Phosphorus starvation boosts carboxylate secretion in P-deficient genotypes of *Lupinus angustifolius* with contrasting root structure

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Table S1. Analysis of variance (ANOVA) of rhizosphere extract pH (a), change in the rhizosphere extract pH in the zero-P and low-P treatments in comparison with the optimal-P treatment (b) and correlation coefficients between the rhizosphere extract pH and exudation of three wild genotypes of *L. angustifolius* grown for 6 weeks in a loamy soil supplied with zero, low (50 μM) or optimal P (400 μM)

a.   ANOVA (Tests of between-subject effects on pH value)

Source	DF	Probability	Significance
Genotype (G)	2	0.001	***
P application (P)	2	0.009	***
Interaction (G × P)	6	0.235	ns

b.   Change in the rhizosphere extract pH due to P starvation in comparison with the optimal-P treatment (*n*=3)

P treatment	#016	#044	#085
Zero P	0.65 *b*	−0.03 *a*	0.45 *b*
Low P	0.41 *c*	−0.16 *a*	−0.10 *b*

c.   Correlation coefficients between the rhizosphere extract pH and exudation of specific organic acid anions

	Malate	Acetate	Citrate	Fumarate	Total acid anions
r	**−0.44***	0.12	**−0.46***	**−0.44***	**−0.43***

DF, degrees of freedom; Test of between-subject effect is significant if $P \leq 0.05$ (*) or $P \leq 0.01$ (**). (b) For each P treatment, data sharing the same letter are not significantly different ($P \leq 0.05$). (c) Correlation coefficients in bold type are significant at $P \leq 0.05$ (*).

Table S2. Correlation coefficients between P acquisition and rhizosphere exudations of organic acid anions by three wild genotypes of *L. angustifolius* grown for 6 weeks in a loamy soil supplied with zero, low (50 μM) or optimal P (400 μM)

Treatment/organic acid anion	P concentration		P total content		PER		PPUE		PUtE	
	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root
Zero-P treatment										
Malate	−0.98	−0.89	−0.83	0.37	**0.93***	0.89	**0.97****	0.87		
Acetate	−0.19	−0.76	−0.84	**0.98***	0.35	0.76	0.38	0.78		
Citrate	−0.63	−0.97	−0.87	0.88	0.75	0.97	0.76	0.98		
Total acid anion	−0.79	**−0.94****	−0.99	0.74	0.88	**0.96****	0.9	**0.99***		
Low-P treatment										
Malate	−0.52	−0.40	0.92	0.99	0.55	0.39	0.85	0.92	0.93	0.49
Acetate	0.70	0.18	−0.8	**−0.92***	−0.73	−0.18	−0.95	−0.82	0.93	0.49
Citrate	−0.06	−0.78	0.97	0.79	0.09	0.78	0.51	0.99	0.52	−0.13
Total acid anions	−0.19	−0.69	**0.99***	0.87	0.23	0.69	0.62	**0.95***	0.84	0.32
Optimal-P treatment										
Malate	**−0.98***	−0.83	0.67	0.46	**0.94***	0.84	0.82	0.71	−0.23	−0.95
Acetate	**−0.95***	−0.89	0.65	0.49	**0.96***	0.87	0.92	0.77	0.33	0.99
Citrate	−0.81	−0.43	0.06	−0.14	0.84	0.39	0.51	0.23	−0.66	−0.68
Total acid anions	−0.99	−0.79	0.50	0.32	0.99	0.76	0.83	0.64	−0.60	−0.74

Correlation coefficients in bold type are significant (* $P \leq 0.05$; ** $P \leq 0.01$). P concentration (g kg^{-1} DM), P total content (mg plant^{-1}); PER, P efficiency ratio, dry mass/P content (kg DM g^{-1} P); PPUE, physiological P use efficiency, dry mass/P concentration (g^2 DM g^{-1} P); PUtE, P utilisation efficiency, dry mass increase/P content increase compared to the zero-P treatment (g DM g^{-1} P); DM = dry mass.

Table S3. Correlation coefficients between P acquisition and root and shoot traits of three wild genotypes of *L. angustifolius* grown for 6 weeks in a loamy soil supplied with zero, low (50 µM) or optimal P (400 µM)

Root / shoot trait	P concentration		P total content		PER		PPUE		PUtE	
	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root
Root mass	0.66	0.63	**0.94****	**0.93****	−0.61	−0.65	0.16	−0.01	−0.49	−0.59
Root length	**0.68***	**0.66***	**0.95****	**0.92****	−0.65	**−0.71***	0.11	−0.12	−0.47	−0.63
Root diameter	−0.47	−0.46	−0.43	−0.40	0.58	0.41	0.35	0.24	0.58	0.49
Root area	**0.71***	**0.68***	**0.96****	**0.94****	−0.66	**−0.72***	0.12	−0.12	−0.47	−0.64
Root volume	**0.70***	**0.68***	**0.96****	**0.95****	−0.65	**−0.72***	0.12	−0.10	−0.47	−0.63
Branch number	**0.75***	**0.66***	**0.86***	**0.94***	−0.58	**−0.70***	0.23	−0.10	−0.42	−0.60
SRL	**0. 90****	**0.91****	**0.93****	**0.94****	**−0.79***	**−0.91****	−0.13	−0.43	−0.42	**−0.88***
SRA	**0.78***	**0.82****	**0.85****	**0.86****	−0.66	**−0.84****	0.05	−0.32	−0.54	**−0.92****
Shoot mass	**0.67***	0.65	**0.96****	**0.93****	−0.64	**−0.70***	0.12	−0.13	−0.44	−0.61
Dead leaflet%	**−0.71***	−0.65	−0.62	0.63	**0.83***	0.63	0.59	0.36	**0.91***	0.62

Correlation coefficients in bold type are significant (* $P \leq 0.05$; ** $P \leq 0.01$). P concentration (g kg^{-1}DM), P total content (mg plant^{-1}); SRL, specific root length (root length/root mass, m g^{-1} dry root); SRA, specific root area (root area/root mass, m^2 g^{-1} dry root); PER, P efficiency ratio, dry mass/P content (kg DM g^{-1} P); PPUE, physiological P use efficiency, dry mass/P concentration (g^2 DM g^{-1} P); PUtE, P utilisation efficiency, dry mass increase/P content increase compared to the zero-P treatment (g DM g^{-1} P); DM = dry mass.