Supplementary material for Hällfors et al. (submitted manuscript): **Translocation of an arctic seashore plant reveals signs of maladaptation to altered climatic conditions**

Text S1
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Text S1. Measuring local adaptation

In their extensive guide to measuring local adaptation, Blanquart, Kaltz, Nuismer, and Gandon (2013) reviewed three conceptually differing definitions of local adaptation (LA) and the subsequent interpretations that can be drawn from experiments based on these. They also highlighted the fact that the estimation of local adaptation is sensitive to the definition used to characterise LA at the population level (Blanquart, Kaltz, Nuismer, & Gandon 2013). One of them (i) gives a general estimate on how local genotypes are adapted to their home environments and other two (ii and iii, reviewed in Kawecki and Ebert 2004) yield information on variation within the species concerned (i.e. genotype specific local adaptation). For an in-depth discussion on these concepts and their implications for measuring local adaptation, please see Kawecki and Ebert (2004) and Blanquart, Kaltz, Nuismer, & Gandon (2013).

i. The sympatric-allopatric contrast (henceforth called ΔSA) is the most straightforward way of estimating LA. In this approach the difference is calculated between the average fitness of genotypes in their home environment and genotypes in their non-home environment. In the case of this study ΔSA for the *subspecies as whole* is the difference between the mean fitness of both varieties in their home environments and that in the test (away) environment:

$$\Delta SA = \frac{p_{NH} + p_{SH}}{2} - \frac{p_{NA} + p_{SA}}{2}$$

ii. The home vs. away approach (henceforth called HA) can conceptually be understood as describing the *home environment quality for each tested genotype*, and is measured by the difference between the fitness of a genotype in its home environment and its fitness in all other tested environments (away). In our study, the Home vs. Away metric (HA) for each *variety* is the difference between the fitness of each variety in its home environment and that in its away environment.

$$HA_S = p_{SH} - p_{SA}$$

$$HA_N = p_{NH} - p_{NA}$$

iii. The local vs. foreign approach (henceforth called LF) can, in turn, be understood conceptually as describing the *genotype quality for each tested home environment*, and is measured by the difference between the fitness of a genotype in its home environment and the mean fitness of all other genotypes when exposed to the same environment. In our study the Local vs. Foreign metric (LF) for each *location* is the difference between the fitness of the local variety and that of the foreign variety.

$$LF_S = p_{SH} - p_{NA}$$

$$LF_N = p_{NH} - p_{SA}$$

TABLE S1. Seed collection information for populations used in experiments. The distance between sampled individuals in a seed sampling sites was approximately between 0.5 and 150 meters. The mean distance between the seed sampling sites of the two varieties was 533.5 kilometers. Herbarium specimens are placed in the herbarium of Finnish Museum of Natural History, Helsinki (H). For each experimental garden, three seed-sampling sites (among A-K) were randomly chosen for both varieties to provide individuals (however, contingent on the availability of individuals; see manuscript). From each seed-sampling site (A-K), five unique individuals were randomly chosen to provide eight seeds for producing experimental plants (again, contingent on seed availability).

Variety	Seed sampling site	Location	Municipality	Country	Latitude	Longitude
Southern; var. jokelae	A	Pauhunlahti	Ii	Finland	65.38027778	25.29333333
Southern; var. jokelae	B	Partalahti	Ii	Finland	65.37583333	25.43722222
Southern; var. jokelae	C	Praava	Ii	Finland	65.28444444	25.30694444
Southern; var. jokelae	D	Halosenniemi	Haukipudas	Finland	65.2575	25.33305556
Southern; var. jokelae	E	Villenniemi	Haukipudas	Finland	65.22638889	25.28611111
Northern; var. finmarchica	F	Svartaksla	Sør-Varanger	Norway	69.71666667	30.13
Northern; var. finmarchica	G	Lille Ropelv	Sør-Varanger	Norway	69.77444444	30.19611111
Northern; var. finmarchica	H	Jakobsnes	Sør-Varanger	Norway	69.7275	30.12861111
Northern; var. finmarchica	I	Lanabukt	Sør-Varanger	Norway	69.74194444	30.46527778
Northern; var. finmarchica	J	Storbukt	Sør-Varanger	Norway	69.6825	30.45305556
Northern; var. finmarchica	K	Jarfjordbotn	Sør-Varanger	Norway	69.66361111	30.30055556

Variety	Seed sampling site	Distance from the centre point of seed sampling sites of said variety (km)	Seed sampling date	N:o of individuals from which seeds were sampled	Herbarium specimen number	Individuals of the population were planted in the following gardens, based on random draw and availablity of individuals
Southern; var. jokelae	A	8.57	27 Aug 2012	7	0140-0146	Oulu
Southern; var. jokelae	B	9.29	27 Aug 2012	57	0147-0202	All gardens
Southern; var. jokelae	C	2.54	27 Aug 2012	51	0203-0252	All gardens
Southern; var. jokelae	D	5.27	27 Aug 2012	10	0253-0262	None of the gardens
Southern; var. jokelae	E	8.98	27 Aug 2012	50	0263-0312	All gardens
Northern; var. finmarchica	F	5.74	1 Sept 2012	50	0313-0362	Tartu, Oulu, and Svanvik
Northern; var. finmarchica	G	7.06	1 Sept 2012	50	0363-0412	Helsinki, Oulu, and Svanvik
Northern; var. finmarchica	H	5.9	1 Sept 2012	50	0413-0462	Tartu, Rauma, and Svanvik
Northern; var. finmarchica	I	7.66	2 Sept 2012	50	0463-0512	Helsinki, Rauma, and Oulu
Northern; var. finmarchica	J	7.78	2 Sept 2012	25	0513-0537	Rauma
Northern; var. finmarchica	K	6.08	2 Sept 2012	50	0538-0587	Tartu and Helsinki

TABLE S2. Description of experimental gardens and dates of procedures on plant individuals planted in each experimental garden. Distance from Southern vs Northern variety refers to the distance in kilometers from the centre of all seed sampling sites of that variety (seed sampling sites presented in Table S1). Experiment supplementation refers to new plants added to the experiment during the summer of 2013 when the experiment was started (see manuscript).

Experimental garden	Coordinates	Distance from center point of seed sampling sites of the Southern variety (km)	Distance from center point of seed sampling sites of the Northern variety (km)	Date of seed sowing	Date of transfer to main glass house	Date of fertilizing	Date of exp. setup	Date of exp. supplementation
Tartu	N58.38, E26.72	772.7	1271.3	18 March 2013	24 April 2013	29 April 2013	17 May 2013	22 August 2013
Helsinki	N60.20, E24.95	567.7	1086.3	26-28 March 2013	2 May 2013	7 May 2013	21 May 2013	10 September 2013
Rauma	N61.13, E21.50	502.1	1035.2	4-5 April 2013	10 May 2013	15 May 2013	29-30 May 2013	2 September 2013
Oulu	N65.06, E25.47	27.5	556.5	25-26 April 2013	1 June 2013	6 June 2015	17-18 June 2013	5 September 2013
Svanvik	N69.45, E30.04	503.1	30.7	2 May 2013	7 June 2013	12 June 2013	27-28 June 2013	3 September 2013

TABLE S3. Number and percent of surviving individuals per year and from previous year in each garden. Also see Fig 3 in the main manuscript for a graphical representation.

Garden	Variety	Planted individuals in 2013	Survival percentage from 2013-2014	Surviving individuals in 2014	Survival percentage from 2014-2015	Surviving individuals in 2015	Survival percentage from 2015-2016	Surviving individuals in 2016 and decreas from 2015	Percent surviving by 2016 per variety, compared to number of individuals planted in 2013	Percent surviving by 2016 across all individuals, compared to number of individuals planted in 2013
Tartu	Southern	80	25.0	20	60.0	12	66.7	8	10.0	5.8
	Northern	75	10.7	8	75.0	6	16.7	1	1.3	
Helsinki	Southern	42	61.9	26	65.4	17	76.5	13	31.0	15.9
	Northern	65	16.9	11	45.5	5	80.0	4	6.2	
Rauma	Southern	61	39.3	24	70.8	17	82.4	14	23.0	11.8
	Northern	66	10.6	7	28.6	2	50.0	1	1.5	
Oulu	Southern	49	55.1	27	77.8	21	57.1	12	24.5	17.2
	Northern	50	28.0	14	71.4	10	50.0	5	10.0	
Svanvik	Southern	51	78.4	40	95.0	38	94.7	36	70.6	51.0
	Northern	51	49.0	25	76.0	19	84.2	16	31.4	

TABLE S4. Estimates, standard errors, t-values or z-values, and p-values for the *Garden* aster model with only fixed effects (left) and including random effects (right). The intercept represents the survival in 2014 of the northern variety in Svanvik.

Garden-model without random effects					Garden-model with random effects			
p-value	z value	Std. Error	Estimate	Variable	Estimate	Std. Error	z value	p-value
<0.001	-4.024	0.155	-0.624	(Intercept)	-0.550	0.171	-3.225	<0.01
<0.001	3.718	0.329	1.223	Survival 2015	1.212	0.328	3.695	<0.001
<0.001	6.547	0.263	1.720	Survival 2016	1.638	0.263	6.228	<0.001
<0.001	-8.066	0.352	-2.843	Flowering 2014	-2.862	0.349	-8.190	<0.001
<0.001	-11.841	0.359	-4.253	Flowering 2015	-4.241	0.356	-11.904	<0.001
<0.001	-8.048	0.373	-3.001	Flowering 2016	-3.029	0.371	-8.175	<0.001
<0.001	10.430	0.170	1.778	Flowering abundance 2014	1.650	0.172	9.571	<0.001
<0.001	13.962	0.163	2.273	Flowering abundance 2015	2.142	0.165	12.966	<0.001
<0.001	12.190	0.167	2.040	Flowering abundance 2016	1.907	0.170	11.229	<0.001
<0.001	6.333	0.015	0.092	Original size	0.132	0.020	6.708	<0.001
<0.001	3.492	0.034	0.119	Southern variety	0.130	0.045	2.870	<0.01
<0.05	-2.546	0.079	-0.200	Oulu	-0.199	0.125	-1.596	0.100
<0.01	-3.133	0.142	-0.445	Rauma	-0.498	0.175	-2.850	<0.01
<0.01	-3.132	0.100	-0.312	Helsinki	-0.344	0.140	-2.455	<0.05
<0.01	-3.303	0.104	-0.343	Tartu	-0.375	0.144	-2.606	<0.01
0.500	0.689	0.086	0.060	Southern:Oulu	0.070	0.093	0.755	0.500
0.080	1.737	0.146	0.254	Southern:Rauma	0.247	0.151	1.637	0.100
<0.01	2.591	0.104	0.270	Southern:Helsinki	0.279	0.109	2.558	<0.05
0.200	1.336	0.109	0.146	Southern:Tartu	0.098	0.113	0.868	0.340
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--	--	--	--	Seed sampling site	0.033	0.024	1.395	0.080

TABLE S5. Estimates, standard errors, t-values or z-values, and p-values for the *Annual temperature* aster model with only fixed effects (left) and including random effects (right). The intercept represents the survival in 2014 of the northern variety in Svanvik.

Temperature-model without random effects					Temperature-model with random effects			
p-value	z value	Std. Error	Estimate	Variable	Estimate	Std. Error	z value	p-value
<0.05	-3.021	0.165	-0.499	(Intercept)	-0.397	0.195	-2.031	0.042
<0.001	3.693	0.329	1.216	Survival 2015	1.207	0.328	3.681	<0.001
<0.001	6.622	0.263	1.739	Survival 2016	1.636	0.263	6.219	<0.001
<0.001	-8.045	0.353	-2.843	Flowering 2014	-2.868	0.350	-8.205	<0.001
<0.001	-11.865	0.360	-4.274	Flowering 2015	-4.251	0.356	-11.932	<0.001
<0.001	-8.039	0.374	-3.005	Flowering 2016	-3.036	0.371	-8.192	<0.001
<0.001	10.643	0.170	1.813	Flowering abundance 2014	1.651	0.172	9.572	<0.001
<0.001	14.231	0.163	2.312	Flowering abundance 2015	2.143	0.165	12.970	<0.001
<0.001	12.451	0.167	2.079	Flowering abundance 2016	1.908	0.170	11.233	<0.001
<0.001	5.923	0.012	0.072	Original size	0.126	0.019	6.618	<0.001
0.980	0.029	0.055	0.002	Southern variety	0.038	0.066	0.580	0.562
<0.001	-5.199	0.014	-0.075	Temperature	-0.082	0.023	-3.586	<0.001
<0.01	3.199	0.015	0.049	Southern:Temperature	0.044	0.016	2.806	<0.01
--	--	--	--	Plot	0.132	0.031	4.290	<0.001
--	--	--	--	Seed sampling site	0.034	0.023	1.521	0.060

TABLE S6. Predictions of plant performance for each variety in each experimental garden based on the Garden fixed-effects aster model. The same data is shown as a barplot in the main manuscript, Fig. 5(a).

Garden	Variety	Predicted value	Std. Error
Svanvik	Northern	1.467	0.387
	Southern	5.691	0.805
Oulu	Northern	0.243	0.147
	Southern	1.687	0.500
Rauma	Northern	0.039	0.036
	Southern	1.048	0.309
Helsinki	Northern	0.100	0.071
	Southern	4.101	0.879
Tartu	Northern	0.080	0.058
	Southern	0.986	0.259

TABLE S7. Predicted values and standard errors of plant performance for each variety per mean annual temperature based on the Temperature fixed-effects aster model. The same data is shown in a plot in the main manuscript, Fig. 5(b).

Annual temp.	Variety	Predicted value	Std. Error
2.00	Northern	1.530	0.403
	Southern	4.846	0.711
2.61	Northern	0.988	0.229
	Southern	4.254	0.567
3.22	Northern	0.644	0.144
	Southern	3.713	0.445
3.83	Northern	0.425	0.101
	Southern	3.224	0.352
4.44	Northern	0.286	0.077
	Southern	2.789	0.288
5.06	Northern	0.195	0.060
	Southern	2.405	0.252
5.67	Northern	0.136	0.047
	Southern	2.069	0.237
6.28	Northern	0.096	0.037
	Southern	1.777	0.232
6.89	Northern	0.068	0.029
	Southern	1.525	0.231
7.50	Northern	0.050	0.023
	Southern	1.309	0.229

TABLE S8. Local adaptation metrics calculated based on overall performance (Table S6) of the two varieties (LF= Local vs. Foreign; HA= Home vs. Away) and for both varieties (ΔSA= Sympatric-Allopatric contrast) in the reciprocal part of the experiment (Oulu and Svanvik).

Variety	HA	LF	*ΔSA*
Southern	-0.71	0.26	-0.25
Northern	0.22	-0.75	

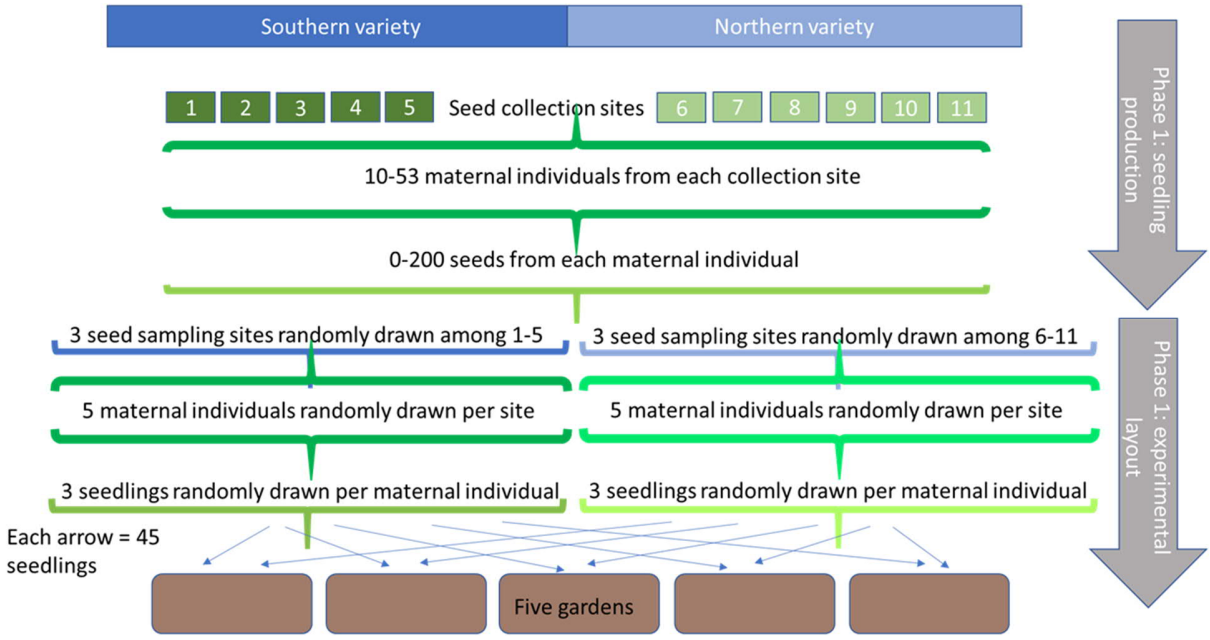

FIGURE S1. Framework for selecting seeds for growing experimental plants.

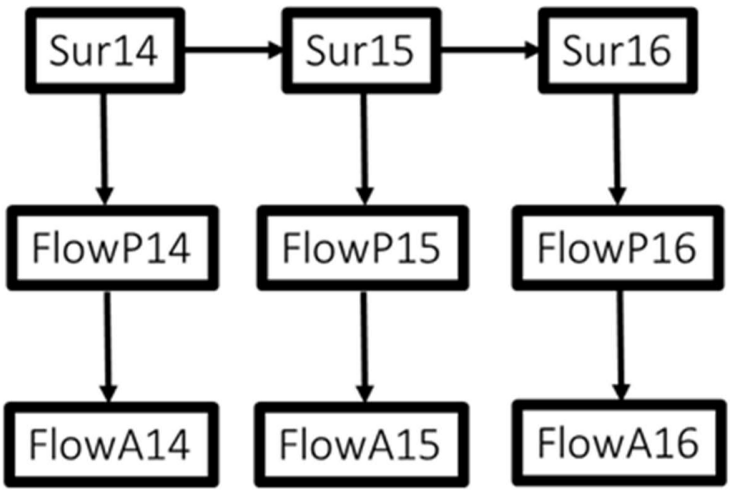

FIGURE S2. Graphical model for estimating overall performance using aster model. Performance measures are represented by the nodes and the arrows represent conditional distribution of the specified error. Specifically, the model included the probability of survival in each year (Sur14, Sur15, Sur16; 0 or 1; Bernoulli error distribution) that are conditional on survival in the previous year. Whether a plant flowered or not (FlowP14, FlowP15, FlowP16; 0 or 1; Bernoulli error distribution) is conditional on that it had survived in that year and in the previous year. The abundance of flowers per individual (FlowA14, FlowA15, FlowA16; count; zero-truncated poisson distribution of error) is conditional on that the individual flowered overall in that year and that it had survived in that year and in the previous year.

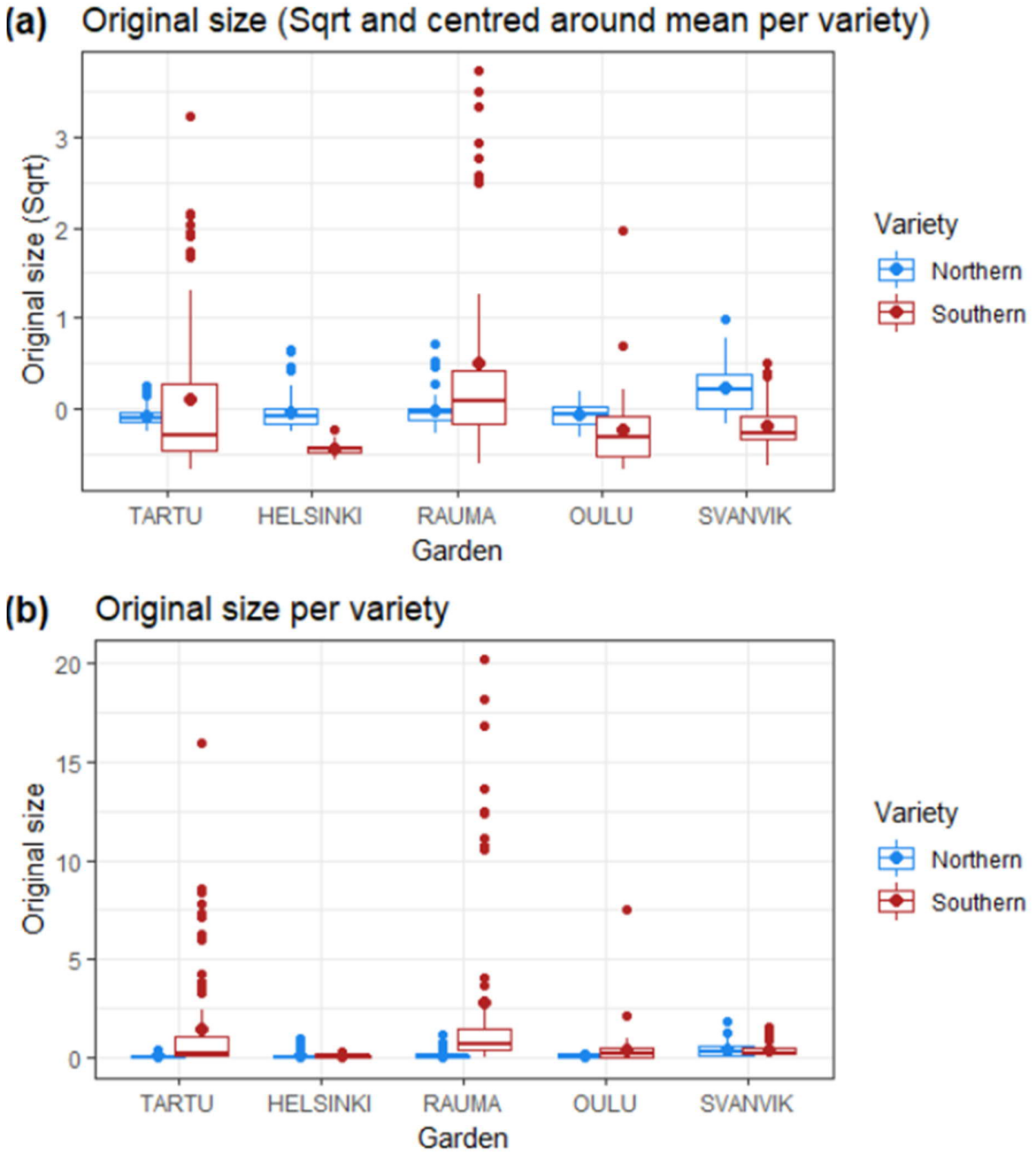

FIGURE S3. Original size of plants at planting in summer 2013. (a) Original size (cm^2) square root and centered around the mean of each variety. (b) Raw original size cm^2. For the analyzes, the square root transformed values were centered around the mean value for each variety separately (see Methods).

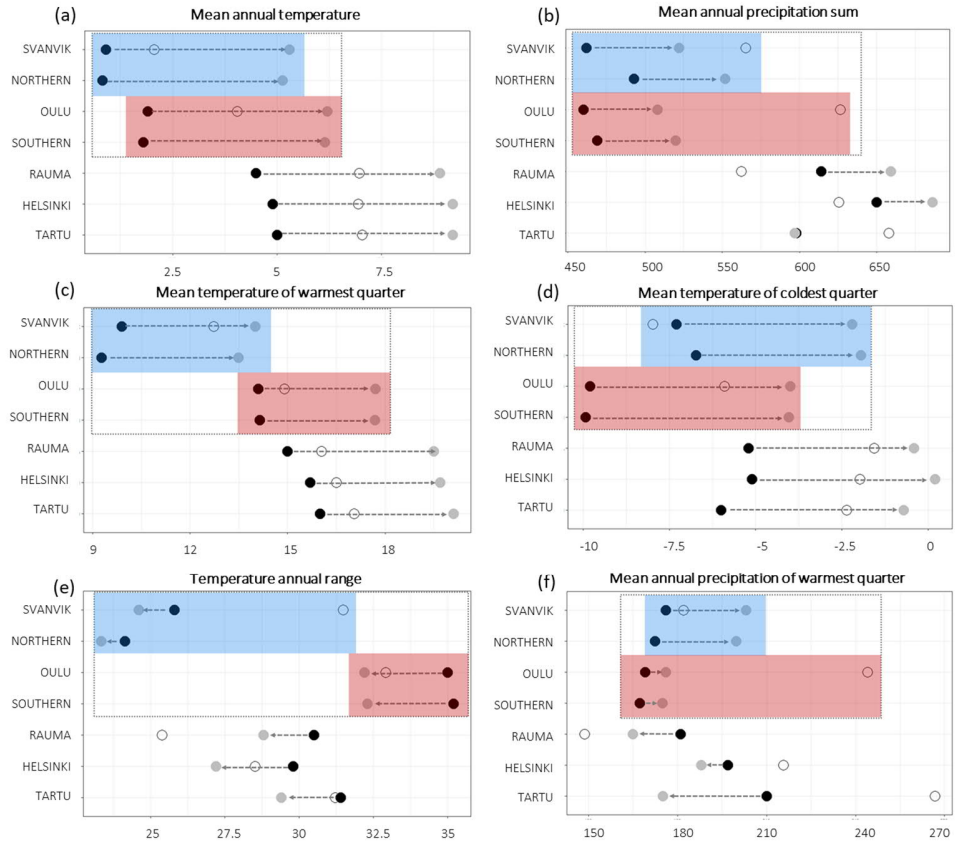

FIGURE S4. Climatic and weather conditions of seed sampling sites and experimental gardens. (a) Mean annual temperature (also shown in manuscript Figure 2); (b) mean annual precipitation sum; (c) mean temperature of the warmest quarter (mean temperature for the three months during which temperatures were highest in each year); (d) mean temperature of coldest quarter (mean temperature for the three months during which temperatures were lowest in that year); (e) temperature annual range (standard deviation * 100); and (e) mean annual precipitation of warmest quarter (the sum of precipitation for the three months during which temperatures were highest in that year). Black points show historic mean climatic conditions (1970-2000; 10 minutes resolution; Fick & Hijmans, 2017) and gray points show the future projections of mean climatic conditions (CMIP5 for 2050, 10 minutes resolution, HADGEM2-ES model; Fick & Hijmans, 2017) for each experimental garden and seed sampling site (Northern= seed sampling sites of the northern variety; Southern= seed sampling sites of the southern variety). For experimental gardens, open circles show mean climatic conditions during the experimental years 2013-2016. The experimental gardens and seed sampling sites within the species range is outlined by a dashed gray box, whereas the blue box indicates the sites within the range of the northern variety and the red box the sites within the range of the southern variety. All bioclim variables for the sites during historical, experimental, and future time periods are available at https://github.com/MariaHallfors/Primula-nutans-translocation.

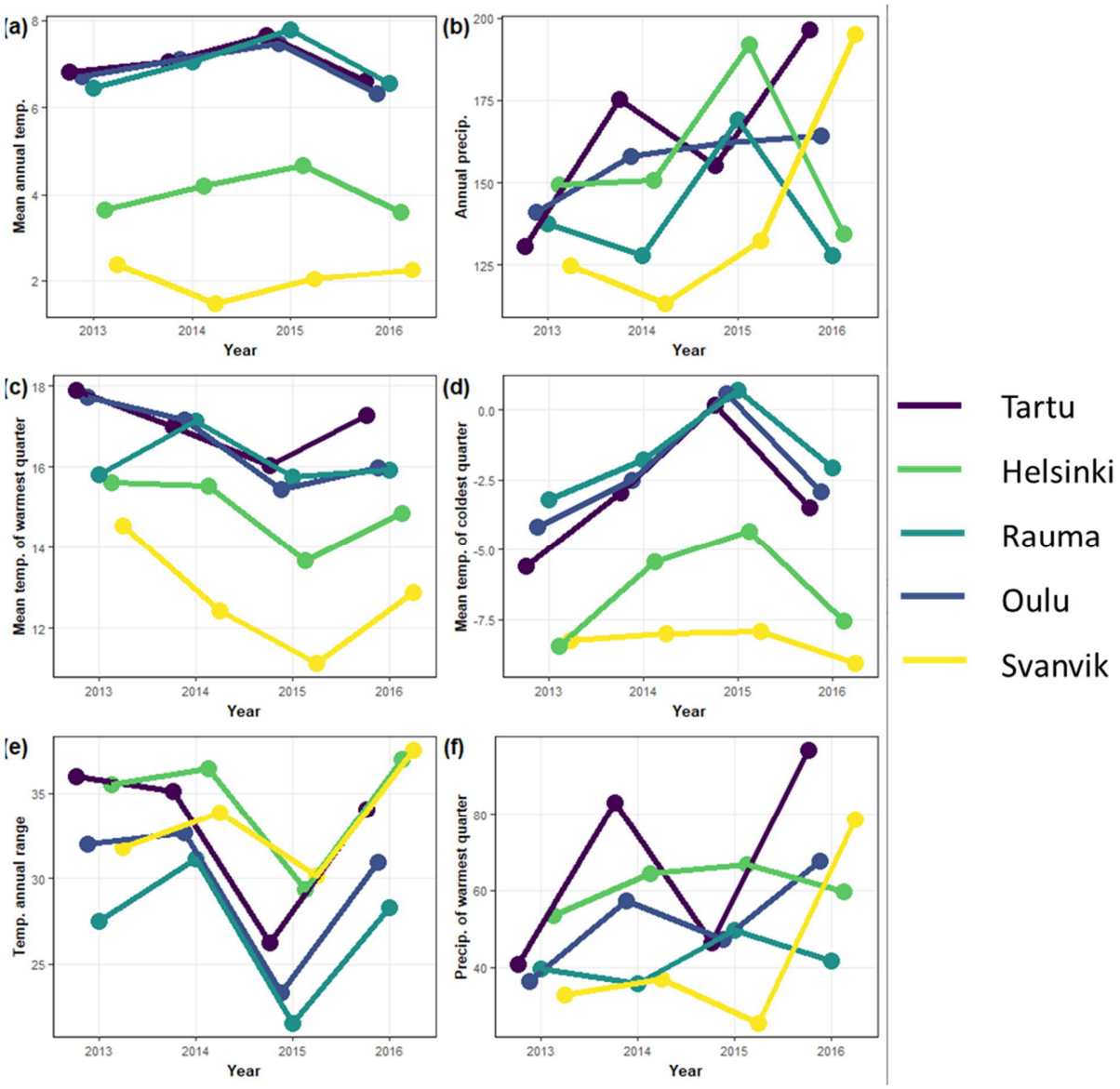

FIGURE S5. Annual weather conditions in the experimental gardens during the experimental years. (a) Mean annual temperature; (b) mean annual precipitation sum; (c) mean temperature of the warmest quarter (mean temperature for the three months during which temperatures were highest in each year); (d) mean temperature of coldest quarter (mean temperature for the three months during which temperatures were lowest in that year); (e) temperature annual range (standard deviation * 100); and (e) mean annual precipitation of warmest quarter (the sum of precipitation for the three months during which temperatures were highest in that year).

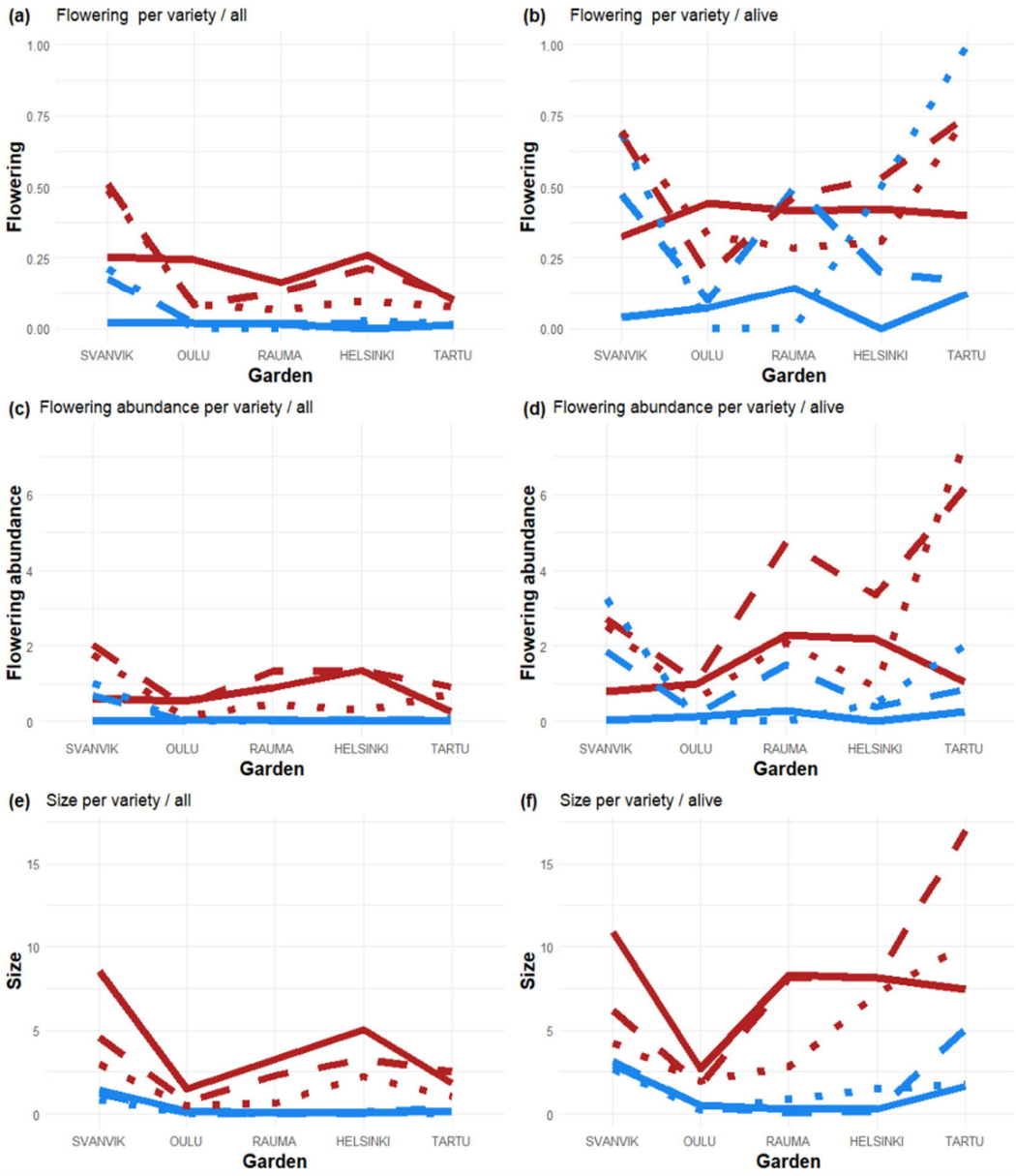

FIGURE S6. Raw data on performance measures per year, variety and experimental garden. Blue line= northern variety; red lines= southern variety; solid line= 2014; dashed line= 2015; dotted line= 2016. Panels in the left column shows yearly proportional means of performance measures (a) flower presence, (c) flowering abundance and (e) size (cm^2) averaged across all individuals were planted of each variety in each experimental garden, i.e. the performance measure is averaged across all planted individual (including dead ones which thus have a value of 0). Panels in the right column shows yearly absolute means of performance measures (b) flower presence, (d) flowering abundance and (f) size (cm^2) averaged across all individuals that were alive in the specific year of each variety in each experimental garden.

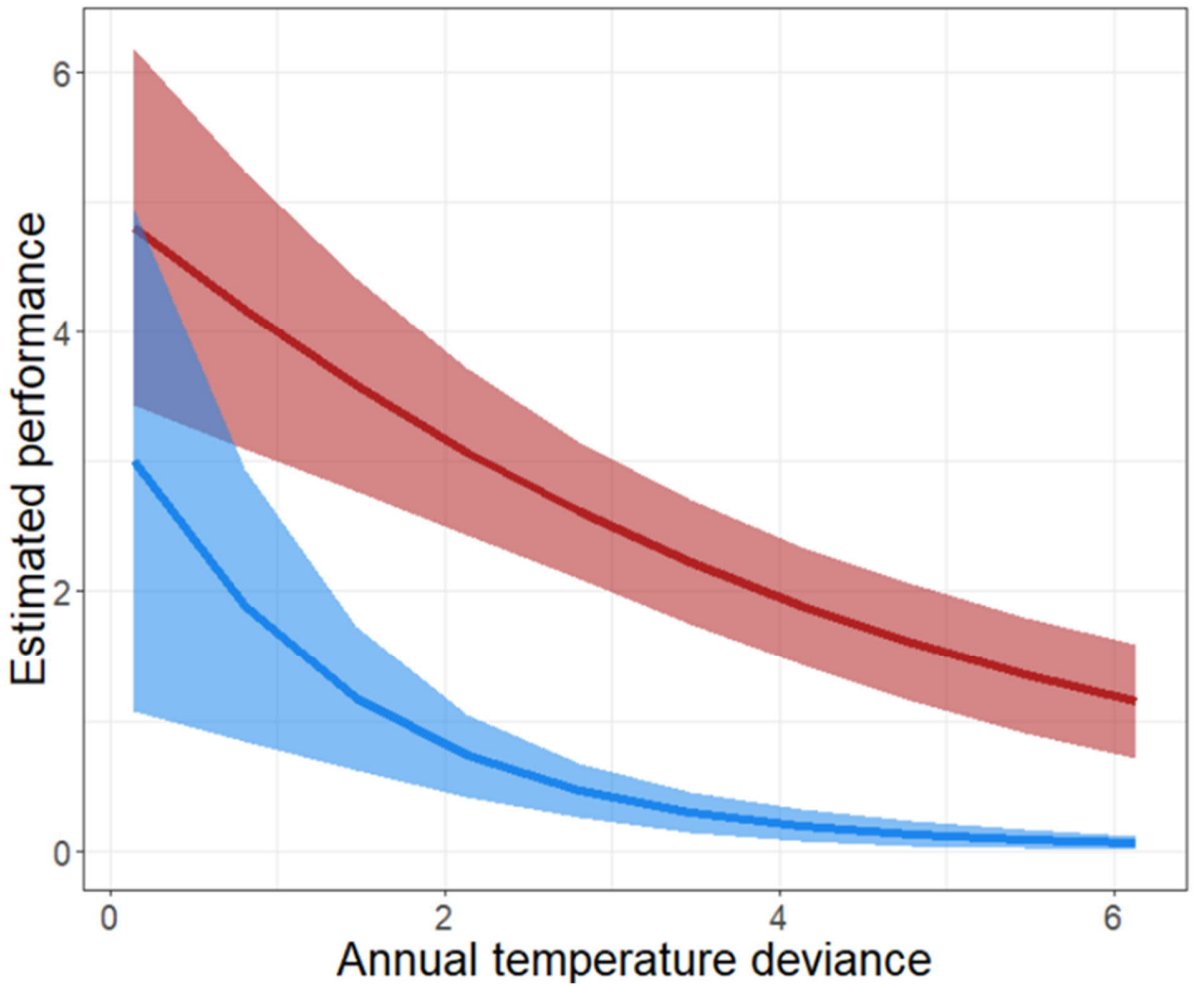

FIGURE S7. The estimated performance of the southern (red) and northern (blue) varieties as a function of experimental site deviation from historical mean annual temperature conditions in the occurrence area of each variety.