

Supplementary material

Development of mechanical soil stability in an initial homogeneous loam and sand under in-situ field conditions

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TABLE S1 Full results for all bulk measurements showing mean and standard errors for individual groups. L = loam, S = sand, WT = wild type, and *rth3* = mutant with suppressed root hair elongation

Parameter [unit]	Group	Substrate	Genotype
σ_{pc} [kPa]	14 cm 2019	L: 31.6 (0.016) ^a	WT: 28.6 (2.266) ^a
		S: 25.2 (0.006) ^b	<i>rth3</i> : 27.9 (1.885) ^a
	34 cm 2019	L: 26.6 (1.460) ^a	WT: 24.8 (1.710) ^b
		S: 28.9 (2.904) ^a	<i>rth3</i> : 31.5 (2.800) ^a
	14 cm 2020	L: 45.5 (4.124) ^a	WT: 37.1 (5.148) ^a
		S: 26.4 (2.724) ^b	<i>rth3</i> : 33.7 (3.536) ^a
	34 cm 2020	L: 39.0 (3.562) ^a	WT: 32.3 (3.601) ^a
		S: 26.8 (1.462) ^b	<i>rth3</i> : 33.7 (2.840) ^a
C_c [log kPa ⁻¹]	14 cm 2019	L: 0.337 (0.014) ^a	WT: 0.200 (0.042) ^a
		S: 0.064 (0.003) ^b	<i>rth3</i> : 0.189 (0.044) ^a
	34 cm 2019	L: 0.363 (0.009) ^a	WT: 0.216 (0.044) ^a
		S: 0.071 (0.003) ^b	<i>rth3</i> : 0.190 (0.048) ^a
	14 cm 2020	L: 0.313 (0.011) ^a	WT: 0.186 (0.035) ^a
		S: 0.067 (0.006) ^b	<i>rth3</i> : 0.183 (0.042) ^a
	34 cm 2020	L: 0.302 (0.007) ^a	WT: 0.179 (0.036) ^a
		S: 0.064 (0.003) ^b	<i>rth3</i> : 0.189 (0.041) ^a
C_s [log kPa ⁻¹]	14 cm 2019	L: 0.127 (0.008) ^a	WT: 0.084 (0.012) ^a
		S: 0.048 (0.004) ^b	<i>rth3</i> : 0.088 (0.015) ^a

	34 cm 2019	L: 0.157 (0.008) ^a S: 0.054 (0.006) ^b	WT: 0.106 (0.014) ^a <i>rth3</i> : 0.095 (0.022) ^a
	14 cm 2020	L: 0.072 (0.006) ^a S: 0.045 (0.003) ^b	WT: 0.061 (0.006) ^a <i>rth3</i> : 0.055 (0.005) ^a
	34 cm 2020	L: 0.088 (0.007) ^a S: 0.032 (0.002) ^b	WT: 0.063 (0.010) ^a <i>rth3</i> : 0.059 (0.011) ^a
El [-]	14 cm 2019	L: 0.049 (0.003) ^b S: 0.120 (0.012) ^a	WT: 0.084 (0.013) ^a <i>rth3</i> : 0.089 (0.016) ^a
	34 cm 2019	L: 0.046 (0.004) ^b S: 0.120 (0.015) ^a	WT: 0.088 (0.016) ^a <i>rth3</i> : 0.084 (0.016) ^a
	14 cm 2020	L: 0.052 (0.005) ^b S: 0.129 (0.013) ^a	WT: 0.081 (0.011) ^a <i>rth3</i> : 0.104 (0.019) ^a
	34 cm 2020	L: 0.045 (0.008) ^b S: 0.129 (0.005) ^a	WT: 0.094 (0.014) ^a <i>rth3</i> : 0.078 (0.015) ^a

TABLE S2 Full ANOVA tables for pre-compression stress with factors substrate, genotype, and their interaction

Source	df	SS	MS	F	p
Pre-compression stress, 14 cm 2019					
Substrate	1	240.2	240.2	6.121	0.023
Genotype	1	0.8	0.8	0.019	0.891
Interaction	1	84.8	84.8	2.162	0.158
Residuals	19	745.5	39.24		
Pre-compression stress, 14 cm 2020					
Substrate	1	2092.1	2092.1	14.434	0.001
Genotype	1	38.3	38.3	0.264	0.613
Interaction	1	58.0	58.0	0.400	0.535
Residuals	19	2754.0	144.9		
Pre-compression stress, 34 cm 2019					
Substrate	1	29.9	29.9	0.700	0.414
Genotype	1	228.6	228.6	5.352	0.033
Interaction	1	307.7	307.7	7.205	0.015
Residuals	18	768.7	42.71		
Pre-compression stress, 34 cm 2020					

Substrate	1	817.3	817.3	9.087	0.008
Genotype	1	10.1	10.1	0.112	0.742
Interaction	1	1.3	1.3	0.014	0.906
Residuals	18	1619.1	89.9		

TABLE S3 Full ANOVA tables for compression index with factors substrate, genotype, and their interaction

Source	df	SS	MS	F	p
Compression index, 14 cm 2019					
Substrate	1	0.4276	0.4276	382.846	4.7E-14
Genotype	1	0.0000	0.0000	0.002	0.964
Interaction	1	0.0000	0.0000	0.006	0.939
Residuals	19	0.0212	0.0011		
Compression index, 14 cm 2020					
Substrate	1	0.3456	0.3456	476.537	6.5E-15
Genotype	1	0.0004	0.0004	0.494	0.491
Interaction	1	0.0023	0.0023	3.161	0.091
Residuals	19	0.0138	0.0007		
Compression index, 34 cm 2019					
Substrate	1	0.4652	0.4652	900.191	<2E-16
Genotype	1	0.0001	0.0001	0.122	0.731
Interaction	1	0.0000	0.0000	0.081	0.780
Residuals	18	0.0093	0.0005		
Compression index, 34 cm 2020					
Substrate	1	0.3110	0.3110	950.639	<2E-16
Genotype	1	0.0006	0.0006	1.734	0.204
Interaction	1	0.0001	0.0001	0.270	0.610
Residuals	18	0.0059	0.0003		

TABLE S4 Full ANOVA tables for swelling index with factors substrate, genotype, and their interaction

Source	df	SS	MS	F	p
Swelling index, 14 cm 2019					
Substrate	1	0.0356	0.0356	85.525	1.8E-08
Genotype	1	0.0003	0.0003	0.639	0.434
Interaction	1	0.0004	0.0004	0.867	0.363
Residuals	19	0.00791	0.00042		
Swelling index, 14 cm 2020					
Substrate	1	0.0043	0.0043	18.178	0.0004
Genotype	1	0.0001	0.0001	0.371	0.550
Interaction	1	0.0001	0.0001	0.311	0.583
Residuals	19	0.004454	0.000243		
Swelling index, 34 cm 2019					
Substrate	1	0.0579	0.0579	113.683	3.3E-09

Genotype	1	0.0000	0.0000	0.003	0.956
Interaction	1	0.0020	0.0020	3.888	0.064
Residuals	18	0.00917	0.00051		
Swelling index, 34 cm 2020					
Substrate	1	0.0165	0.0165	56.562	8.4E-07
Genotype	1	0.0003	0.0003	0.948	0.344
Interaction	1	0.0000	0.0000	0.004	0.953
Residuals	18	0.004964	0.000292		

TABLE S5 Full ANOVA tables for elasticity index with factors substrate, genotype, and their interaction

Source	df	SS	MS	F	p
Elasticity index, 14 cm 2019					
Substrate	1	0.2887	0.2887	26.602	5.6E-05
Genotype	1	0.0000	0.0000	0.026	0.875
Interaction	1	0.0000	0.0000	0.015	0.905
Residuals	19	0.020619	0.001085		
Elasticity index, 14 cm 2020					
Substrate	1	0.0334	0.0334	33.557	1.4E-05
Genotype	1	0.0022	0.0022	2.185	0.156
Interaction	1	0.0032	0.0032	3.239	0.088
Residuals	19	0.01891	0.00100		
Elasticity index, 34 cm 2019					
Substrate	1	0.02943	0.02943	18.889	0.0004
Genotype	1	0.000591	0.000591	0.380	0.546
Interaction	1	0.000691	0.000691	0.443	0.514
Residuals	18	0.028049	0.001558		
Elasticity index, 34 cm 2020					
Substrate	1	0.0387	0.0387	86.046	2.8e-08
Genotype	1	0.0014	0.0014	3.190	0.091
Interaction	1	0.0000	0.0000	0.005	0.944
Residuals	18	0.00810	0.00045		

TABLE S6 ANOVA tables for bulk density for loam and sand with factors depth, year, and their interaction. Bulk densities are a mean of two values

Source	df	SS	MS	F	p
Bulk density, loam					
Depth	1	0.0040	0.0040	1.496	0.228
Year	1	0.0196	0.0196	7.285	0.010
Interaction	1	0.0016	0.0016	0.604	0.442
Residuals	40	0.107	0.003		
Bulk density, sand					
Depth	1	0.013	0.013	9.856	0.003
Year	1	0.00002	0.00002	0.016	0.900

Interaction	1	0.0001	0.0001	0.067	0.797
Residuals	44	0.058	0.001		

TABLE S7 Full ANOVA tables for pre-compression stress with factors depth, year, and their interaction

Source	df	SS	MS	F	p
Pre-compression stress, L WT					
Depth	1	373.8	373.8	2.352	0.141
Year	1	998.4	998.4	6.282	0.021
Interaction	1	15.9	15.9	0.100	0.755
Residuals	20	3178	158.9		
Pre-compression stress, L <i>rth3</i>					
Depth	1	29.1	29.1	0.827	0.378
Year	1	861.7	861.7	24.454	0.0002
Interaction	1	1.4	1.4	0.039	0.847
Residuals	15	528.6	35.2		
Pre-compression stress, S WT					
Depth	1	2.7	2.7	0.070	0.794
Year	1	60.3	60.3	1.546	0.228
Interaction	1	1.7	1.7	0.043	0.837
Residuals	20	780.6	39.03		
Pre-compression stress, S <i>rth3</i>					
Depth	1	164.3	164.3	2.230	0.152
Year	1	82.2	82.2	1.116	0.304
Interaction	1	80.2	80.2	1.089	0.310
Residuals	19	1399.7	73.67		

TABLE S8 Full ANOVA tables for compression index with factors depth, year, and their interaction

Source	df	SS	MS	F	p
Compression index, L WT					
Depth	1	0.00055	0.00055	0.442	0.514
Year	1	0.01574	0.01574	12.673	0.002
Interaction	1	0.00111	0.00111	0.894	0.356
Residuals	20	0.02484	0.00124		
Compression index, L <i>rth3</i>					
Depth	1	0.00003	0.00003	0.026	0.873
Year	1	0.00461	0.00461	3.885	0.067
Interaction	1	0.00281	0.00281	2.373	0.144
Residuals	15	0.01779	0.00119		
Compression index, S WT					
Depth	1	0.00003	0.00003	0.097	0.758
Year	1	0.00000	0.00000	0.002	0.962
Interaction	1	0.00053	0.00053	1.941	0.179
Residuals	20	0.00546	0.00027		

Compression index, <i>S rth3</i>					
Depth	1	0.00023	0.00023	2.104	0.163
Year	1	0.00007	0.00007	0.617	0.442
Interaction	1	0.00000	0.00000	0.007	0.936
Residuals	19	0.00210	0.00011		

TABLE S9 Full ANOVA tables for swelling index with factors depth, year, and their interaction

Source	df	SS	MS	F	p
Swelling index, L WT					
Depth	1	0.00345	0.00345	5.833	0.025
Year	1	0.01634	0.01634	27.623	3.8E-05
Interaction	1	0.00013	0.00013	0.211	0.651
Residuals	20	0.01183	0.00059		
Swelling index, L <i>rth3</i>					
Depth	1	0.00213	0.00213	5.570	0.032
Year	1	0.02550	0.02550	51.557	3.2E-06
Interaction	1	0.00059	0.00059	1.201	0.290
Residuals	15	0.00742	0.00050		
Swelling index, S WT					
Depth	1	0.0000	0.00000	0.001	0.972
Year	1	0.00114	0.00114	9.345	0.006
Interaction	1	0.00118	0.00118	9.628	0.006
Residuals	20	0.00245	0.00122		
Swelling index, S <i>rth3</i>					
Depth	1	0.00022	0.00022	0.833	0.373
Year	1	0.00066	0.00066	2.487	0.132
Interaction	1	0.00015	0.00015	0.570	0.460
Residuals	18	0.00480	0.00027		

TABLE S10 Full ANOVA tables for elasticity index with factors depth, year, and their interaction

Source	df	SS	MS	F	p
Elasticity index, L WT					
Depth	1	0.00004	0.00004	0.090	0.767
Year	1	0.00031	0.00031	0.726	0.404
Interaction	1	0.000001	0.000001	0.002	0.969
Residuals	20	0.00842	0.00042		
Elasticity index, L <i>rth3</i>					
Depth	1	0.00039	0.00039	2.218	0.157
Year	1	0.00018	0.00018	1.010	0.331
Interaction	1	0.00010	0.00010	0.550	0.470
Residuals	15	0.00265	0.00018		
Elasticity index, S WT					

Depth	1	0.00227	0.00227	1.731	0.203
Year	1	0.00005	0.00005	0.035	0.854
Interaction	1	0.00053	0.00053	0.405	0.531
Residuals	20	0.02622	0.00131		
Elasticity index, <i>S rth3</i>					
Depth	1	0.00256	0.00256	1.266	0.275
Year	1	0.00236	0.00236	1.169	0.293
Interaction	1	0.00051	0.00051	0.254	0.620
Residuals	19	0.03838	0.00202		

TABLE S11 Full ANOVA tables for energy required for a root of 1 mm diameter to grow 1 m with factors substrate, genotype, and interaction. Data were log-transformed and grouped according to depth, year, and matric potential

Source	df	SS	MS	F	p
Energy, 14 cm 2019, -3 kPa					
Substrate	1	0.0145	0.0145	0.452	0.509
Genotype	1	0.0004	0.0004	0.011	0.917
Interaction	1	0.0983	0.0983	3.061	0.096
Residuals	19	0.6102	0.03211		
Energy, 14 cm 2019, -12.5 kPa					
Substrate	1	0.0011	0.0011	0.057	0.813
Genotype	1	0.2063	0.2063	10.467	0.004
Interaction	1	0.0026	0.0026	0.131	0.722
Residuals	19	0.3744	0.01971		
Energy, 14 cm 2019, -50 kPa					
Substrate	1	0.0268	0.0268	1.037	0.321
Genotype	1	0.0636	0.0636	2.457	0.134
Interaction	1	0.0504	0.0504	1.949	0.179
Residuals	19	0.4917	0.02588		
Energy, 34 cm 2019, -3 kPa					
Substrate	1	0.1323	0.1323	3.874	0.065
Genotype	1	0.0630	0.0630	1.846	0.191
Interaction	1	0.0542	0.0542	1.588	0.224
Residuals	18	0.6145	0.03414		
Energy, 34 cm 2019, -12.5 kPa					
Substrate	1	0.0009	0.0009	0.033	0.858
Genotype	1	0.0005	0.0005	0.018	0.896
Interaction	1	0.0036	0.0036	0.136	0.716
Residuals	19	0.5072	0.026695		
Energy, 34 cm 2019, -50 kPa					
Substrate	1	0.0020	0.0020	0.093	0.763
Genotype	1	0.0002	0.0002	0.011	0.919
Interaction	1	0.0145	0.0145	0.692	0.416
Residuals	19	0.3989	0.020997		

Energy, 14 cm 2020, -3 kPa					
Substrate	1	0.0031	0.0031	0.084	0.775
Genotype	1	0.0360	0.0360	0.974	0.336
Interaction	1	0.0232	0.0232	0.626	0.439
Residuals	19	0.7028	0.03699		
Energy, 14 cm 2020, -12.5 kPa					
Substrate	1	0.0077	0.0077	0.640	0.434
Genotype	1	0.0092	0.0092	0.760	0.394
Interaction	1	0.0328	0.0328	2.723	0.115
Residuals	19	0.2290	0.01205		
Energy, 14 cm 2020, -50 kPa					
Substrate	1	2.9278	2.9278	49.733	1.0E-06
Genotype	1	0.0579	0.0579	0.983	0.334
Interaction	1	0.1370	0.1370	2.326	0.144
Residuals	19	1.1185	0.0589		
Energy, 34 cm 2020, -3 kPa					
Substrate	1	0.1626	0.1626	1.477	0.239
Genotype	1	0.0007	0.0007	0.006	0.939
Interaction	1	0.0004	0.0004	0.004	0.953
Residuals	19	2.0914	0.11007		
Energy, 34 cm 2020, -12.5 kPa					
Substrate	1	1.2604	1.2604	9.526	0.006
Genotype	1	0.0757	0.0757	0.572	0.459
Interaction	1	0.0030	0.0030	0.023	0.882
Residuals	19	2.5140	0.1323		
Energy, 34 cm 2020, -50 kPa					
Substrate	1	2.9198	2.9198	22.445	0.0001
Genotype	1	0.6705	0.6705	5.154	0.035
Interaction	1	0.1384	0.1384	1.064	0.315
Residuals	19	2.4717	0.1301		
Energy, sand 2020, airdry (one-factorial)					
Genotype	1	7.153	7.153	1.88	0.185
Residuals	21	79.92	3.806		

TABLE S12 ANOVA tables for energy required for a root with 1 mm diameter to grow 1 m. Data were grouped according to substrate and matric potential. Loam data were log-transformed prior to statistical analysis

Source	df	SS	MS	F	p
Energy, loam, -3 kPa					
Depth	1	1.986	1.986	7.136	0.011
Year	1	0.000	0.000	0.000	0.998
Interaction	1	0.096	0.096	0.346	0.560
Residuals	40	11.129	0.278		
Energy, loam-12.5 kPa					

Depth	1	0.036	0.036	0.239	0.628
Year	1	0.000	0.000	0.002	0.964
Interaction	1	0.886	0.886	5.801	0.021
Residuals	40	6.107	0.153		
Energy, loam -50 kPa					
Depth	1	0.893	0.893	5.841	0.020
Year	1	0.001	0.001	0.004	0.948
Interaction	1	0.200	0.200	1.309	0.259
Residuals	40	6.113	0.153		
Energy, sand, -3 kPa					
Depth	1	0.028	0.028	7.263	0.010
Year	1	0.023	0.023	6.178	0.017
Interaction	1	0.007	0.007	1.881	0.178
Residuals	42	0.159	0.004		
Energy, sand, -12.5 kPa					
Depth	1	0.073	0.073	4.224	0.046
Year	1	0.178	0.178	10.302	0.0025
Interaction	1	0.007	0.007	0.381	0.540
Residuals	43	0.744	0.017		
Energy, sand, -50 kPa					
Depth	1	0.073	0.073	1.882	0.177
Year	1	1.907	1.907	49.107	1.3E-08
Interaction	1	0.017	0.017	0.428	0.517
Residuals	43	1.670	0.039		
Energy, sand 2020, airdry (one-factorial)					
Depth	1	0.011	0.011	0.003	0.959
Residuals	21	87.06	4.146		