

Article – Supplementary materials

Laboratory Extractions of Soil Phosphorus Do Not Reflect the Fact That Liming Increases Rye Phosphorus Content and Yield in an Acidic Soil

Miguel Ángel Olego 1,* , Mateo D. Cuesta-Lasso 2, Fernando Visconti Reluy 3, Roberto López 4, Alba López-Losada 1 and Enrique Garzón-Jimeno 1,2

1 Research Institute of Vine and Wine, Universidad de León, Avenida de Portugal, 41, 24071 León, Spain

2 RGA Bioinvestigación S.L., 24071 León, Spain

3 Departamento de Ecología, Centro de Investigaciones sobre Desertificación-CIDE (CSIC, UVEG, GVA), Carretera CV-315, km 10.7, 46113 Moncada, Spain

4 Department of Applied Chemistry and Physics, Faculty of Biology and Environmental Sciences, Universidad

de León, Campus de Vegazana, 24071 León, Spain

* Correspondence: molem@unileon.es

SUPPLEMENTARY MATERIALS

Table S1. Averages and standard deviations (SD) of soil properties pH, CaECEC, MgECEC and AlECEC (effective cation exchange capacity of calcium, magnesium and aluminium respectively, in cmol (+)/kg), P (in mg/kg) and SOM (in %) during 2002-2010. Y: Year of sampling; H: Soil horizon of sampling (Ap1 horizon: 0-12 cm; Ap2 horizon: 12-25 cm; AB horizon: 25-35 cm); T: Liming treatment (C: control; DL: dolomitic limestone; L: limestone; SF: sugar foam).

Y	H	T	pH		CaECEC		MgECEC		AlECEC		P		SOM	
			Avera ge	SD	Avera ge	SD	Avera ge	SD	Avera ge	SD	Avera ge	SD	Avera ge	SD
2002	Ap1	C	3.97	0.01	6.70	0.81	2.51	1.34	83.8	4.94	18.5	1.18	2.27	0.53
2002	Ap1	DL	6.49	0.60	62.6	4.54	35.8	4.26	0.34	0.12	16.1	2.26	2.35	0.61
2002	Ap1	L	5.70	0.86	94.9	1.27	2.75	0.76	0.88	0.52	11.2	1.89	2.26	0.48
2002	Ap1	SF	4.98	0.51	87.7	4.14	3.83	1.61	6.16	3.94	16.1	0.78	2.16	0.23
2002	Ap2	C	4.01	0.02	8.73	4.83	1.91	0.75	84.7	6.07	24.3	3.42	2.06	0.54
2002	Ap2	DL	4.78	0.57	39.7	4.48	40.6	18.8	19.6	26.4	17.6	2.29	1.69	0.41
2002	Ap2	L	4.16	0.06	52.1	6.44	5.44	0.19	36.8	4.53	12.0	5.23	2.44	0.53
2002	Ap2	SF	4.24	0.09	43.2	28.6	2.88	1.39	50.7	29.2	10.8	2.45	2.20	0.18
2002	AB	C	4.13	0.04	19.0	3.83	2.08	1.14	75.7	3.70	10.3	1.66	1.03	0.54
2002	AB	DL	4.19	0.14	24.1	9.09	19.0	2.89	57.2	14.0	7.63	1.50	0.72	0.10
2002	AB	L	4.21	0.15	35.0	16.0	2.18	0.53	59.8	15.9	4.74	2.85	0.90	0.45
2002	AB	SF	4.20	0.23	16.2	6.12	1.98	0.90	73.2	16.0	9.13	3.78	1.04	0.13
2003	Ap1	C	3.79	0.07	10.1	2.84	2.20	1.61	82.3	1.52	16.8	1.23	1.92	0.32
2003	Ap1	DL	6.02	0.60	71.7	3.66	26.1	4.72	0.65	0.44	17.1	2.88	1.81	0.18
2003	Ap1	L	5.31	0.15	94.3	4.04	1.48	0.40	1.95	2.13	9.05	1.26	2.13	0.26
2003	Ap1	SF	6.37	0.99	92.2	6.94	3.06	2.46	0.89	0.17	16.4	2.34	1.70	0.23
2003	Ap2	C	3.79	0.04	14.6	3.98	2.46	0.44	78.4	3.74	23.8	1.09	1.98	0.28
2003	Ap2	DL	4.95	0.57	65.6	19.1	23.7	15.7	3.37	3.30	21.0	0.98	1.74	0.16
2003	Ap2	L	4.09	0.17	56.1	33.1	1.55	0.83	39.9	33.5	8.63	1.94	1.92	0.18
2003	Ap2	SF	4.56	0.07	78.3	5.50	3.73	2.50	12.6	4.12	10.6	3.59	1.38	0.26
2003	AB	C	3.91	0.03	5.55	5.03	4.03	3.14	86.6	5.24	10.0	0.62	0.90	0.43
2003	AB	DL	4.22	0.21	50.9	14.6	16.5	13.7	29.7	22.8	8.55	3.70	0.97	0.42
2003	AB	L	4.04	0.08	38.8	7.39	2.18	0.61	48.3	20.6	3.12	1.25	0.80	0.05
2003	AB	SF	4.25	0.10	56.3	6.62	3.52	2.16	32.6	12.9	7.81	4.80	0.94	0.28
2004	Ap1	C	3.84	0.05	14.4	2.53	0.58	0.31	81.3	5.72	15.9	3.14	2.40	0.33
2004	Ap1	DL	6.74	0.52	57.6	4.21	18.3	14.4	14.0	5.86	7.92	0.72	2.30	0.11
2004	Ap1	L	5.32	0.65	85.4	3.59	2.15	1.23	11.0	3.11	10.9	1.82	2.01	0.15
2004	Ap1	SF	5.70	0.90	68.3	9.92	0.45	0.30	30.3	10.6	13.7	2.15	2.42	0.38
2004	Ap2	C	4.01	0.25	10.8	7.05	0.60	0.50	81.2	13.6	8.58	4.68	2.20	0.94
2004	Ap2	DL	5.01	0.27	35.4	5.89	33.8	10.0	35.6	16.9	8.05	3.60	1.83	0.52
2004	Ap2	L	4.36	0.24	67.4	19.3	2.00	1.33	28.6	20.2	11.1	3.45	2.34	0.11
2004	Ap2	SF	4.52	0.30	38.6	5.52	1.68	1.63	53.9	14.4	19.1	1.94	2.05	0.15
2004	AB	C	4.00	0.08	17.2	13.7	1.15	0.93	79.6	13.9	3.86	1.82	0.67	0.11
2004	AB	DL	4.15	0.18	26.6	14.7	10.5	6.99	48.2	8.41	2.52	0.78	0.83	0.09
2004	AB	L	4.11	0.06	38.4	2.08	3.10	0.48	56.8	2.42	3.07	1.51	0.79	0.18
2004	AB	SF	4.29	0.07	30.8	17.0	0.95	0.86	67.2	18.6	4.25	0.93	0.72	0.09

Y	H	T	pH		CaECEC		MgECEC		AlECEC		P		SOM	
			Average	SD	Average	SD	Average	SD	Average	SD	Average	SD	Average	SD
2005	Ap1	C	3.74	0.06	3.40	2.10	0.51	0.28	86.9	1.36	17.0	1.50	2.33	0.08
2005	Ap1	DL	6.42	0.23	73.0	4.52	15.6	6.85	5.38	1.91	15.7	4.03	2.37	0.76
2005	Ap1	L	5.26	0.24	85.3	1.49	1.88	0.69	9.38	3.92	17.9	0.48	2.51	0.41
2005	Ap1	SF	6.50	0.68	88.0	5.67	0.48	0.20	10.2	5.69	15.5	1.03	2.21	0.13
2005	Ap2	C	3.76	0.04	8.30	7.10	1.25	0.61	86.6	8.95	20.1	2.22	2.30	0.23
2005	Ap2	DL	4.34	0.24	42.4	20.7	28.1	4.59	22.2	21.9	15.7	0.46	2.43	0.66
2005	Ap2	L	4.05	0.14	37.7	6.61	0.48	0.17	60.5	6.03	13.4	1.47	2.03	0.13
2005	Ap2	SF	4.18	0.29	50.7	23.2	0.25	0.21	48.2	22.8	14.1	1.05	1.89	0.28
2005	AB	C	3.84	0.03	9.90	7.46	0.73	0.49	87.8	9.53	12.4	7.05	0.65	0.22
2005	AB	DL	3.93	0.19	11.9	4.77	14.5	3.40	68.4	12.4	10.9	7.51	1.03	0.50
2005	AB	L	3.88	0.04	19.6	7.94	1.20	1.30	78.4	9.69	2.13	0.71	0.81	0.15
2005	AB	SF	4.04	0.18	27.4	19.0	1.29	0.13	69.6	20.6	13.2	8.88	0.85	0.25
2006	Ap1	C	3.93	0.09	9.45	6.19	1.30	1.40	82.1	7.64	16.3	0.96	2.54	0.44
2006	Ap1	DL	5.77	1.23	77.9	6.20	10.2	2.26	6.16	1.49	14.4	4.46	2.24	0.42
2006	Ap1	L	5.49	0.35	90.6	6.36	0.83	0.38	6.55	4.96	7.66	1.31	2.15	0.47
2006	Ap1	SF	6.48	0.80	92.2	1.78	0.53	0.15	5.88	0.73	10.2	1.66	2.28	0.18
2006	Ap2	C	4.07	0.14	4.58	1.17	0.98	0.13	88.5	0.72	11.5	0.75	1.72	0.38
2006	Ap2	DL	5.06	0.86	52.4	22.0	26.2	5.73	16.4	17.0	9.45	2.17	1.67	0.25
2006	Ap2	L	4.15	0.06	48.0	13.9	0.34	0.20	50.9	14.4	11.4	1.00	2.23	0.26
2006	Ap2	SF	4.34	0.01	74.7	7.47	0.61	0.12	23.7	7.35	12.5	5.00	1.90	0.14
2006	AB	C	3.92	0.06	18.3	8.47	2.09	0.40	79.0	9.56	7.90	5.77	0.48	0.04
2006	AB	DL	3.95	0.08	19.5	6.04	28.0	7.51	51.7	8.70	7.60	4.22	0.57	0.10
2006	AB	L	4.00	0.12	22.8	11.5	0.68	0.38	75.4	12.8	5.01	3.58	1.02	0.28
2006	AB	SF	4.10	0.12	23.4	2.59	1.10	0.12	72.7	7.54	6.49	5.84	0.58	0.24
2007	Ap1	C	3.92	0.06	8.75	4.81	2.38	0.46	86.1	6.24	14.6	2.52	2.22	0.31
2007	Ap1	DL	6.04	0.66	69.1	5.18	15.3	3.36	11.1	3.89	9.24	2.48	2.43	0.65
2007	Ap1	L	4.67	0.27	73.3	18.3	1.00	0.66	24.4	18.6	10.6	0.56	2.58	0.32
2007	Ap1	SF	6.29	0.20	79.1	2.91	2.18	0.24	14.9	7.41	10.4	0.74	1.98	0.14
2007	Ap2	C	3.98	0.05	4.35	3.42	2.64	0.54	90.7	2.24	12.3	0.67	1.92	0.46
2007	Ap2	DL	4.57	0.07	31.8	12.8	26.1	8.72	34.2	22.4	10.7	2.25	1.97	0.27
2007	Ap2	L	4.30	0.17	54.0	21.1	0.69	0.47	43.9	21.5	10.5	3.64	2.18	0.31
2007	Ap2	SF	5.17	0.28	54.4	3.91	2.55	1.81	35.3	9.12	9.74	3.57	2.19	0.35
2007	AB	C	4.05	0.06	6.28	5.63	2.55	0.54	89.1	6.01	9.35	6.92	0.58	0.18
2007	AB	DL	4.00	0.16	8.08	6.66	8.83	6.73	82.3	6.62	14.2	4.56	0.63	0.09
2007	AB	L	4.00	0.05	15.3	5.34	1.95	0.98	79.2	9.26	12.4	5.38	0.66	0.12
2007	AB	SF	4.15	0.12	6.34	5.43	1.71	0.54	90.0	5.67	16.4	3.60	0.68	0.21
2008	Ap1	C	4.07	0.11	7.50	7.58	2.45	1.34	84.0	4.24	16.0	3.48	2.12	0.15
2008	Ap1	DL	6.07	0.38	65.6	7.98	14.8	5.72	17.2	9.62	11.8	4.25	2.13	0.13
2008	Ap1	L	5.48	0.36	78.5	13.5	1.78	0.17	17.1	13.1	7.01	0.65	2.29	0.13

Y	H	T	pH		CaECEC		MgECEC		AlECEC		P		SOM		
			Avera ge	SD	Avera ge	SD	Avera ge	SD	Avera ge	SD	Avera ge	SD	Avera ge	SD	
2008	Ap1	SF	5.67	0.27	88.7	1.63	0.68	0.24	10.3	1.39	14.4	4.58	2.20	0.17	
2008	Ap2	C	4.11	0.04	7.83	7.25	2.33	0.82	84.7	6.85	15.5	3.35	2.07	0.48	
2008	Ap2	DL	5.56	0.75	67.8	6.36	19.1	1.95	12.1	3.08	12.3	3.91	1.99	0.39	
2008	Ap2	L	4.72	0.25	72.0	16.4	1.20	0.70	19.2	7.37	14.7	3.54	2.31	0.29	
2008	Ap2	SF	5.16	0.49	66.8	15.8	1.18	0.28	31.6	16.2	15.8	6.43	2.28	0.36	
2008	AB	C	4.16	0.15	9.50	5.54	1.09	0.70	86.6	5.69	12.1	4.39	0.89	0.14	
2008	AB	DL	4.98	0.27	46.3	17.7	19.7	1.97	24.1	8.52	10.3	2.42	1.44	0.66	
2008	AB	L	4.42	0.23	51.4	27.3	0.85	0.71	46.6	29.0	7.25	1.18	1.67	0.14	
2008	AB	SF	4.66	0.43	40.4	8.74	0.88	0.82	52.1	3.72	11.7	3.09	1.34	0.36	
2010	Ap1	C	3.83	0.09	5.13	2.33	1.95	1.22	88.1	3.11	20.6	0.95	2.03	0.41	
2010	Ap1	DL	5.62	0.02	73.3	8.89	20.9	9.71	4.05	1.62	13.8	1.09	1.85	0.03	
2010	Ap1	L	4.81	0.36	86.9	0.59	1.01	0.58	8.45	3.33	14.4	1.47	1.90	0.03	
2010	Ap1	SF	5.65	0.16	92.9	2.93	0.89	0.14	4.70	2.60	13.1	2.99	2.05	0.11	
2010	Ap2	C	4.12	0.38	6.51	3.09	3.40	1.88	81.7	0.78	8.94	1.18	1.77	0.31	
2010	Ap2	DL	4.70	0.57	60.1	8.26	20.3	5.90	21.8	13.0	8.01	5.27	1.58	0.13	
2010	Ap2	L	4.42	0.31	76.0	8.17	2.23	1.23	17.8	7.68	9.64	3.38	1.76	0.09	
2010	Ap2	SF	4.69	0.55	90.9	2.56	1.61	0.25	5.59	2.10	8.45	2.06	1.81	0.11	
2010	AB	C	4.31	0.35	6.08	6.70	1.69	1.00	87.9	5.09	3.65	0.79	0.70	0.13	
2010	AB	DL	4.08	0.09	16.3	9.27	7.87	1.81	71.4	11.2	4.33	2.94	0.60	0.09	
2010	AB	L	4.04	0.12	30.0	14.3	0.96	0.74	65.8	16.5	2.78	0.87	0.63	0.16	
2010	AB	SF	4.11	0.10	39.1	6.47	2.33	1.50	56.4	5.05	3.39	1.27	0.68	0.04	

Table S2. Averages and standard deviations (SD) of biomass (Spike: spike rye biomass; Stem: stem rye biomass (all of them in kg/ha)) and stem phosphorus levels (P-Rye (%)) during 2002-2010. Y: Year of sampling; T: Liming treatment (C: control; DL: dolomitic limestone; L: limestone; SF: sugar foam).

Y	T	Spike		Stem		P-Rye	
		Average	SD	Average	SD	Average	SD
2002	C	1190	79.3	1550	41.6	0.03	0.01
2002	DL	2260	181	2970	340	0.02	0.01
2002	L	2030	148	2740	322	0.02	0.00
2002	SF	2480	88.4	3160	709	0.04	0.01
2003	C	836	62.4	1270	166	0.03	0.01
2003	DL	1430	258	2030	243	0.04	0.02
2003	L	1340	72.9	2090	76.0	0.04	0.00
2003	SF	1430	31.4	2060	124	0.03	0.01
2004	C	520	142	693	42.8	0.02	0.00
2004	DL	1310	110	1670	187	0.02	0.01
2004	L	1000	193	1350	217	0.02	0.01
2004	SF	1110	346	1390	520	0.03	0.01
2005	C	578	27.9	1000	159	0.02	0.01
2005	DL	1180	42.7	1640	203	0.02	0.01
2005	L	1210	36.4	1720	104	0.02	0.01
2005	SF	1310	94.4	2010	119	0.03	0.01
2006	C	1350	294	1500	58.6	0.01	0.00
2006	DL	1860	63.0	2110	45.4	0.02	0.00
2006	L	1990	85.1	2310	171	0.02	0.01
2006	SF	1930	81.8	2200	336	0.02	0.00
2007	C	80.0	35.5	93.4	39.3	0.03	0.01
2007	DL	430	96.7	565	121	0.05	0.00
2007	L	450	116	633	77.5	0.05	0.01
2007	SF	550	157	450	89.0	0.07	0.00
2008	C	970	151	1470	220	0.03	0.01
2008	DL	1000	488	1430	766	0.05	0.00
2008	L	1220	279	1690	403	0.03	0.00
2008	SF	888	165	1300	299	0.04	0.00
2010	C	1300	20.9	1720	58.2	0.02	0.00
2010	DL	1710	133	2140	186	0.05	0.01
2010	L	1610	188	1950	138	0.03	0.01
2010	SF	1580	90.7	2010	227	0.03	0.00