Supporting Information for:

Nanoparticle surface charge influences uptake, translocation, and leaf distribution in vascular plants with contrasting anatomy

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Number of Pages: 18
Number of Figures: 14
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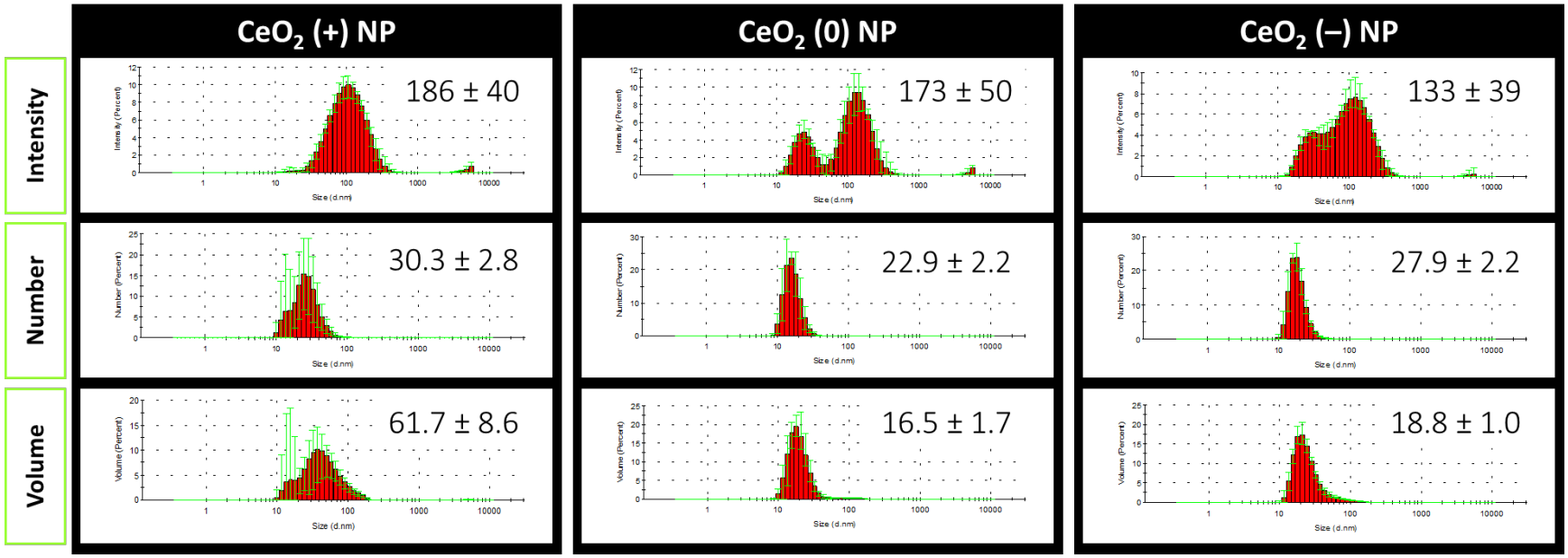

Figure S1. Intensity, number, and volume weighted distributions of the hydrodynamic diameters (nm) of CeO_2(+), CeO_2(0), and CeO_2(−) NPs at 50 mg-Ce/L in exposure medium (basal salt solution, pH=5.6). Values are presented with standard deviation over 5 replicates.

Table S1: Dissolved fraction of Ce remaining in solution after 48 h of hydroponic exposure to 50 mg-Ce/L as CeO_2(+), CeO_2(0) or CeO_2(−) NPs. The dissolved fraction was calculated as a percent of Ce concentration in ultra-filtered (3 kDa cutoff) suspensions divided by the total Ce concentration of the solution. Measurements were made in triplicate. Majority of the remaining Ce is not dissolved.

	Positive	**Neutral**	**Negative**
Corn	0.14 ± 0.08 %	0.02 ± 0.01 %	0.01 ± 0.01 %
Rice	0.04 ± 0.01 %	0.00 ± 0.01 %	0.05 ± 0.01 %
Tomato	0.04 ± 0.01 %	0.04 ± 0.01 %	0.02 ± 0.01 %
Lettuce	0.12 ± 0.01 %	0.03 ± 0.01 %	0.01 ± 0.01 %

Table S2: Total Ce concentrations on/in dried plant roots after 48 h of hydroponic exposure to 50 mg-Ce/L as CeO_2(+), CeO_2(0) or CeO_2(−) NPs. The reported values are means averaged from four replicates ± SD. Plant root surface area (SA) approximations were also averaged over four sets of plant roots per species.

Plant Species	Root SA (cm^2)	NP Surface Charge	Ce association with roots (mg/kg)
Corn	6.6 ± 1.2	(+)	13,640 ± 7,200
		(0)	5,730 ± 2,270
		(−)	3,700 ± 1,110
Rice	0.6 ± 0.2	(+)	20,780 ± 6,380
		(0)	2,230 ± 500
		(−)	1,470 ± 670
Tomato	11.3 ± 3.2	(+)	47,330 ± 3,100
		(0)	11,640 ± 1,320
		(−)	2,410 ± 1,450
Lettuce	1.3 ± 1.0	(+)	31,530 ± 4,690
		(0)	1,470 ± 670
		(−)	1,150 ± 770

Table S3: Ce L_{III} XANES linear combination fitting (LCF) results of roots after 48 h of hydroponic exposure to 50 mg-Ce/L as CeO_2(+), CeO_2(0) or CeO_2(−) NPs. Roots were rinsed for 30s in Ce-free medium prior to lyophilization and analysis. Spectra are shown in **Figure 4**.

	Positive				**Neutral**				**Negative**			
	Corn	Rice	Tomato	Lettuce	Corn	Rice	Tomato	Lettuce	Corn	Rice	Tomato	Lettuce
Ce(III)	-	-	-	-	18.0%	10.5%	18.8%	31.5%	-	7.6%	10.4%	23.9%
Ce(IV)	98.8%	96.9%	100.5%	89.4%	88.5%	89.8%	87.9%	80.6%	105.5%	94.3%	93.7%	85.8%
R Factor	0.0025	0.0008	0.0007	0.0035	0.0018	0.0018	0.0015	0.0094	0.0026	0.0032	0.0024	0.1910
Red. $\chi 2$	0.0011	0.0003	0.0004	0.0017	0.0008	0.0007	0.0084	0.0048	0.0013	0.0013	0.0014	0.0410

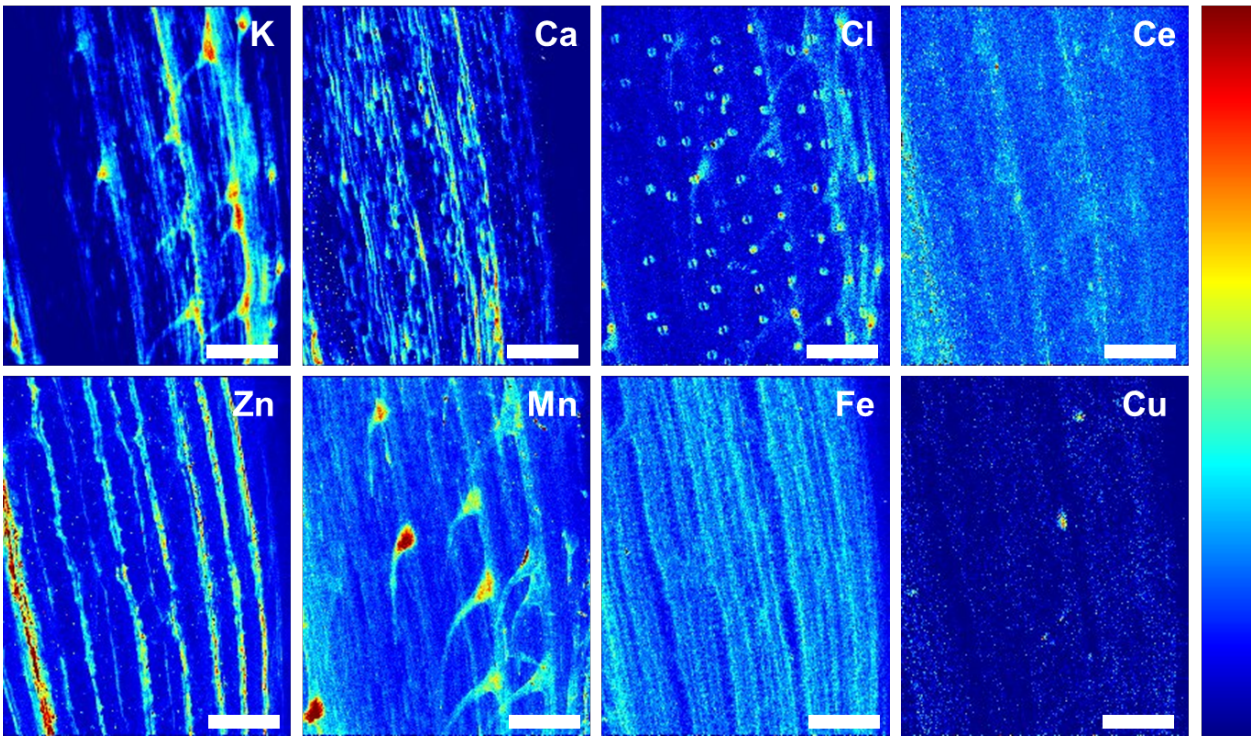

Figure S2. XRF maps showing elemental distribution in a corn leaf after 48 h of hydroponic exposure to 50 mg-Ce/L as CeO_2(−) NPs. Ce signal was not sufficient to perform μ-XANES. Scale bar=200 μm.

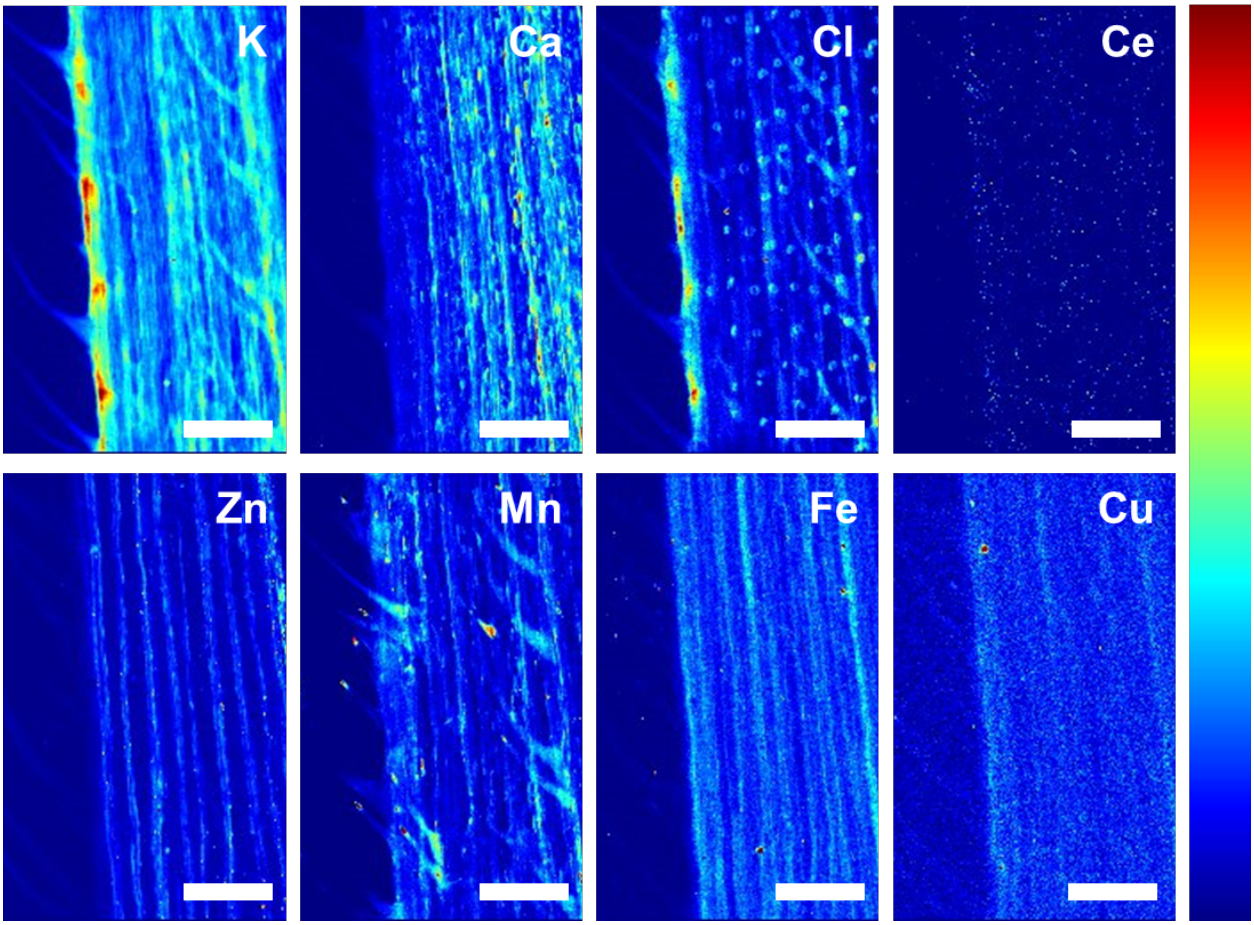

Figure S3. XRF maps showing elemental distributions in a corn leaf after 48 h of hydroponic exposure to 50 mg-Ce/L as CeO_2(0) NPs. Ce signal was not sufficient to perform μ-XANES. Scale bar=200 μm.

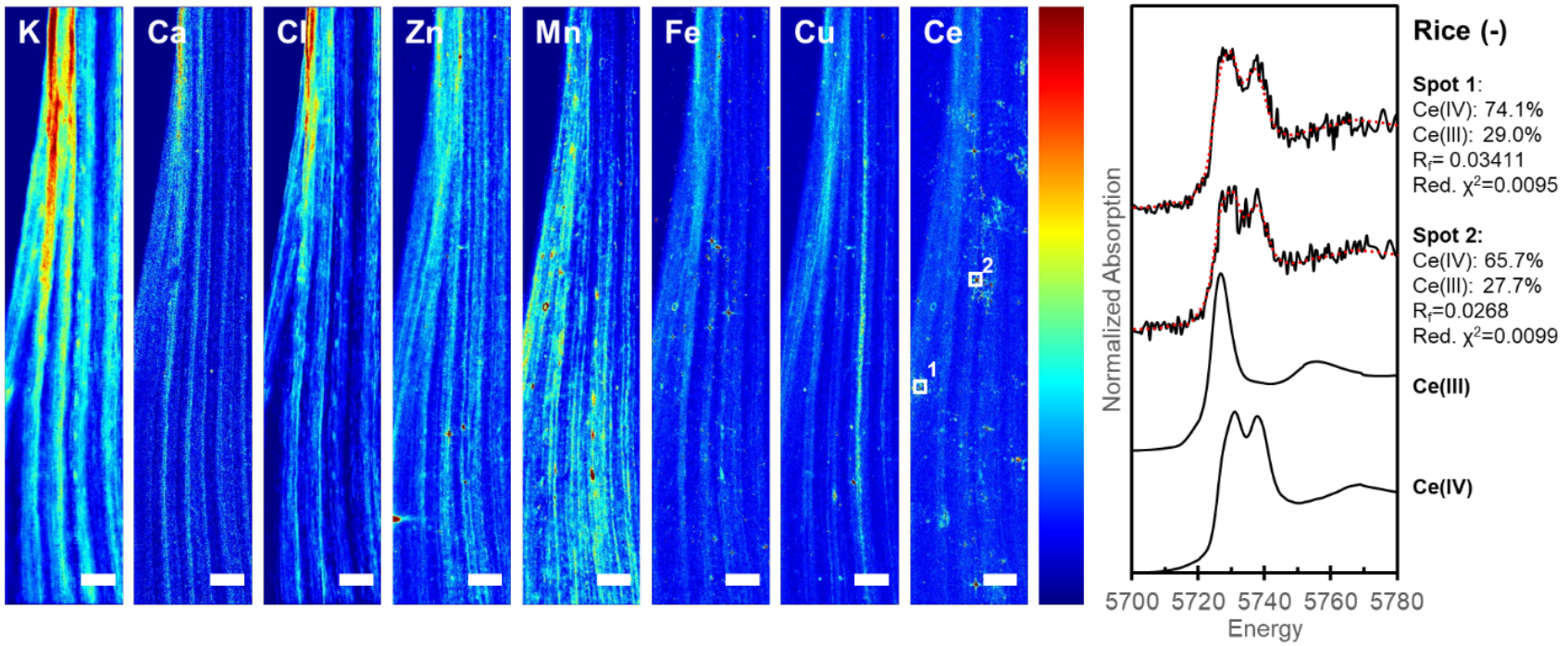

Figure S4. XRF maps showing elemental distributions in a rice leaf after 48 h of hydroponic exposure to 50 mg-Ce/L as CeO_2(−) NPs. Ce L(III) μ-XANES spectra (solid, black) from high intensity spots are indicated with white boxes on the Ce map. LCF results (dotted, red) are presented with fitting statistics and Ce(III) and Ce(IV) model compounds. Scale bar=200 μm

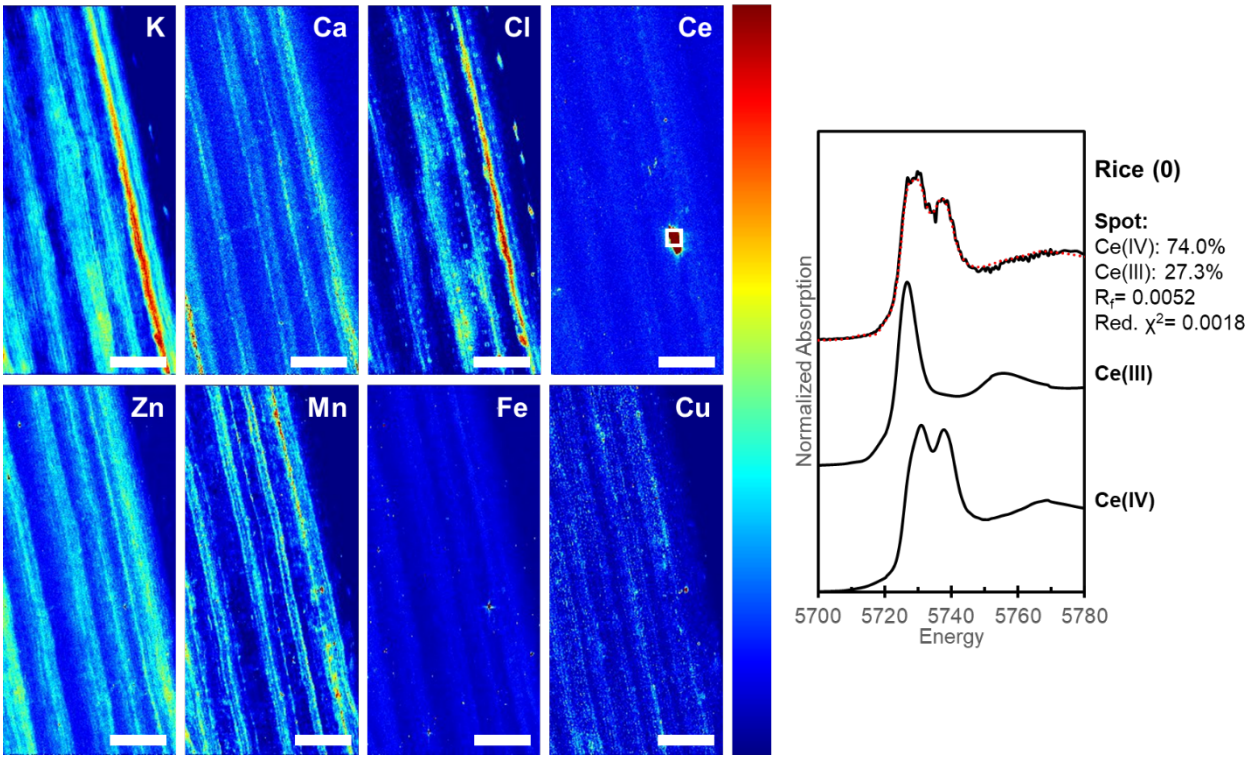

Figure S5. XRF maps showing elemental distributions in a rice leaf after 48 h of hydroponic exposure to 50 mg-Ce/L as CeO_2(0) NPs. Ce L(III) μ-XANES spectrum (solid, black) from high intensity spot is indicated with a white box on the Ce map. LCF result (dotted, red) is presented with fitting statistics and Ce(III) and Ce(IV) model compounds. Scale bar=200 μ

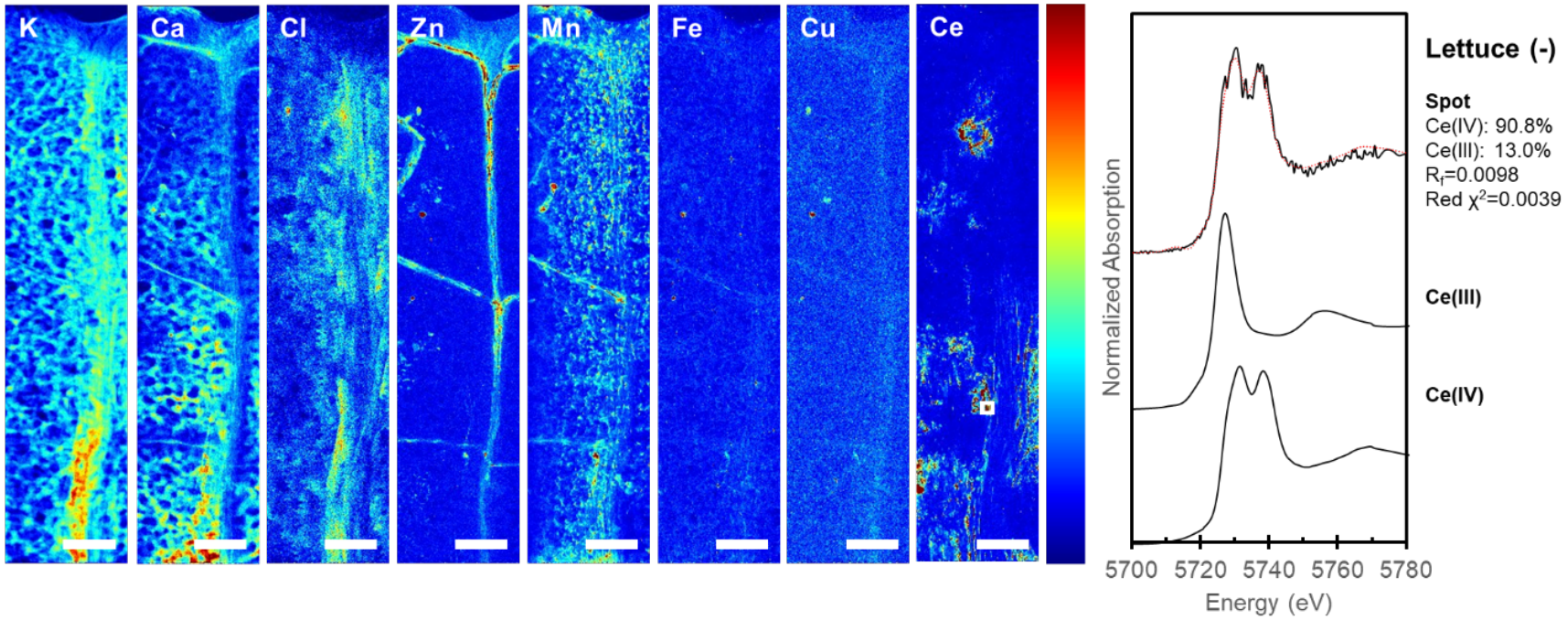

Figure S6. XRF maps showing elemental distribution in a lettuce leaf after 48 h of hydroponic exposure to 50 mg-Ce/L as CeO_2(−) NPs. Ce L(III) μ-XANES spectrum (solid, black) from high intensity spot is indicated with a white box on the Ce map. LCF result (dotted, red) is presented with fitting statistics and Ce(III) and Ce(IV) model compounds. Scale bar=200 μm.

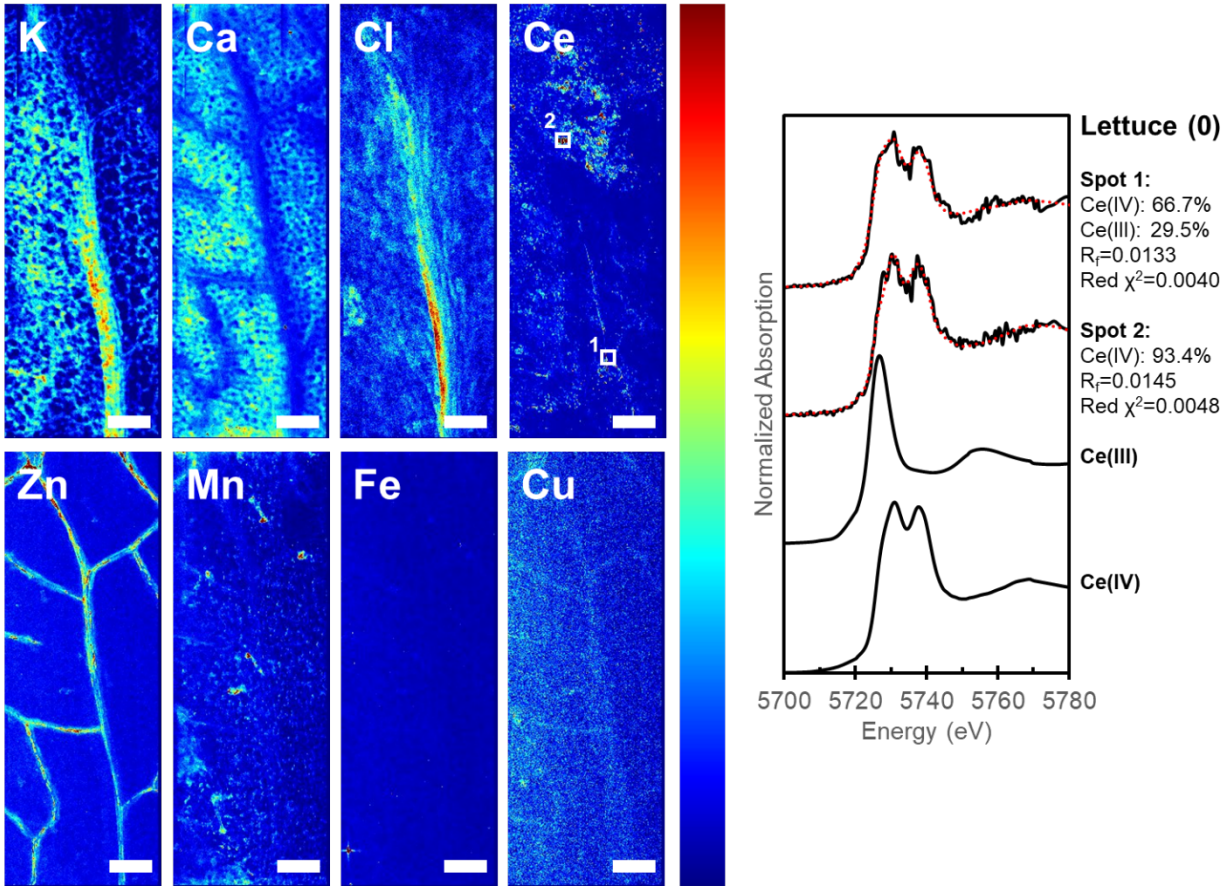

Figure S7. XRF maps showing elemental distribution in a lettuce leaf after 48 h of hydroponic exposure to 50 mg-Ce/L as CeO_2(0) NPs. Ce L(III) μ-XANES spectra (solid, black) from high intensity spots are indicated with white boxes on the Ce map. LCF results (dotted, red) are presented with fitting statistics and Ce(III) and Ce(IV) model compounds. Scale bar=200 μm.

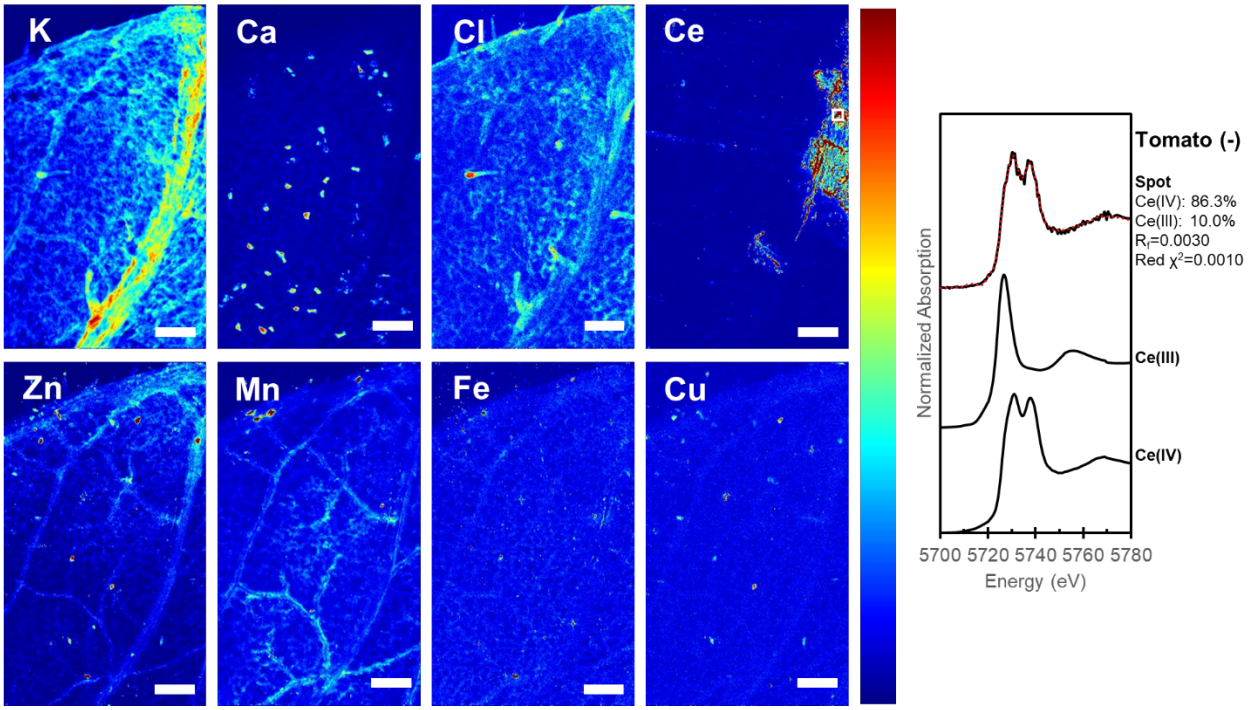

Figure S8. XRF maps showing elemental distributions in a tomato leaf after 48 h of hydroponic exposure to 50 mg-Ce/L as CeO_2 (−) NP. Ce L(III) μ-XANES spectrum (solid, black) from high intensity spot is indicated with a white box on the Ce map. LCF result (dotted, red) is presented with fitting statistics and Ce(III) and Ce(IV) model compounds. Scale bar=200 μm

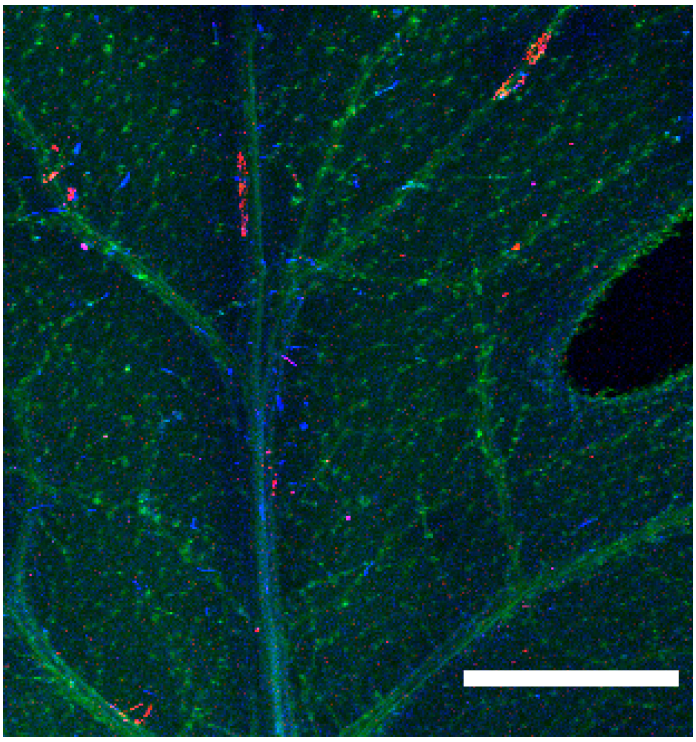

Figure S9. Tri-colored XRF map showing Ce (red), K (green), and Mn (blue) distributions in a tomato leaf after 48 h of hydroponic exposure to 50 mg-Ce/L as CeO_2 (−) NP. Collected at NSLS-II on BL 4-BM. Elemental maps were collected using a step size of 15 µm and a dwell time of 0.1 s. Scale bar=1 mm

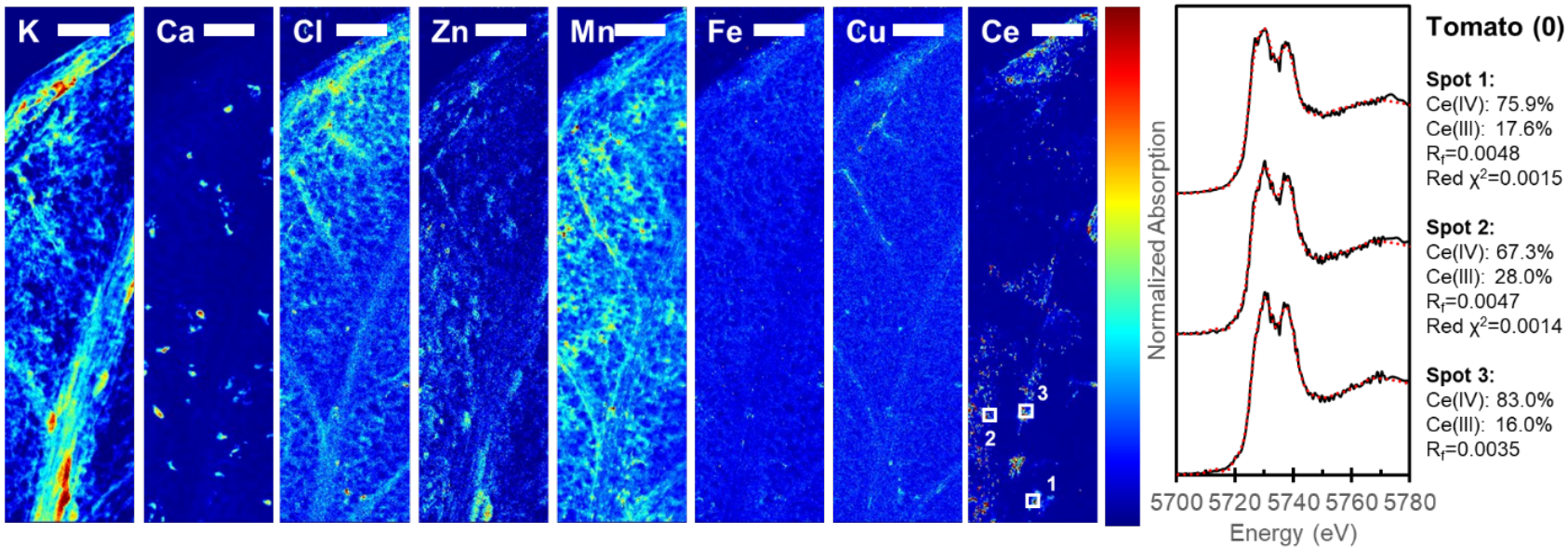

Figure S10. XRF maps showing elemental distributions in a tomato leaf after 48 h of hydroponic exposure to 50 mg-Ce/L as CeO_2(0). Ce L(III) μ-XANES spectra (solid, black) from high intensity spots are indicated with white boxes on the Ce map. LCF results (dotted, red) are presented with fitting statistics. Scale bar=200 μm.

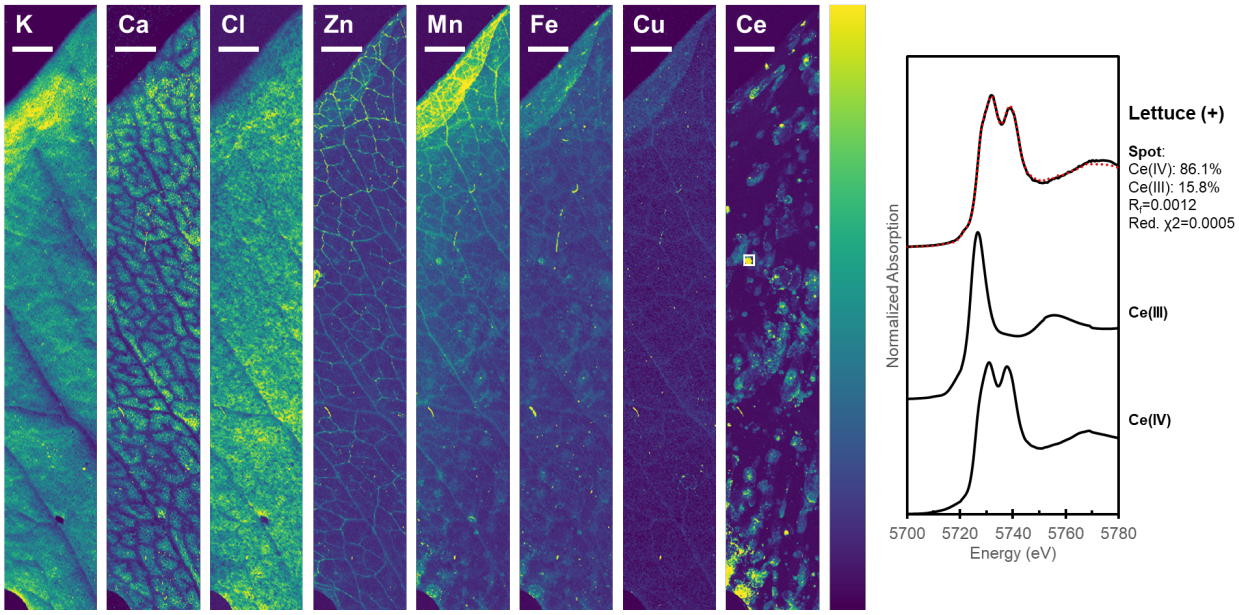

Figure S11. XRF maps showing elemental distributions in a lettuce leaf after 48 h of hydroponic exposure to 50 mg-Ce/L as CeO_2 (+). Ce L(III) μ-XANES spectrum (solid, black) from high intensity spot is indicated with a white box on the Ce map. LCF result (dotted, red) is presented with fitting statistics and Ce(III) and Ce(IV) model compounds. Scale bar= 1 mm.

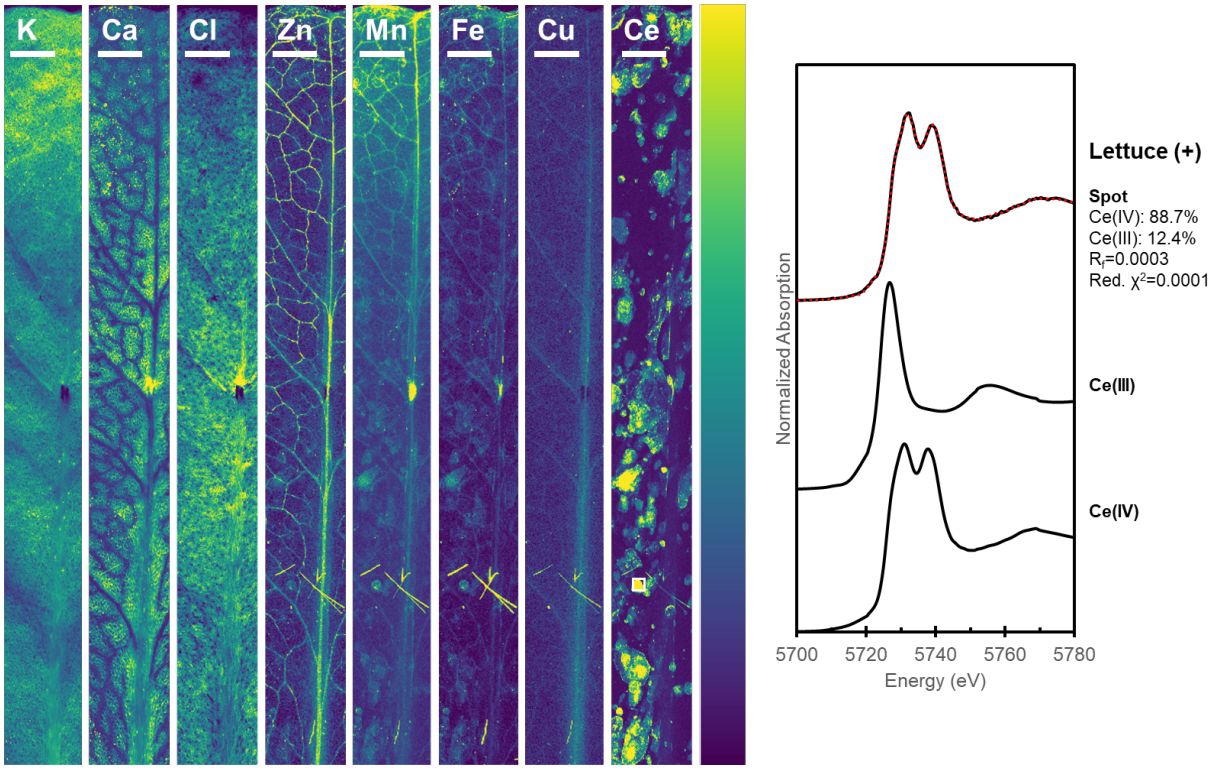

Figure S12. XRF maps showing elemental distributions in the central vein of a lettuce leaf after 48 h of hydroponic exposure to 50 mg-Ce/L as CeO_2 (+). Ce L(III) μ-XANES spectrum (solid, black) from high intensity spot is indicated with a white box on the Ce map. LCF result (dotted, red) is presented with fitting statistics and Ce(III) and Ce(IV) model compounds. Scale bar= 1 mm.

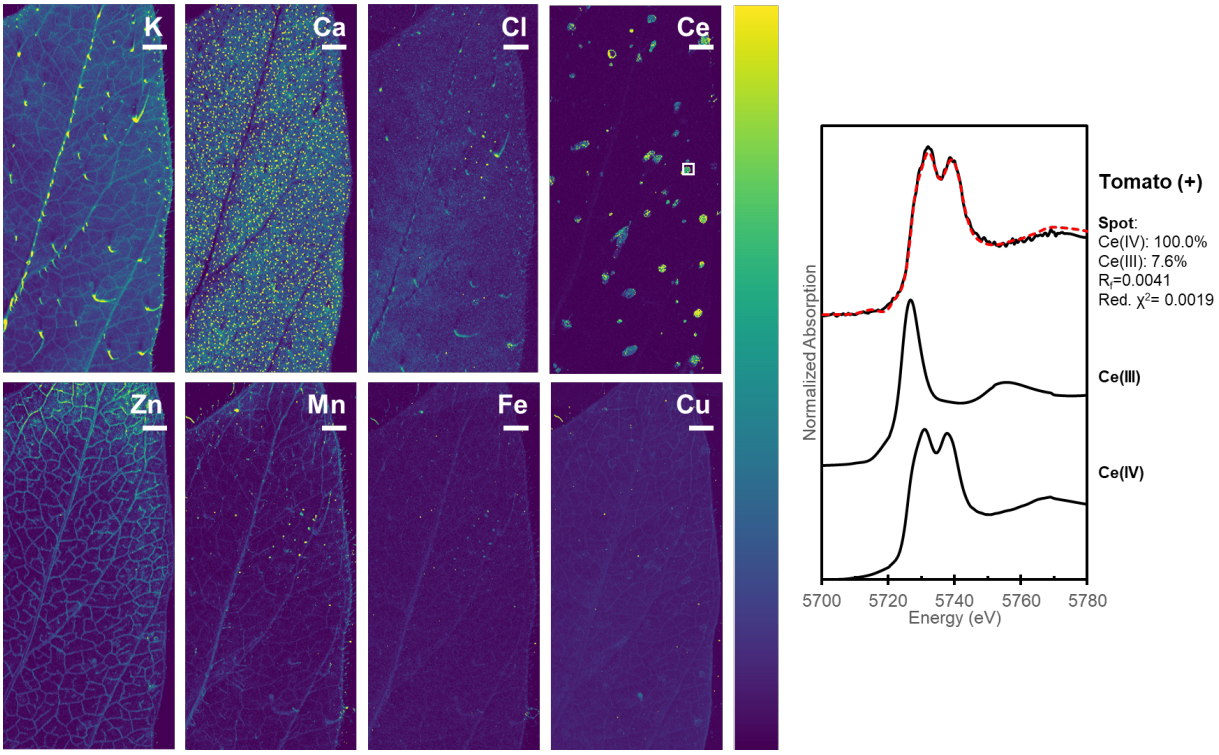

Figure S13. XRF maps showing elemental distributions in a tomato leaf after 48 h of hydroponic exposure to 50 mg-Ce/L as CeO_2 (+). Ce L(III) μ-XANES spectrum (solid, black) from high intensity spot is indicated with a white box on the Ce map. LCF result (dotted, red) is presented with fitting statistics and Ce(III) and Ce(IV) model compounds. Scale bar= 1 mm.

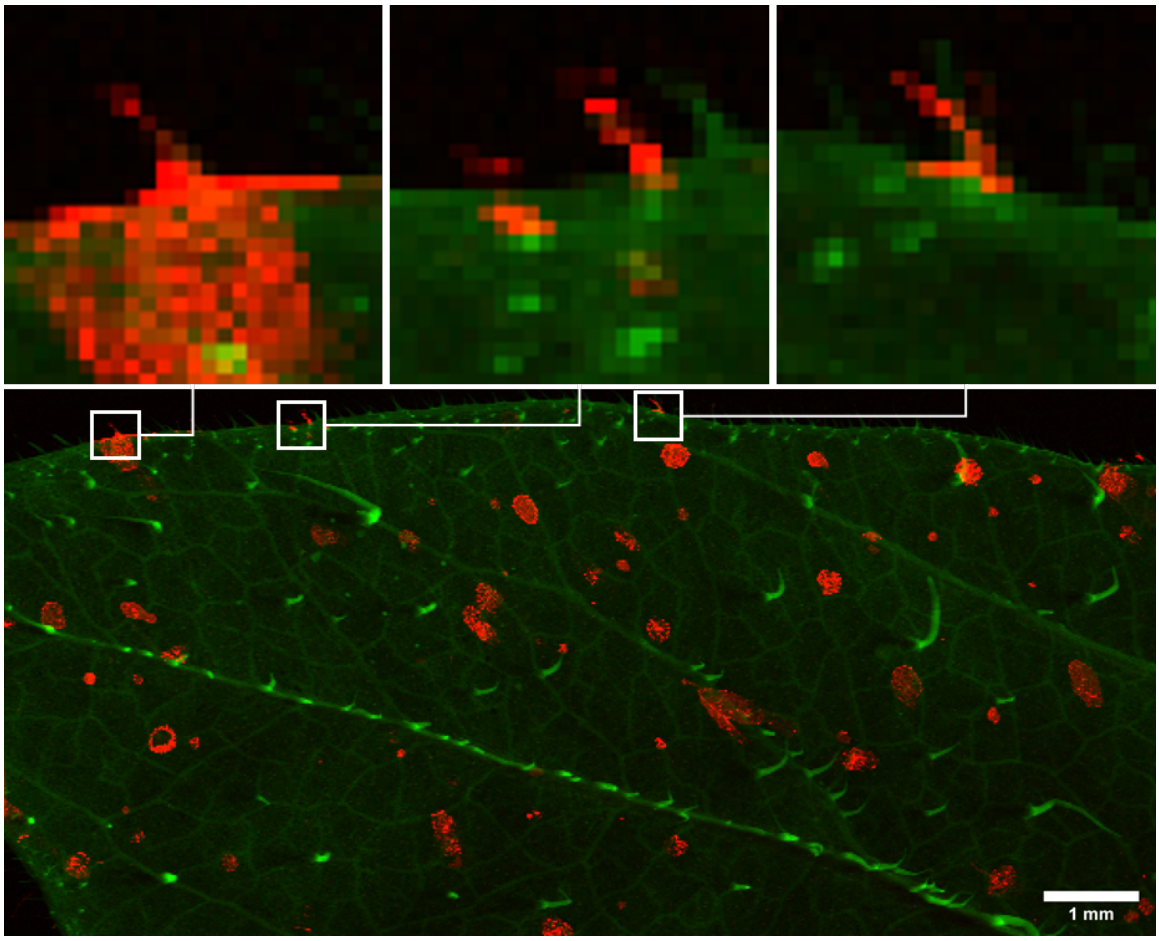

Figure S14. Dual-colored XRF map showing Ce (red) and K (green) distribution in a tomato leaf after 48 h of hydroponic exposure to 50 mg-Ce/L of CeO_2(+) NPs. White boxes (500 µm x 500 µm) indicate Ce-trichome colocalization.

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