Supporting Information

Wilczek et al. 10.1073/pnas.1406314111

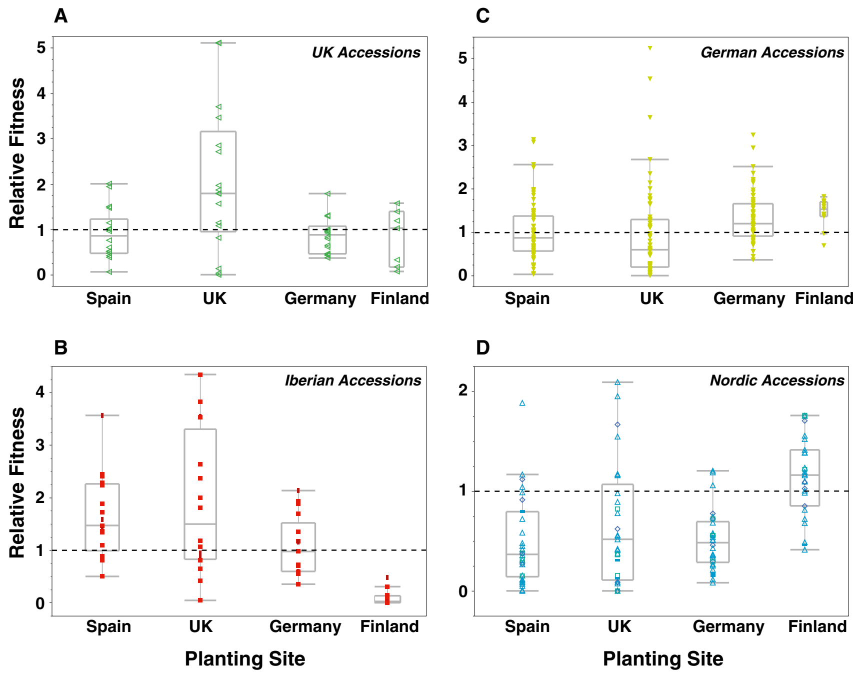

Fig. S1. Performance of accessions from each region—(*A*) UK, (*B*) German, (*C*) Iberian, and (*D*) Nordic—across autumn cohorts at each planting site. A value above a relative fitness value of 1 signifies that, in that planting, accessions originating from the region had higher than average fitness compared with accessions originating from other locations. Box-and-whisker plots of relative fitness for ecotypes from each region within each autumn planting are displayed.

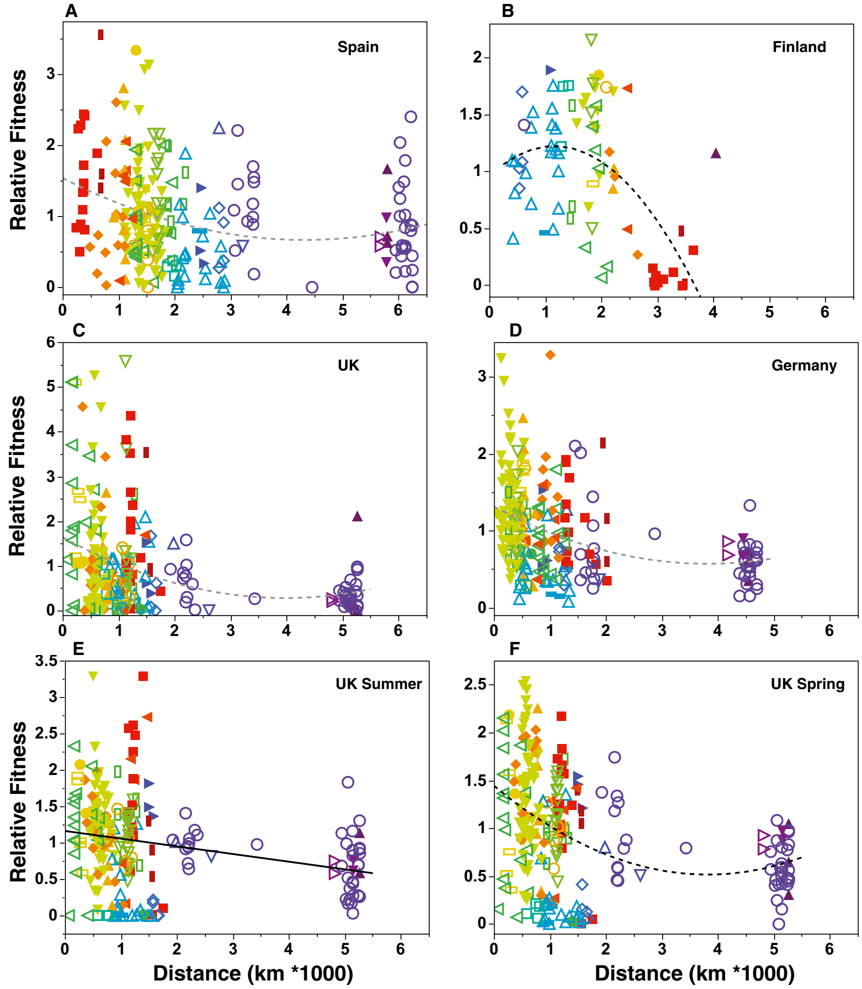

Fig. S2. Geographic local adaptation in a large sample of accessions from throughout the native range of *A. thaliana*. In autumn cohorts in (*A*) Valencia, Spain; (*B*) Oulu, Finland; (*C*) Norwich, United Kingdom; and (*D*) Halle, Germany, selection favored accessions from locations close to the growth environment. A similar pattern was observed in (*E*) summer and (*F*) spring cohorts planted into the Norwich, UK common garden site. Lines of linear (solid) or quadratic (dashed) best fit, significant at $P \leq 0.05$ are shown (Tables S3 and S4). Polynomial fits that were marginally significant ($0.006 < P < 0.05$) are shown in gray rather than black ($P < 0.006$). In each case, where the polynomial fit was marginal, the linear fit was significant at $\alpha = 0.006$. Warmer-colored symbols denote accessions from more southerly locations, with each color and shape combination characterizing a single country of origin (legend details in Fig. 1).

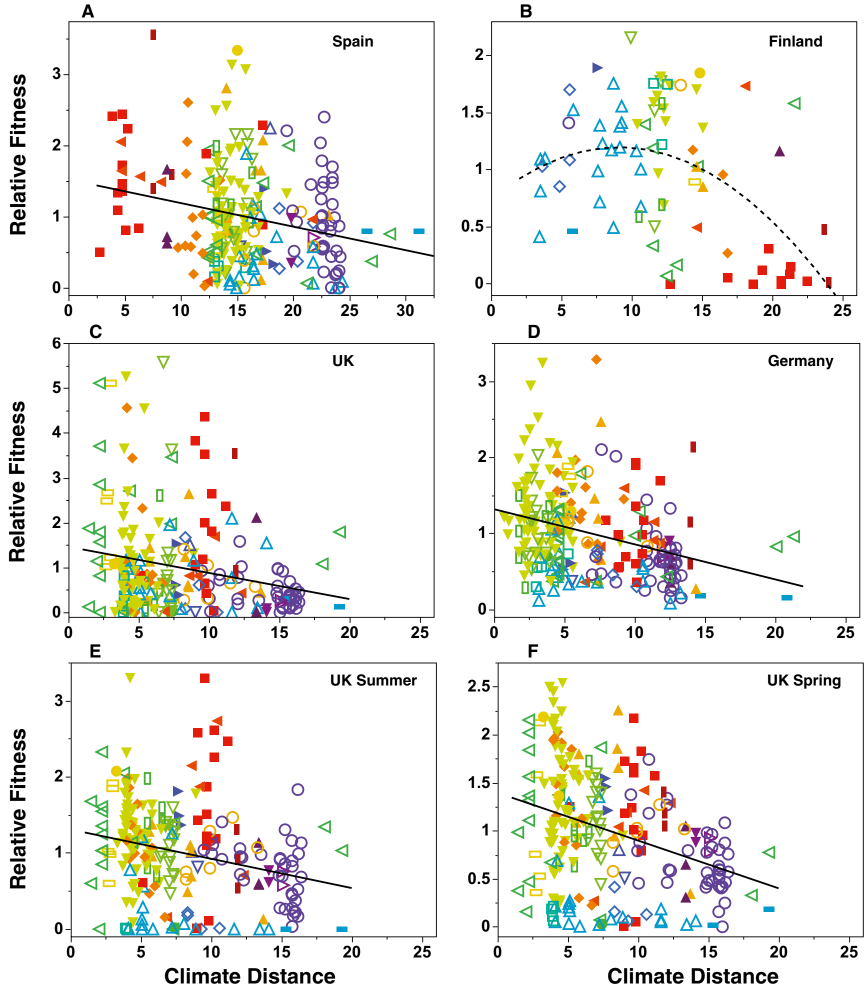

Fig. S3. Adaptation to climate in a large sample of accessions from throughout the native range of *A. thaliana*. In autumn cohorts in (*A*) Valencia, Spain; (*B*) Oulu, Finland; (*C*) Norwich, United Kingdom; and (*D*) Halle, Germany, performance declined as climate distance from site of origin to the growth site increased. Seasonal variation in selection on climate at accession origin is shown for (*E*) summer and (*F*) spring cohorts planted into the Norwich, UK, common garden site. Warmer-colored symbols denote accessions from more southerly locations, with each color and shape combination characterizing a single country of origin (legend details in Fig. 1). Lines of linear (solid) or quadratic (dashed) best fit, significant at $P \leq 0.006$, are shown (Table S3).

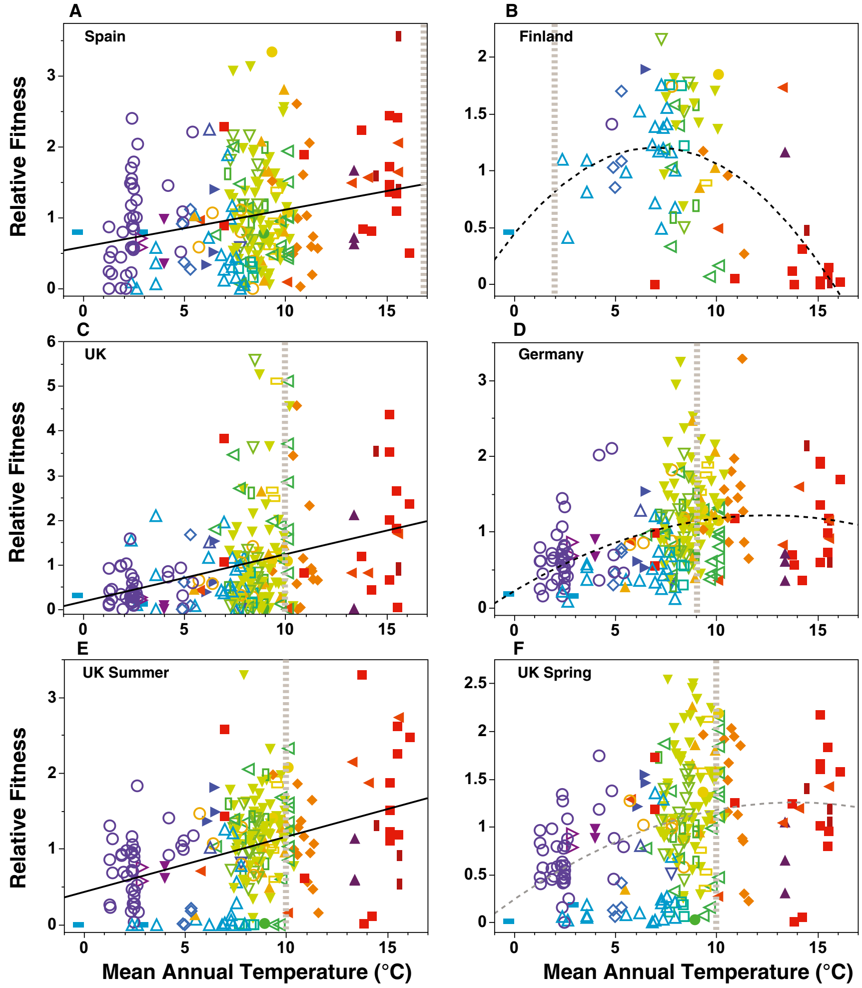

Fig. S4. Lagging adaptation to mean annual temperature in a large sample of accessions from throughout the native range of *Arabidopsis thaliana*. In autumn cohorts in (*A*) Valencia, Spain; (*B*) Oulu, Finland; (*C*) Norwich, United Kingdom; and (*D*) Halle, Germany, selection favored accessions from historically warmer climates. A similar pattern was observed in (*E*) summer and (*F*) spring cohorts planted into the Norwich, UK, common garden site although slightly cooler temperatures were favored in the spring cohort demonstrating seasonal variation in adaptation to climate. Lines of linear (solid) or quadratic (dashed) best fit, significant at $P \leq 0.05$ are shown (Table S4). Polynomial fits that were marginally significant ($0.006 < P < 0.05$) are shown in gray rather than black ($P < 0.006$). In each case, where the polynomial fit was marginal, the linear fit was significant at $\alpha = 0.006$. Warmer-colored symbols denote accessions from more southerly locations, with each color and shape combination characterizing a single country of origin (legend details in Fig. 1). Vertical gray lines show the recent historic mean annual temperature.

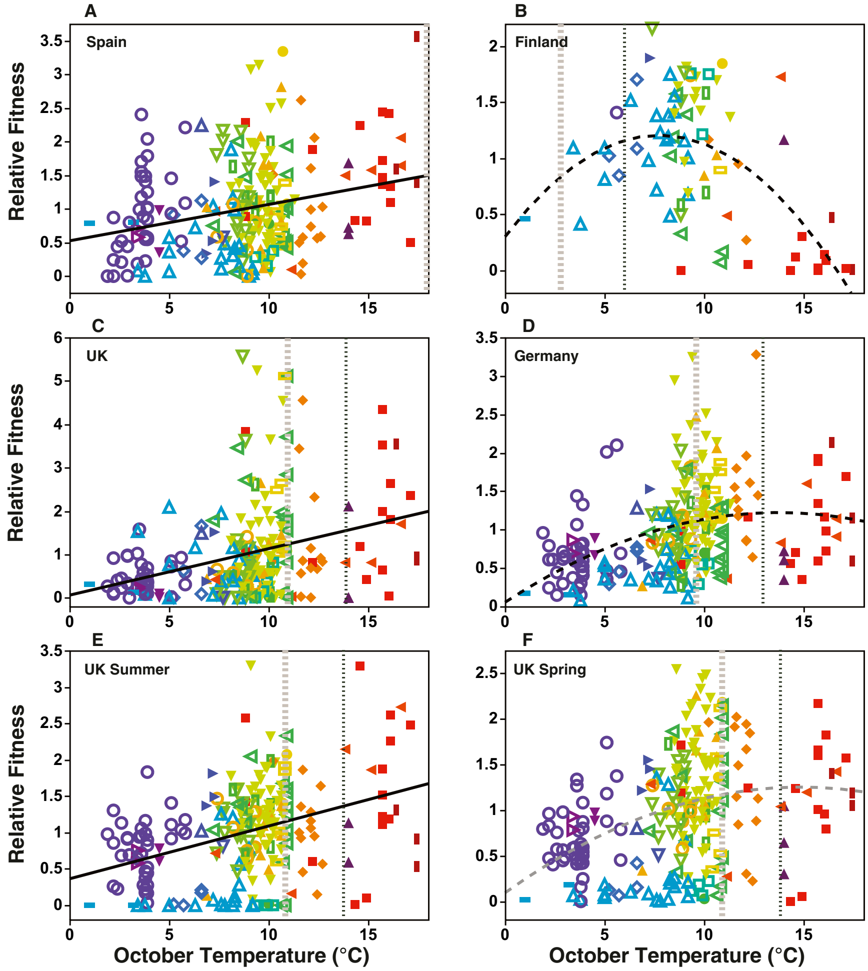

Fig. S5. Lagging adaptation to October temperature in a large sample of accessions from throughout the native range of *A. thaliana*. In autumn cohorts in (*A*) Valencia, Spain; (*B*) Oulu, Finland; (*C*) Norwich, UK; and (*D*) Halle, Germany, historic October temperatures were cooler than experienced October temperatures, which were closer to the predicted optimum. Selection also favored accessions from historically warmer climates in (*E*) summer and (*F*) spring cohorts planted into the Norwich, UK, common garden site. Lines of linear (solid) or quadratic (dashed) best fit, significant at $P \leq 0.05$ are shown (Table S4). Polynomial fits that were marginally significant ($0.006 < P < 0.05$) are shown in gray rather than black ($P < 0.006$). In each case, where the polynomial fit was marginal, the linear fit was significant at $\alpha = 0.006$. Warmer-colored symbols denote accessions from more southerly locations, with each color and shape combination characterizing a single country of origin (legend details in Fig. 1). Vertical gray lines show the recent historic October temperature, whereas vertical black lines show the October temperature during the experimental planting at each site (except in the Valencia autumn cohort where plants were established in November).

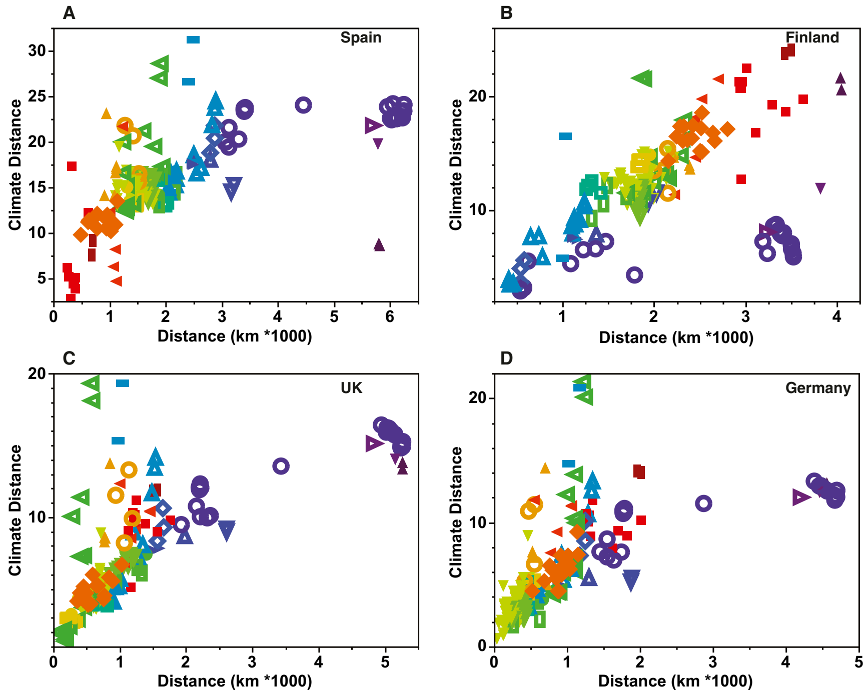

Fig. S6. Climate distance increases with increasing physical distance from each of the four common garden sites, (*A*) Norwich, UK; (*B*) Halle, Germany; (*C*) Valencia, Spain; and (*D*) Oulu, Finland.

Table S1. The timing, accession sample, and distribution of fitness for each experimental planting

Planting	Date of planting	*n* (ecotypes)	Replicates (no. of blocks)	Median relative fitness	SE	*n* (individuals)	Mean absolute fitness	Median absolute fitness	SE
Norwich summer	05-22-07	230	6	1.02	0.04	1,283	3,011	2,430	81
Norwich spring	02-27-07	232	7	0.98	0.04	1,557	4,283	3,489	102
Norwich autumn	09-06-06	231	5	0.63	0.07	1,114	4,683	540	261
Halle autumn	10-04-06	241	6	0.88	0.04	1,240	24,324	18,927	599
Valencia autumn	11-08-06	241	5	0.88	0.04	959	7,487	5,040	283
Oulu autumn	09-12-07	78	15	1.09	0.07	1,061	1,875	1,339	64

Metrics for relative fitness are based on accession family means, whereas those for absolute fitness reflect individual plant measurements.

Table S2. Heritability and cross-environment correlations of relative fitness

Planting	Norwich summer	Norwich spring	Norwich autumn	Halle autumn	Valencia autumn	Oulu autumn
Norwich summer	***0.281***	0.859	0.509	0.575	0.546	−0.030
Norwich spring	**0.649**	***0.311***	0.508	0.808	0.584	−0.026
Norwich autumn	**0.378**	**0.419**	***0.205***	0.354	0.141	−0.292
Halle autumn	**0.400**	**0.606**	**0.267**	***0.271***	0.598	0.206
Valencia autumn	**0.299**	**0.362**	0.083	**0.293**	***0.107***	−0.299
Oulu autumn	−0.021	0.013	−0.151	0.184	**−0.227**	***0.232***

Numbers in italics on the diagonal represent broad-sense heritabilities estimated by restricted maximum likelihood (REML), all of which were significantly different from zero at $\alpha = 0.05$. Below the diagonal are cross-environment correlations calculated using family means with entries in bold significantly different from zero at $\alpha = 0.05$. Above the diagonal are cross-environment correlations calculated from REML variance components.

Table S3. Geographic variation in climatic optima as demonstrated by the relationship between relative fitness and the climate and location of origin for each accession

		Climate distance				Physical distance				Latitude				Longitude			
Planting	Regression fit	R^2 adjusted	*P* value	Estimate	Optimum	R^2 adjusted	*P* value	Estimate	Optimum, km	R^2 adjusted	*P* value	Estimate	Optimum, ° N	R^2 adjusted	*P* value	Estimate	Optimum, ° E
Norwich summer	Linear	0.063	**<0.001**	−0.0384	≤0	0.060	**<0.001**	−0.1055	≤0	0.106	**<0.001**	−0.0410	43.7	0.067	**<0.001**	−0.0067	≤−8.6
	Quadratic	0.060	ns	—	≤0	0.069	ns	—	≤0	0.138	**0.003**	−0.0057	43.7	0.076	ns	—	≤−8.6
Norwich spring	Linear	0.119	**<0.001**	−0.0497	≤0	0.098	**<0.001**	−0.1261	≤0	0.092	**<0.001**	−0.0369	46	0.093	**<0.001**	−0.0075	≤−8.6
	Quadratic	0.118	ns	—	≤0	0.126	**0.004**	0.1273	≤0	0.157	**<0.001**	−0.0076	46	0.098	ns	—	≤−8.6
Norwich autumn	Linear	0.045	**<0.001**	−0.0582	≤0	0.070	**<0.001**	−0.1978	≤0	0.021	*0.016*	−0.0350	≤37	0.091	**<0.001**	−0.0136	≤−8.6
	Quadratic	0.042	ns	—	≤0	0.083	*0.042*	0.1711	≤0	0.017	ns	—	≤37	0.129	**0.001**	0.0009	≤−8.6
Halle autumn	Linear	0.107	**<0.001**	−0.0461	≤0	0.117	**<0.001**	−0.1419	≤0	0.054	**<0.001**	−0.0262	46.8	0.110	**<0.001**	−0.0076	≤−8.6
	Quadratic	0.103	ns	—	≤0	0.131	*0.029*	0.1022	≤0	0.103	**<0.001**	−0.0062	46.8	0.109	ns	—	≤−8.6
Valencia autumn	Linear	0.055	**<0.001**	−0.0331	≤0	0.034	**0.002**	−0.0807	≤0	0.070	**<0.001**	−0.0360	≤37	0.019	*0.019*	−0.0042	≤−8.6
	Quadratic	0.056	ns	—	≤0	0.059	*0.008*	0.0933	≤0	0.066	ns	—	≤37	0.021	ns	—	≤−8.6
Oulu autumn	Linear	0.133	**<0.001**	−0.0451	9.1	0.205	**<0.001**	−0.3199	1,160 km	0.171	**<0.001**	0.0383	54.2	0.147	**<0.001**	0.0220	39.3
	Quadratic	0.208	**0.006**	−0.0109	9.1	0.280	**0.004**	−0.3883	1,160 km	0.333	**<0.001**	−0.0105	54.2	0.231	**0.003**	−0.0011	39.3
Halle 2007	Linear	0.012	ns	−0.0329	—	0.028	ns	−0.2671	—	0.115	*0.043*	−0.0362	≤37	−0.038	ns	−0.0001	—
	Quadratic	0.018	ns	−0.0082	—	−0.006	ns	−0.1361	—	0.177	ns	−0.0038	≤37	0.050	ns	−0.0024	—
Valencia 2007	Linear	0.160	*0.022*	−0.0741	≤0	0.160	*0.022*	−0.4628	≤0	0.143	*0.029*	−0.0535	≤37	0.062	ns	−0.0283	—
	Quadratic	0.126	ns	−0.0009	≤0				≤0				≤37				—

Estimates of the selection differentials (*S*), gradients (γ), significances (uncorrected *P* values), and fits (adjusted R^2) are shown. Bolded values are significant at $P < 0.006$ and italicized values are significant at $0.006 < P < 0.05$. For details of calculation, see *Methods*. ns, not significant.

Table S4. Geographic variation in climatic optima as demonstrated by the relationship between relative fitness and the climate of origin

Planting	Regression fit	Mean annual temperature (BIO1) R^2 adjusted	Mean annual temperature (BIO1) *P* value	Mean annual temperature (BIO1) Estimate	Mean annual temperature (BIO1) Optimum, °C	April Temperature R^2 adjusted	April Temperature *P* value	April Temperature Estimate	April Temperature Optimum, °C	October temperature R^2 adjusted	October temperature *P* value	October temperature Estimate	October temperature Optimum, °C	Annual precipitation (BIO12) R^2 adjusted	Annual precipitation (BIO12) *P* value	Annual precipitation (BIO12) Estimate	Annual precipitation (BIO12) Optimum, mm
Norwich summer	Linear	0.149	**<0.001**	0.0728	≥16	0.185	**<0.001**	0.0980	≥15	0.143	**<0.001**	0.0727	≥17	0.008	ns	—	1,166
	Quadratic	0.145	ns	—	≥16	0.193	ns	—	≥15	0.139	ns	—	≥17	0.047	**0.002**	−1.615E-06	1,166
Norwich spring	Linear	0.125	**<0.001**	0.0640	13.9	0.163	**<0.001**	0.0884	11.4	0.119	**<0.001**	0.0635	14.8	0.017	*0.027*	3.790E-04	1,146
	Quadratic	0.142	*0.020*	−0.0105	13.9	0.200	**<0.001**	−0.0199	11.4	0.135	*0.022*	−0.0106	14.8	0.102	**<0.001**	−2.241E-06	1,146
Norwich autumn	Linear	0.098	**<0.001**	0.1056	≥16	0.054	**<0.001**	0.0963	≥15	0.098	**<0.001**	0.1072	≥17	0.021	*0.015*	7.728E-04	1,308
	Quadratic	0.094	ns	—	≥16	0.049	ns	—	≥15	0.094	ns	—	≥17	0.046	*0.010*	−2.343E-06	1,308
Halle autumn	Linear	0.129	**<0.001**	0.0600	12.5	0.148	**<0.001**	0.0777	11.2	0.126	**<0.001**	0.0605	13.7	0.015	*0.030*	3.379E-04	1,143
	Quadratic	0.160	**0.002**	−0.0127	12.5	0.186	**<0.001**	−0.0184	11.2	0.155	**0.003**	−0.0124	13.7	0.090	**<0.001**	−1.989E-06	1,143
Valencia autumn	Linear	0.065	**<0.001**	0.0524	≥16	0.091	**<0.001**	0.0745	≥15	0.066	**<0.001**	0.0541	≥17	−0.001	ns	—	—
	Quadratic	0.070	ns	—	≥16	0.093	ns	—	≥15	0.072	ns	—	≥17	0.005	ns	—	—
Oulu autumn	Linear	0.141	**<0.001**	−0.0725	7.0	0.050	*0.027*	−0.0463	5.4	0.159	**<0.001**	−0.0780	≥17	−0.013	ns	—	—
	Quadratic	0.308	**<0.001**	−0.0311	7.0	0.169	**<0.001**	−0.0289	5.4	0.305	**<0.001**	−0.0302	≥17	−0.019	ns	—	—
Halle 2007	Linear	0.036	ns	0.0471	—	0.066	ns	0.0597	—	0.005	ns	0.0360	—	−0.035	ns	−1.812E-04	—
	Quadratic	0.049	ns	−0.0086	—	0.131	ns	−0.0135	—	0.060	ns	−0.0119	—	0.063	ns	−7.686E-06	—
Valencia 2007	Linear	0.157	*0.023*	0.1020	≥16	0.147	*0.028*	0.1081	≥15	0.140	*0.031*	0.0981	≥17	−0.016	ns	6.763E-04	—

Bolded values are significant at $P < 0.006$ and italicized values are significant at $0.006 < P < 0.05$.

Table S5. Characterization of the native climate space of *A. thaliana*

	PC1	PC2	PC3	PC4
Temperature variables				
Eigenvalue	18.1321	3.3043	1.1512	0.6863
Percent explained	75.5503	13.7678	4.7967	2.8598
Frost days				
January	−0.1973	−0.2525	0.0291	0.1808
February	−0.2057	−0.2192	−0.0597	0.1705
March	−0.2209	−0.1246	−0.0604	0.2389
April	−0.2189	0.0615	−0.0583	0.3525
May	−0.1991	0.2226	0.1050	0.3079
June	−0.1870	0.2613	0.2901	0.0599
July	−0.1611	0.2126	0.4865	−0.2934
August	−0.1742	0.2085	0.4694	−0.2028
September	−0.2096	0.1123	0.2294	0.1249
October	−0.2217	−0.0395	0.1102	0.2672
November	−0.2204	−0.0743	0.0685	0.2914
December	−0.2048	−0.2259	0.0733	0.1764
Mean temperature				
January	0.1869	0.3101	−0.0428	0.2400
February	0.2022	0.2510	0.0138	0.2040
March	0.2189	0.1442	0.0660	0.1992
April	0.2251	−0.0532	0.1356	0.1532
May	0.2031	−0.2389	0.1845	0.0931
June	0.1828	−0.3007	0.2567	0.0662
July	0.1858	−0.2715	0.3075	0.0758
August	0.1974	−0.2389	0.2741	0.0821
September	0.2205	−0.1161	0.2252	0.0986
October	0.2290	0.0553	0.1157	0.1539
November	0.2174	0.1691	0.0167	0.2128
December	0.1914	0.2924	−0.0520	0.2486
Precipitation variables				
Eigenvalue	16.6739	2.8065	2.2977	1.1253
Percent explained	69.4744	11.6937	9.5736	4.6888
Precipitation				
January	0.2146	−0.2628	0.0572	−0.0145
February	0.2072	−0.2819	0.1131	0.0636
March	0.2174	−0.2360	0.1104	−0.0061
April	0.1981	−0.1446	0.2835	0.1172
May	0.1705	0.0361	0.4290	0.1929
June	0.1614	0.2404	0.3923	−0.0688
July	0.1863	0.2317	0.2323	−0.2979
August	0.2165	0.1168	0.1937	−0.2040
September	0.2288	−0.1049	0.0449	−0.2038
October	0.2200	−0.2125	0.0326	−0.1800
November	0.2172	−0.2458	0.0657	−0.1103
December	0.2158	−0.2598	0.0527	−0.0652
Rainy days				
January	0.2147	−0.0168	−0.2680	0.1243
February	0.2111	−0.0556	−0.1829	0.2371
March	0.2191	0.0114	−0.1744	0.2699
April	0.1982	0.1310	−0.0329	0.4319
May	0.1636	0.2319	0.1137	0.5221
June	0.1723	0.4016	0.0462	0.0152
July	0.1745	0.3634	−0.0823	−0.2432
August	0.2021	0.2871	−0.1159	−0.1240
September	0.2161	0.1149	−0.2334	−0.1820
October	0.2188	−0.0309	−0.2643	−0.0655
November	0.2149	−0.0013	−0.2846	−0.0442
December	0.2165	0.0095	−0.2728	−0.0400

Loading of climate normals onto the first four principal component (PC) axes when PC analysis was performed separately for climate and precipitation variables. The eight PCs were used to characterize the climate of our experimental sites and accessions and to measure climate distance between ecotype and experimental site.

Dataset S1. ***A. thaliana*** **accessions, geographic location of origin, and field-measured fitness for each experimental planting**

Dataset S1

Stock numbers beginning in “cs” correspond to Arabidopsis Biological Resource Center stocks, and those beginning in “N” correspond to Nottingham Arabidopsis Stock Centre stocks. Stock numbers beginning with “ks” were donated by K. J. Schmid and are described in Schmid et al. (1) and Schmuths et al. (2). Where accessions were absent from an experimental planting (i.e., not planted), the fitness is given as “NA.” Fitness was estimated as the product of the silique number and the length of a representative silique (in millimeters).

1. Schmid KJ, et al. (2006) Evidence for a large-scale population structure of Arabidopsis thaliana from genome-wide single nucleotide polymorphism markers. *Theor Appl Genet* 112(6): 1104–1114.
2. Schmuths H, Hoffmann MH, Bachmann K (2004) Geographic distribution and recombination of genomic fragments on the short arm of chromosome 2 of Arabidopsis thaliana. *Plant Biol (Stuttg)* 6(2):128–139.