10.1071/FP18203_AC

Supplementary Material: *Functional Plant Biology*, 2019, 46(2), 175–186.

Supplementary Material

Costs and benefits of photosynthetic stems in desert species from southern California

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Expressing photosynthetic rate and stomatal conductance on a half-stem surface area basis and on a total stem surface area basis

Gas exchange measurements, such as photosynthetic rate (A_{max}) and stomatal conductance (g_s) of green stems were also calculated: (1) on a half-stem surface area basis, given the fact that the light source inside the Li-Cor chamber does not behave like the sun does (single point source of radiation); and (2) on a total surface area basis. (1) In the field, only the projected area of a stem is being lit by the sun rays at any time point. However, inside the Li-Cor chamber, light from LEDs shine radially from the source points, illuminating half of the surface area of the stem completely. When we re-calculated A_{max} and g_s on a half-stem surface area basis and compared these between green stems and leaves of non-green-stemmed species we found that both organs have the same A_{max} and g_s values, with *p*-values from Multifactorial ANOVAS of 0.93 and 0.99,

respectively. (2) It is also possible that in the field and inside the Li-Cor chamber, the lower half of the stem is being lit (by diffused light and light reflected from the walls of the chamber, respectively), so that this half is also contributing to the CO_2 assimilation and H_2O loss. When we re-calculated A_{max} and g_s on a total stem surface area basis and compared these between green stems and leaves of non-green-stemmed species we found that A_{max} and g_s are lower in green stems than in leaves of non-green-stemmed species, with *P*-value from Multifactorial ANOVAS of <0.001 for both traits. Nilsen (1992) recognised that "an appropriate comparison between leaf and stem photosynthesis can only be made in a cuvette designed to surround each organ with light. Then photosynthetic comparisons between leaf and stem can be made on a surface area basis." However, the way stem photosynthesis is expressed does not modify our conclusion that green stems have a positive effect on the carbon economy of plants bearing them, and that green stems are not structurally constrained by their shape (cylinder *versus* flat surfaces in leaves).

Reference

Nilsen ET (1992) The influence of water stress on leaf and stem photosynthesis in *Spartium junceum* L. *Plant, Cell & Environment* **15**, 455–461 doi:10.1111/j.1365-3040.1992.tb00996.x

Table S1. Average diameter (mm) of the stems used for gas exchange measurements in each sampling campaign

Values are species means of three individuals (n = 3) ± s.e. NA, plants had died back and were not measured

	Feb 2016	Apr 2016	Jun 2016	Jul 2016	Aug 2016	Oct 2016	Nov 2016	Jan 2017	Mar 2017
Ambrosia dumosa	1.66 ± 0.94	2.80 ± 0.29	2.39 ± 0.24	1.62 ± 0.18	1.44 ± 0.22	2.75 ± 0.18	2.11 ± 0.21	2.22 ± 0.42	1.42 ± 0.24
Ambrosia salsola	1.56 ± 0.29	1.32 ± 0.05	1.51 ± 0.23	1.32 ± 0.09	1.52 ± 0.19	1.37 ± 0.14	1.46 ± 0.17	1.90 ± 0.09	1.04 ± 0.01
Bebbia juncea	1.83 ± 0.29	1.66 ± 0.25	1.22 ± 0.14	1.32 ± 0.31	1.45 ± 0.20	1.22 ± 0.10	1.13 ± 0.18	1.37 ± 0.13	1.06 ± 0.07
Condea emoryi	1.41 ± 0.03	2.13 ± 0.21	1.32 ± 0.08	1.93 ± 0.37	2.92 ± 0.61	1.60 ± 0.12	2.46 ± 0.11	1.49 ± 0.18	1.56 ± 0.36
Eriogonum inflatum	2.81 ± 0.09	2.22 ± 0.37	1.82 ± 0.09	1.63 ± 0.17	0.92 ± 0.46	1.84 ± 0.05	NA	NA	2.55 ± 0.24
Krameria bicolor	2.25 ± 0.43	1.95 ± 0.45	1.72 ± 0.24	1.46 ± 0.17	1.67 ± 0.34	1.75 ± 0.38	1.63 ± 0.07	1.75 ± 0.08	1.18 ± 0.04

Larrea tridendata	2.39 ± 0.15	2.34 ± 0.23	2.49 ± 0.29	2.10 ± 0.34	1.95 ± 0.38	2.20 ± 0.17	2.26 ± 0.33	2.36 ± 0.17	1.72 ± 0.28
Menodora spinescens	2.91 ± 0.1	2.61 ± 0.30	2.45 ± 0.17	3.00 ± 0.14	3.60 ± 1.00	2.92 ± 0.62	2.60 ± 0.45	2.72 ± 0.01	4.44 ± 0.99
Psorothamnus arborescens	3.06 ± 0.28	3.12 ± 0.34	3.35 ± 0.42	2.22 ± 0.32	3.16 ± 0.47	2.33 ± 0.19	2.46 ± 0.07	2.60 ± 0.13	2.16 ± 0.12
Scutellaria mexicana	2.06 ± 0.36	1.77 ± 0.22	1.43 ± 0.15	1.75 ± 0.22	1.34 ± 0.07	1.44 ± 0.22	1.86 ± 0.15	1.70 ± 0.22	1.10 ± 0.04
Senna armata	2.15 ± 0.08	2.01 ± 0.25	1.77 ± 0.09	2.02 ± 0.14	1.98 ± 0.09	2.44 ± 0.32	2.12 ± 0.24	2.19 ± 0.08	2.11 ± 0.24
Senegalia greggii	2.41 ± 0.33	2.58 ± 0.35	2.60 ± 0.41	2.62 ± 0.15	2.39 ± 0.34	2.85 ± 0.13	2.91 ± 0.24	3.06 ± 0.24	2.32 ± 0.19
Simmondsia chinensis	4.62 ± 0.76	3.42 ± 0.64	2.45 ± 0.31	3.37 ± 0.32	2.89 ± 0.43	2.11 ± 0.21	2.78 ± 0.38	2.80 ± 0.13	1.99 ± 0.28
Stillingia linearifolia	1.36 ± 0.09	1.15 ± 0.02	1.28 ± 0.06	1.52 ± 0.01	1.37 ± 0.25	1.90 ± 0.53	NA	NA	1.49 ± 0.15

Thamnosma montana	2.30 ± 0.22	2.76 ± 0.19	2.13 ± 0.39	2.73 ± 0.11	2.14 ± 0.07	1.78 ± 0.22	1.92 ± 0.04	3.07 ± 0.53	2.25 ± 0.31

Table S2. Stem CO_2 exchange measurements on a projected stem surface area basis

Values are species means of three individuals (n = 3) ± s.e. NA, plants had died back and were not measured

	Feb 2016	Apr 2016	Jun 2016	Jul 2016	Aug 2016	Oct 2016	Nov 2016	Jan 2017	Mar 2017
Ambrosia dumosa	-15.90 ± 11.33	-6.93 ± 1.33	2.19 ± 0.45	-2.46 ± 1.14	-1.27 ± 4.04	1.84 ± 4.40	1.78 ± 0.27	1.29 ± 2.64	-3.97 ± 7.56
Ambrosia salsola	26.56 ± 10.18	9.67 ± 8.06	6.04 ± 2.68	10.30 ± 1.08	17.83 ± 8.61	34.38 ± 12.11	16.62 ± 6.39	12.14 ± 2.55	10.73 ± 5.99
Bebbia juncea	19.24 ± 3.11	18.95 ± 9.38	15.28 ± 4.75	14.14 ± 4.57	14.65 ± 0.59	27.33 ± 7.80	32.08 ± 5.37	25.60 ± 5.05	43.89 ± 6.94
Condea emoryi	-8.87 ± 6.10	0.72 ± 2.83	-3.31 ± 0.65	-6.13 ± 2.13	-3.45 ± 1.74	-0.78 ± 5.37	-1.68 ± 0.87	-6.78 ± 3.39	-4.23 ± 2.86
Eriogonum inflatum	20.19 ± 6.99	12.22 ± 9.30	2.92 ± 0.73	23.56 ± 1.23	6.53 ± 9.09	41.17 ± 4.87	NA	NA	5.51 ± 8.59
Krameria bicolor	-3.17 ± 3.39	0.16 ± 5.22	12.80 ± 13.41	7.81 ± 4.57	17.40 ± 9.42	8.23 ± 3.20	5.82 ± 0.92	-4.50 ± 0.90	5.67 ± 1.97

Larrea tridendata	-20.55 ± 15.32	-8.98 ± 6.83	0.26 ± 1.80	-2.83 ± 3.45	-0.01 ± 1.68	4.59 ± 0.44	-1.17 ± 1.57	-2.80 ± 1.23	-1.47 ± 6.44
Menodora spinescens	11.05 ± 1.10	6.29 ± 3.38	2.99 ± 0.74	1.31 ± 0.31	3.55 ± 2.03	10.00 ± 3.71	8.57 ± 2.23	8.92 ± 0.46	15.51 ± 2.47
Psorothamnus arborescens	-6.72 ± 5.53	-7.29 ± 1.91	-3.20 ± 2.37	2.66 ± 3.04	-2.26 ± 1.28	-0.80 ± 1.69	-4.38 ± 1.08	-4.37 ± 1.42	0.61 ± 3.76
Scutellaria mexicana	13.18 ± 2.09	0.68 ± 7.13	20.48 ± 7.18	8.73 ± 3.37	2.32 ± 1.79	16.41 ± 6.31	7.71 ± 2.13	2.29 ± 2.77	0.99 ± 4.57
Senna armata	-1.47 ± 6.65	12.47 ± 3.91	21.25 ± 12.83	7.56 ± 4.67	15.56 ± 3.51	14.78 ± 1.76	9.99 ± 4.15	2.90 ± 4.80	10.81 ± 6.24
Senegalia greggii	0.30 ± 2.82	-8.41 ± 1.64	-0.57 ± 1.00	7.11 ± 1.92	-1.64 ± 2.58	-1.99 ± 1.64	-3.12 ± 3.04	1.22 ± 0.49	-6.07 ± 0.82
Simmondsia chinensis	-1.91 ± 1.66	-4.34 ± 2.02	-5.31 ± 3.23	0.05 ± 2.05	-1.80 ± 2.36	2.56 ± 0.07	0.52 ± 0.74	-0.65 ± 3.41	7.69 ± 3.62
Stillingia linearifolia	12.27 ± 7.03	26.86 ± 10.56	9.98 ± 1.54	9.89 ± 1.54	16.63 ± 5.40	13.95 ± 4.29	NA	NA	15.79 ± 2.59

Thamnosma montana	10.90 ± 4.23	12.24 ± 4.59	3.03 ± 1.39	3.36 ± 3.28	14.88 ± 4.49	13.36 ± 5.64	7.53 ± 4.09	2.66 ± 4.31	13.73 ± 3.94

Table S3. Stem CO_2 exchange measurements on a half-stem surface area basis

Values are species means of three individuals (n = 3) ± s.e. NA, plants had died back and were not measured

	Feb 2016	Apr 2016	Jun 2016	Jul 2016	Aug 2016	Oct 2016	Nov 2016	Jan 2017	Mar 2017
Ambrosia dumosa	-10.12 ± 7.21	-4.41± 0.85	1.39 ± 0.29	-1.57 ± 0.72	-0.81 ± 2.57	1.17 ± 2.80	1.13 ± 0.28	0.82 ± 1.68	-2.53 ± 4.81
Ambrosia salsola	16.91 ± 6.15	6.15 ± 5.13	3.84 ± 1.70	6.56 ± 0.69	11.35 ± 5.48	21.88 ± 7.71	10.58 ± 4.07	7.73 ± 1.62	6.83 ± 3.81
Bebbia juncea	12.25 ± 1.98	12.06 ± 5.97	9.73 ± 3.02	9.00 ± 2.91	9.33 ± 0.37	17.40 ± 4.96	20.42 ± 3.42	16.30 ± 3.22	27.94 ± 4.42
Condea emoryi	-5.65 ± 3.88	0.46 ± 1.80	-2.11 ± 0.41	-3.90 ± 1.36	-2.20 ± 1.11	-0.49 ± 3.42	-1.07 ± 0.55	-4.32 ± 2.16	-2.69 ± 1.82
Eriogonum inflatum	12.86 ± 4.45	7.78 ± 5.92	1.86 ± 0.47	15.00 ± 0.79	4.16 ± 5.79	26.21 ± 3.10	NA	NA	3.51 ± 5.47
Krameria bicolor	-2.02 ± 2.16	0.10 ± 3.32	8.15 ± 8.54	4.97 ± 2.91	11.08 ± 6.00	5.24 ± 2.04	3.70 ± 0.59	-2.87 ± 0.57	3.61 ± 1.25

Larrea tridendata	-13.08 ± 9.76	-5.72 ± 4.35	0.16 ± 1.15	-1.80 ± 2.20	0.00 ± 1.07	2.92 ± 0.28	-0.75 ± 1.00	-1.78 ± 0.78	-0.94 ± 4.10
Menodora spinescens	7.03 ± 0.70	4.01 ± 2.15	1.90 ± 0.47	0.83 ± 0.20	2.26 ± 1.29	6.37 ± 2.36	5.45 ± 1.42	5.68 ± 0.29	9.88 ± 1.57
Psorothamnus arborescens	-4.28 ± 3.52	-4.64 ± 1.22	-2.03 ± 1.51	1.69 ± 1.93	-1.44 ± 0.82	-0.51 ± 1.08	-2.79 ± 0.69	-2.78 ± 0.90	0.39 ± 2.40
Scutellaria mexicana	8.39 ± 1.33	0.43 ± 4.54	13.04 ± 4.57	5.56 ± 2.14	1.47 ± 1.14	10.45 ± 4.02	4.91 ± 1.36	1.46 ± 1.76	0.63 ± 2.91
Senna armata	-0.90 ± 4.23	7.94 ± 2.49	13.53 ± 8.17	4.81 ± 2.97	9.91 ± 2.23	9.41 ± 1.12	6.36 ± 2.64	1.85 ± 3.06	6.88 ± 3.97
Senegalia greggii	0.19 ± 1.80	-5.35 ± 1.04	-0.36 ± 0.63	4.52 ± 1.22	-1.05 ± 1.64	-1.27 ± 1.04	-1.99 ± 1.94	0.78 ± 0.31	-3.87 ± 0.52
Simmondsia chinensis	-1.21 ± 1.05	-2.76 ± 1.29	-3.38 ± 2.06	0.03 ± 1.30	-1.15 ± 1.50	1.63 ± 0.05	0.33 ± 0.47	-0.41 ± 2.17	4.90 ± 2.31
Stillingia linearifolia	7.81 ± 4.48	17.10 ± 6.72	6.35 ± 0.98	6.30 ± 2.26	10.59 ± 3.44	8.88 ± 2.73	NA	NA	10.06 ± 1.65

Thamnosma montana	6.94 ± 2.69	7.79 ± 2.92	1.93 ± 0.88	2.14 ± 2.09	9.47 ± 2.86	8.50 ± 3.59	4.79 ± 2.61	1.70 ± 2.74	8.74 ± 2.51

Table S4. Stem CO_2 exchange measurements on a total stem surface area basis

Values are species means of three individuals (n = 3) ± s.e. NA, plants had died back and were not measured

	Feb 2016	Apr 2016	Jun 2016	Jul 2016	Aug 2016	Oct 2016	Nov 2016	Jan 2017	Mar 2017
Ambrosia dumosa	-5.06 ± 3.61	-2.21 ± 0.42	0.70 ± 0.14	-0.78 ± 0.36	-0.41 ± 1.29	0.59 ± 1.40	0.57 ± 0.09	0.41 ± 0.84	-1.26 ± 2.41
Ambrosia salsola	8.45 ± 3.24	3.08 ± 2.57	1.92 ± 0.85	3.28 ± 0.34	5.67 ± 2.74	10.94 ± 3.85	5.29 ± 2.03	3.87 ± 0.81	3.42 ± 1.91
Bebbia juncea	6.12 ± 0.99	6.03 ± 2.98	4.86 ± 1.51	4.50 ± 1.46	4.66 ± 0.19	8.70 ± 2.48	10.21 ± 1.71	8.15 ± 1.61	13.97 ± 2.21
Condea emoryi	-2.82 ± 1.94	0.23 ± 0.90	-1.06 ± 0.21	-1.95 ± 0.68	-1.10 ± 0.55	-0.25 ± 1.71	-0.53 ± 0.28	-2.16 ± 1.08	-1.35 ± 0.91
Eriogonum inflatum	6.43 ± 2.22	3.89 ± 2.96	0.93 ± 0.23	7.50 ± 0.39	2.08 ± 2.89	13.10 ± 1.55	NA	NA	1.75 ± 2.74
Krameria bicolor	-1.01 ± 1.08	0.05 ± 1.66	4.07 ± 4.27	2.49 ± 1.46	5.54 ± 3.00	2.62 ± 1.02	1.85 ± 0.29	-1.43 ± 0.29	1.81 ± 0.63

Larrea tridendata	-6.54 ± 4.88	-2.86 ± 2.17	0.08 ± 0.57	-0.90 ± 1.10	0.00 ± 0.54	1.46 ± 0.14	-0.37 ± 0.50	-0.89 ± 0.39	-0.47 ± 2.05
Menodora spinescens	3.52 ± 0.35	2.00 ± 1.07	0.95 ± 0.24	0.42 ± 0.10	1.13 ± 0.65	3.18 ± 1.18	2.73 ± 0.71	2.84 ± 0.15	4.94 ± 0.79
Psorothamnus arborescens	-2.14 ± 1.76	-2.32 ± 0.61	-1.02 ± 0.75	0.85 ± 0.97	-0.72 ± 0.41	-0.26 ± 0.54	-1.40 ± 0.35	-1.39 ± 0.45	0.19 ± 1.20
Scutellaria mexicana	4.19 ± 0.66	0.22 ± 2.27	6.52 ± 2.28	2.78 ± 1.07	0.74 ± 0.57	5.22 ± 2.01	2.45 ± 0.68	0.73 ± 0.88	0.31 ± 1.46
Senna armata	-0.45 ± 2.12	3.97 ± 1.24	6.76 ± 4.08	2.41 ± 1.49	4.95 ± 1.12	4.70 ± 0.56	3.18 ± 1.32	0.92 ± 1.53	3.44 ± 1.99
Senegalia greggii	0.10 ± 0.90	-2.68 ± 0.52	-0.18 ± 0.32	2.26 ± 0.61	-0.52 ± 0.82	-0.63 ± 0.52	-0.99 ± 0.97	0.39 ± 0.16	-1.93 ± 0.26
Simmondsia chinensis	-0.61 ± 0.53	-1.38 ± 0.64	-1.69 ± 1.03	0.02 ± 0.65	-0.57 ± 0.75	0.82 ± 0.02	0.16 ± 0.24	-0.21 ± 1.09	2.45 ± 1.15
Stillingia linearifolia	3.91 ± 2.24	8.55 ± 3.36	3.18 ± 0.49	3.15 ± 1.13	5.29 ± 1.72	4.44 ± 1.37	NA	NA	5.03 ± 0.82

Thamnosma montana	3.47 ± 1.35	3.90 ± 1.46	0.97 ± 0.44	1.07 ± 1.05	4.74 ± 1.43	4.25 ± 1.79	2.40 ± 1.30	0.85 ± 1.37	4.37 ± 1.26

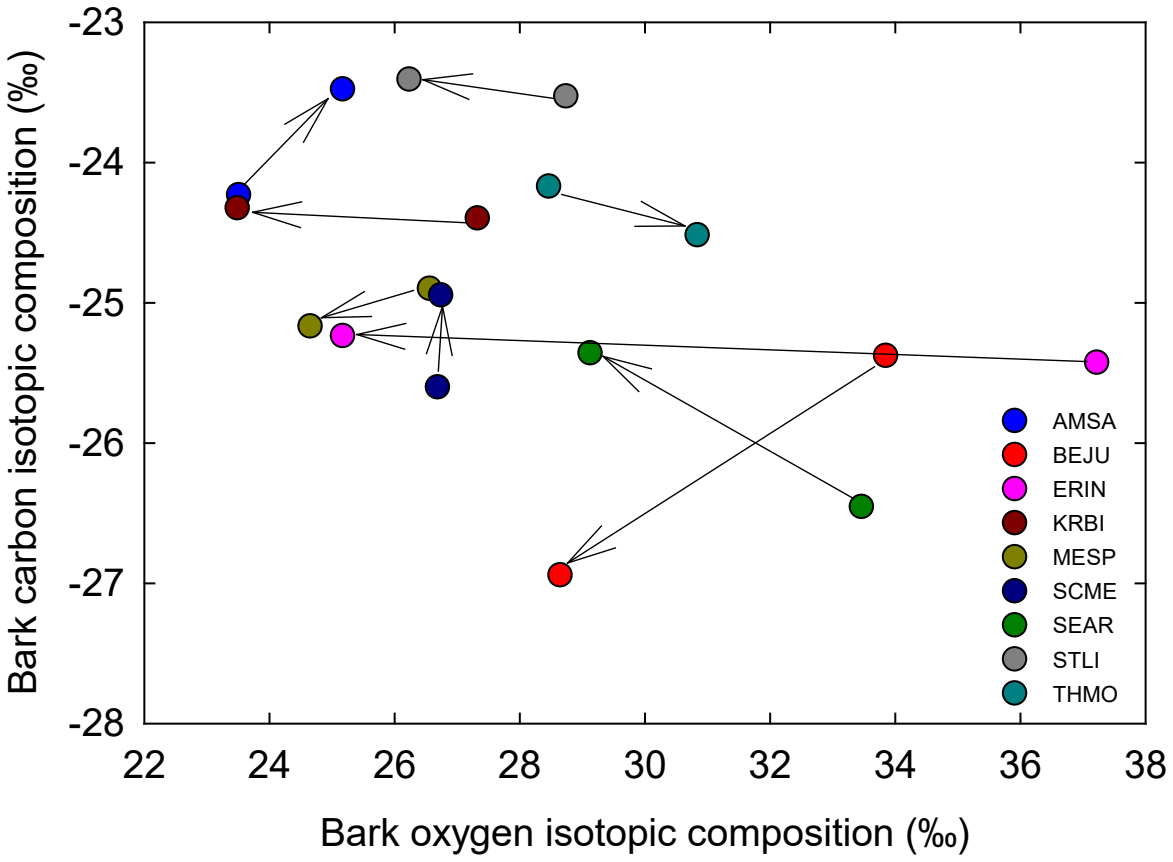

Fig. S1. Directional changes in carbon and oxygen isotopic composition from wet to dry seasons in the bark of green-stemmed species. AMSA, *Ambrosia salsola*; BEJU, *Bebbia juncea*; ERIN, *Eriogonum inflatum*; KRBI, *Krameria bicolor*; MESP, *Menodora spincescens*; SCME, *Scutellaria mexicana*; SEAR, *Senna armata*; STLI, *Stillingia linearifolia*; THMO, *Thamnosma montana*.