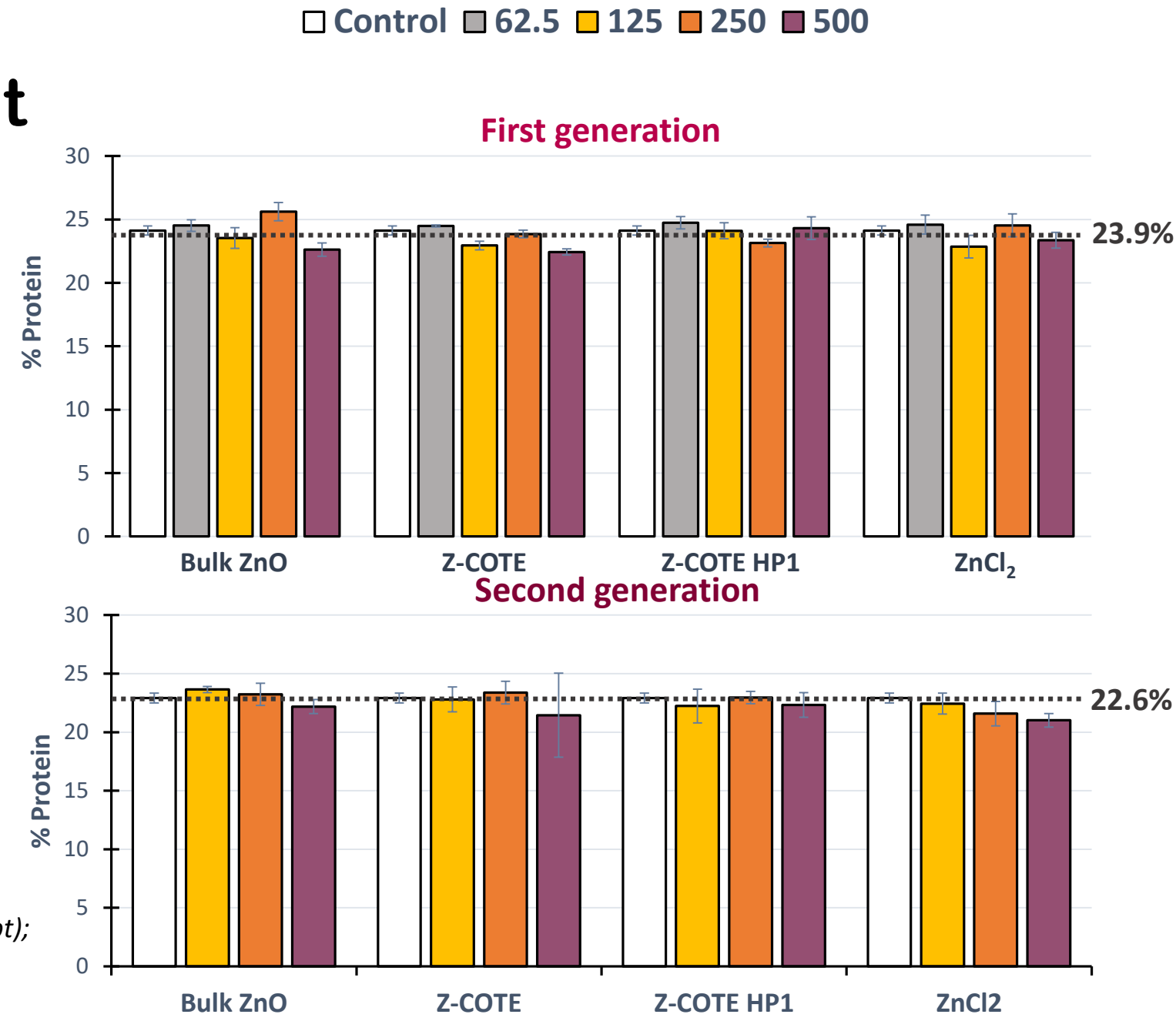
Second generation

Ni	↓ 63% - Z-COTE · 500 ↓ 62% - Z-COTE HP1 · 125 ↓ 76% Z-COTE HP1 · 500
Ca	↑ 54% - Bulk · 500

Medina-Velo et al. (2017) Environ Sci Nano (in press); Medina-Velo et al. (manuscript in preparation)

Protein content

- Protein content remained unaffected in both generations

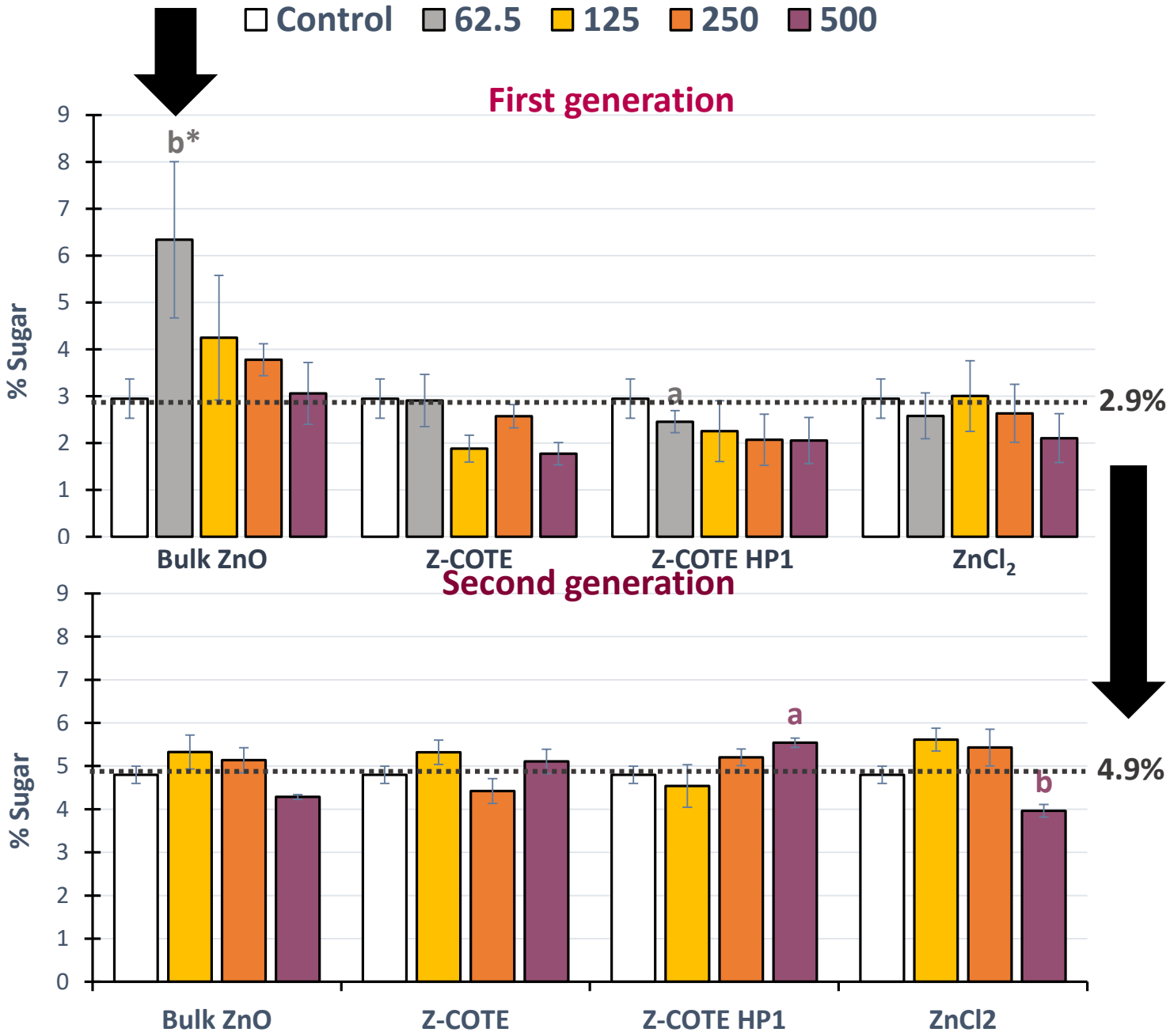


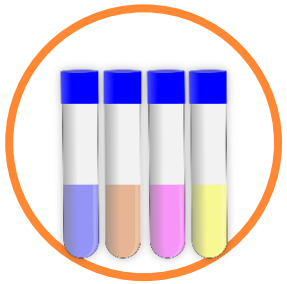
Medina-Velo et al. (2017) Environ Sci Nano (accepted manuscript);
Medina-Velo et al. (manuscript in preparation)

Sugar content

- In first generation seeds, bulk ZnO at 62.5 mg/kg increased sugar accumulation in the seeds
- Seeds from bulk ZnO had the highest sugar
- Sugar was generally not compromised
- Sugar in seeds increased in the second generation

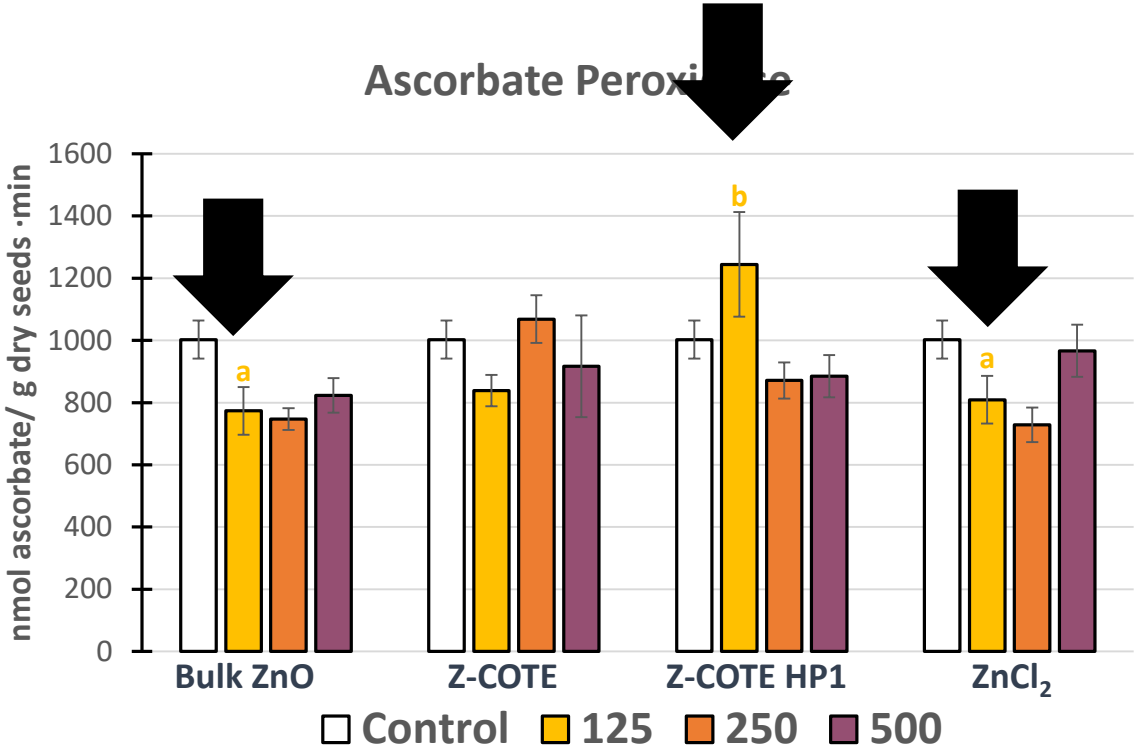
Medina-Velo et al. (2017) Environ Sci Nano (in press)





Enzymatic activity of young seeds from the second generation

- Activity of ascorbate peroxidase increased with 125 ppm of Z-COTE HP1 in comparison to bulk and $ZnCl_2$



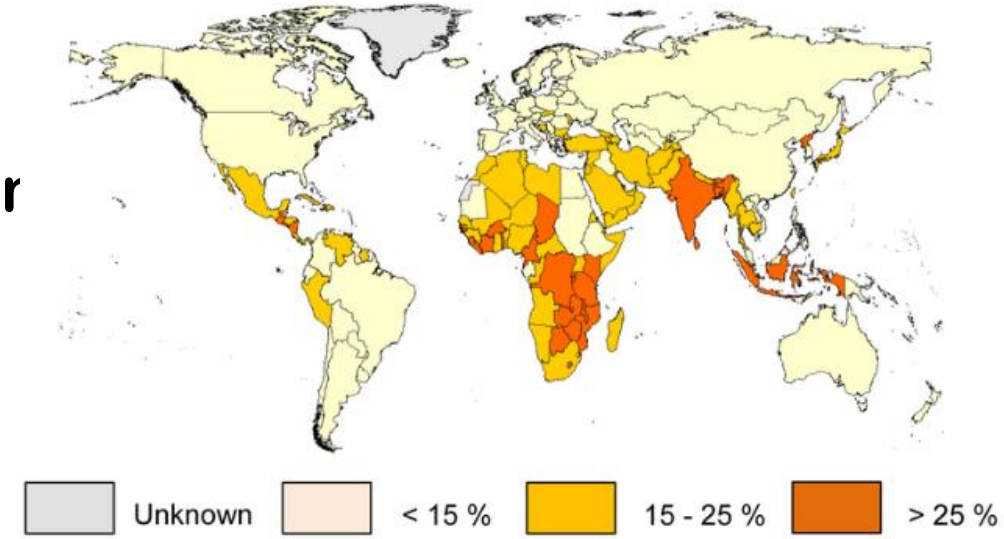
- Catalase remained unaffected

Medina-Velo et al. (manuscript in preparation)

Conclusions

- Zn accumulates in a dose-dependent fashion
- No residual accumulation of Zn in second generation
- ZnO NMs did not have negative effects in seed production and nutrients (except Ni)
- Further studies in the residual effect on seed Ni are required
- Use of ZnO NMs could be possibly used in Zn-deficient soils without negative impact in bean nutrients and productior
  - Zn-enriched beans

Estimated country-specific prevalence of inadequate zinc intake



Wesells, K.R. and Brown, K.H. (2012) PLos ONE 7 (11) 50568

Acknowledgments

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Consejo Nacional de Ciencia y Tecnología

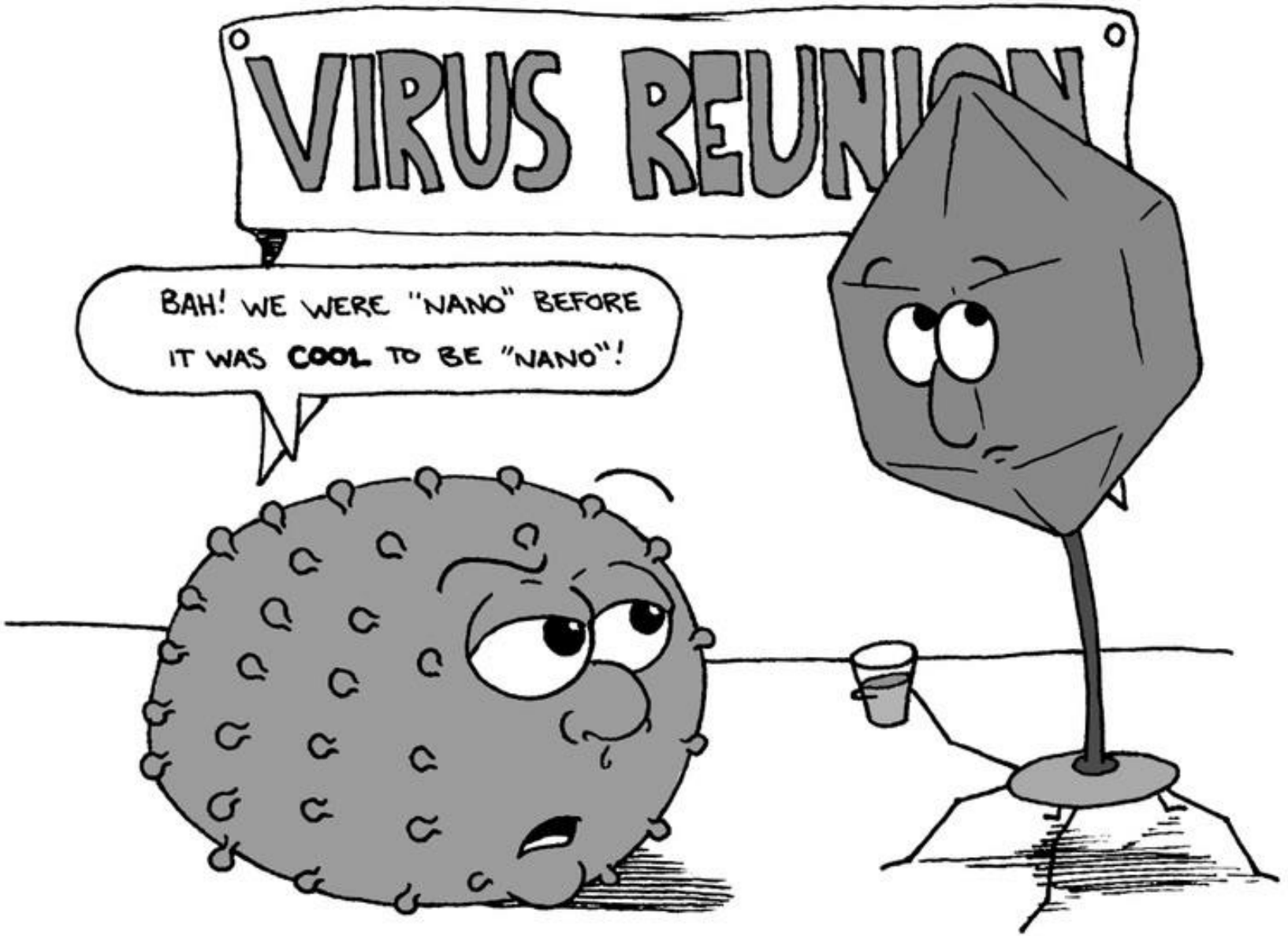
USDA

NEWT

CAES
The Connecticut Agricultural Experiment Station
Putting Science to Work for Society since 1875

♦Dudley family for the Endowed Research Professorship

♦Dr. James Kelly, Michigan State University



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