

Quantitative genetic variation and adaptive clines in Pacific Dogwood (*Cornus nuttallii*): Evidence of weak local adaptation

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Introduction

Patterns of local adaptation provide insight into evolutionary history and enable prediction of adaptive responses to climate change. Local adaptation is well documented in many temperate tree species¹, but has not been investigated in Pacific dogwood (*Cornus nuttallii* Aud.) (Figure 1). Pacific dogwood is a small-statured, insect-pollinated, genetically depauperate tree. We used a common garden to investigate patterns of local adaptation in this species.

Methods

A common garden containing 12 blocks was established using 825 seedlings from 86 open-pollinated families within 9 populations from across the species range (Figure 2). Quantitative genetic traits assessed for each tree included first- and second-year height, diameter, bud flush, drought tolerance, cold injury at -25 C (I_{-25}), 50% lethal low temperature (LT_{50}), 5% and 95% height growth completion dates, and duration of growth (5-95%). For each trait, regressions were performed against population mean values for geoclimatic variables, and heritability (h^2) was estimated. The proportion of total genetic variation due to differences among populations for each trait (Q_{ST}) was compared to a population differentiation estimate for microsatellite markers (F_{ST})². If Q_{ST} exceeds F_{ST} , this suggests that populations are undergoing divergent selection and are thus locally adapted.

Results

Significant linear regressions were found for first- and second-year height, diameter, bud-flush score, and 5-95% growth duration, but not for any other traits (Table 1). When estimable, Q_{ST} and h^2 values were relatively low, and the majority of variance was found within populations (Table 2).



Figure 1. Pacific dogwood in Sequoia National Park, California.



Figure 2. Pacific dogwood range map and provenance locations.

Quantitative trait	Geoclimatic variable																		
	Latitude (°N)			Longitude (°W)			Elevation (m)			Mean Annual Temperature (°C)			Mean Warmest-Month Temperature (°C)			Mean Coldest-Month Temperature (°N)			
	sign	R ²	p	sign	R ²	p	sign	R ²	p	sign	R ²	p	sign	R ²	p	sign	R ²	p	
First-year height		0.1792	0.2565		0.0497	0.5641		0.0448	0.5847		0.3190	0.1131		0.0406	0.6032	(+)	0.5039	0.0322	
Second-year height		0.3296	0.1060	(-)	0.4756	0.0398		0.2803	0.1427	(+)	0.5656	0.0194	(+)	0.5179	0.0289		0.2709	0.1510	
Diameter		0.2978	0.1286		0.1590	0.2878		0.3700	0.3700		0.4153	0.0610		0.1253	0.3499	(+)	0.4643	0.0433	
Bud-flush score	(+)	0.5394	0.0242		0.3510	0.0927		0.4148	0.0612	(-)	0.5863	0.0162		0.2806	0.1424	(-)	0.5808	0.0170	
Growth duration (5-95%)		0.0182	0.7296		0.4425	0.0505		0.1736	0.2646		0.1001	0.4068		(-)	0.4580	0.0453		0.0061	0.8422

Quantitative trait	Geoclimatic variable											
	Mean Annual Precipitation (mm)			Mean Summer Precipitation (mm)		Mean Frost-Free Period (°C)		Mean Growing-Degree Days >5°C				
	sign	R ²	p	sign	R ²	p	sign	R ²	p			
First-year height		0.1560	0.2928		0.1008	0.4051	(+)	0.6161	0.0122		0.2151	0.2085
Second-year height		0.3017	0.1256		0.2663	0.1550		0.3804	0.0769	(+)	0.5922	0.0153
Diameter		0.2965	0.1295		0.3617	0.0867	(+)	0.4511	0.0476		0.3463	0.3463
Bud-flush score		0.3526	0.0918	(+)	0.5007	0.0330	(-)	0.4803	0.0385	(-)	0.4902	0.0357
Growth duration (5-95%)		0.2075	0.2178		0.0278	0.6681		0.0260	0.8961		0.1643	0.2791

Table 2. Estimates of population differentiation (Q_{ST}) and heritability (h^2) of quantitative genetic traits, and proportions of total genetic variance among (σ^2_{GA}) and within (σ^2_{GW}) populations. Population differentiation for five microsatellite markers (F_{ST}) is included for comparison.

Quantitative genetic trait	Q_{ST}	h^2	σ^2_{GA} (%)	σ^2_{GW} (%)
First-year height	0.088	0.235	16.1	83.9
Second-year height	0.109	0.213	19.7	80.3
Diameter	0.295	0.175	45.5	54.5
Bud-flush score	0.113	0.383	20.3	79.7
Drought tolerance score	—	—	—	—
I_{-25}	0.261	0.158	41.4	58.6
LT_{50}	—	0.195	—	—
5% growth completion date	—	—	—	—
95% growth completion date	—	—	—	—
Growth duration (5-95%)	—	—	—	—
Molecular genetic trait	F_{ST}			
Microsatellite markers ²	0.071			

Table 1. Selected regression results for adaptive clines. No significant results were found for drought tolerance score, I_{-25} , LT_{50} , and 5% or 95% growth dates. Higher bud-flush score indicates earlier bud flush. (+) and (-) refer to the signs of significant correlations between variables.

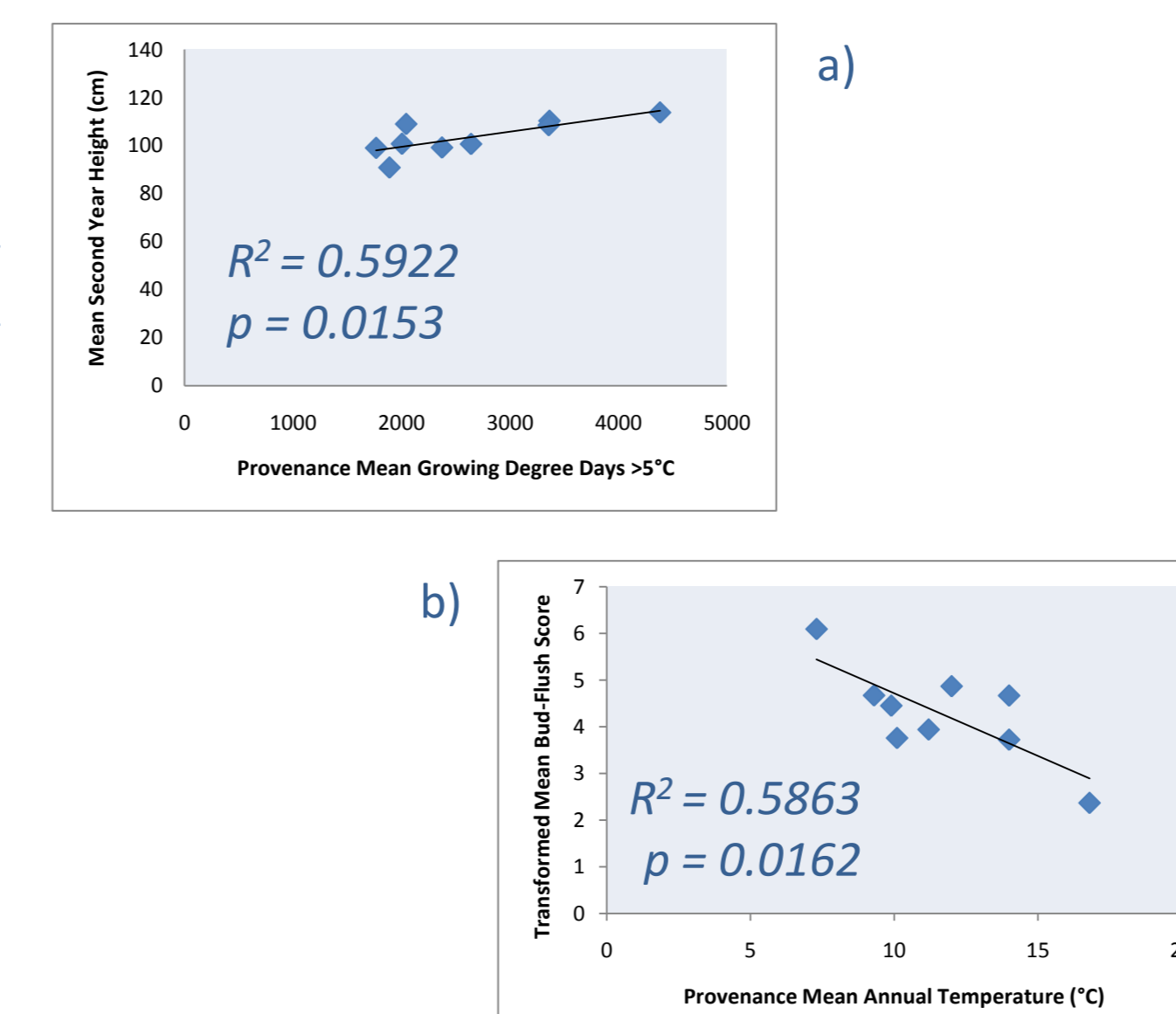


Figure 3. Examples of statistically significant adaptive clines. Note that higher bud-flush score indicates earlier bud flush.

Discussion

Compared to other western North American tree species, Pacific dogwood is only weakly locally adapted: adaptive clines were found for only 5 out of 10 traits; differences among population means were small (data not shown), resulting in relatively shallow clines (Figure 3); and Q_{ST} values were low, and were only slightly higher than F_{ST} , indicating that most genetic variance was within rather than among populations. The strongest adaptive clines were temperature related. Growth was greatest in populations from generally warmer provenances. Bud flush occurred later in populations from warmer, more southern provenances, perhaps as a result of selection for higher chilling and heat sum requirements in warmer provenances.

Lack of strong local adaptation may be partially related to a lack of genetic diversity in nuclear microsatellite markers and chloroplast DNA². Current guidelines for most species, which recommend using local seed for reforestation or the nearest southern source in anticipation of climate change, seem conservative for Pacific dogwood in the absence of strong local adaptation. In the short-term future, the species may fare comparatively well under climate change, as it is not strongly adapted to current local conditions, and hypothesized high dispersal ability² could facilitate northward migration. In the longer term, however, inability to locally adapt may put isolated populations at greater risk of extirpation due to interspecific competition with species more able to adapt, or due to other biotic or abiotic stresses.

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