



Supplementary

Effects of using titanium dioxide nanoparticles in seed submersion and soil amendment on rice growth and yield

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Supplementary Figures



Fig. S1 Pearson correlation coefficients between quantities of Pathum Thani 1 rice significantly impacted by titanium dioxide nanoparticle treatment for Ti accumulation in soil, rice leaves, roots and stems, rice height, SPAD indices, number of panicles per hill, days to 50% flowering and harvest, fresh and dry weights, number of grains and percentage of good-quality grains

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Variable	Soil Ti	Leaf Ti	Root Ti	Stem Ti	Height	SPAD	Panicles #	50% flowering	50% harvest	Fresh weight	Dry weight	Grain #	Good grain %
Soil Ti	1												
Leaf Ti	0.896704	1											
Root Ti	0.902315	0.999891	1										
Stem Ti	0.901675	0.998991	0.999357	1									
Height	0.385009	0.598272	0.597012	0.616625	1								
SPAD	0.890908	0.990841	0.991383	0.994252	0.674867	1							
Panicles #	0.237331	0.462808	0.461178	0.483272	0.985078	0.551991	1						
50% flowering	0.138337	0.402526	0.399830	0.422693	0.955132	0.492730	0.987210	1					
50% harvest	0.313480	0.529837	0.528574	0.549912	0.995824	0.614121	0.996474	0.975192	1				
Fresh weight	0.277562	0.494754	0.493078	0.513395	0.991394	0.578272	0.995312	0.969371	0.996489	1			
Dry weight	0.306241	0.509520	0.508399	0.529195	0.993424	0.593899	0.993801	0.963925	0.997158	0.999168	1		
Grain #	0.300518	0.513543	0.511998	0.532024	0.993629	0.595506	0.993099	0.963868	0.996452	0.999647	0.999516	1	
Good grain %	0.301394	0.514247	0.512735	0.532915	0.993956	0.597252	0.994253	0.966238	0.997300	0.999683	0.999605	0.999887	1

Variable	Soil Ti	Leaf Ti	Root Ti	Stem Ti	Height	SPAD	Panicles #	50% flowering	50% harvest	Fresh weight	Dry weight	Grain #	Good grain %
Soil Ti	1												
Leaf Ti	0.898403	1											
Root Ti	0.914062	0.999134	1										
Stem Ti	0.906047	0.998032	0.997925	1									
Height	0.425565	0.643450	0.618797	0.637750	1								
SPAD	0.896168	0.987967	0.986346	0.984274	0.715547	1							
Panicles #	0.145591	0.430366	0.397461	0.424699	0.952965	0.497870	1						
50% flowering	0.216113	0.458301	0.428940	0.440157	0.958494	0.546876	0.960937	1					
50% harvest	0.320334	0.572284	0.543433	0.562956	0.989189	0.639251	0.978916	0.976632	1				
Fresh weight	0.278875	0.514361	0.485875	0.506934	0.986492	0.593527	0.983780	0.982704	0.994519	1			
Dry weight	0.395540	0.579897	0.556296	0.574644	0.992579	0.665325	0.947473	0.966222	0.981373	0.988573	1		
Grain #	0.297340	0.526141	0.498368	0.518582	0.989024	0.606877	0.979123	0.982913	0.993940	0.999679	0.991811	1	
Good grain %	0.306633	0.535431	0.507754	0.528375	0.990486	0.614379	0.979026	0.980575	0.994972	0.999567	0.992165	0.999866	1

Variable	Soil Ti	Leaf Ti	Root Ti	Stem Ti	Height	SPAD	Panicles #	50% flowering	50% harvest	Fresh weight	Dry weight	Grain #	Good grain %
Soil Ti	1												
Leaf Ti	0.900985	1											
Root Ti	0.903200	0.999818	1										
Stem Ti	0.879345	0.998306	0.997711	1									
Height	0.412910	0.639843	0.631446	0.663903	1								
SPAD	0.840938	0.924375	0.921507	0.923185	0.831553	1							
Panicles #	0.219331	0.430442	0.420716	0.457137	0.967472	0.691172	1						
50% flowering	0.102377	0.335355	0.326376	0.364371	0.935934	0.608535	0.989749	1					
50% harvest	0.297869	0.509322	0.500736	0.533143	0.984252	0.754607	0.994161	0.979413	1				
Fresh weight	0.284855	0.505088	0.496302	0.531102	0.985302	0.744359	0.995512	0.980898	0.998997	1			
Dry weight	0.239214	0.426909	0.417916	0.446746	0.954469	0.707021	0.988832	0.981735	0.990042	0.984815	1		
Grain #	0.296873	0.514563	0.505784	0.540669	0.986847	0.751018	0.994696	0.977896	0.998402	0.999803	0.982231	1	
Good grain %	0.310473	0.523667	0.514820	0.548659	0.988276	0.760943	0.994068	0.975394	0.999003	0.999545	0.984182	0.999707	1

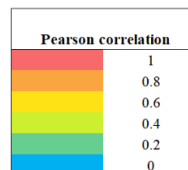


Fig. S2 Pearson correlation coefficients between quantities of KDML105 rice significantly impacted by titanium dioxide nanoparticle treatment for Ti accumulation in soil, rice leaves, roots and stems, rice height, SPAD indices, number of panicles per hill, days to 50% flowering and harvest, fresh and dry weights, number of grains and percentage of good-quality grains

Supplementary Tables

Table S1 Weight of seeds (mean $\pm$ SD) from rice subjected to titanium dioxide nanoparticle (TNP) exposure

TNP concentration (mg/L)	Weight of 100 seeds (g) for TNP size (nm)		
	20–30	80–120	400–600
(Pathum Thani 1) 0	-†	-	-
10	3.03 $\pm$ 0.06	2.99 $\pm$ 0.09	3.00 $\pm$ 0.13
50	2.98 $\pm$ 0.13	2.99 $\pm$ 0.14	2.95 $\pm$ 0.11
100	2.97 $\pm$ 0.10	3.05 $\pm$ 0.14	3.04 $\pm$ 0.10
250	2.99 $\pm$ 0.12	3.07 $\pm$ 0.08	3.13 $\pm$ 0.09
1,000	3.02 $\pm$ 0.07	2.98 $\pm$ 0.08	3.06 $\pm$ 0.10
<i>p</i> -Value, %CV	0.84, 3.19	0.49, 3.60	0.47, 3.57
(KDML105) 0	-	-	-
10	3.06 $\pm$ 0.11	2.97 $\pm$ 0.12	2.95 $\pm$ 0.12
50	3.05 $\pm$ 0.12	3.03 $\pm$ 0.04	2.94 $\pm$ 0.04
100	3.03 $\pm$ 0.06	3.04 $\pm$ 0.04	3.00 $\pm$ 0.07
250	3.01 $\pm$ 0.18	3.01 $\pm$ 0.09	2.99 $\pm$ 0.14
1,000	2.90 $\pm$ 0.08	2.93 $\pm$ 0.07	3.03 $\pm$ 0.14
<i>p</i> -Value, %CV	0.16, 4.15	0.07, 2.85	0.63, 3.56

CV = coefficient of variance.

† = no seeds produced by rice.

Table S2 Width and length of seeds (mean $\pm$ SD) from rice subjected to titanium dioxide nanoparticle (TNP) exposure

TNP concentration (mg/L)	Seed width (mm) for TNP size (nm)			Seed length (mm) for TNP size (nm)		
	20–30	80–120	400–600	20–30	80–120	400–600
(Pathum Thani 1) 0	-†	-	-	-	-	-
10	2.07 $\pm$ 0.21	1.94 $\pm$ 0.14	1.95 $\pm$ 0.16	10.35 $\pm$ 0.25	10.57 $\pm$ 0.47	10.68 $\pm$ 0.37
50	1.89 $\pm$ 0.17	2.04 $\pm$ 0.11	1.85 $\pm$ 0.11	10.58 $\pm$ 0.54	10.74 $\pm$ 0.69	10.84 $\pm$ 0.60
100	1.83 $\pm$ 0.24	1.98 $\pm$ 0.27	1.92 $\pm$ 0.29	10.61 $\pm$ 0.53	10.99 $\pm$ 0.65	10.83 $\pm$ 0.60
250	1.92 $\pm$ 0.22	1.96 $\pm$ 0.15	1.94 $\pm$ 0.20	10.37 $\pm$ 0.45	10.51 $\pm$ 0.57	11.04 $\pm$ 0.34
1,000	1.95 $\pm$ 0.18	1.98 $\pm$ 0.21	2.08 $\pm$ 0.18	11.02 $\pm$ 0.43	10.80 $\pm$ 0.62	10.72 $\pm$ 0.87
<i>p</i> -Value, %CV	0.39, 10.7	0.92, 8.77	0.36, 10.2	0.11, 4.60	0.66, 5.47	0.85, 5.19
(KDML105) 0	-	-	-	-	-	-
10	1.90 $\pm$ 0.19	1.83 $\pm$ 0.12	1.96 $\pm$ 0.22	10.61 $\pm$ 0.72	10.64 $\pm$ 0.43	11.11 $\pm$ 0.65
50	2.11 $\pm$ 0.25	1.88 $\pm$ 0.23	1.90 $\pm$ 0.26	10.63 $\pm$ 0.58	10.46 $\pm$ 0.69	11.06 $\pm$ 0.51
100	2.08 $\pm$ 0.22	2.06 $\pm$ 0.14	2.03 $\pm$ 0.18	10.50 $\pm$ 0.71	10.78 $\pm$ 0.47	10.99 $\pm$ 0.48
250	2.15 $\pm$ 0.15	1.96 $\pm$ 0.20	2.07 $\pm$ 0.25	10.58 $\pm$ 0.46	10.82 $\pm$ 0.74	10.71 $\pm$ 0.42
1,000	1.99 $\pm$ 0.04	2.04 $\pm$ 0.21	1.98 $\pm$ 0.20	10.77 $\pm$ 0.39	10.92 $\pm$ 0.29	11.02 $\pm$ 0.59
<i>p</i> -Value, %CV	0.27, 10.5	0.16, 9.93	0.85, 10.9	0.98, 5.17	0.64, 4.99	0.73, 4.71

CV = coefficient of variance.

† = no seeds produced by rice.

Table S3 Fat and ash contents (mean $\pm$ SD) in grains from rice subjected to titanium dioxide nanoparticle (TNP) exposure

TNP concentration (mg/L)	Fat content (%) in grains for TNP size (nm)			Ash content (%) in grains for TNP size (nm)		
	20–30	80–120	400–600	20–30	80–120	400–600
(Pathum Thani 1) 0	-†	-	-	-	-	-
10	0.46 $\pm$ 0.17	0.51 $\pm$ 0.09	0.51 $\pm$ 0.09	0.37 $\pm$ 0.03	0.40 $\pm$ 0.04	0.37 $\pm$ 0.07
50	0.52 $\pm$ 0.09	0.53 $\pm$ 0.07	0.50 $\pm$ 0.05	0.39 $\pm$ 0.04	0.34 $\pm$ 0.07	0.36 $\pm$ 0.04
100	0.52 $\pm$ 0.07	0.51 $\pm$ 0.11	0.57 $\pm$ 0.05	0.39 $\pm$ 0.04	0.37 $\pm$ 0.05	0.35 $\pm$ 0.07
250	0.53 $\pm$ 0.11	0.46 $\pm$ 0.11	0.56 $\pm$ 0.11	0.35 $\pm$ 0.05	0.38 $\pm$ 0.04	0.36 $\pm$ 0.05
1,000	0.47 $\pm$ 0.12	0.46 $\pm$ 0.06	0.47 $\pm$ 0.12	0.38 $\pm$ 0.02	0.37 $\pm$ 0.05	0.38 $\pm$ 0.03
<i>p</i> -Value, %CV	0.73, 23.0	0.57, 18.1	0.30, 17.7	0.32, 10.1	0.36, 13.7	0.86, 14.2
(KDML105) 0	-	-	-	-	-	-
10	0.58 $\pm$ 0.11	0.55 $\pm$ 0.10	0.54 $\pm$ 0.05	0.25 $\pm$ 0.04	0.30 $\pm$ 0.02	0.29 $\pm$ 0.04
50	0.51 $\pm$ 0.10	0.50 $\pm$ 0.09	0.48 $\pm$ 0.11	0.29 $\pm$ 0.03	0.27 $\pm$ 0.03	0.30 $\pm$ 0.03
100	0.43 $\pm$ 0.11	0.52 $\pm$ 0.09	0.50 $\pm$ 0.08	0.26 $\pm$ 0.06	0.29 $\pm$ 0.05	0.29 $\pm$ 0.03
250	0.51 $\pm$ 0.11	0.52 $\pm$ 0.08	0.54 $\pm$ 0.06	0.29 $\pm$ 0.02	0.28 $\pm$ 0.03	0.30 $\pm$ 0.04
1,000	0.47 $\pm$ 0.06	0.54 $\pm$ 0.08	0.54 $\pm$ 0.07	0.27 $\pm$ 0.05	0.25 $\pm$ 0.05	0.29 $\pm$ 0.04
<i>p</i> -Value, %CV	0.13, 21.1	0.83, 15.6	0.55, 14.8	0.32, 16.2	0.32, 13.9	0.98, 12.2

CV = coefficient of variance.

† = no grains produced by rice.

Table S4 Humidity content (mean $\pm$ SD) in grains from rice subjected to titanium dioxide nanoparticle (TNP) exposure

TNP concentration (mg/L)	Humidity (%) in grains for TNP size (nm)		
	20–30	80–120	400–600
(Pathum Thani 1) 0	-†	-	-
10	11.27 $\pm$ 0.31	11.20 $\pm$ 0.38	11.94 $\pm$ 0.44
50	11.82 $\pm$ 0.59	11.54 $\pm$ 0.45	11.65 $\pm$ 0.95
100	11.52 $\pm$ 0.59	11.80 $\pm$ 0.54	11.74 $\pm$ 0.64
250	11.76 $\pm$ 0.50	11.31 $\pm$ 0.49	11.61 $\pm$ 0.59
1,000	11.29 $\pm$ 0.49	11.64 $\pm$ 0.52	11.78 $\pm$ 0.50
<i>p</i> -Value, %CV	0.22, 4.56	0.21, 4.33	0.91, 5.21
(KDML105) 0	-	-	-
10	11.46 $\pm$ 0.70	12.10 $\pm$ 0.31	11.65 $\pm$ 0.55
50	11.72 $\pm$ 0.61	11.97 $\pm$ 0.58	11.89 $\pm$ 0.47
100	11.43 $\pm$ 0.53	11.62 $\pm$ 0.57	11.78 $\pm$ 0.62
250	11.75 $\pm$ 0.47	11.63 $\pm$ 0.66	11.29 $\pm$ 0.21
1,000	11.42 $\pm$ 0.51	11.45 $\pm$ 0.46	11.49 $\pm$ 0.54
<i>p</i> -Value, %CV	0.73, 4.76	0.22, 4.68	0.28, 4.37

CV = coefficient of variance.

† = no grains produced by rice.

Table S5 Calcium and potassium contents (mean $\pm$ SD) in grains from rice subjected to titanium dioxide nanoparticle (TNP) exposure

TNP concentration (mg/L)	Calcium content (%) in grains for TNP size (nm)			Potassium content (%) in grains for TNP size (nm)		
	20–30	80–120	400–600	20–30	80–120	400–600
(Pathum Thani 1) 0	-†	-	-	-	-	-
10	0.08 $\pm$ 0.01	0.08 $\pm$ 0.01	0.08 $\pm$ 0.01	0.15 $\pm$ 0.02	0.16 $\pm$ 0.03	0.15 $\pm$ 0.03
50	0.08 $\pm$ 0.01	0.08 $\pm$ 0.01	0.08 $\pm$ 0.01	0.15 $\pm$ 0.03	0.15 $\pm$ 0.01	0.14 $\pm$ 0.02
100	0.08 $\pm$ 0.01	0.08 $\pm$ 0.01	0.09 $\pm$ 0.01	0.16 $\pm$ 0.02	0.16 $\pm$ 0.01	0.16 $\pm$ 0.02
250	0.08 $\pm$ 0.01	0.09 $\pm$ 0.01	0.08 $\pm$ 0.01	0.14 $\pm$ 0.03	0.16 $\pm$ 0.02	0.14 $\pm$ 0.02
1,000	0.08 $\pm$ 0.01	0.09 $\pm$ 0.01	0.08 $\pm$ 0.01	0.14 $\pm$ 0.02	0.15 $\pm$ 0.02	0.14 $\pm$ 0.02
<i>p</i> -Value, %CV	0.84, 11.4	0.76, 9.12	0.23, 10.3	0.55, 15.2	0.90, 10.7	0.61, 15.0
(KDML105) 0	-	-	-	-	-	-
10	0.07 $\pm$ 0.01	0.08 $\pm$ 0.01	0.08 $\pm$ 0.01	0.18 $\pm$ 0.02	0.17 $\pm$ 0.02	0.17 $\pm$ 0.01
50	0.08 $\pm$ 0.01	0.08 $\pm$ 0.01	0.08 $\pm$ 0.01	0.18 $\pm$ 0.02	0.18 $\pm$ 0.02	0.18 $\pm$ 0.03
100	0.08 $\pm$ 0.01	0.08 $\pm$ 0.01	0.09 $\pm$ 0.01	0.18 $\pm$ 0.02	0.19 $\pm$ 0.02	0.18 $\pm$ 0.02
250	0.08 $\pm$ 0.01	0.08 $\pm$ 0.01	0.08 $\pm$ 0.01	0.19 $\pm$ 0.02	0.18 $\pm$ 0.03	0.20 $\pm$ 0.02
1,000	0.08 $\pm$ 0.01	0.08 $\pm$ 0.01	0.08 $\pm$ 0.01	0.18 $\pm$ 0.02	0.18 $\pm$ 0.02	0.19 $\pm$ 0.03
<i>p</i> -Value, %CV	0.31, 10.1	0.85, 11.0	0.23, 10.7	0.73, 11.0	0.40, 10.9	0.16, 11.7

CV = coefficient of variance.

† = no grains produced by rice.