Supplementary Information for

Zinc oxide nanofertilizer significantly modified the properties of iron plaque and arsenic accumulation in rice in a life cycle study

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This supporting information file includes: 1 table, and 9 figures.

Table S1. Soil characteristics of topsoil (0-15 cm) from Eagle Lake, TX by the Soil, Water and Forage Testing Laboratory at Texas A&M University.

Soil parameters	Units	Values
pH	/	4.63 ± 0.05
Conductivity	umho/cm	320.0 ± 91.4
Nitrate-N	mg/kg	42.0 ± 5.5
Phosphorus	mg/kg	19.3 ± 0.5
Potassium	mg/kg	59.0 ± 6.2
Calcium	mg/kg	343.5 ± 55.7
Magnesium	mg/kg	89.0 ± 4.8
Sulfur	mg/kg	88.5 ± 33.0
Sodium	mg/kg	16.0 ± 2.2
Iron	mg/kg	30.4 ± 0.8
Zinc	mg/kg	0.4 ± 0.07
Manganese	mg/kg	14.0 ± 2.0
Copper	mg/kg	0.28 ± 0.10
Silt	%	19
Clay	%	15
Organic carbon	%	2.5
Texture	/	Silt loam

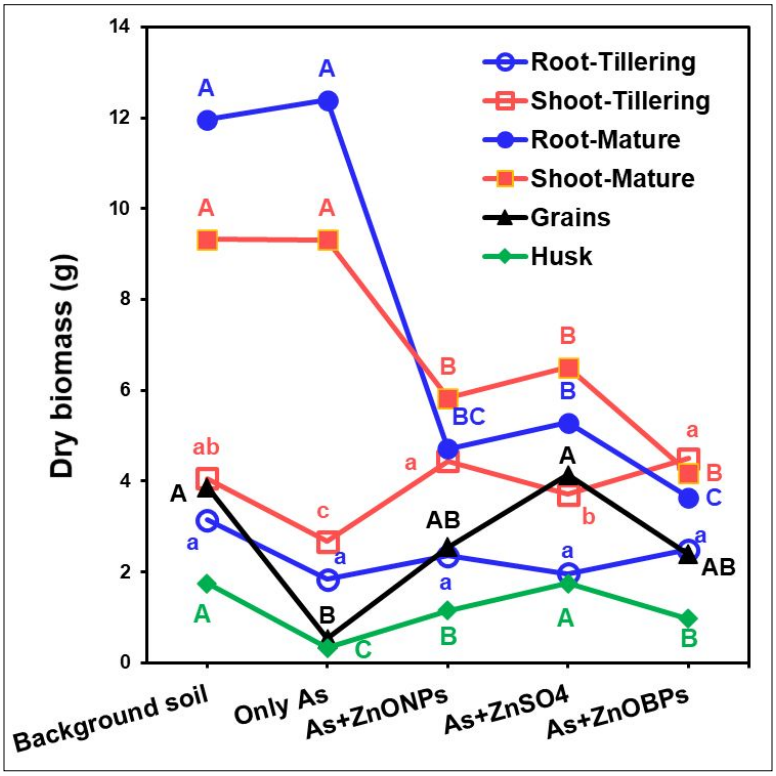

Figure S1. The biomass of root and shoot of rice at the maximum tillering (empty symbols) and mature stage (solid symbols), and the biomass of husk and de-husked grains at the mature stage. Different letters indicated significant differences ($p \leq 0.05$) according to one-way ANOVA followed by Tukey's test.

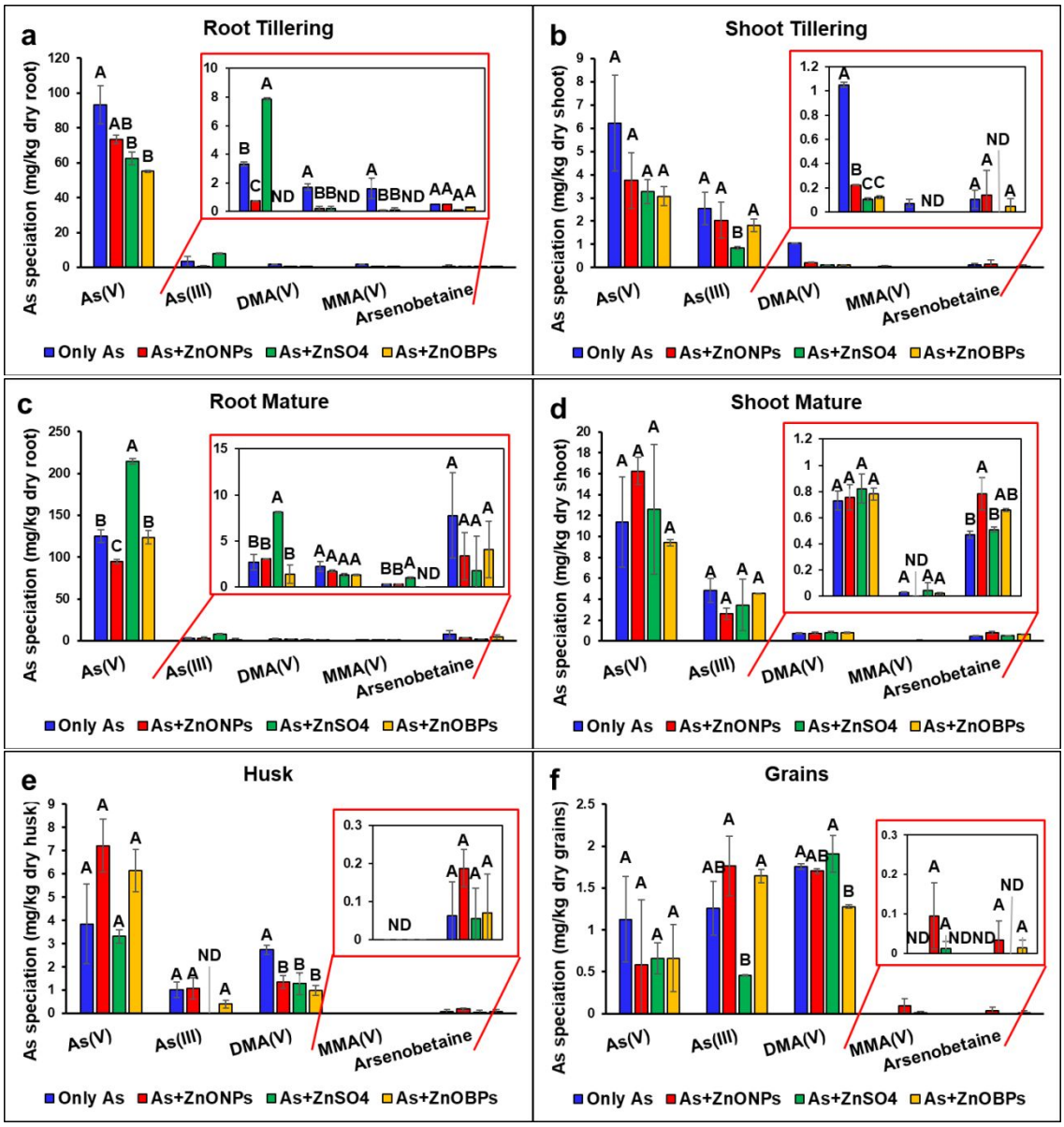

Figure S2. The effects of different Zn amendments on As speciation in rice (a) root and (b) shoot at the maximum tillering stage (empty symbols); and (c) root, (d) shoot, (e) husk, and (f) grains at the mature stage (solid symbols). Values represent mean ± SD (n = 4), with different letters indicating significant differences ($p \leq 0.05$) according to one-way ANOVA for each As species followed by Tukey's test. ND indicated the specific As species were not detected in the rice tissues.

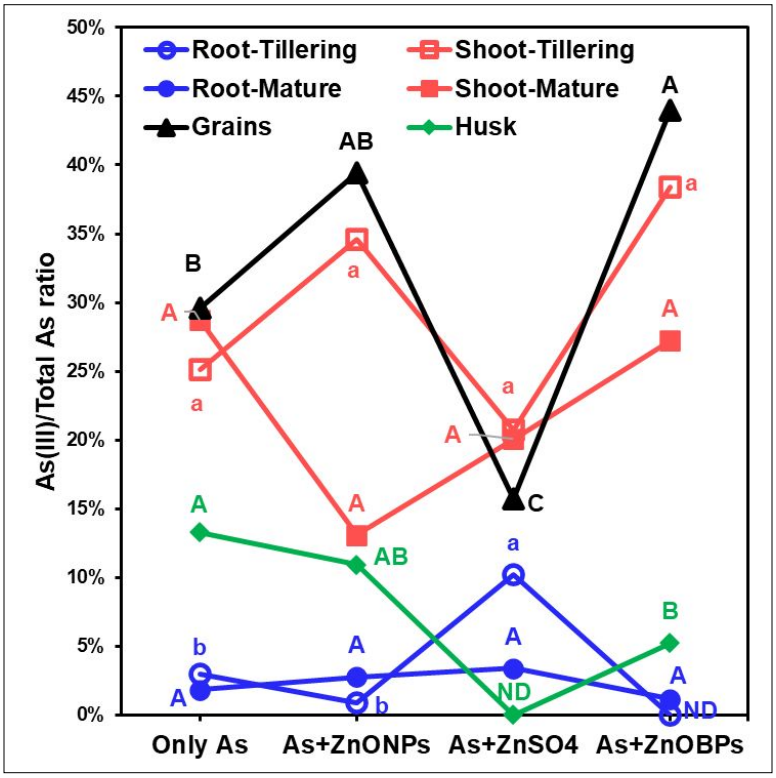

Figure S3. The impact of different Zn amendments on the As(III) to total As ratio in rice root, shoot, husk and de-husked grains. Different letters indicated significant differences ($p \leq 0.05$) according to one-way ANOVA followed by Tukey's test.

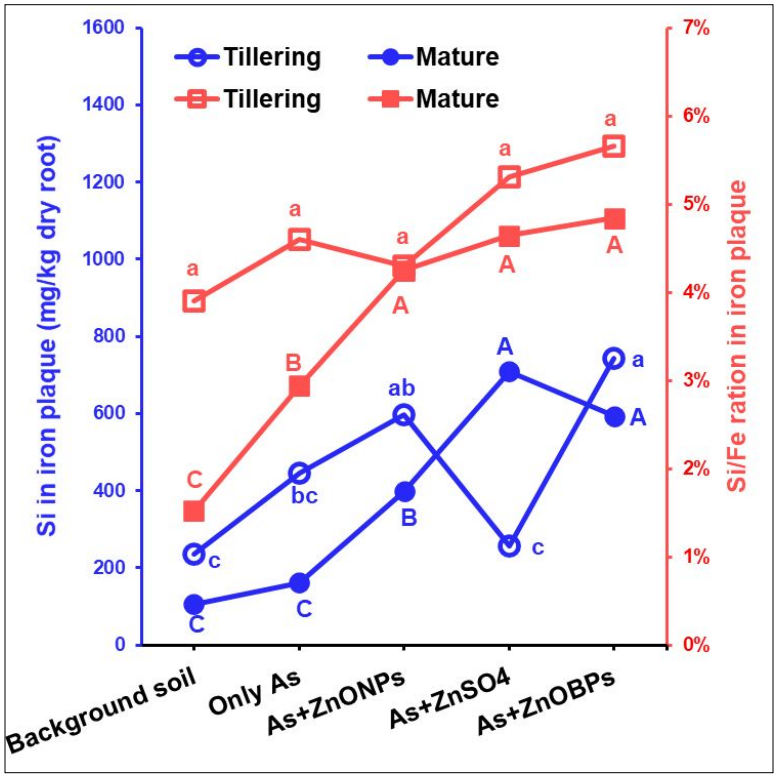

Figure S4. DCB-extractable silicon in iron plaque and the Si/Fe ratio from different treatments at the maximum tillering stage (empty symbols) and the mature stage (solid symbols).

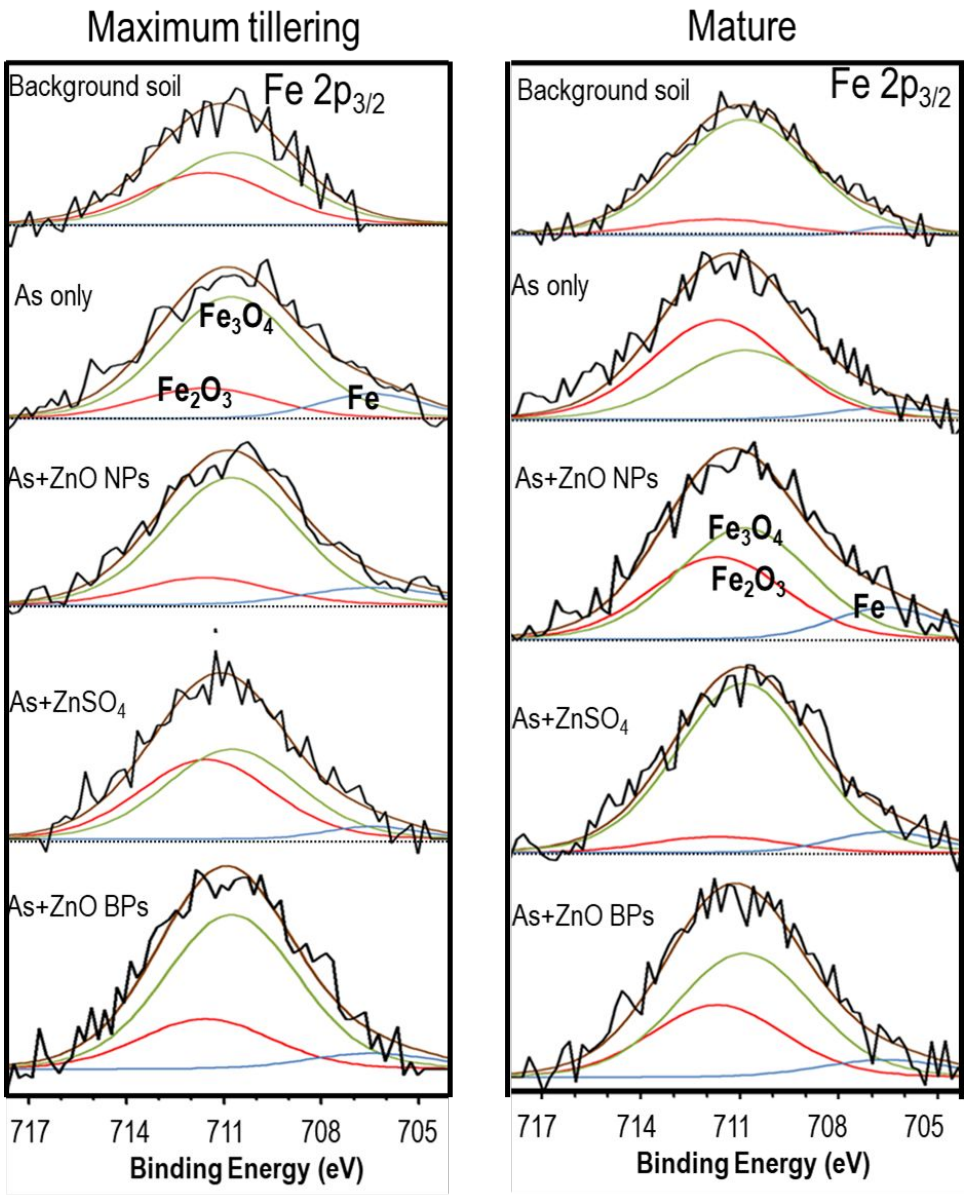

Figure S5. XPS high-resolution spectra of the Fe $2p_{3/2}$ with deconvoluted components Fe_2O_3 (red), Fe_3O_4 (green) and Fe (blue) in the iron plaque from different treatments at the maximum tillering stage and the mature stage.

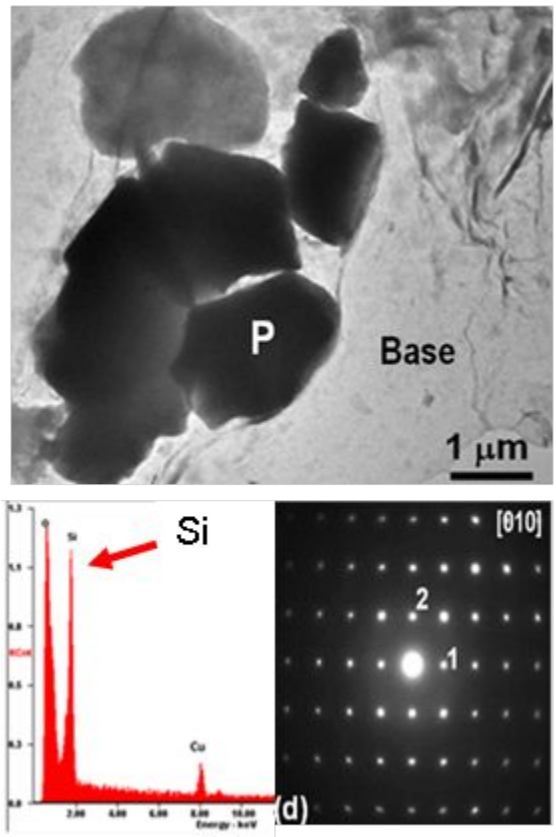

Figure S6. (a) TEM image of SiO_2 particles in iron plaque from roots grown in background soil at the mature stage. 'P' represents SiO_2 particles. 'Base' the is transparent thin sheet structures consisting of mostly C and minor elements such as K and Ca. (b) EDS analysis of the particles confirming the dominant elements of Si and O, (c) SAED pattern of the SiO_2 particles.

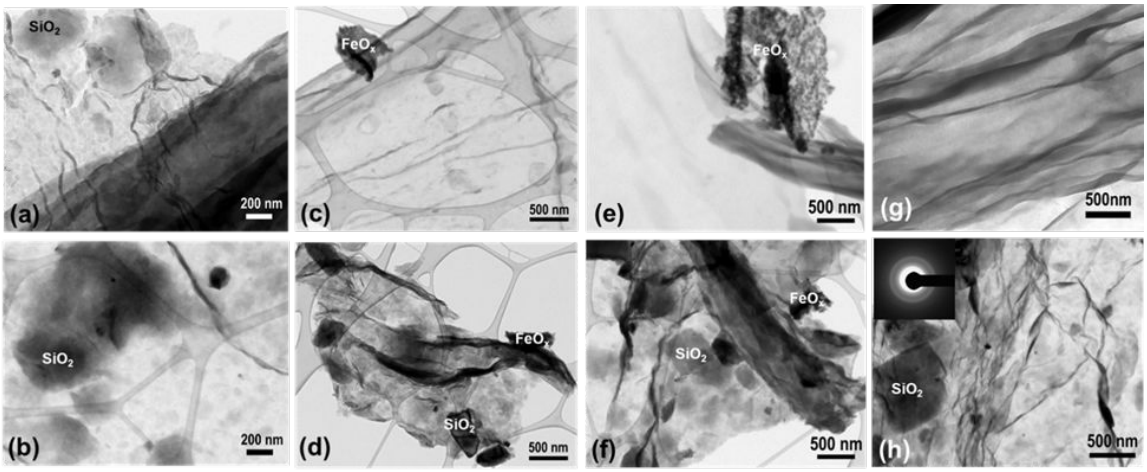

Figure S7. TEM image of SiO_2 particles in iron plaque from roots grown in soils with elevated As (a) or As and different Zn amendments: ZnONPs (b), Zn^{2+} (c), and ZnOBPs (d). Iron plaques on the top row were obtained at the maximum tillering stage and at the bottom row were from the mature stage.

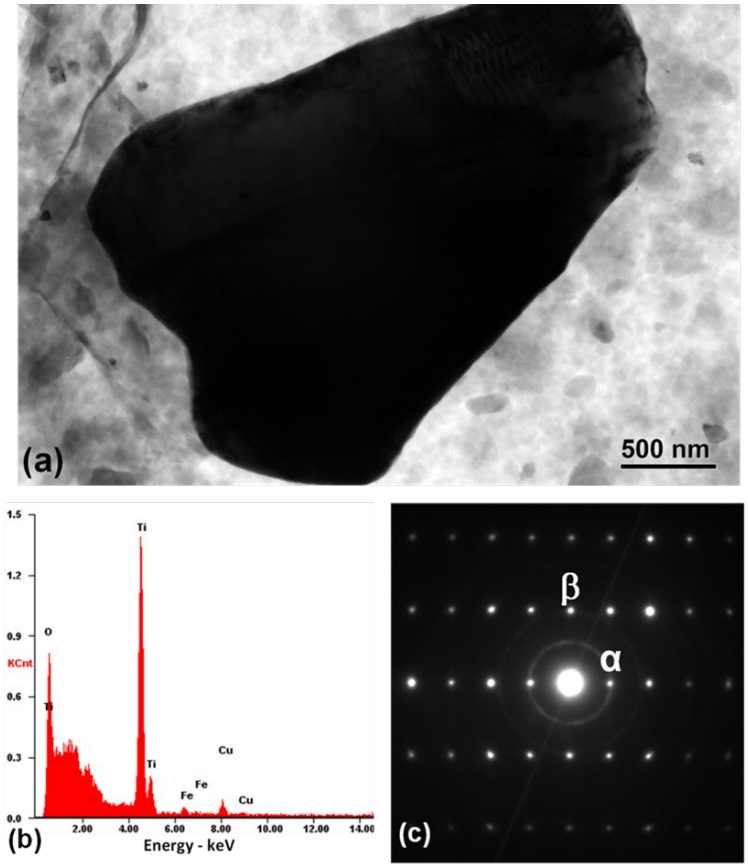

Figure S8. (a) TEM of titanium oxide particles (TiO_2) in rice roots grown in the soils treated with joint As and Zn BPs at the mature stage. (b) EDS and (c) SAED pattern from a TiO_2 particle.

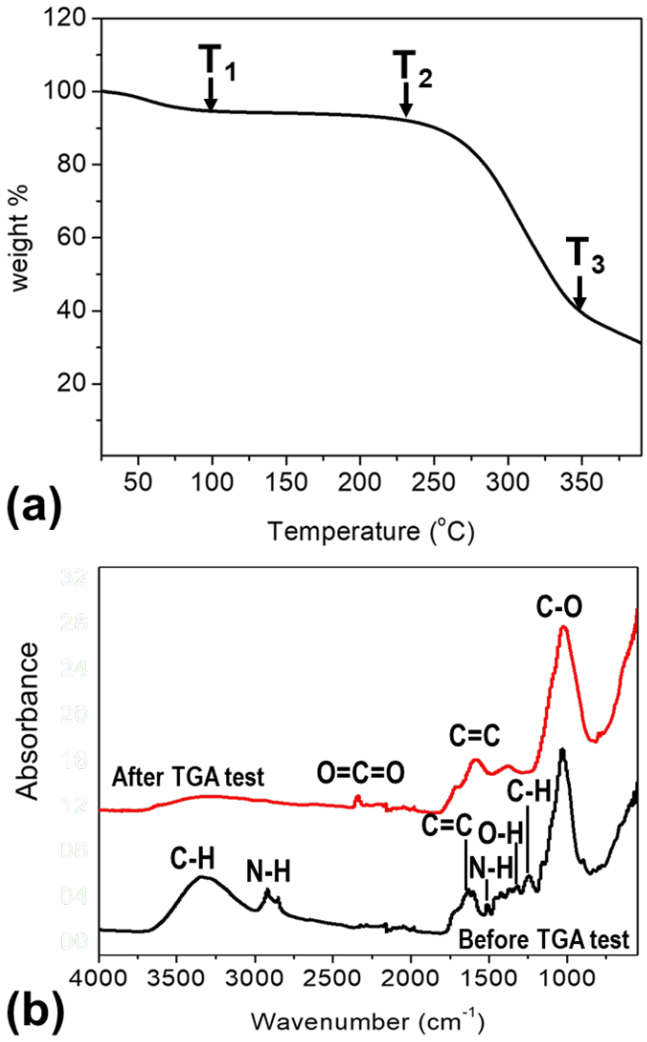

Figure S9. (a) Thermogravimetric analysis (TGA) curve of the rice roots at the mature stage grown in the background soil. (b) FTIR absorption spectra for the same rice roots before (bottom) and after (top) TGA test.