Exploring the rhizosphere of perennial wheat: potential for plant growth promotion and biocontrol applications

Gianluigi Giannelli[1], Lorenzo Del Vecchio[1], Martina Cirlini[1], Marco Gozzi[1], Laura Gazza[2], Gianni Galaverna[1], Silvia Potestio[3] and Giovanna Visioli[3*]

[1]Department of Food and Drug, University of Parma, Parma, Italy; gianluigi.giannelli@unipr.it (G.Gi.); lorenzo.delvecchio@unipr.it (L.D.V.); martina.cirlini@unipr.it (M.C.); marco.gozzi@unipr.it (M.G.); gianni.galaverna@unipr.it (G.Ga.);

[2]CREA, Research Centre for Engineering and Agro-Food Processing, Rome, Italy; laura.gazza@crea.gov.it (L.G.)

[3]Department of Chemistry, Life Sciences and Environmental Sustainability, University of Parma, Parma, Italy; giovanna.visioli@unipr.it (G.V.); silvia.potestio@unipr.it (S.P.)

*Corresponding author: giovanna.visioli@unipr.it (G.V.)

Table S1. Identification and plant growth promotion traits of the forty-three bacterial strains isolated from the rhizosphere of the OK72 perennial wheat line

Strain	Homology (%)	GenBank accession no.	IAA (µg/mL)	PSU (%)	Biofilm formation (Abs units)	ACC-deaminase activity [a]	Protease activity (SI) [b]	Phosphate solubilization index (SI)[c]
OK_1	*Variovorax boronicumulans* (99.76)	PQ015127	0	66.98 ± 3.11	0.092 ± 0.033	+	-	-
OK_2	*Microbacterium yannicii* (100)	PQ015128	6.07 ± 2.89	58.07 ± 4.73	0.122 ± 0.043	-	-	-
OK_4	*Microbacterium proteolyticum (100)*	PQ015129	36.68 ± 7.95	44.93 ± 6.22	0.080 ± 0.011	-	2	-
OK_5	*Microbacterium hibisci (98.69)*	PQ015130	3.27 ± 1.86	56.64 ± 0.80	0.144 ± 0.068	-	-	-
OK_6	*Pedobacter petrophilus* (98.93)	PQ015131	10.96 ± 1.73	50.62 ± 9.45	0.084 ± 0.005	-	3.1 ± 0.1	-
OK_7	*Pedobacter borealis* (99.55)	PQ015132	15.38 ± 2.13	72.62 ± 12.36	0.258 ± 0.065	-	2.9 ± 0.1	-
OK_8	*Dyadobacter luteus* (97.21)	PQ015133	3.32 ± 0.34	50.94 ± 1.10	0.278 ± 0.165	-	-	-
OK_9	*Plantibacter auratus* (99.78)	PQ015134	99.39 ± 7.77	74.71 ± 12.38	0.504 ± 0.020	-	2.6 ± 0.2	-
OK_11	*Caulobacter soli (99.78)*	PQ015135	8.14 ± 3.55	38.49 ± 3.99	0.068 ± 0.001	-	-	-
OK_12	n.d.	n.d.	1.65 ± 0.24	14.66 ± 0.14	0.218 ± 0.025	-	2.9 ± 0.3	-
OK_13	n.d.	n.d.	0	18.41 ± 2.23	0.585 ± 0.086	-	2.8 ± 0.3	-
OK_14	*Dyadobacter ginsengisoli* (98.24)	PQ015136	0	38.31 ± 4.15	0.177 ± 0.049	-	-	-
OK_15	*Flavobacterium bizetiae* (99.17)	PQ015137	0	88.94 ± 2.65	0.112 ± 0.023	-	-	-
OK_16	*Variovoax paradoxus (99.70)*	PQ015138	0	90.43 ± 2.48	0.373 ±0.015	-	-	-
OK_17	*Pseudomonas azotoformans* (99.89)	PQ015139	0.92 ± 0.35	87.54 ± 4.25	0.838 ± 0.078	-	3.5 ± 0.9	2.7 ± 0.1
OK_18	*Microbacterium oleivorans*(100)	PQ015140	61.026 ± 10.49	58.64 ± 5.85	0.107 ± 0.029	-	2	-
OK_20	*Paenibacillus silagei (99.67)*	PQ015141	6.46 ± 2.57	48. 55 ± 0.64	0.338 ± 0.038	-	-	-
OK_21	*Epilithonimonas lactis (97.43)*	PQ015142	7.45 ± 2.6	14.90 ± 1.72	0.064 ± 0.004	-	2.5 ± 0.4	-
OK_22	*Frigoribacterium endophyticum* (99.30)	PQ015143	48.22 ± 10.59	50.05 ± 5.30	0.255 ± 0.071	-	-	-
OK_23	*Pseudomonas petroselini (100)*	PQ015144	0	86.94 ± 5.72	0.083 ± 0.002	-	-	3.8 ± 0.1
OK_26	*Aeromicrobium ginsengisoli* (97.99)	PQ015145	0	72.21 ± 10.52	0.831 ± 0.064	-	5.6 ± 0.6	-
OK_27	*Microbacterium aurantiacum* (99.86)	PQ015146	19.05 ± 5.70	38.18 ± 9.55	0.098 ± 0.008	-	2.3 ± 0.8	-
OK_28	*Curtobacterium herbarum* (99.75)	PQ015147	0	42.89 ± 8.56	0.085 ± 0.021	-	3.1 ± 0.5	-
OK_30	*Pseudomonas brassicacearum (98.84)*	PQ015148	2.78 ± 1.49	95.80 ± 6.09	0.086 ± 0.016	-	-	2.8 ± 0.1
OK_31	*Pseudomonas nabeulensis* (100)	PQ015149	4.03 ± 1.62	92.93 ± 9.77	0.097 ± 0.006	-	2.6 ± 0.3	2.4 ± 0.1
OK_32	*Flavobacterium olei* (99.53)	PQ015150	0	47.05 ± 5.10	0.067 ± 0.016	-	2.7 ± 0.1	-
OK_33	*Rhodococcus qingshengii* (100)	PQ015151	44.18 ± 6.88	42.91 ± 12.99	0.086 ± 0.013	+	-	-
OK_35	*Okibacterium fritillariae* (99.82)	PQ015152	57.52 ± 6.12	65.71 ± 7.06	0.045 ± 0.003	-	-	-
OK_39	*Pseudomonas lactis* (100)	PQ015153	7.9 ± 0.74	85.65 ± 4.27	0.554 ± 0.033	-	+	2.5 ± 0.1

OK_41	*Acinetobacter guillouiae (100)*	PQ015154	0	7.76 ± 4.98	0.800 ± 0.012	-	-	-
OK_42	*Pseudomonas canavaninivorans* (100)	PQ015155	12.51 ± 3.68	89.91 ± 0.30	0.096 ± 0.014	+	-	4.1 ± 0.1
OK_44	*Agrobacterium arsenijevicii (99.88)*	PQ015156	4.45 ± 0.66	14.33 ± 1.47	0.093 ± 0.032	-	+	-
OK_45	*Pseudomonas lactis* (99.58)	PQ015157	17.02 ± 2.46	73.02 ± 0.25	n.d.	-	2.3 ± 0.4	-
OK_46	n.d.	n.d.	33.92 ± 3.18	48.61 ± 0.55	0.061 ± 0.010	-	+	-
OK_47	*Caulobacter rhizosphaerae (99.88)*	PQ015158	0	23.44 ± 0.98	0.050 ± 0.010	-	-	-
OK_50	n.d.	n.d.	3.82 ± 0.46	5.14	n.d.	-	-	-
OK_52	*Pseudoxanthomonas wuyuanensis* (99.10)	PQ015159	1.95 ± 0.04	21.41 ± 1.29	n.d.	-	3.6 ± 0.5	-
OK_54	*Pseudomonas brassicacearum (98.17)*	PQ015160	88.58 ± 1.05	88.43 ± 1.44	0.078 ± 0.004	-	-	3.3 ± 0.1
OK_58	*Polaromonas ginsengisoli* (99.90)	PQ015161	0	n.d.	0.143 ± 0.023	-	-	-
OK_59	*Cellulosimicrobium funkei* (99.44)	PQ015162	n.d.	n.d.	0.056 ± 0.023	+	n.d.	n.d.
OK_64	*Pseudomonas brassicacearum* (99.66)	PQ015163	9.5 ± 1.1	79.68 ± 1.05	0.058 ± 0.002	-	+	3.3 ± 0.3
OK_71	n.d.	n.d.	15.94 ± 0.54	2.59 ± 1.71	n.d.	-	-	-
OK_90	*Plantibacter flavus* (99.55)	PQ015164	44.43 ± 3.96	40.46 ± 6.17	0.055 ± 0.009	-	-	-

[(a)] ACC-deaminase activity: (-) no bacterial growth on medium containing 1-aminocyclopropane-1-carboxylate as the only N source; (+) bacterial growth on medium containing 1-aminocyclopropane-1-carboxylate as the only source of N.

[(b)] (-) no protease activity detected while (+) indicates positive protease activity but the morphology of the colony did not allow the measurement to be made.

[(c)] (-) no phosphate solubilization detected.

n.d. Not determined.

Data are average of three independent experiments ± standard deviation (S.D.).

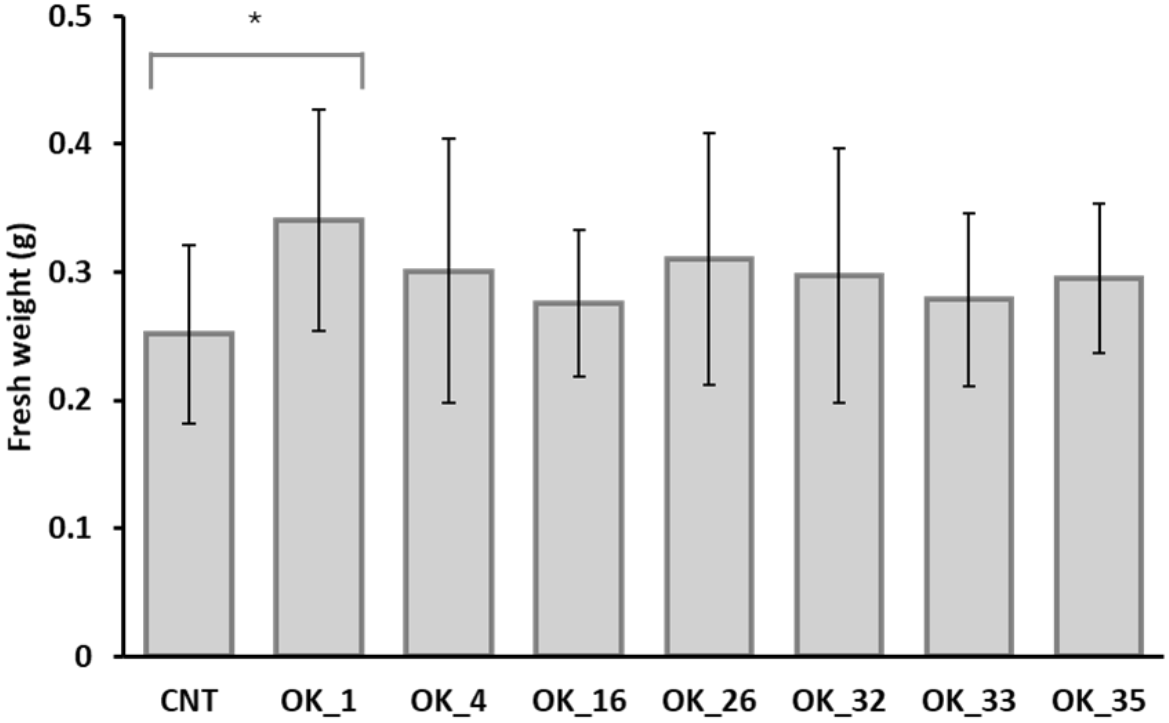

Figure S1. Growth-promoting activity exerted by bacteria on the fresh weight of the commercial wheat line. (A) Effect of the inoculation of the commercial wheat (*cv* Bologna) seeds with bacterial strains on fresh weight after ten days of growth. Data are presented as mean of thirty plantlets ± S.D. All the data showed significant differences compared to control conditions according to One-way ANOVA and Tukey's test ($p < 0.05$). Asterisk indicates significant differences between plants inoculated with respect to control condition (uninoculated) (One-way ANOVA and Tukey's test, *$p < 0.05$)