Sustainable Nanotechnology Organization
Research | Education | Responsibility

Trans-generational effects of nano-TiO_2 with different surface properties on basil (*Ocimum basilicum*)

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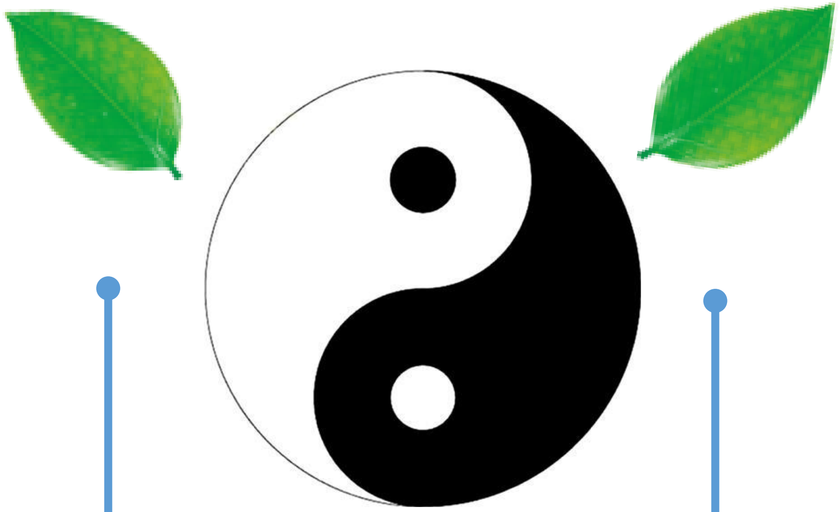
Background – Taiji, nanotechnology, and plants

- **Properties:** Size, surface functionalization, surface area, band gap, electroconductivity, antibacterial, and among others.

- **Application:** Pigment, food additive, herbicide, skin care, glass, fertilizer, water treatment, medicine care, and among others.

(Nel. et al., 2013)



Everything begins with two poles, the white is yang, and the black is yin.

----- I Ching

- The fate, speciation, and translocation of nanomaterials (Gardea-Torresdey et al., 2014)

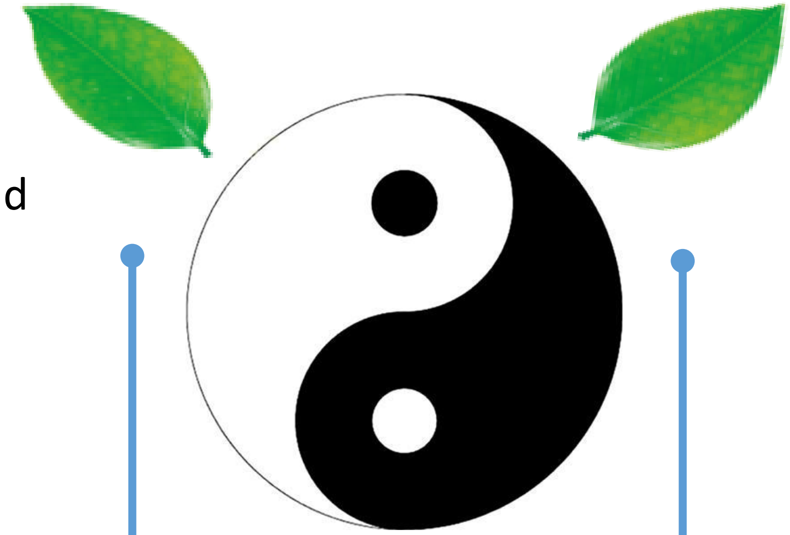
- Understanding of molecular and biochemical responses of plants to NMs stress (Ma et al., 2015)

- Long-term impacts in plant system (Servin and White, 2016)

Background – Taiji of TiO_2 Nanoparticles

Manufactured products

- **Food additive:** E171 (extracted from a natural white mineral)
- **Pigment:** P25 (mixture of anatase and rutile)
- **Skin care:** M212, M262 (rutile, with coatings)
- **Photocatalyst:** Fluka, A.R. (rutile)
- **Plastic, painting:** TR28, TR92, R1530 (rutile, with coatings)

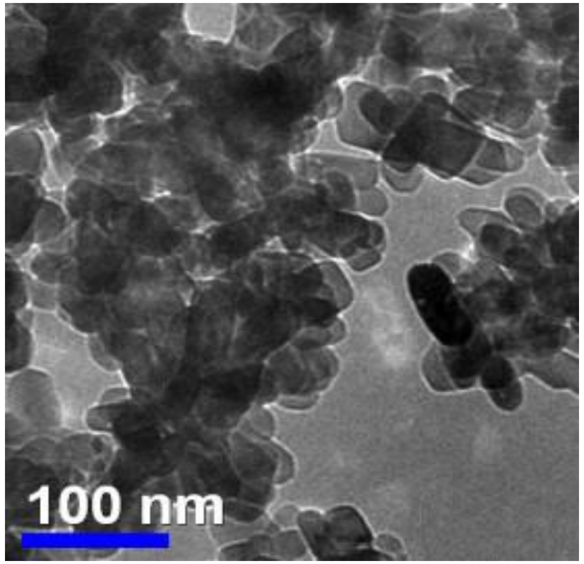


- **Cucumber:** root-to-fruit translocation (Servin et al., 2013)
- **Lettuce:** paint-aged *n*-TiO_2, shoot-to-root translocation (Larue et al., 2014)
- **Onion:** decrease mitotic index and increase chromosomal aberrations (Pakrashi et al., 2014)
- **Flax and Fennel:** enhance germination rate and root length (Clément et al., 2013)
- **Spinach:** increase enzymatic activities (Hong et al., 2005)

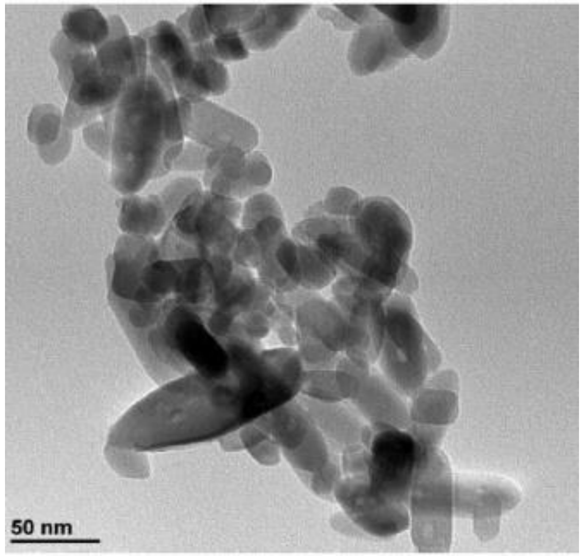
Multi-generational effects

The role of surface coating

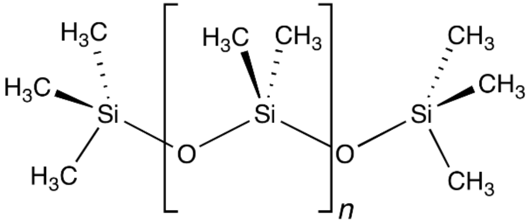
Methodology – Characterization of nano-TiO_2

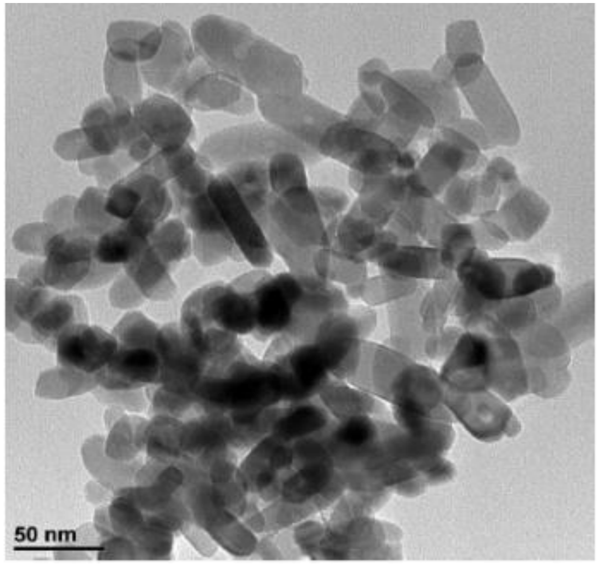


Pristine: plain rutile nano-TiO_2

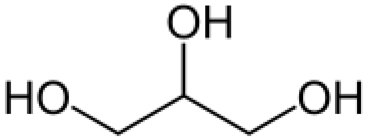


Hydrophobic: M262, capped with Al_2O_3 and encapsulated with dimethicone





Hydrophilic: M212, coated with Al_2O_3 and encapsulated with glycerol



US research Nanomaterials, Inc. & C. Chang et al.

Methodology – Characterization of nano-TiO_2

Properties	Nanoparticles		
	Pristine TiO_2	Hydrophobic TiO_2	Hydrophilic TiO_2
Size (nm)	25-70	25-70	25-70
Crystal phase	Tetragonal, rutile	Tetragonal, rutile	Tetragonal, rutile
Surface area (m^2/g)	20-40	47.6	55.7
Hydrodynamic size (nm)	341 ± 10	261± 5	282 ± 7
Zeta potential in DI water (mV)	-14.7 ± 0.5	27.0 ± 0.9	26.9 ± 0.5

Anatase and rutile mixture, P25 (Previous studies)

Rutile, preferential translocation in cucumber (Servin et al., 2012)

US research Nanomaterials, Inc. & C. Chang et al.

Background – Basil (*Ocimum basilicum*)

http://www.precisionnutrition.com/wordpress/wp-content/uploads/2009/11/basil-bsp.jpg

https://en.wikipedia.org/wiki/Pesto#/media/File:Pasta_with_pesto.jpg

https://en.wikipedia.org/wiki/Pho#/media/File:Pho_in_Saigon.jpg

http://www.bing.com/images/search?q=Basil&view=detailv2&&id=8B54A65E2B0E7DD90372F5DF8E8D94958FF06F30&selectedIndex=7&ccid=D%2bvsxykc&simid=608031507288426172&thid=OIP.M0febecc7291cf254480adfcfe94c044ao0&ajaxhist=0

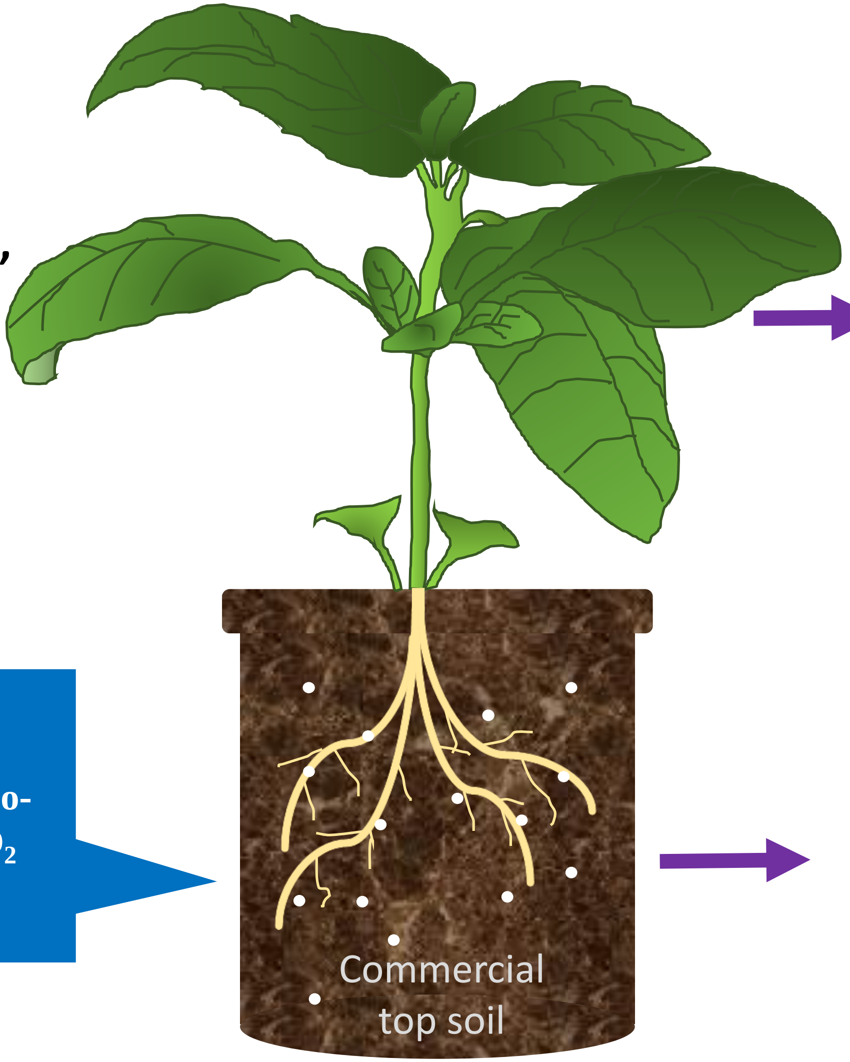
- **A culinary herb prominently featured in European and Asian cuisine. → Fresh**
- **Essential oil, medicinal value.**
- **Shoots, roots and seeds.**

UTEP · United States Environmental Protection Agency · NSF · USDA · UC CEIN

Previous project

Harvested at 65 days, flowering time

Pristine
Hydrophobic } nano-TiO_2
Hydrophilic



750 mg·kg^{-1}		
Physiological and biochemical effects		
Pristine	↓	Biomass
		Reducing sugar
		CAT, APOX
Hydrophobic	↓	Germination rate
		Biomass
		Root length
		Starch
		CAT, APOX
Hydrophilic	↓	Germination rate
		Total sugar
		APOX

Ti accumulation in root (mg·kg^{-1})	
Control	15.3 ± 5.0 c
Pristine	86.1 ± 9.4 b
Hydrophobic	160.4 ± 13.2 a
Hydrophilic	113.9 ± 14.9 b

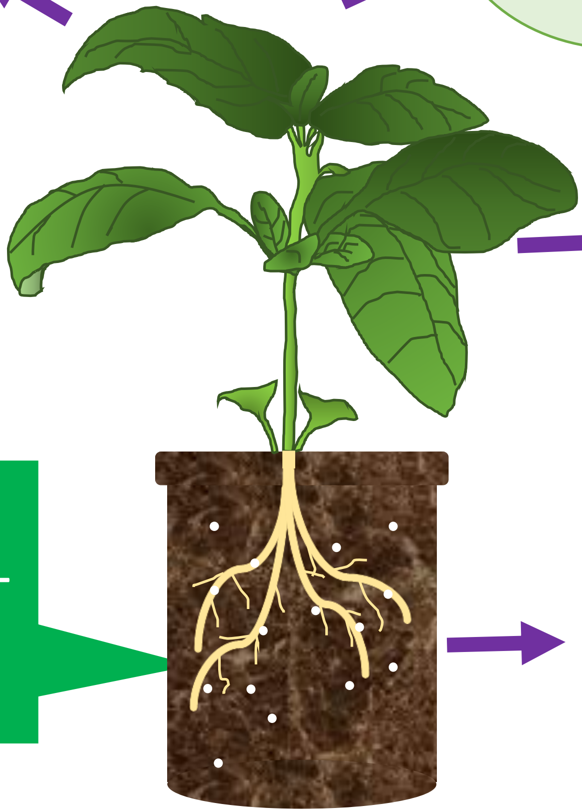
W. Tan et al., Environmental Pollution, submitted.

Methodology

Nanoparticles-treated parents plants (135 days)

Pristine
Hydrophobic
Hydrophilic

nano-TiO_2



Chlorophyll content
UV/Vis

Agronomical parameters

Photosynthesis parameters
gas exchange system

Nutritional elements
ICP-OES

Experimental design

Type of NPs	Name	Seeds from parent plants (without, -; with +)	Same TiO_2 nanoparticles at 750 mg·kg^{-1} (without, -; with +)
	Control-0	-	-
Pristine Hydrophobic Hydrophilic nano-TiO_2	Control-750	-	+
	Treated-0	+	-
	Treated-750	+	+

Effects caused

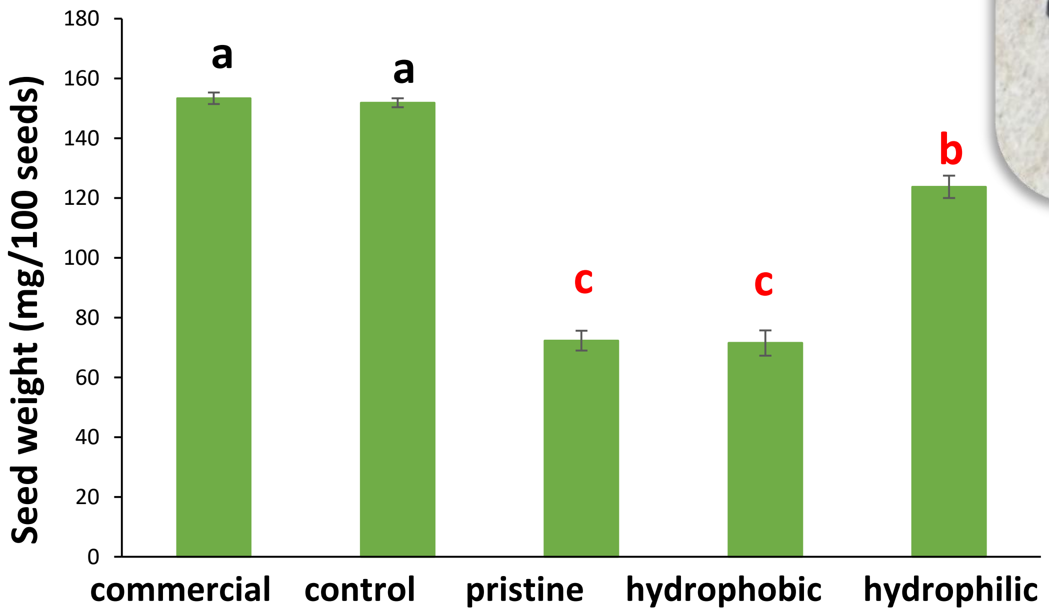
Behaviors of second generation seeds

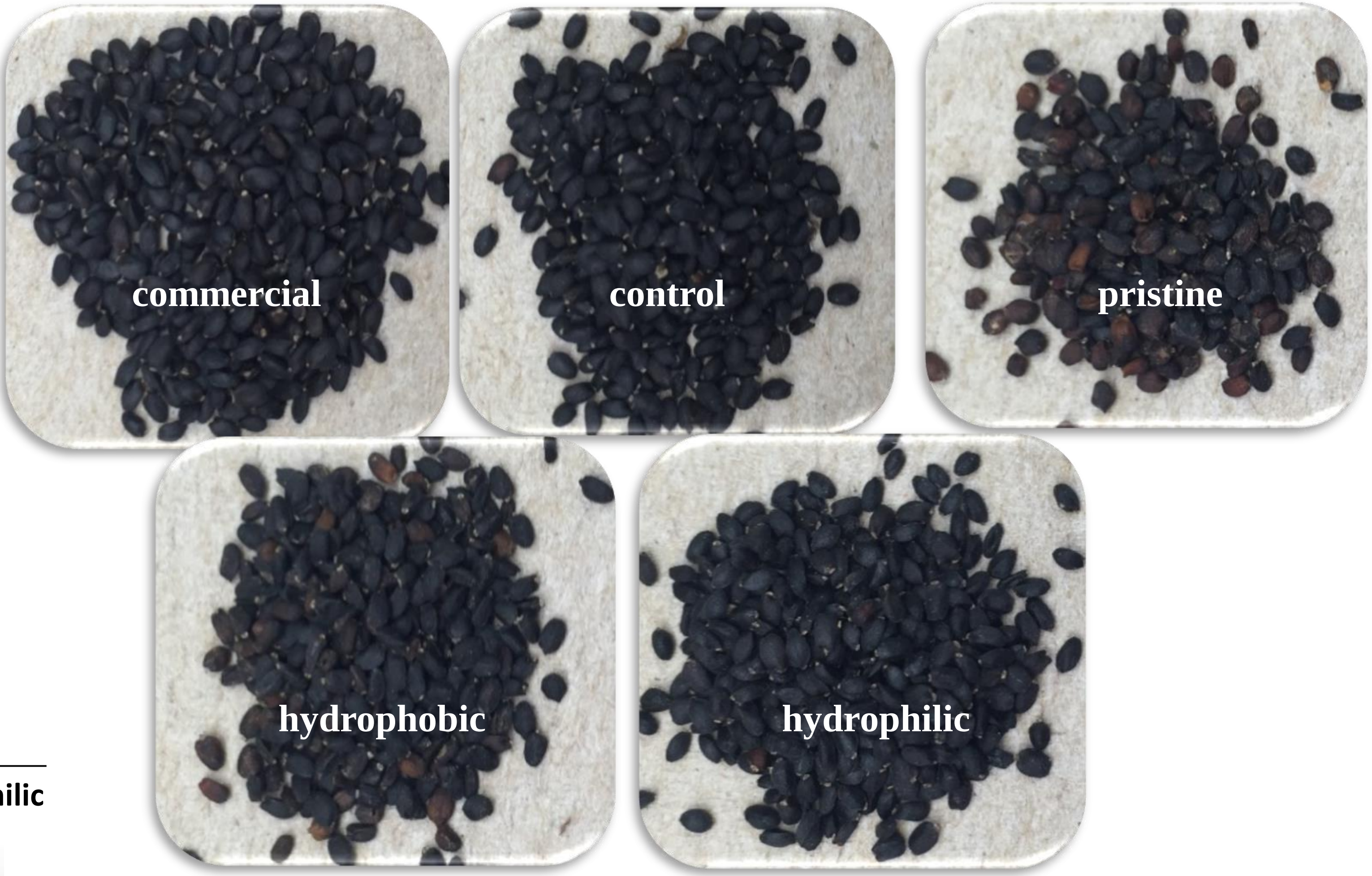
Interaction of treated seeds and nano-TiO_2

Wang Q, Ebbs SD, Chen Y, et al. Metallomics,

Results - Seed production

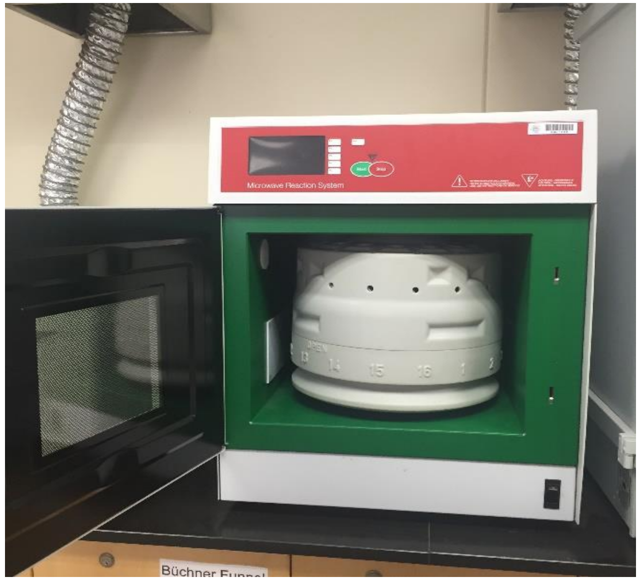
At 135 days, harvested seeds from control, or treated with pristine, hydrophobic, and hydrophilic nano-TiO_2 at 750 $mg \cdot kg^{-1}$





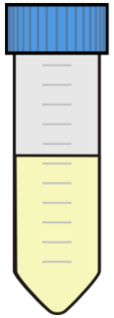
Results - Nutritional elements

Dry tissue sample

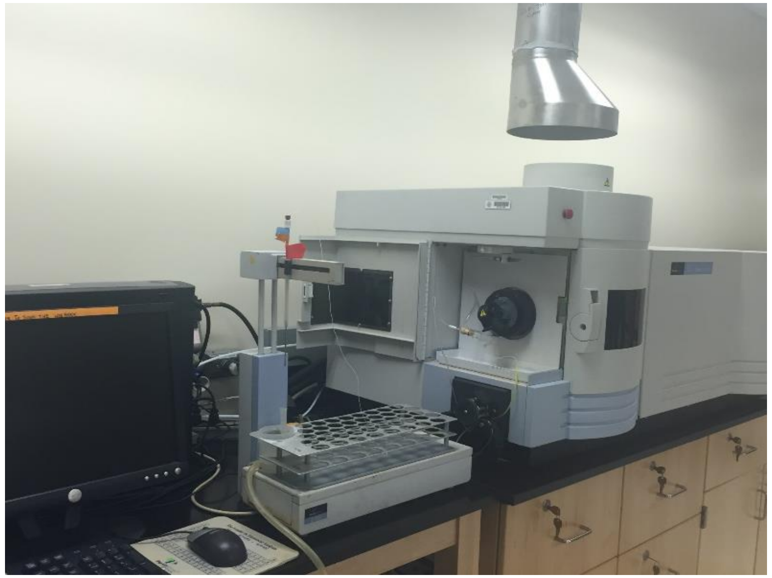


2 ml HNO_3,
1 ml H_2O_2,
5 ml H_2SO_4

C. Larue et al., J Hazard Mate 2014, 273, 17-26

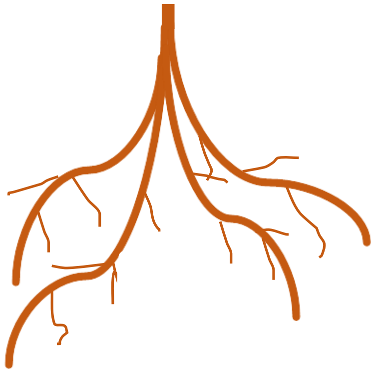


ICP-OES



Macro-elements
Al, Ca, Mg, K, S, P
Micro-elements
Fe, Se, Zn, Cu, Mn, B, Mo, Ni, Co

Results - Nutritional elements



Tissue	Treatment	Element
Pristine	Control-750	Zn
	Treated-0	Zn
	Treated-750	Mg, Zn
Hydrophobic	Control-750	Al, Co, Fe
	Treated-0	--
	Treated-750	--

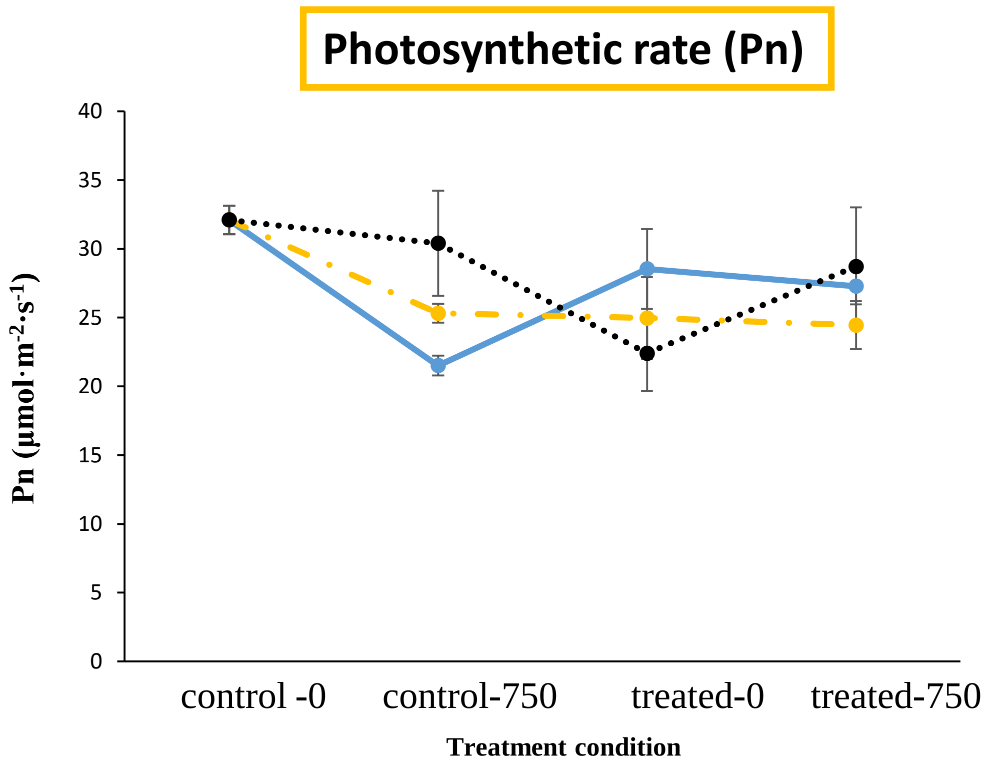
Tissue	Treatment	Element
Pristine	Control-750	Ni
	Treated-0	--
	Treated-750	Fe
Hydrophobic	Control-750	--
	Treated-0	--
	Treated-750	Mg

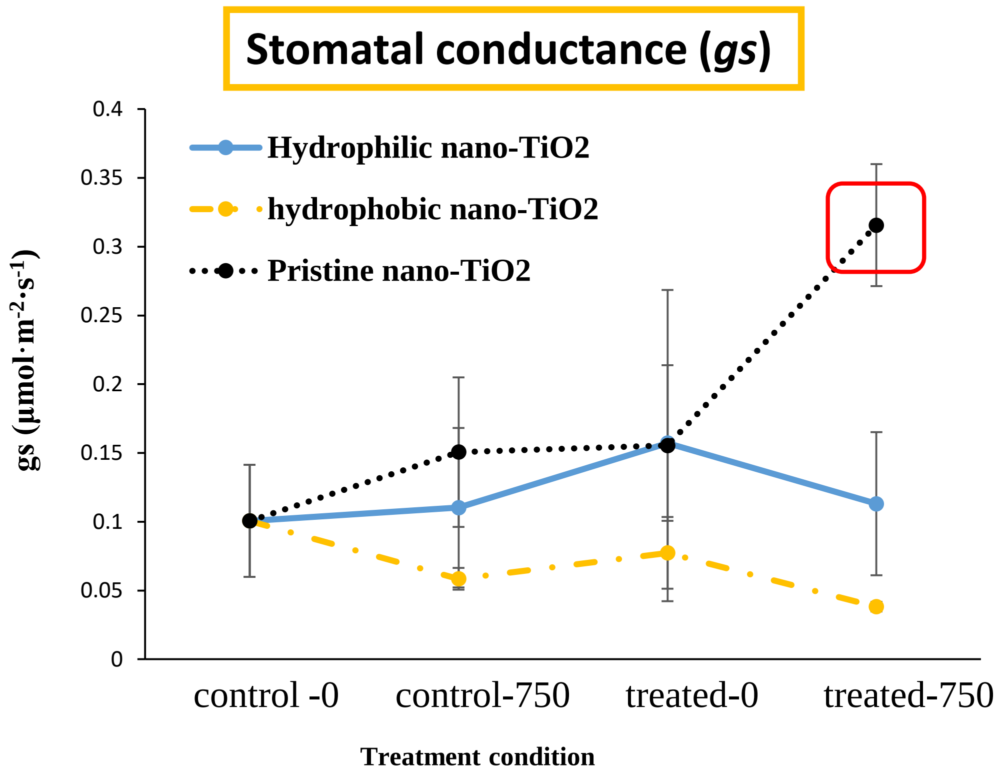
Results – Agronomical parameters

No significant difference in germinated seeds number, and root length

	Treatment	Pristine	Hydrophobic	Hydrophilic
Shoot length (cm)	Control-0	35.5 ± 2.2	35.5 ± 2.2 b	35.5 ± 2.2
	Control-750	38.0 ± 1.9	35.5 ± 1.5 b	37.1 ± 4.0
	Treated-0	39.4 ± 2.3	43.0 ± 1.6 a	35.6 ± 1.7
	Treated-750	39.3 ± 0.4	42.2 ± 0.6 a	35.5 ± 1.3
Biomass (%)	Control-0	9.5 ± 0.8	9.5 ± 0.8 b	9.5 ± 0.8
	Control-750	11.0 ± 1.5	13.4 ± 1.6 ab	12.0 ± 1.5
	Treated-0	10.7 ± 1.0	13.2 ± 1.3 ab	12.3 ± 0.6
	Treated-750	9.9 ± 1.0	13.8 ± 0.5 a	12.1 ± 1.5

Results - Photosynthetic parameters





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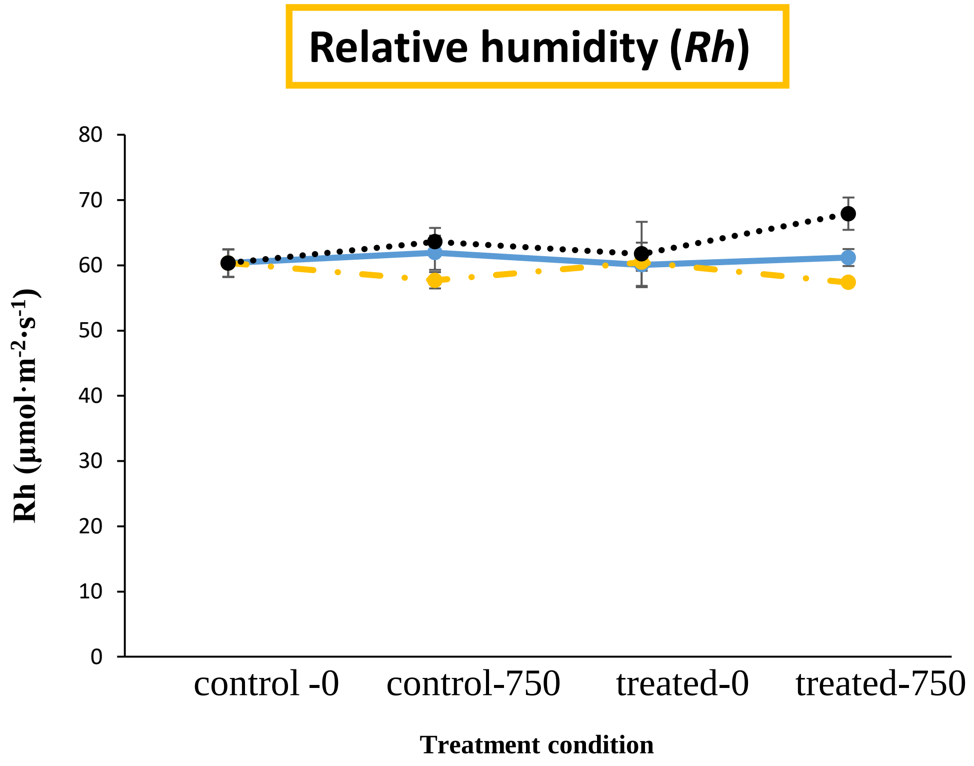
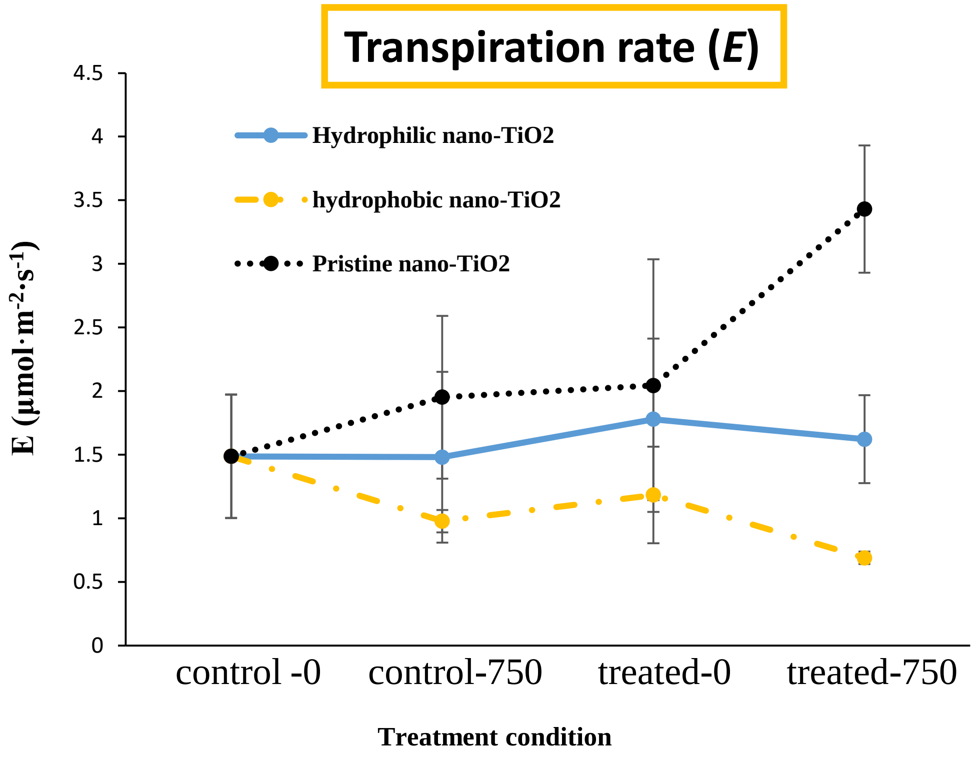
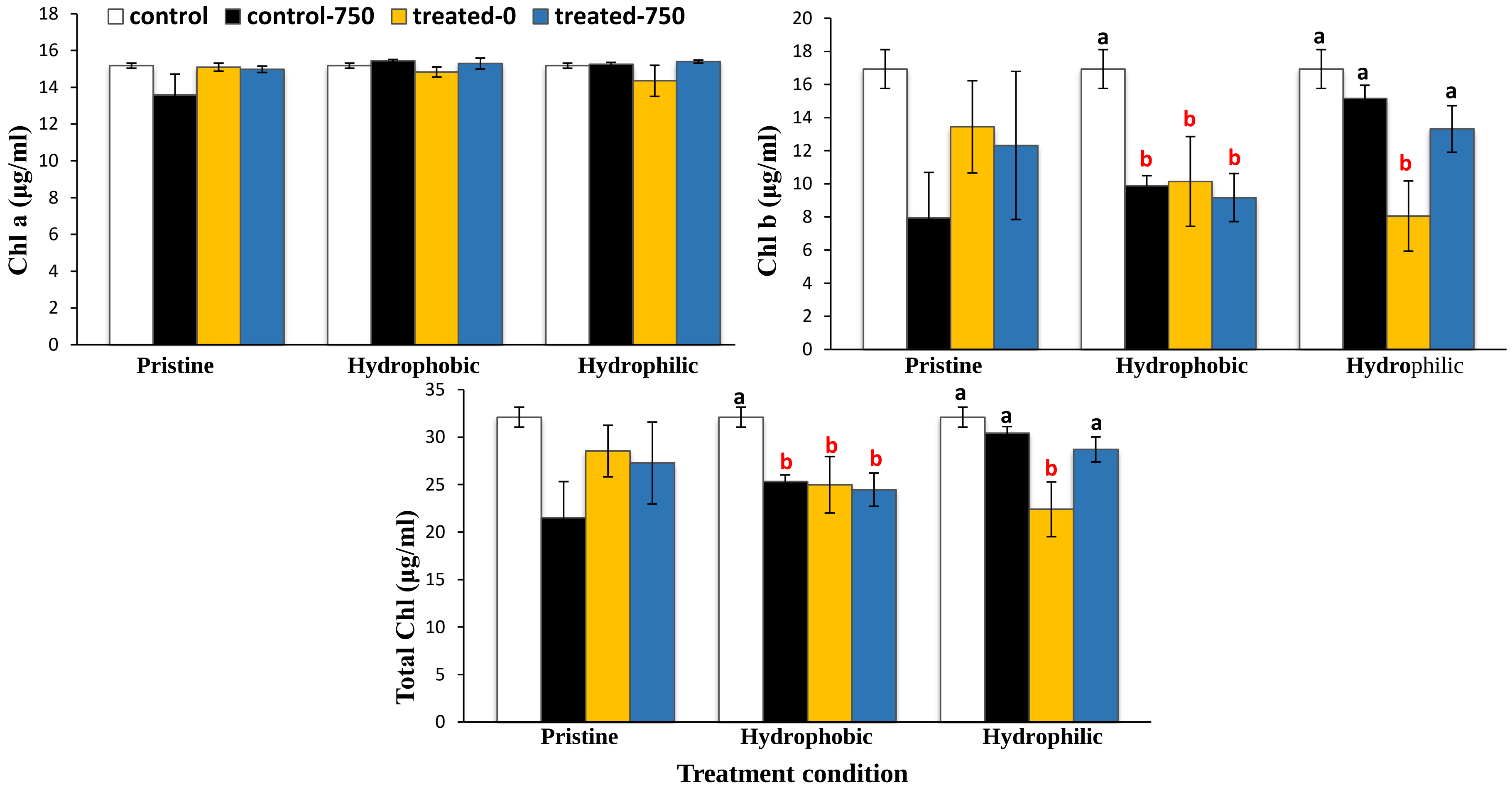
Results - Photosynthetic parameters





Results - Chlorophyll content



Conclusion - Transgenerational effect

Effects by NPs

- ❖ **Hydrophobic → lower chlorophyll b and total chlorophyll content**
- ❖ **Pristine → higher Mg, Zn in root and Ni in shoot**

2^{nd}-gen seeds

- ❖ **Hydrophobic → longer shoot length.**
- ❖ **Hydrophobic, hydrophilic → lower chlorophyll b and total chlorophyll content**

Interaction of 2^{nd}-gen seeds and NPs

- ❖ **Hydrophobic → higher biomass and shoot length; lower chlorophyll b and total chlorophyll content**
- ❖ **Pristine → increase of stomatal conductance.**

Conclusion – Surface property

Pristine

- Treated-750: a significant increase of stomatal conductance
- Treated-0: lower chlorophyll b content
- increase of Mg, Zn, Fe, and Ni.

Hydrophobic

- Treated-750: higher biomass and shoot length
- Control-750: lower chlorophyll b content
- increase of Al, Co, Fe, Zn, Mg

Hydrophilic

- Control-750: lower chlorophyll b content

Acknowledgements

Go, miners!