Supporting information

Biosynthesized iron oxide nanoparticles using *Trichoderma harzianum* with applications for phytopathogen control

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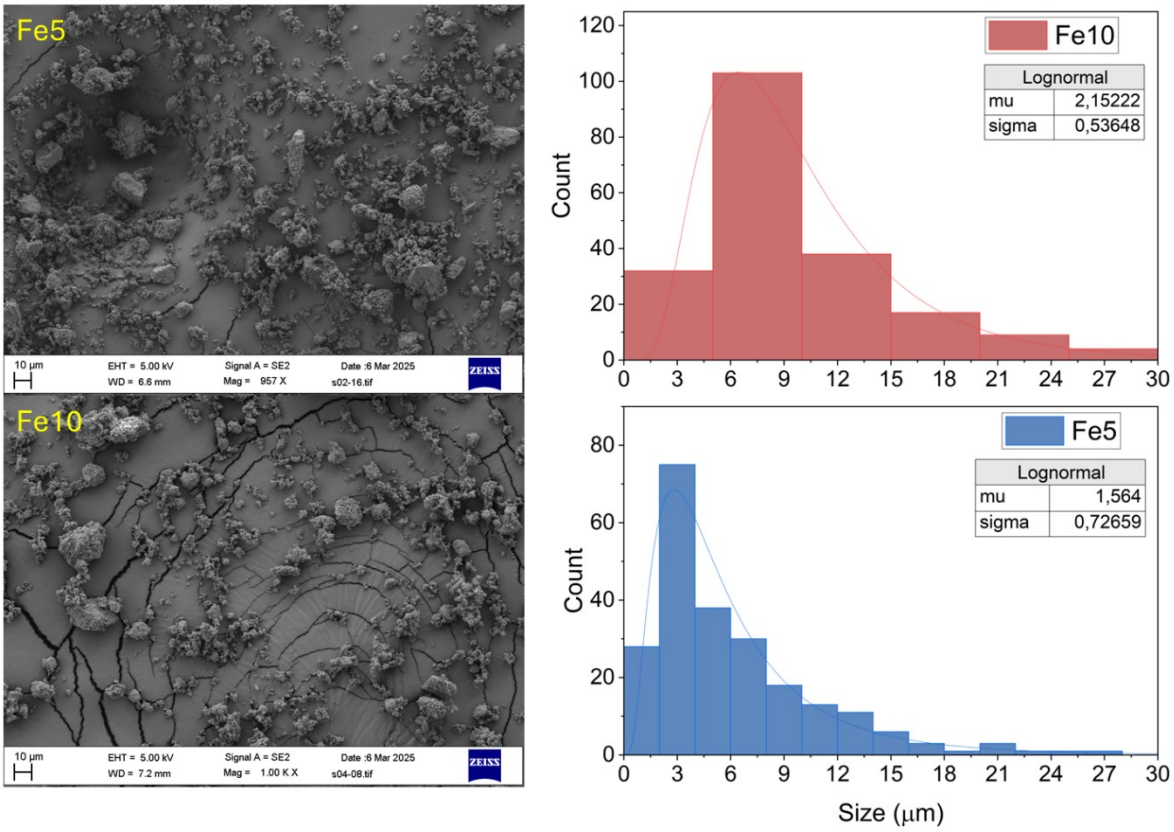
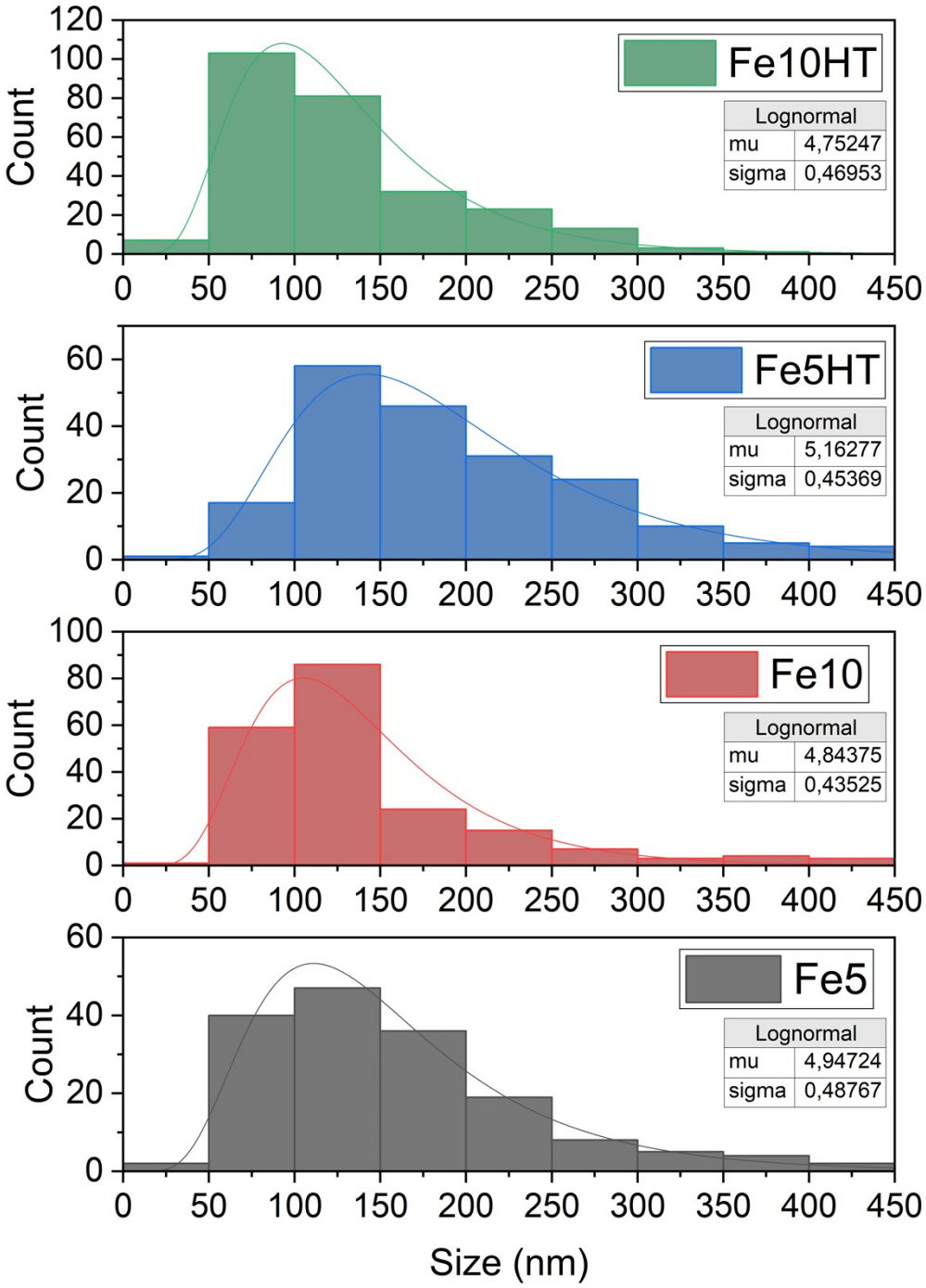
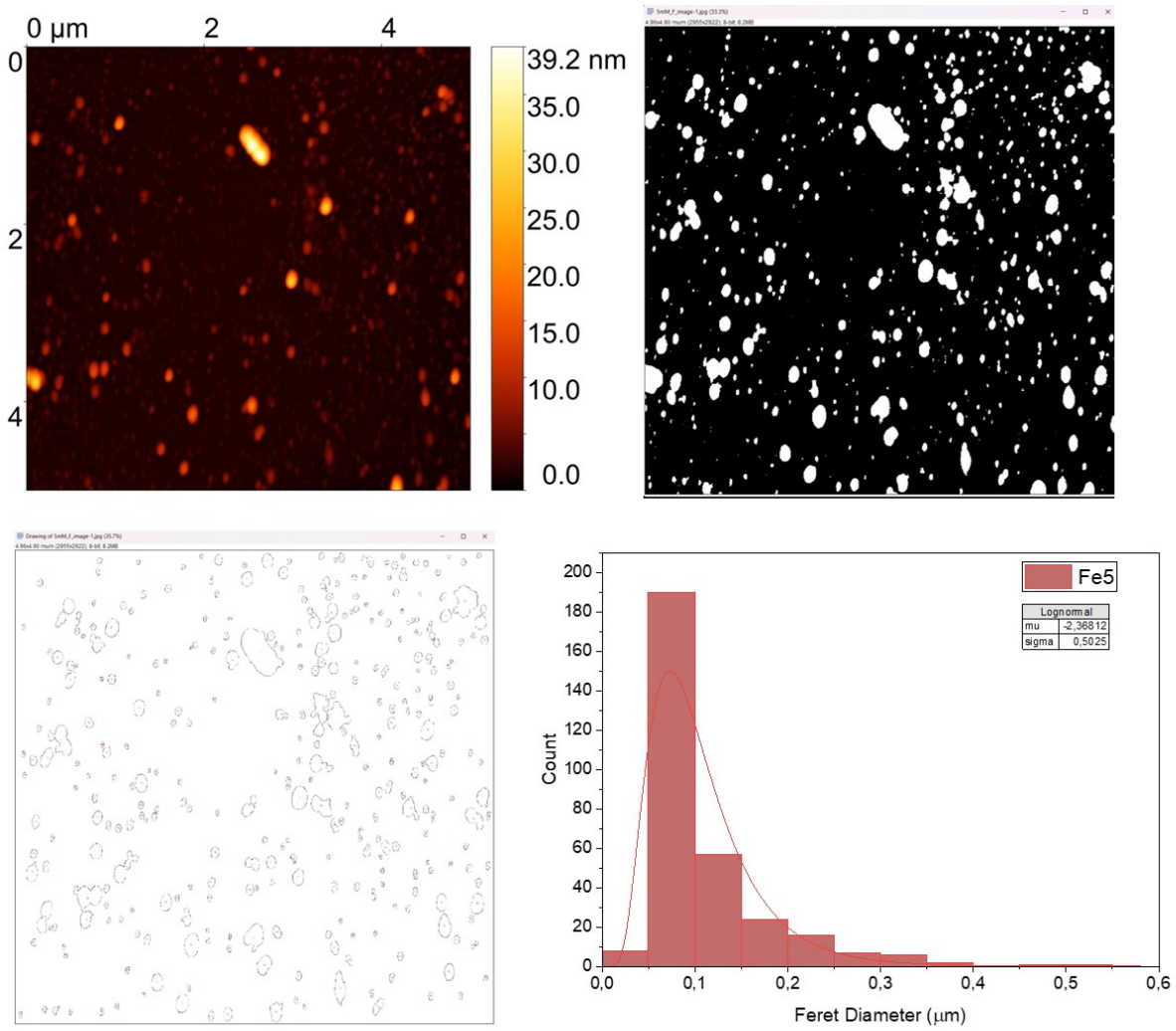


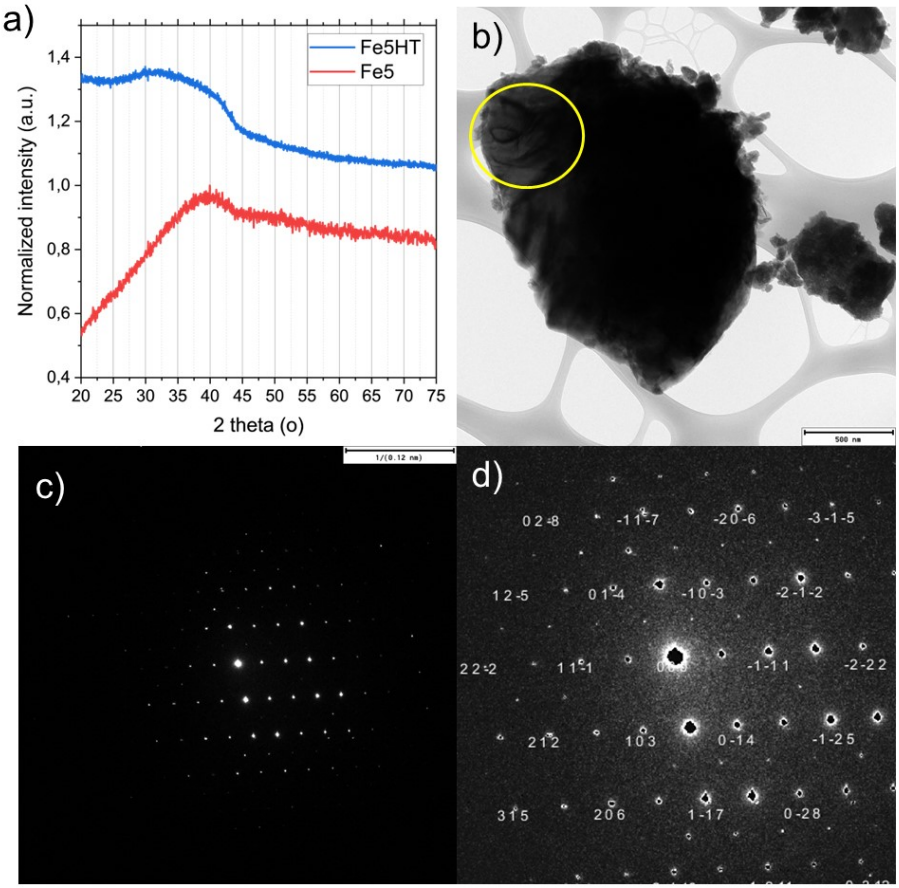
SI 1. Higher-magnification SEI-SEM images of the Fe5 and Fe10 samples highlighting their microstructural features. Corresponding size distribution histograms were generated through statistical analysis using ImageJ software.



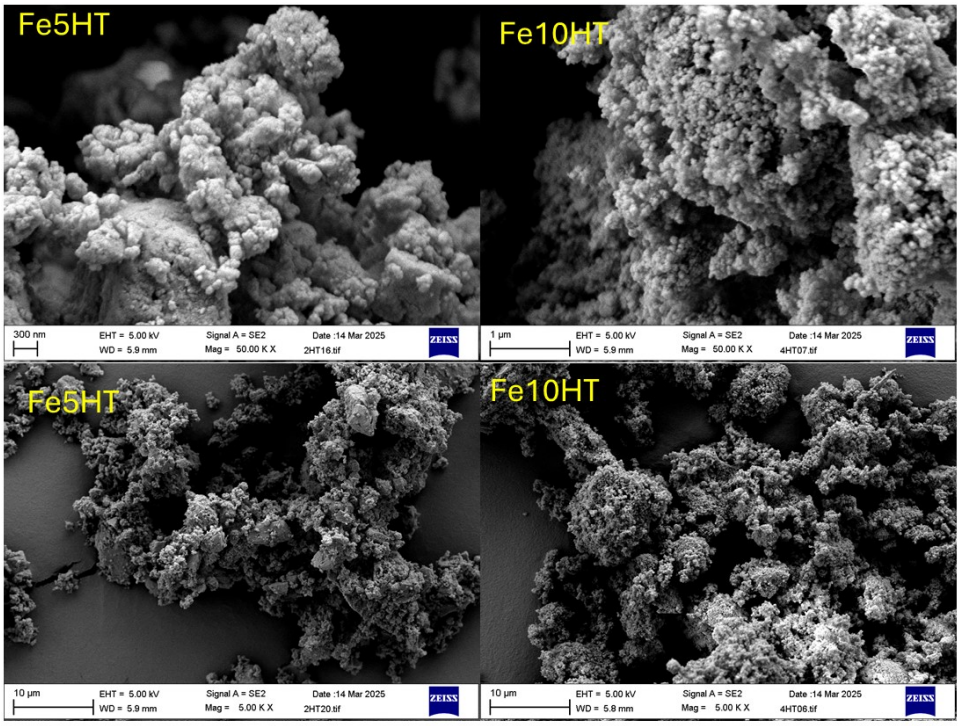
SI 2. Size distribution histograms of the nanostructures shown in Figure 1, obtained by statistical analysis of SEM images using ImageJ software.



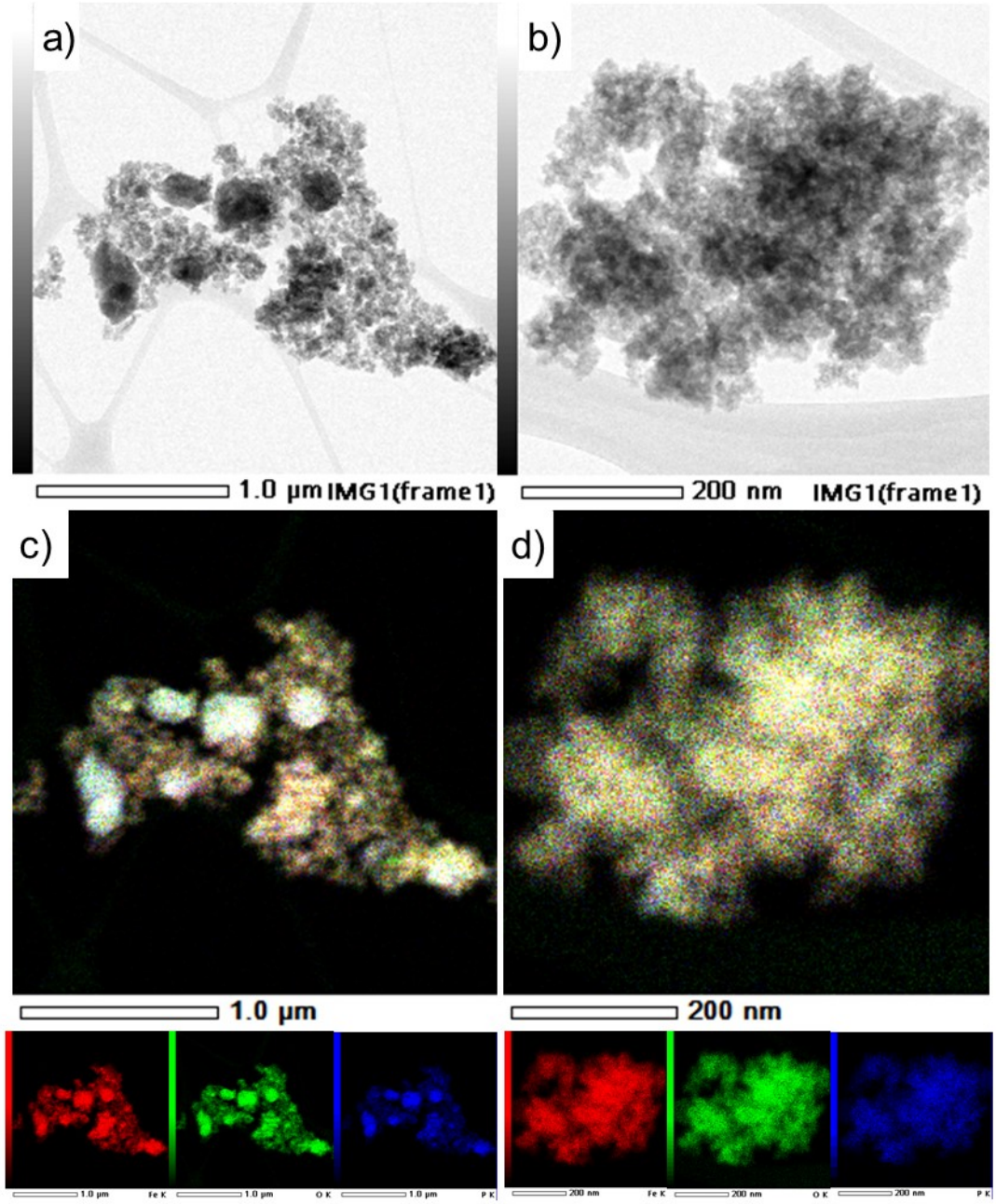
SI 3. Image J particle analysis routine for size determination in AFM micrograph of Fe5 sample.



SI 4. (a) XRD patterns of Fe5 and Fe5HT collected using Co Kα radiation. (b) TEM image of Fe5HT indicating the selected area for (c) SAED, indexed to the (d) Fe_2O_3 crystal structure.



SI 5. SEI-SEM images of Fe5HT and Fe10HT samples.



SI 6. Elemental maps showing the spatial distribution of major elements in the Fe10 (a, c) and Fe10HT (b, d) samples. RGB overlay images based on Fe (red), O (green), and P (blue) channels for Fe10 and Fe10HT, respectively.

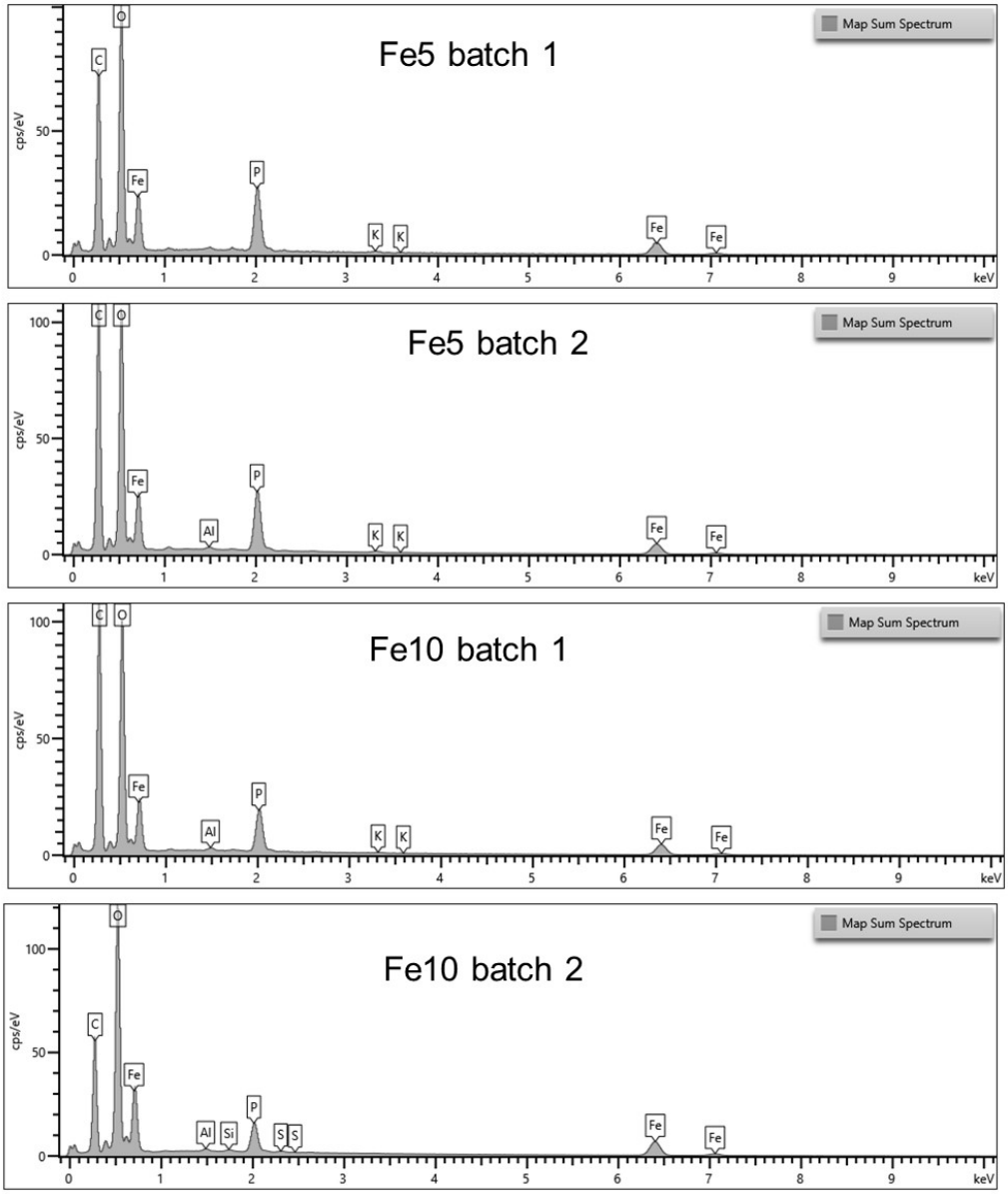
Table S1. EDS elemental compositions of Fe10 and Fe10HT samples.

Fe10			
Element	(keV)	Mass%	Atom%
C K	0.3	21.4	42.7
N K	0.4	0.1	0.2
O K	0.5	20.7	31.1
Na K	1.0	0.1	0.1
P K	2.0	3.7	2.8
K K	3.3	0.0	0.0

Fe K	6.4	54.0	23.2
Total		100	100
Fe10 HT			
Element	(keV)	Mass%	Atom%
C K	0.3	5.9	18.5
N K	0.4	0.0	0.0
O K	0.5	9.7	22.7
Na K	1.0	0.0	0.0
P K	2.0	3.7	4.5
K K	3.3	0.0	0.0
Fe K	6.4	80.6	54.2
Total		100.0	100.0

Table S2. Iron content (mass % Fe) determined by TEM-EDS and SEM-EDS for Fe5 and Fe10 samples obtained from independent synthesis batches.

Sample	Batch	Fe Mass %	Signal
Fe5	1	55.6	SEM-EDS
Fe5	2	52.4	SEM-EDS
Fe10	1	56.0	SEM-EDS
Fe10	2	64.0	SEM-EDS
Fe10	3	54.0	TEM-EDS
Fe10	4	58.1	TEM-EDS

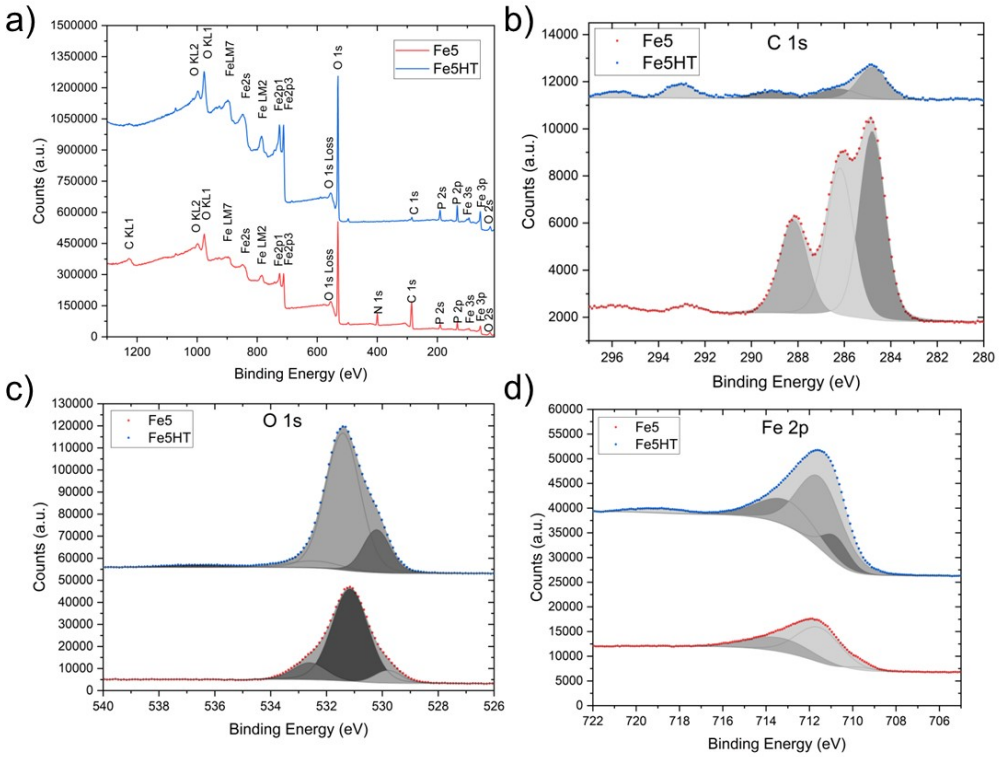


SI 7. SEM-EDS compositional characterization for independent batches of Fe5 and Fe10 samples.

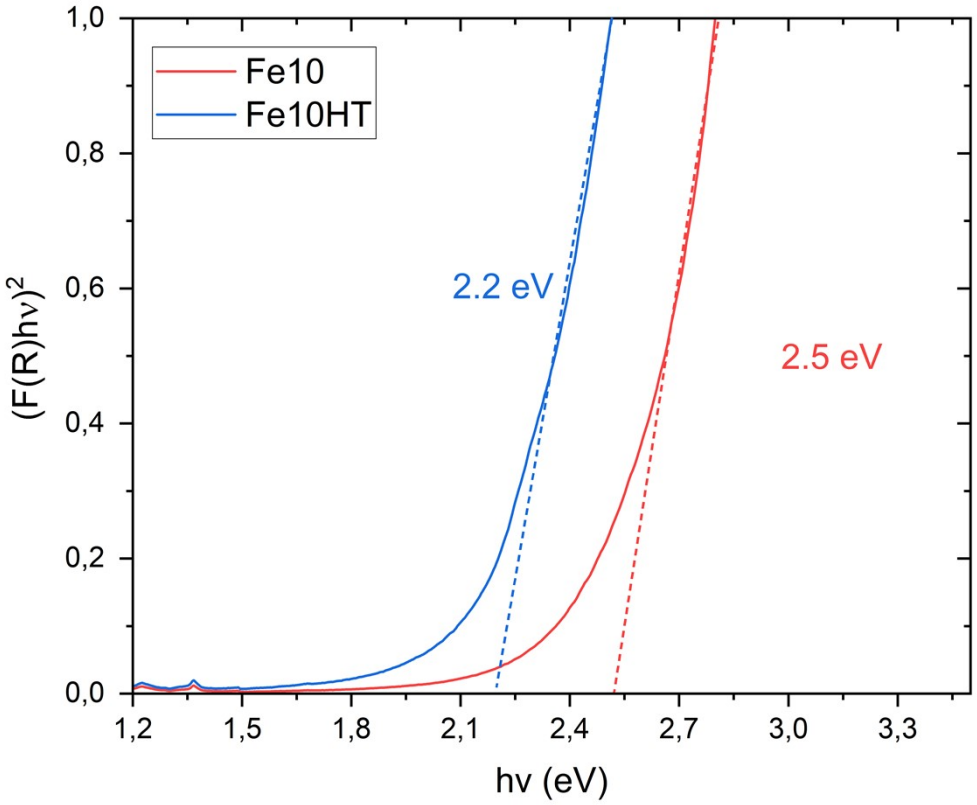
Table S3. HRXPS deconvolution details for samples Fe5, Fe10, Fe5HT and Fe10HT using Avantage software.

	Fe10			Fe5		
Deconvolution component	Peak BE (eV)	Area (CPS eV)	FWHM (eV)	Peak BE (eV)	Area (CPS eV)	FWHM (eV)
A	708.3	194.1	0.7	708.9	1295.8	1.6
B	710.6	24226.3	1.0	710.7	19313.7	2.4
C	712.5	13193.2	0.5	712.6	10982.4	3.4
D	718.7	598.0	0.0	-	-	-

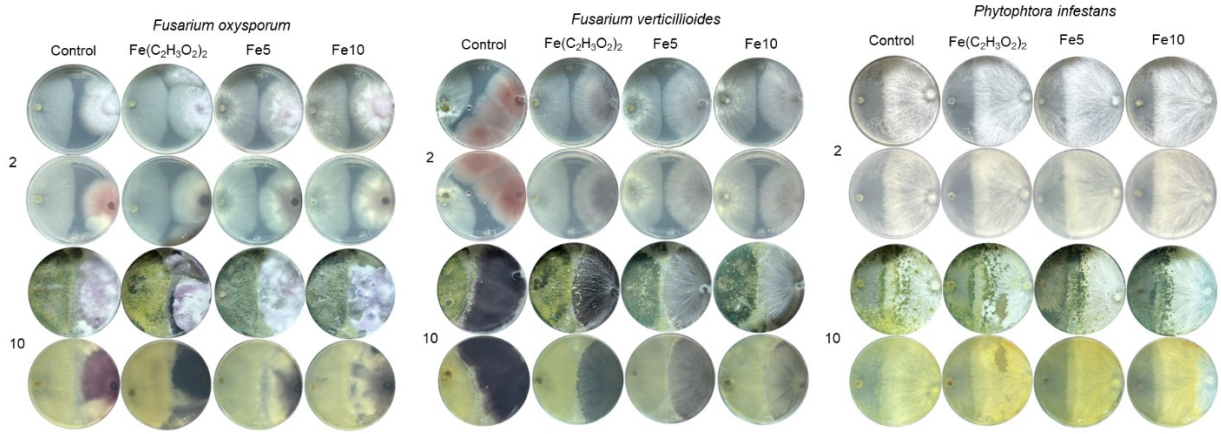
Deconvolution component	Fe10HT			Fe5HT		
A	710.6	4485.0	1.2	710.8	8854.1	1.5
B	711.4	37734.5	2.3	711.5	39533.7	2.4
C	712.9	33496.2	3.5	713.0	18281.6	3.1
D	719.0	4466.1	3.4	719.0	2786.2	2.8



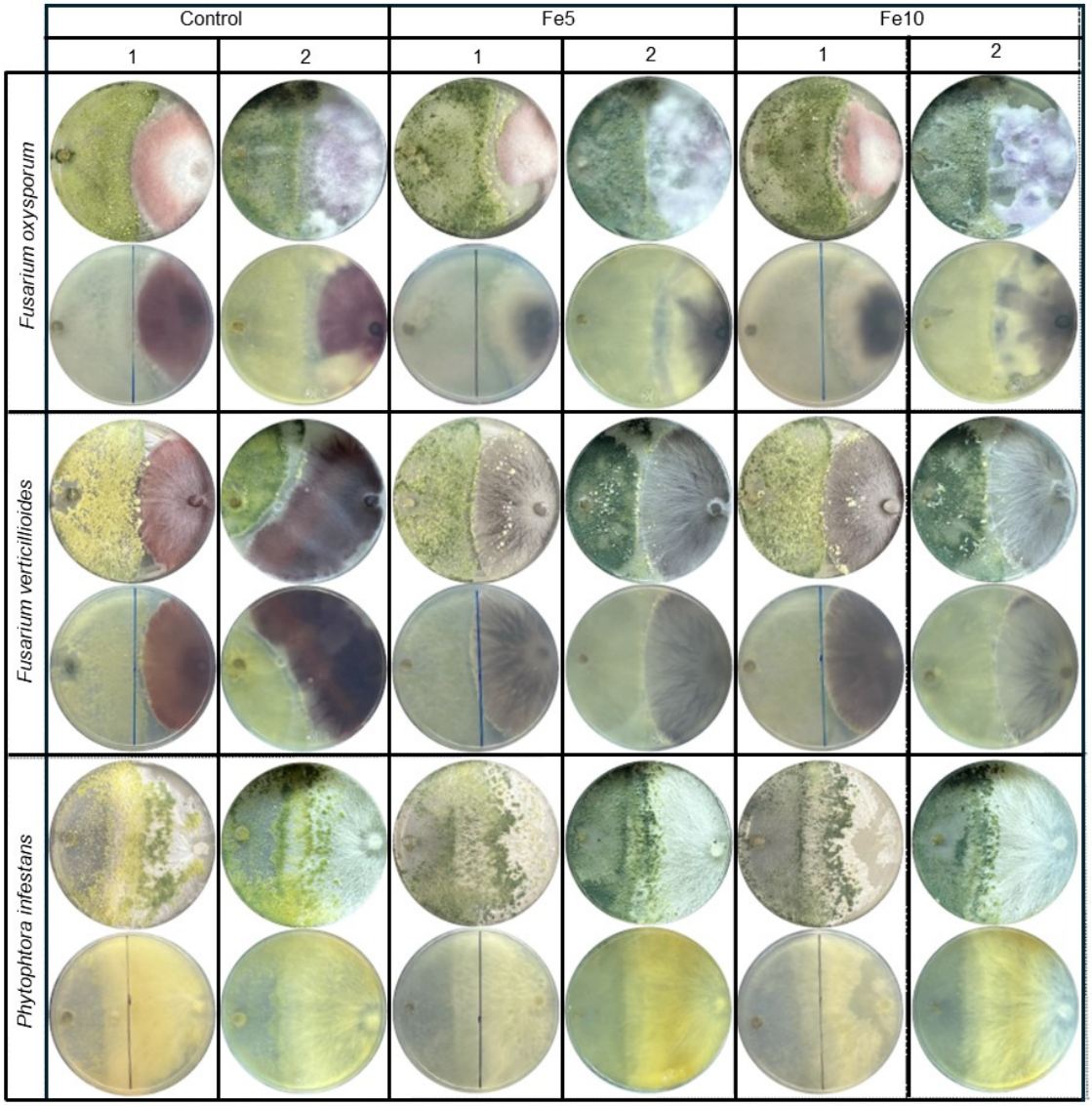
SI 8. XPS measurements (a) survey, (b) C1s, (c) O1s and (d) Fe2p of samples Fe5 and Fe5HT.



SI 9. Tauc plot fitting for Fe10 and Fe10HT samples assuming direct bandgap transition.



SI 10. Antagonistic interactions between *Trichoderma harzianum* and phytopathogenic fungi under biosynthesized iron nanoparticle supplementation at 2 and 10 days.



SI 11. Antagonistic interactions between *Trichoderma harzianum* and phytopathogenic fungi under Fe5 and Fe10 supplementation treatments after 10 days. For each condition, two independent biological replicates (1 and 2) are shown.