Leaf economic and hydraulic traits signal disparate climate adaptation patterns in two co-occurring woodland eucalypts

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Supplementary Material

Table S1. Estimates of species least-squares means and standard errors (s.e.) for altitude and climate variables studied, with population minimum and maximum values being given in parentheses (. The results obtained from the significance test (*F*-statistic, and associated P-value provided within parenthesis) undertaken for testing the difference between species in a given response variable (see the footnote of the table) are also given. The statistics a presented are based on the 22 paired samples from co-occurring populations of either species. Climate variable codes follow Table A5.

| | Least-squares means ± s.e. | | Species effect[a] |
| | | | *F*-statistic |
	E. ovata (min, max)	*E. pauciflora* (min, max)	
Altitude (m)	322 ± 40 (9, 746)	319 ± 43 (16, 824)	0.0 (0.969)
TANN (°C)	10.8 ± 0.3 (8.2, 13.3)	10.8 ± 0.3 (7.7, 13.3)	0.0 (0.957)
TMXWW (°C)	22.3 ± 0.3 (19.8, 24.3)	22.3 ± 0.3 (19.4, 24.5)	0.0 (0.980)
TDRYQ (°C)	12.9 ± 0.65 (6.3, 17.0)	12.9 ± 0.65 (6.3, 17.1)	0.01 (0.928)
TWETQ (°C)	9.7 ± 0.6 (4.6, 14.7)	9.6 ± 0.6 (4.2, 14.9)	0.01 (0.919)
TSPAN	20.9 ± 0.4 (17.0, 23.6)	20.9 ± 0.4 (17.0, 23.5)	0.0 (0.945)
RANN (mm)	660 ± 36 (451, 1077)	657 ± 33 (501, 1042)	0.01[b] (0.927)
RDRYW (mm)	7.9 ± 0.3 (5.8, 15.4)	7.9 ± 0.3 (6.2, 20.7)	0.0[b] (0.982)
RCVAR	18.0 ± 1.3 (10.2, 34.2)	18.1 ± 1.3 (10.6, 34.0)	0.0[b] (0.984)
RRL (W m⁻²)	4.85 ± 0.04 (4.35, 5.14)	4.85 ± 0.04 (4.39, 5.12)	0.0 (0.971)
MIH	0.96 ± 0.01 (0.82, 1.00)	0.96 ± 0.01 (0.87, 1.00)	0.15 (0.700)

[a] A one-way fixed-effects linear model was fitted to population-level altitude and climate data (i.e. 22 observations per species for a given response variable), using species as a classification predictor variable) and separate (heterogeneous) residual variances for the two species. The model was fitted using the procedure GLIMMIX of SAS (Version 9.4) with a Gaussian distribution of residual variances

[b] analysis based on ln (1+X) transformed data

Table S2. Results of vector projections into the ordination space defined by the two discriminant axes, derived from separate discriminant analyses of the *E. ovata* and *E. pauciflora* populations. For a given variable, the proportion of the total variance explained by a single trait projected in the two-dimensional discriminant ordination (R^2) and the significance of this fit are provided.

Traits	*E. ovata*		*E. pauciflora*	
	R^2	p	R^2	p
Performance				
Maximum height (m)	0.0970	0.3708	0.0757	0.4649
Stem diameter (mm)	0.2622	0.0576	0.0314	0.7270
Leaf economic				
Leaf area (cm^2)	0.0362	0.7004	0.7659	**0.0001**
Leaf Thickness (mm)	0.7354	**0.0001**	0.8628	**0.0001**
Leaf Density (mg mm^{-3})	0.6062	**0.0003**	0.1284	0.2745
Specific Leaf Area (mm^2 mg^{-1})	0.9167	**0.0001**	0.8220	**0.0001**
Leaf hydraulic				
Stomatal Density (mm^{-2})	0.9601	**0.0001**	0.5105	**0.0009**
Stomatal Length (μ)	0.4160	**0.0059**	0.1156	0.3201
Stomatal Length per area (μ mm^{-2})	0.8985	**0.0001**	0.5817	**0.0003**
Vein Density (mm mm^{-2})	0.5132	**0.0010**	0.5243	**0.0011**
Climate variables				
TANN	0.2942	**0.0394**	0.2610	0.0579
TMXWW	0.5609	**0.0006**	0.3036	**0.0341**
TSPAN	0.2995	**0.0330**	0.0521	0.5986
TWETQ	0.2089	0.1096	0.0748	0.4731
TDRYQ	0.0946	0.3794	0.2332	0.0799
lnRANN	0.2811	**0.0423**	0.0999	0.3699
lnRCVAR	0.1499	0.2149	0.4199	**0.0065**
lnRDRYW	0.1693	0.1755	0.0226	0.8030
RRL	0.0539	0.5959	0.1043	0.3485
MIH	0.2839	**0.0400**	0.1641	0.1782
Geographic				
Altitude	0.3734	**0.0130**	0.3234	**0.0250**
Longitude	0.0177	0.8401	0.1523	0.2035
Latitude	0.1507	0.2152	0.1630	0.1827

Table S3. Location details for the paired populations of *E. pauciflora* and *E. ovata* sampled from 22 localities across their overlapping native range in Tasmania.

site#	*E. pauciflora*	Latitude	Longitude	*E. ovata*	Latitude	Longitude
1	Avoca	-41.71	147.83	Avoca	-41.82	147.75
2	Bignells Bothwell	-42.40	147.10	Bignells Bothwell	-42.40	147.11
3	Brushy Lagoon	-41.41	146.75	Brushy Lagoon	-41.39	146.73
4	Cressy	-41.72	147.10	Connorville Dam	-41.89	147.13
5	Curringa	-42.57	146.77	Curringa	-42.57	146.77
6	Dukes Marshes	-41.72	148.13	Coals Marsh	-41.76	148.11
7	Ellesmere	-42.40	147.30	Ellesmere	-42.41	147.29
8	Gatehouse Marsh	-42.59	147.78	The Thumbs	-42.59	147.80
9	Interlaken	-42.15	147.14	Woods Lake	-42.08	147.03
10	Lake Leake	-42.02	147.82	Lake Leake	-42.01	147.80
11	Nunamara	-41.37	147.32	Nunamara	-41.37	147.27
12	Osterley	-42.35	146.74	Osterley	-42.35	146.74
13	Ross	-42.00	147.53	Ross	-42.00	147.56
14	South Arm	-43.03	147.42	South Arm	-43.00	147.48
15	Stonor	-42.43	147.43	Stonor	-42.43	147.44
16	Symmons Plains	-41.66	147.25	Epping Forest	-41.77	147.31
17	Tin Dish Rivulet	-42.31	147.44	Andover	-42.31	147.49
18	Tooms Lake	-42.22	147.79	Tooms Lake	-42.21	147.79
19	Tunbridge	-42.12	147.36	Tunbridge	-42.14	147.40
20	Tyne River	-41.47	147.82	Tyne River	-41.47	147.85
21	Uralla	-42.55	146.86	Uralla	-42.55	146.86
22	Waterhouse	-40.91	147.66	Mt Cameron	-40.94	147.82

Table S4. Best multiple linear regression models relating performance and leaf traits to climate variables for *E. ovata* and *E. pauciflora*, showing parameter estimates. All models and parameter estimates (except constants) are significant at P<0.05 or P<0.1[§] (see Table 6 for further model statistics).

Trait	*Eucalyptus ovata*	*Eucalyptus pauciflora*
Performance		
Maximum height (m)	-124.2 - 29.00 lnRCVAR + 4.96 TMXWW + 23.88 lnRANN	1.13 + 0.115 TANN[§]
Stem diameter (mm)	-2.07 - 1.01 lnRCVAR + 0.116 TMXWW + 0.855 lnRANN	
Leaf economic		
Leaf area (cm^2)		9.79 + 1.22 TANN[§]
Leaf Thickness (mm)	0.41 + 0.043 lnRCVAR - 0.006 TMXWW	1.31 - 0.539 MIH - 0.013 TMXWW
Leaf Thickness (mm)		0.73 - 0.077 lnRCVAR
Leaf Density (mg mm^{-3})	0.60 - 0.008 TMXWW	
Specific Leaf Area (mm^2 mg^{-1})	3.46 + 0.232 TMXWW - 0.867 lnRCVAR	-4.32 + 5.89 MIH + 0.159 TMXWW
Specific Leaf Area (mm^2 mg^{-1})	3.52 + 0.161 TANN - 0.853 lnRCVAR + 0.159 TSPAN	2.62 + 0.781 lnRCVAR
Leaf hydraulic		
Stomatal Density (mm^{-2})	28.5 + 6.13 TMXWW	80.0 + 21.51 lnRCVAR
Stomatal Density (mm^{-2})	8.6 + 42.2 lnRCVAR + 3.49 TWETQ	37.6 - 68.3 lnRDRYW + 39.2 lnRANN
Mean Stomatal Length (μ)	53.96 - 0.660 TMXWW - 4.13 lnRDRYW	52.07 - 0.257 lnRANN[§]
Mean Stomatal Length (μ)	15.18 - 0.651 TMXWW + 4.53 RRL + 2.62 lnRCVAR	
Stomatal Length per area (μ mm^{-2})		3941 + 77.5 TDRYQ
Vein Density (mm mm^{-2})	8.33 + 0.486 TANN	

Table S5. Climate variables extracted and considered for inclusion in the climate-trait analysis. The data were extracted from the climate surfaces of ANUClim (v6.1) and the Atlas of Living Australia (ALA) using the latitude and longitude of each of the five trees sampled in a population and then population averages were used in subsequent analyses.

Variable code	Description (unit of measurement)	Data source	Data range
TANN	Annual mean temperature (°C)	ANUClim v6.1	7.7—13.3
TMDR	Mean diurnal temperature range (°C)	ANUClim v6.1	8.3—12.3
TISO	Isothermality (diurnal vs annual temperature range)	ANUClim v6.1	0.49—0.52
TCVAR	Temperature seasonality (Coefficient of variation)	ANUClim v6.1	0.98—1.34
TMXWW	Max temperature of warmest week (°C)	ANUClim v6.1	19.—24.5
TMNCW	Min temperature of coldest week (°C)	ANUClim v6.1	-0.9—5.2
TSPAN	Temperature annual range (°C)	ANUClim v6.1	17.0—23.6
TWETQ	Mean temperature of wettest quarter (°C)	ANUClim v6.1	4.2—14.9
TDRYQ	Mean temperature of driest quarter (°C)	ANUClim v6.1	6.3—17.1
TWMQ	Mean temperature of warmest quarter (°C)	ANUClim v6.1	12.2—17.2
TCLQ	Mean temperature of coldest quarter (°C)	ANUClim v6.1	3.4—9.7
RANN	Annual precipitation (mm)	ANUClim v6.1	451.5—
RWETW	Precipitation of wettest week (mm)	ANUClim v6.1	10.2—34.4
RDRYW	Precipitation of driest week (mm)	ANUClim v6.1	5.8—12.5
RCVAR	Precipitation seasonality (Coefficient of variation %)	ANUClim v6.1	10.2—34.2
RWETQ	Precipitation of wettest quarter (mm)	ANUClim v6.1	127.4—
RDRYQ	Precipitation of driest quarter (mm)	ANUClim v6.1	99.0—210.2
RWMQ	Precipitation of warmest quarter (mm)	ANUClim v6.1	108.3—
RCLQ	Precipitation of coldest quarter (mm)	ANUClim v6.1	5.9—6.9
RRANN	Annual mean radiation (W m^{-2})	ANUClim v6.1	13.3—14.4
RRH	Highest weekly radiation (W m^{-2})	ANUClim v6.1	21.6—24.3
RRL	Lowest weekly radiation (W m^{-2})	ANUClim v6.1	4.4—5.2
RRCVAR	Radiation seasonality (Coefficient of variation)	ANUClim v6.1	46.4—51.5
RRWETQ	Radiation of wettest quarter (W m^{-2})	ANUClim v6.1	6.0—21.9
RRDRYQ	Radiation of driest quarter (W m^{-2})	ANUClim v6.1	5.9—20.2
RRWMQ	Radiation of warmest quarter (W m^{-2})	ANUClim v6.1	19.7—22.2
RRCLQ	Radiation of coldest quarter (W m^{-2})	ANUClim v6.1	5.9—6.9
MIANN	Annual Mean Moisture Index	ANUClim v6.1	0.5—0.9
MIH	Highest weekly moisture index	ANUClim v6.1	0.82—1.0
MIL	Lowest weekly moisture index	ANUClim v6.1	0.16—0.54
MICVAR	Moisture index seasonality (C of V)	ANUClim v6.1	15.8—47.9
MIMWETQ	Mean moisture index of wettest quarter	ANUClim v6.1	0.78—1.0
MIMDRYQ	Mean moisture index of driest quarter	ANUClim v6.1	0.22—0.68
MIMWMQ	Mean moisture index of warmest quarter	ANUClim v6.1	0.226—
MIMCLQ	Mean moisture index of coldest quarter	ANUClim v6.1	0.72—1.0
AIANN	Annual aridity index	ALA	0.6—2.2
AIMMAX	Maximum month aridity index	ALA	0.18—0.50
AIMMIN	Minimimum month aridity index	ALA	1.4—5.9
RANNSEASONALITY	Annual precipitation seasonality	ALA	-0.8—0.06
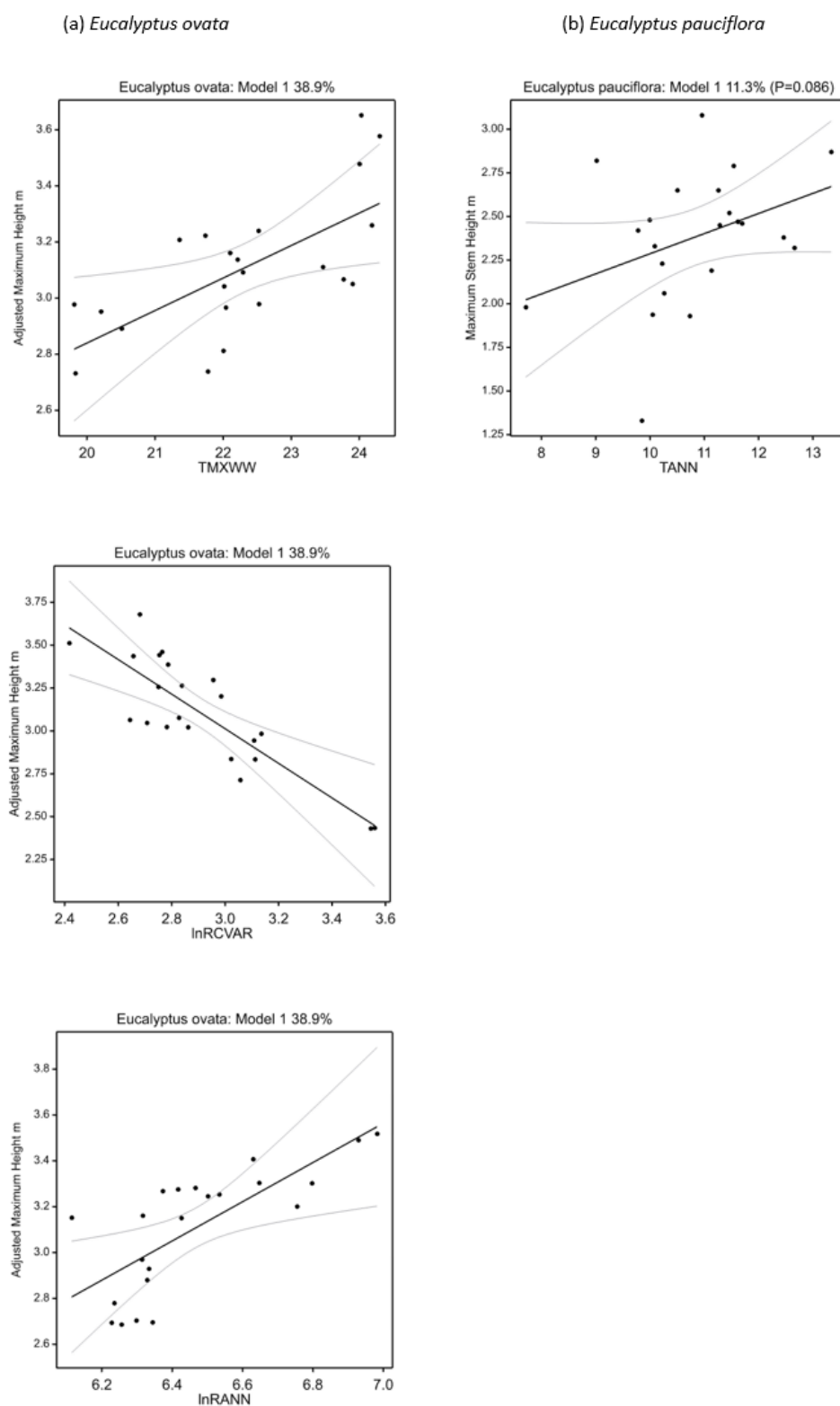
Figure S1. Partial dependency plots for selected regression models for plant height: (a) *E. ovata*, and (b) *E. pauciflora* (see Table 6). The percentage of the total variance explained (R^2) in the response variable is provided for each full model, and the relationships of height with each of the climate predictor variables included in a given model are shown (adjusted for other predictors modelled where appropriate). The overall models and their regression parameters for the climate predictors were statistically significant at $P < 0.05$. The 95% confidence intervals are also shown.