Supporting Information

Uptake and Translocation of ZnO Nanoparticles in Rice Tissues Studied by Single Particle-ICP-MS

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Text S1

Enzyme extraction of ZnO-NPs

0.2 g Macerozyme R-10 (containing 0.2 unit·mg^{-1} of cellulose, 0.5 unit·mg^{-1} of hemicellulose, and 1.0 unit·mg^{-1} pectinase) was added to the plant material at a ratio of plant (0.1 g) to enzyme powder of 1:2 in 5 ml deionized water. The mixture was then digested for 24 h at 35°C. The residue was subsequently washed three times with deionized water.

Next, 0.2 g Carbohydrate-Active enzymes (1.0 unit·mg^{-1}) were added to the residue and incubated in 5 mL deionized water for 24 h at 35°C. After mixing all the digestion solutions, they were filtered through a 0.45 μm membrane. A 1 ml aliquot of the resulting supernatant was diluted 100-fold for SP-ICP-MS analysis.

Extraction of available Zn (DTPA-Zn)

Soil available Zn (DTPA-Zn) was extracted with 0.005 mol/L Diethylene triamine Penta acetic acid (DTPA) in a 0.01 mol·L^{-1} $CaCl_2$ buffered solution at pH 7.3 with 0.1 mol·L^{-1} triethanolamine (TEA) at a soil: water ratio of 1:2. Soil Zn

fractionation was carried out using a modified Tessier's sequential extraction procedure as described in reference [1].

Analysis of the trace element content

0.05 g soil samples were weighed into a Teflon bomb and moistened with a few drops of ultrapure water. 1.5 ml HCl+1 ml HNO_3 were added and left to stand overnight at 30°C. Then the sealed bomb was heated at 190°C in an oven for 48 h. The bomb was opened and the solution was evaporated at 105°C to dryness. This was followed by adding 1 ml HNO_3 and evaporating for a second round of dryness. Then, the resultant salt was re-dissolved by adding 3 ml of 30% HNO_3 and resealed and heated in the bomb at 190°C for 12 h. Finally, the final solution was diluted to 100 g with a mixture of 2% HNO_3, awaiting analysis.

Text S2

The Rh element was used as the internal standard in the traditional ICP-MS method. Since all the samples were sufficiently diluted, the matrix effect of the samples can be ignored. National standard reference materials (including GSS-2, GSS-6, and GBW10020 (citrus leaves, GSB-11)) were used to verify the accuracy of the experiment. The results of multi-element analysis indicate an accuracy of 90-110% for the method, with a relative standard deviation (RSD) of less than 5%. However, the Rh element is almost impossible to contain in each particle, so an external standard method is used for calibration. Calibration standards (0-100 $\mu g \cdot L^{-1}$ dissolved Zn) were prepared in a 1000-fold diluted control plant digestate to match the sample matrix for each plant tissue. And the 0, 30, and 50 nm ZnO-NPs were used for the single-particle calibration standards.

Table S1 Parameters of ICP–OES

ICP-OES modle	PerkinElmer Optima 2100DV
Power W	1350
Parameter	Setting
Auxiliary gas flow ($L \cdot min^{-1}$)	0.22
Plasma argon flow rate ($L \cdot min^{-1}$)	15
Nebuliser gas	Ar
Nebuliser gas flow ($L \cdot min^{-1}$)	0.83
Sample flow rate ($mL \cdot min^{-1}$)	1.2
Replicates	3
Measurement	Mg 279.079 nm
	K 766.490 nm
	Ca 317.933 nm
	P 213.618 nm

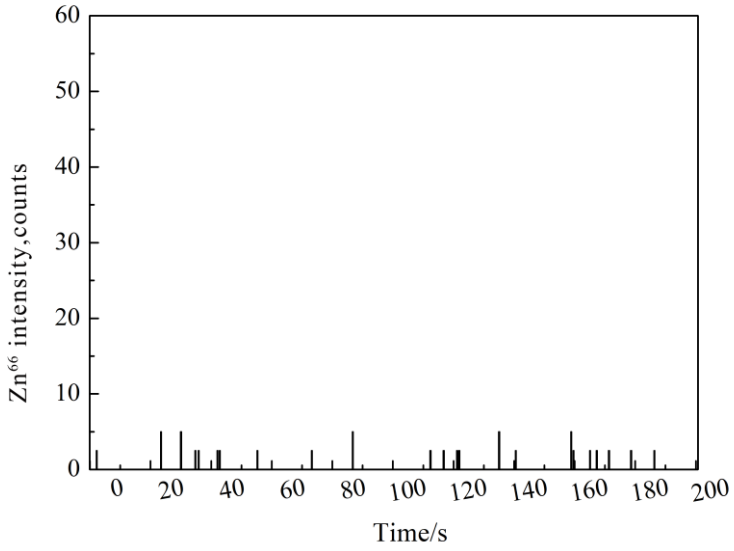

Fig. S1 A particle signal from the background signal.

Table S2 Recovery rate of spiked ZnO-NPs in the actual sample digestion solution, n=3

Samples	Particle size of actual samples(nm)	Values of ZnO-NPs in actual samples (Particles·g^{-1})	Particle size distribution spiked recovery rate %	Particle size distribution RSD%	Average particle size of ZnO-NPs after spiking (nm)	Average particle size on RSD%
50 nm	46±6					
Roots	＜14	＜$2.36*10^5$	93.7±6	3.6	42±5	8.4
Stems	＜14	＜$2.36*10^5$	99.7±5	7.4	48±7	9.6
Leaves	＜14	＜$2.36*10^5$	108.1±4	3.2	41±6	7.4
Grains	＜14	＜$2.36*10^5$	93.5±6	2.8	46±3	8.4

Table S3 Correlation coefficient (R) between 13 common elements and Zn concentration in rice (* is stand for $P < 0.05$, ** is stand for $P < 0.01$)

	B	Al	Mg	K	Ca	Cd	Co	Fe	Mn	P	Pb	Sr	As	Zn
	0.481	0.002	0.274	0.937	-0.126	-0.093	-0.124	-0.164	0.028	-0.202	0.542	-0.113	-0.204	0.251
B	1	0.767	0.876	0.519	0.712**	0.617	0.671	0.619	0.727	0.57	0.091	0.656	0.667	-0.239
Al		1	0.573	0.004	0.869**	0.582	0.888	0.907	0.941*	0.821	-0.217	0.948	0.835	-0.129
Mg			1	0.287	0.74*	0.557	0.734	0.755*	0.835	0.645	0.032	0.84	0.746*	0.769*
K				1	-0.008	-0.032	-0.068	-0.166	0.017	-0.177	0.439	-0.073	-0.161	0.104
Ca					1	0.498	0.919	0.849	0.844	0.868*	-0.372	0.869	0.883	0.414
Cd						1	0.445	0.455	0.49	0.343	-0.104	0.47	0.434	-0.821*
Co							1	-0.966	0.948	0.975	-0.563	0.945	0.905	-0.143
Fe								1	0.972	0.968	-0.541	0.957	0.904	-0.669*
Mn									1	0.922	-0.433	0.964	0.85	-0.565
P										1	-0.626	0.907	0.921**	-0.461
Pb											1	-0.469	-0.403	-0.851**
Sr												1	0.867	-0.156
As													1	-0.615**
Zn														1

References

1. X. Lu, J. Cui, X. Tian, J. E. Ogunniyi, W. J. Gale, and A. Zhao, *Agron. J.*, 2012, **104**. 963-969. https://doi.org/10.2134/agronj2011.0417