Supplementary Material

Lupine Cultivation Affects Soil's P Availability and Nutrient Uptake in Four Contrasting Soils

Table S1. Initial soil properties before the establishment of the experiment.

Site (soil type†)	PBray1	NH$^+_4$-N	NO$^-_3$-N	Ca^{2+}	Mg^{2+}	K$^+$	Na$^+$	Al^{3+} exch.	pH
	mg kg^{-1}			cmolc kg^{-1}					
Site 1 (Pachic Argiudoll)	12.0	16.4	21.9	14.5	3.0	1.0	0.2	0.05	5.17
Site 2 (Typic Dystrutepts)	15.6	25.7	0.3	4.6	1.2	0.3	0.1	0.05	5.32
Site 3 (Typic Argiudoll)	10.3	7.8	0.9	17.7	2.8	1.4	0.2	0.02	6.00
Site 4 (Typic Hapludults)	5.8	10.9	12.1	1.4	0.5	0.1	0.1	0.16	4.50

†USDA source: Keys to soil taxonomy. Soil Conservation Service. 2014.
https://www.nrcs.usda.gov/resources/guides-and-instructions/keys-to-soil-taxonomy

Table S2. ANOVA for soil PBray1 concentration at 87 days after planting.

Factor	gl	Valor de F	P > F†
Especie	2	17,77	**< 0.0001**
C1: Lupino vs. avena	1		**< 0.0001**
C2: L. albus vs. L. angustifolius	1		0.0556
Tipo de suelo	3	46,40	**< 0.0001**
Tipo de suelo x Especie	6	1,32	0.2721

† Significant effects (p < 0.05) are in bold.
Note: For this model species and soil type were considered as fixed factors.

Table S3. ANOVA for soil PBray1 concentration at 103 days after planting.

Treatment effect	DF	F Value	Pr > F†
Species	2	23.40	**<0.0001**
Soil type	3	60.09	**<0.0001**
Species x Soil type	6	3.81	**0.0048**
C1: Lupine vs. Oat in Site 1	1		**0.0008**
C1: Lupine vs. Oat in Site 2	1		**0.0002**
C1: Lupine vs. Oat in Site 3			**0.0340**
C1: Lupine vs. Oat in Site 4	1		**0.0009**
C2: L. albus vs L.angustifolius in Site 1	1		**0.0039**
C2: L. albus vs L.angustifolius in Site 2	1		**0.0290**
C2: L. albus vs L.angustifolius in Site 3	1		**0.0301**
C2: L. albus vs L.angustifolius in Site 4	1		0.1849

† Significant effects ($p < 0.05$) are in bold.
Note: For this model species and soil type were considered as fixed factors.

Table S4. ANOVA for soil pH at 87 days after planting.

Treatment effect	DF	F Value	Pr > F†
Species	2	28.25	**<0.0001**
Soil type	3	65.05	**<0.0001**
Species x Soil type	6	2.56	**0.0365**
C1: Lupine vs. Oat in Site 1	1		**0.0372**
C1: Lupine vs. Oat in Site 2	1		**0.0005**
C1: Lupine vs. Oat in Site 3			**<.0001**
C1: Lupine vs. Oat in Site 4	1		**0.0001**
C2: L. albus vs L.angustifolius in Site 1	1		0.9322
C2: L. albus vs L.angustifolius in Site 2	1		0.8250
C2: L. albus vs L.angustifolius in Site 3	1		**0.0017**
C2: L. albus vs L.angustifolius in Site 4	1		0.2385

† Significant effects ($p < 0.05$) are in bold.
Note: For this model species and soil type were considered as fixed factors.

Table S5. Orthogonal contrasts for biomass measurements.

Constrast Label	Aboveg. biomass	Plant P conc.	Plant P content	Plant N conc.	Plant N content
C1: Oat vs lupine in Site 1	**0.0058**	0.2001	**0.0201**	**<.0001**	**<.0001**
C1: Oat vs lupine in Site 2	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**0.0173**
C1: Oat vs lupine in Site 3	0.1525	0.6802	0.1277	**<.0001**	**<.0001**
C1: Oat vs lupine in Site 4	**0.0005**	**0.0399**	0.3391	**<.0001**	0.9579
C2:L.albus vs L. angustifolius in Site 1	**0.0046**	0.4438	**0.0040**	0.0853	**<.0001**
C2:L.albus vs L. angustifolius in Site 2	**0.0032**	0.7289	**0.0002**	**0.0002**	**<.0001**
C2:L.albus vs L. angustifolius in Site 3	**0.0009**	**0.0008**	**0.0354**	0.7395	**<.0001**
C2:L.albus vs L. angustifolius in Site 4	**0.0491**	0.0876	0.0906	0.336	**0.0394**

Significant effects (p<0.05) are in bold.

Table S6. Mean values of BNF proportion (Ndfa) and N fixed content of lupines as affected by species and soil type.

	Ndfa		N fixed content	
Species	%		mg pot^{-1}	
Lupinus albus	66.2	ns	237.4	a
Lupinus angustifolius	60.3	ns	105.3	b
Site (Soil type)				
Site 1 (Pachic Argiudoll)	71.7	b	197.0	a
Site 2 (Typic Dystrutepts)	59.4	c	187.9	a
Site 3 (Typic Argiudoll)	82.5	a	244.7	a
Site 4 (Typic Hapludults)	39.3	d	55.9	b
Significance of treatment effect				
Species	<0.1206		**<.0001**	
Soil type	**<0.0001**		**0.0011**	
Species*soil type	<0.0644		0.8933	

Significant effects (p < 0.05) are in bold. Different lowercase letters within a column indicate differences between species or sites, at p-level of 0.05. ns: means no significant difference.

Table S7. Pearson correlation coefficients (r) within each species across four soils types.

Variables		L. albus		L. angustifolius		A. strigosa	
ΔpH- initial	Shoot dry weight	-0.61	*	-0.75	*	-0.71	**
ΔpH- initial	Plant N content	-0.72	***	-0.71	*	-0.42	
ΔpH- initial	Plant P content	-0.75	**	-0.71	*	-0.91	***
pH_87 dap	Plant Mn concentration	0.66	**	-0.76	*	-0.06	
pH_48 dap	Plant Mn concentration	0,52	*	-0,77	**	-0.36	
PBray1-48dap	Plant Mn concentration	-0.21		0.30		-0.58	*
PBray1-48dap	Plant P concentration	0.56	*	0.16		0.63	*
PBray1-48dap	ΔpH- initial	-0.51	*	-0.12		-0.86	***
PBray1-48dap	Plant N content	0.60	*	0.16		0.34	
PBray1-48dap	Plant P content	0.80	**	0.22		0.87	***
PBray1-48dap	Shoot dry weight	0.51	*	0.31		-0.57	*
Plant P concentration	Plant Mn concentration	-0.26		0.13		-0.59	*
Plant N content	Plant P content	0.94	***	0.93	***	0.65	**

Significant at *p <0.05; **p <0.01; ***p <0.001.

Table S8. Pearson correlation coefficients (r) within each species across three soils types (excluding Site 4).

Variables		L. albus		L. angustifolius		A. strigosa	
ΔpH- initial	Shoot dry weight	-0.18		-0.51		-0.88	***
ΔpH- initial	Plant N content	-0.49		-0.40		-0.69	*
ΔpH- initial	Plant P content	-0.56		-0.40		-0.86	***
pH_48 dap	Plant Mn concentration	0.68	*	-0.85	**	-0.10	
PBray1-48dap	Plant Mn concentration	-0.63	*	0.27		-0.05	
PBray1-48dap	Plant P concentration	0.07		-0.35		-0.33	
PBray1-48dap	ΔpH- initial	-0.09		0.38		-0.55	
PBray1-48dap	Plant N content	-0.05		-0.22		0.62	*
PBray1-48dap	Plant P content	-0.00		-0.16		0.73	**
PBray1-48dap	Shoot dry weight	-0.07		-0.02		0.63	*
Plant P concentration	Plant Mn concentration	-0.50		0.03		-0.17	
Plant N content	Plant P content	0.83	***	0.92	***	0.87	***

Significant at *p <0.05; **p <0.01; ***p <0.001.