Evolution of invasiveness through increased resource use in a vacant niche

Supplementary Table 1. Locality details for source populations used in the common garden.

Site	Location	Latitude	Longitude	Site	Location	Latitude	Longitude
Europe				North America			
Etch	Armenia	40.162500	44.474167	CLV	USA (CA)	36.916300	-119.793490
K113	Armenia	40.131528	44.762472	COL	USA (CA)	38.926820	-122.007000
K125	Armenia	40.282861	44.195722	DIA	USA (CA)	37.865260	-121.977850
K126	Armenia	40.282861	44.195694	GIL	USA (CA)	37.033730	-121.536740
K132	Armenia	40.110028	44.084639	LEB	USA (CA)	34.827360	-118.870970
K146	Armenia	40.172444	44.585722	MAR	USA (CA)	38.019000	-122.605800
K149	Armenia	40.169167	44.271500	NEE	USA (CA)	36.850500	-120.762210
Bu24	Bulgaria	43.382222	28.457667	ORC	USA (CA)	36.935150	-119.051460
CAZ	France	43.748420	3.770610	ORO	USA (CA)	39.493980	-121.687880
GR18	Greece	39.542222	22.327533	RB	USA (CA)	40.270830	-122.271040
GR20	Greece	40.238433	22.334110	RED	USA (CA)	40.670810	-122.241920
GR21	Greece	40.942000	23.258283	RES	USA (CA)	40.918250	-122.398770
HU01	Hungary	47.182400	18.089283	SER	USA (CA)	39.001506	-122.357025
HU29	Hungary	47.317850	21.033850	SIE	USA (CA)	38.781617	-120.416386
RO25	Romania	44.124733	28.634183	TE	USA (CA)	35.145320	-118.470110
CAN	Spain	41.000330	-4.897180	TRI	USA (CA)	37.461780	-119.792180
CUE	Spain	40.129460	-2.139500	UKI	USA (CA)	39.163630	-123.227050
GRA	Spain	37.268360	-3.664970	VET	USA (CA)	38.099960	-120.589470
SAL	Spain	40.990030	-5.658560	YRE	USA (CA)	41.691610	-122.639880
SAZ	Spain	39.835230	-2.511430	GOL	USA (OR)	42.435500	-123.043590
TER	Spain	41.705520	0.748940				
TK23	Turkey	41.751233	27.247883				

Supplementary Table 2. REML models of size

Response variable		df	F or X^2	P value
Effect type	Effect			
Size index at 3.5 weeks				
Fixed	region	1	12.338	0.0005
Fixed	population w/in region	40	4.1335	<0.0001
Fixed	observer[a]	3	2.2633	0.08
Fixed	seed mass	1		NS[d]
Fixed	age at measurement[b]	1		NS[d]
Fixed	age at measurement x region	1		NS[d]
Random	block[c]			NS[d]
Size index at 5 weeks				
Fixed	region	1	47.7822	<0.0001
Fixed	population w/in region	40	3.0482	<0.0001
Fixed	observer[a]	3	2.38	0.07
Fixed	age at measurement[b]	1		NS[d]
Fixed	age at measurement x region	1		NS[d]
Random	block[c]			NS[d]
Size index at 5 weeks: seed mass covariate				
Fixed	region	1	6.7324	0.01
Fixed	population w/in region	40	3.1285	<0.0001
Fixed	observer[a]	3	2.2278	0.08
Fixed	seed mass	1	5.7823	0.02
Final Biomass				
Fixed	region	1	5.1401	0.02
Fixed	population w/in region	40	1.9051	0.003
Fixed	harvest day[e]	1		NS[d]
Fixed	seed mass	1		NS[d]

Supplementary Table 3. REML models of reproduction

Response variable		df	F or X^2	P value
Effect type	Effect			
Probability of flowering				
Fixed	region	1	0.00006	0.99 (NS)
Fixed	population w/in region	40	79.3173	0.0002
Number of capitula				
Fixed	region	1	25.2397	<0.0001
Fixed	population w/in region	35	2.6082	<0.0001
Fixed	harvest day[a]	1	4.6458	0.03
Fixed	seed mass	1		NS[b]
Number of capitula: date of first flower covariate				
Fixed	region	1	0.6345	0.43 (NS)
Fixed	population w/in region	35	2.1562	0.002
Fixed	harvest day[a]	1	4.0595	0.047
Fixed	date of first flower	1	84.8509	<.0001

[a]Harvest day is the age of the plant at harvest, and was recorded to account for error in the ascertainment of full senescence in YST, which can continue to reproduce after all aboveground biomass appears non-photosynthetic and physiologically inactive.

[b]Highly non-significant (NS) correlates ($P > 0.1$) were removed from final models.

Supplementary Table 4. ANCOVA models of plant size versus bioclimatic variables

Model effects[a]	P values for models of size at	
	3.5 weeks	5 weeks
mean annual temperature (b1)	NS	0.03
region (native vs. invading)	0.002	<0.0001
temperature seasonality (b4)	**0.0004**	**<0.0001**
region (native vs. invading)	**<0.0001**	**<0.0001**
temperature of the driest quarter (b9)	NS	NS
region (native vs. invading)	NS	0.0007
annual precipitation (b12)	NS	NS
region (native vs. invading)	0.01	0.002
precipitation seasonality (b15)	NS	NS
region (native vs. invading)	0.04	NS
precipitation of the driest quarter (b17)	NS	NS
region (native vs. invading)	0.005	0.01
solar radiation seasonality (b23)	NS	NS
region (native vs. invading)	0.005	0.0003

[a]All models included interactions between bioclimatic variable and region; interactions were non-significant and excluded in all cases. For both bioclimatic variable (continuous) and region (categorical), df = 1. Samples are 20 invading and 22 native population Least Squares Means estimates of size in each model. Bioclimatic variables values for each site were interpolated from CliMond datasets using ArcGIS.

Supplementary Table 5. REML models of response to drought

| Response variable				
Effect type	Effect	df	F or X^2	*P* value
Drought tolerance (days to wilt)				
Fixed	region	1	19.4245	<0.0001
Fixed	population w/in region	40	2.8508	<0.0001
Random	block[a]			NS[b]
Drought tolerance (days to wilt): size index at 5 weeks covariate				
Fixed	region	1	5.1555	0.02
Fixed	population w/in region	40	2.2153	<0.0001
Fixed	size at 5 weeks	1	124.4332	<0.0001
Fixed	size at 5 weeks x region			NS[b]

[a]Blocks were used to account for environmental variation across the glasshouse space, and included five spatial blocks of each treatment, each including two individuals per population randomized within the block.

[b]Highly non-significant (NS) correlates (*P* > 0.1) were removed from final models.

Supplementary Table 6. Correlation coefficients[a] **(r²) among CliMond Bioclim variables**

Variable	Description	b1	b4	b9	b12	b15	b17	b23
bio1	Annual mean temperature (°C)	*						
bio8	Mean temperature of wettest quarter (°C)	0.77						
bio10	Mean temperature of warmest quarter (°C)	0.91						
bio11	Mean temperature of coldest quarter (°C)	0.93						
bio24	Radiation of wettest quarter (W m⁻²)	0.76						
bio4	Temperature seasonality (C of V)		*					
bio7	Temperature annual range (bio5-bio6) (°C)		0.86					
bio9	Mean temperature of driest quarter (°C)			*				
bio25	Radiation of driest quarter (W m⁻²)			0.84				
bio12	Annual precipitation (mm)				*			
bio16	Precipitation of wettest quarter (mm)				0.97			
bio19	Precipitation of coldest quarter (mm)				0.94			
bio28	Annual mean moisture index				0.91			
bio32	Mean moisture index of wettest quarter				0.89			
bio35	Mean moisture index of coldest quarter				0.88			
bio15	Precipitation seasonality (C of V)					*		
bio3	Isothermality (bio2 ÷ bio7)					0.67		
bio31	Moisture index seasonality (C of V)					0.88		
bio17	Precipitation of driest quarter (mm)						*	
bio18	Precipitation of warmest quarter (mm)						0.96	
bio33	Mean moisture index of driest quarter						0.96	
bio34	Mean moisture index of warmest quarter						0.96	
bio23	Radiation seasonality (C of V)							*
bio20	Annual mean radiation (W m⁻²)							-0.82
bio26	Radiation of warmest quarter (W m⁻²)							-0.83
bio27	Radiation of coldest quarter (W m⁻²)							-0.92

[a]Correlation coefficients (r²) are shown for each variable with its closest representative among the seven focal variables (bio1,4,9,12,15,17,23). Correlations are across values extracted for YST occurrences in North America and Europe (N = 525). Correlations over 0.6 were grouped by hierarchical clustering.
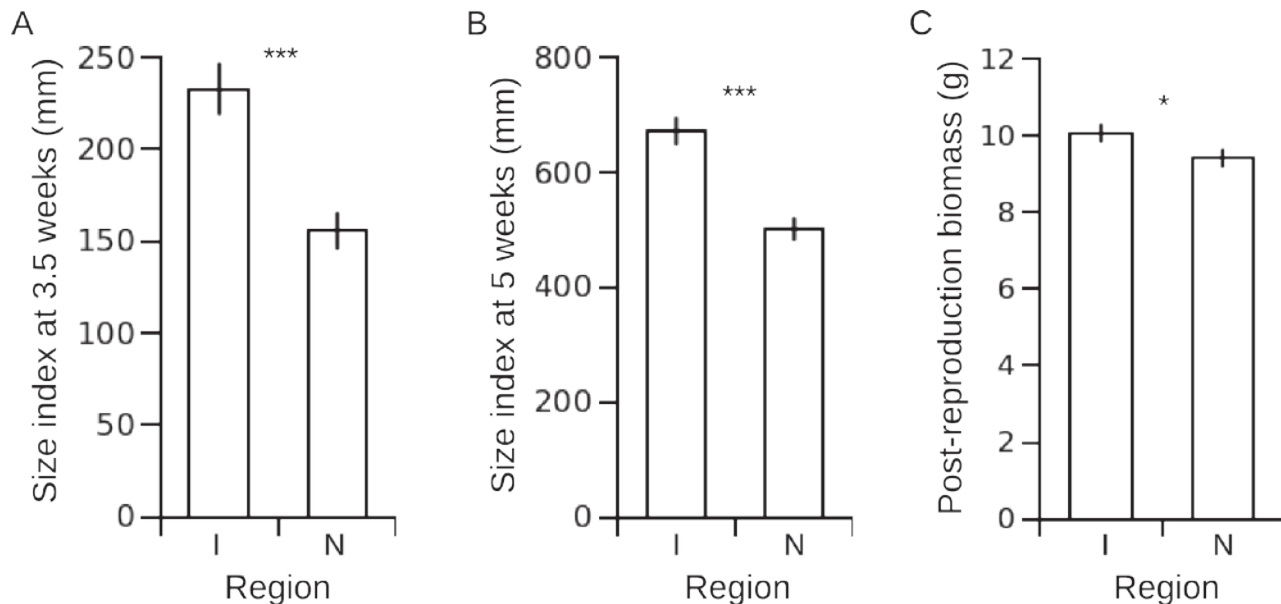
Supplementary Figure 1. Size differences between invading (I) and native (N) populations at three times points. The size index (see Methods) measured at 3.5 weeks (A) and 5 weeks (B) was ln transformed for analysis; figures show LSMs +/- SEM from the model fit, back-transformed to a linear scale. Biomass collections (C) were made after flowering, when the basal rosette of leaves has senesced during the production of a reproductive stem and flowering heads (capitula); all biomass remaining on the plant was collected, including capitula, stems, and any remaining senescent leaves. (*$P < 0.05$; ***$P < 0.0001$)
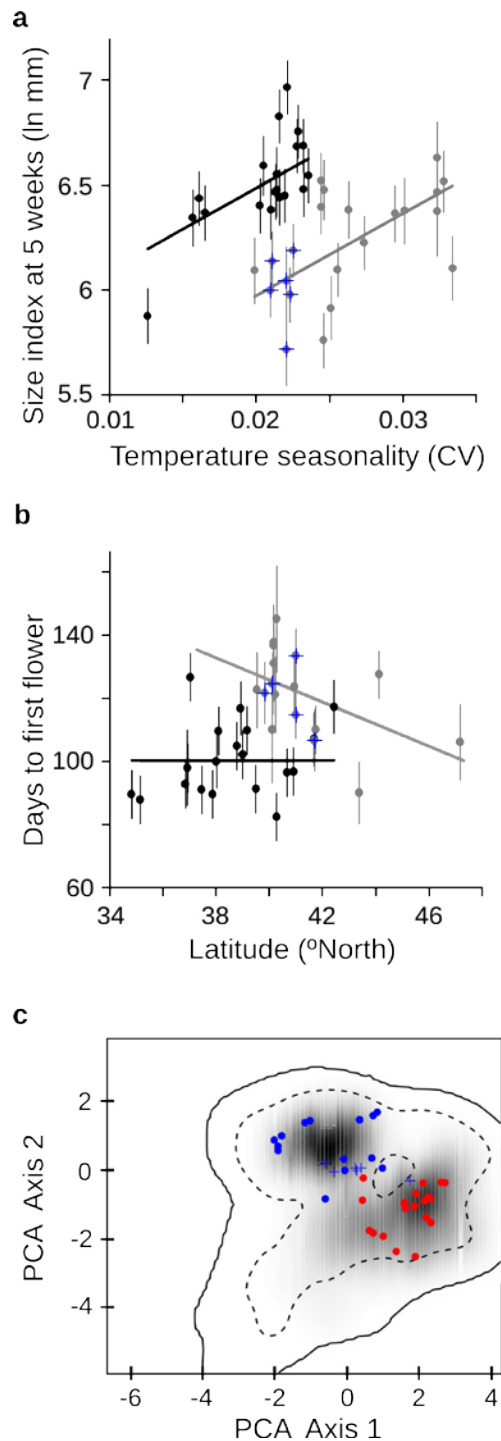
Supplementary Figure 2. Growth, flowering, and niche properties of six Spanish populations studied here (blue crosses) shown for comparison with the invading and other native populations. Spain appears to be the major source of invading Californian genotypes, though there is also evidence for admixture with eastern European sources (Gerlach 1997; Erikson et al. 2014), making no one source region a fully representative comparison for evolutionary change. (A) Size at 5 weeks is as in Fig 2B; (B) Days to flower is as in Fig 2D, for plants from five populations that flowered; and (C) position in Californian niche space is as in Fig 1Em where all native populations (blue) have been superimposed with invading populations (red). Spanish genotypes are among the smallest in size and most divergent in flowering time, though they occupy some of the most similar niche space to the Californian invasion.