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*Supplement of*

**Contributions of dynamic environmental signals during life-cycle transitions to early life-history traits in lodgepole pine (*Pinus contorta* Dougl.)**

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**Figure S1** Geographical distribution of the 83 populations (green triangles) on the map regarding AMT value (A) and ecosystem zones (B) of British Columbia, Canada.

**Figure S2** The distribution of the samples based on mean annual temperature (MAT) against annual heat moisture index (AHM).

**Figure S3** Schematic representation of the cumulative germination curve parameters used to characterize seed dormancy.

*DI* (dormancy index): the gray shaded area, the difference of area under germination curves (*AUC*) of control and any other treatment; *GS* (germination speed): the number of days to reach 50% of final germination; *GC* (germination capacity): the final germination percentage.

**Figure S4** PLS biplot of 194 climatic variables (green), 83 populations (red), and 21 (above) 20 (below) categories for 83 population habitats (blue).

**Figure S5** PCA for 194 climatic variables. The 15 most correlated climatic variables were marked in red.

**Figure S6** Seed dormancy (*DI*, a) and weight (*SW*, b) distribution for the 83 populations labeled on the map of British Columbia, Canada.

**Figure S7** Linear relationship between 1,000-seed weight and 'predicted' 1,000-seed weight using 83 populations.

**Figure S8** The amount of changes for *DD\_0\_winter*, *DD5\_spring*, and *DD5* in 2050s relative to present.

Note: The population was ranked as per its current *DI* in ascending order. Each data point is the average of predictions using three methods (RCP2.6, 4.5, and 8.5). Bars indicate the SEM.

**Table S1** A list of important climatic variables

Abbreviations	Full names
<i>Eref</i> 06, 07, 08, 09, <i>_summer</i> , and <i>_autumn</i>	June, July, August, September, summer, and autumn hargreaves reference evaporation (calculated by temperature and solar radiation)
<i>DD_0_summer</i>	summer degree-days below 0°C
<i>PPT</i> 06, 07, 09, 10, and <i>_autumn</i>	June, July, September, October, and autumn precipitation (mm)
<i>Tmax</i> 07 and <i>_summer</i>	July and summer maximum mean temperatures (°C)
<i>PAS</i> 04, 05, and <i>_spring</i>	April, May, and spring precipitation as snow (mm)
<i>DD18_04, _06, _07, 09, _10, _spring</i> , and <i>_autumn</i>	April, June, July, September, October, spring, and autumn degree-days above 18°C
<i>DD18</i>	annual degree-days above 18°C
<i>DD5_07, 09</i> , and <i>_autumn</i>	July, September, and autumn degree-days above 5°C
<i>Tmin</i> 04, 10, 11, <i>_spring</i> and <i>_autumn</i>	April, October, November, spring and autumn minimum mean temperatures (°C)
<i>CMD</i> 09 and <i>_autumn</i>	September and autumn hargreaves climatic moisture deficit (calculated by <i>Eref</i> and precipitation)
<i>NFFD</i> 10	October number of frost-free days
<i>MAT</i>	mean annual temperature (°C)
<i>MAP</i>	mean annual precipitation (mm)
<i>AHM</i>	annual heat-moisture index ( $(MAT+10)/(MAP/1000)$ )
<i>Tave</i> 09, 10, <i>_spring</i> , and <i>_autumn</i>	September, October, spring and autumn mean temperature (°C)

**Table S2 Canonical correlation analysis (CCA) and MANOVA test criteria**

A)

Canonical function	Likelihood ratio	Approximate <i>F</i> -value	Num DF <sup>†</sup>	Den DF <sup>†</sup>	Pr > <i>F</i> <sup>††</sup>
1	0.1371	2.89	60	102	<b>&lt;0.0001</b>
2	0.5776	1.31	29	52	0.1943

<sup>†</sup> Num DF and Den DF represent numerator and denominator degrees of freedom, respectively.

<sup>††</sup> Hypothesis is, H<sub>0</sub>: none of the canonical functions is significant; H<sub>a</sub>: at least one of the canonical functions is significant ( $P < 0.05$ ).

B)

MANOVA tests <sup>†</sup>	<i>F</i> Value	Num DF <sup>††</sup>	Den DF <sup>††</sup>	Pr > <i>F</i>
Wilks' Lambda	3.30	42	120	<b>&lt;0.0001</b>
Pillai's Trace	3.27	42	122	<b>&lt;0.0001</b>
Hotelling-Lawley Trace	3.34	42	105.24	<b>&lt;0.0001</b>
Roy's Greatest Root	4.53	21	61	<b>&lt;0.0001</b>

<sup>†</sup> null hypothesis for the statistic tests is the centroids of life-history traits are equal across the 22 ecosystem zones ( $P < 0.05$ ).

<sup>††</sup> Num DF and Den DF represent numerator and denominator degrees of freedom, respectively.

**Table S3 Errors from ecosystem zone for seed dormancy and weight models**

Ecosystem zone	DF	Seed dormancy model				Seed weight model			
		Estimate	STD Pred	t Value	Pr >  t	Estimate	STD Pred	t Value	Pr >  t
BB	58	-0.8391	1.5939	-0.53	0.6006	0.09572	0.0974	0.98	0.3300
BLK	58	-1.1614	1.6123	-0.72	0.4742	-0.04007	0.1055	-0.38	0.7060
CHL	58	0.1542	1.7931	0.09	0.9318	-0.1539	0.1218	-1.26	0.2110
CP	58	1.8555	1.669	1.11	0.2708	-0.0866	0.1099	-0.79	0.4340
CT	58	-0.6866	1.8897	-0.36	0.7177	0.1130	0.1515	0.75	0.4590
DK	58	0.0068	1.7932	0.00	0.9970	-0.1033	0.1319	-0.78	0.4370
EK	58	1.8960	1.7285	1.10	0.2772	0.05822	0.0989	0.59	0.5590
FIN	58	0.2597	1.641	0.16	0.8748	-0.1450	0.1054	-1.38	0.1740
FN	58	0.2124	1.811	0.12	0.9070	0.1040	0.1377	0.76	0.4530
GL	58	0.6919	1.8805	0.37	0.7143	0.0824	0.1525	0.54	0.5910
HH	58	0.5785	1.5921	0.36	0.7177	0.1606	0.1103	1.46	0.1510
M	58	-1.0011	1.7276	-0.58	0.5645	0.1579	0.1440	1.10	0.2780
MGR	58	0.4678	1.8017	0.26	0.7961	-0.2729	0.1316	-2.07	<b>0.0430</b>
MRB	58	-1.2299	1.8959	-0.65	0.5191	-0.0010	0.1509	-0.01	0.9950
NCH	58	-0.3918	1.6630	-0.24	0.8146	-0.0329	0.1127	-0.29	0.7720
NST	58	-2.1080	1.6615	-1.27	0.2096	-0.2655	0.1111	-2.39	<b>0.0200</b>
QL	58	0.0288	1.8147	0.02	0.9874	-0.0751	0.1338	-0.56	0.5770
SA	58	-0.7419	1.6473	-0.45	0.6541	-0.0279	0.1064	-0.26	0.7940
SM	58	-0.4658	1.6725	-0.28	0.7816	-0.1020	0.1200	-0.85	0.3990
TOA	58	0.9769	1.6045	0.61	0.5450	0.2323	0.0996	2.33	<b>0.0230</b>
TOD	58	1.4143	1.6246	0.87	0.3876	0.2303	0.0984	2.34	<b>0.0230</b>
WK	58	0.0826	1.7959	0.05	0.9635	0.0716	0.1203	0.60	0.5540

The ecosystem zones in BC are abbreviated BB, BLK, CHL, CP, CT, DK, EK, FIN, FN, GL, HH, M, MGR, MRB, NCH, NST, QL, SA, SM, TOA, TOD and WK; these denote Big Bar, Bulkley, Chilcotin, Central Plateau, Cariboo Transition, Dease Klappan, East Kootenay, Finlay, Ft. Nelson, Georgia Lowlands, Hudson Hope, Maritime zones, McGregor, Mt. Robson, Nechako, Nass Skeena Transition, Quesnel Lakes, Shuswap Adams, Submaritime, Tompson Okanagan Arid, Tompson Okanagan Dry, and West Kootenay, respectively.

**Table S4 Parameter estimates and statistical tests for the geographic variables-based hierarchical models regarding seed dormancy and seed weight**

(A) Seed dormancy model

Effect	Estimate	Standard Error	DF	Statistic	<i>P</i>
Intercept <sup>¶</sup> ( $\beta_0$ )	146.32	32.3917	21	$t = 4.52$	<b>0.0002</b>
Longitude ( $\beta_1$ )	0.9794	0.3150	58	$F = 9.66$	<b>0.0029</b>
Elevation ( $\beta_2$ )	0.0029	0.0020	58	$F = 1.98$	0.1643
Latitude ( $\beta_3$ )	-0.1070	0.3808	58	$F = 0.08$	0.7797

*Note:* the same model as described in the text but using geographic variables as independent variables,

$$(\text{life-history trait})_{ij} = (\beta_0' + \varepsilon_j) + \beta_1' \times \text{Long}_{ij} + \beta_2' \times \text{Elev}_{ij} + \beta_3' \times \text{Lat}_{ij} + \varepsilon_{ij}$$

where  $i$  and  $j$  represent two levels, i.e.,  $i^{\text{th}}$  population in  $j^{\text{th}}$  ecosystem zone;  $\text{Long}_{ij}$ ,  $\text{Elev}_{ij}$  and  $\text{Lat}_{ij}$  represent the longitude, elevation, latitude for  $i^{\text{th}}$  population within  $j^{\text{th}}$  ecosystem zone;  $\varepsilon_j$  and  $\varepsilon_{ij}$  represent errors from ecosystem zone and population, respectively. Intercept ( $\beta_0' + \varepsilon_j$ ) and coefficients ( $\beta_1'$ ,  $\beta_2'$  and  $\beta_3'$ ) were estimated using our experiment data.

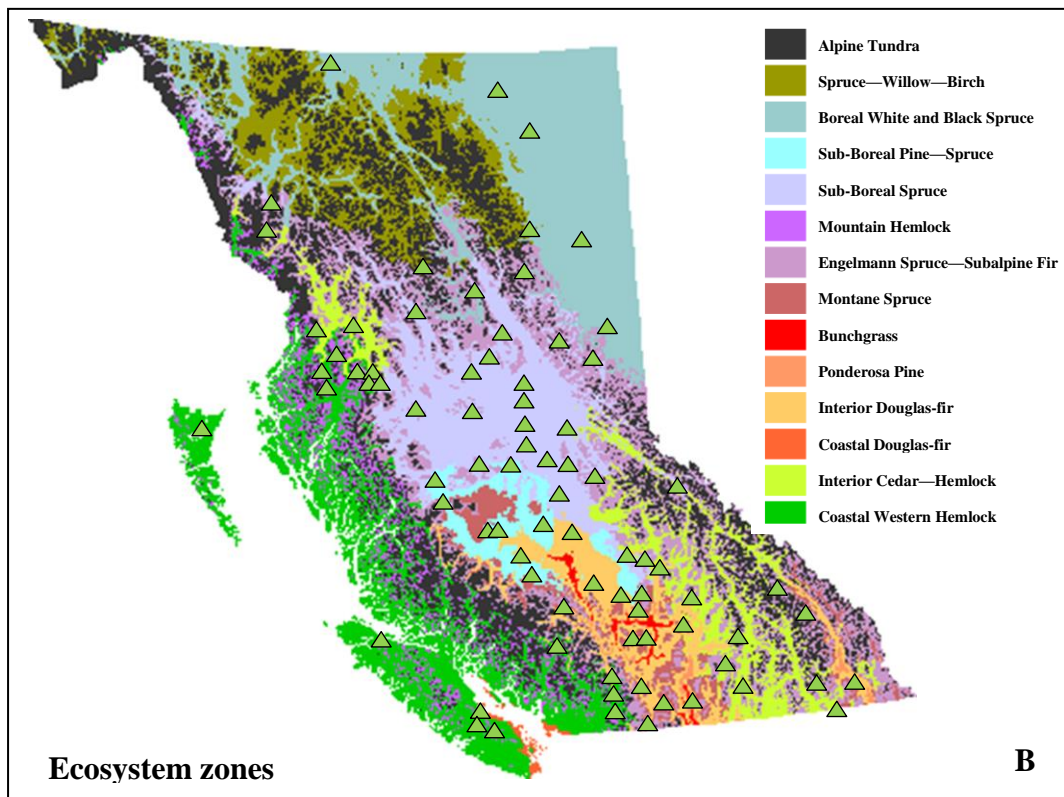
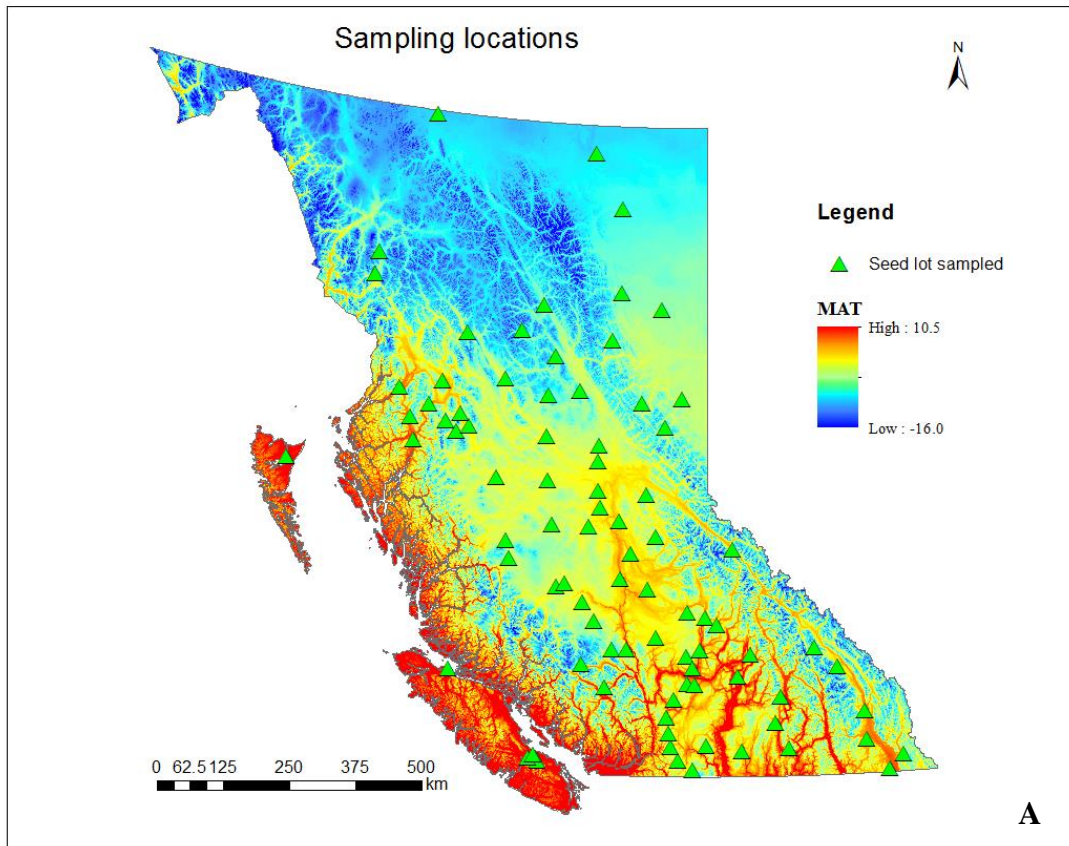
(B) Seed weight model

Effect	Estimate	Standard Error	DF	Statistic	<i>P</i>
Intercept <sup>¶</sup> ( $\beta_0$ )	10.8374	1.6076	21	$t = 6.74$	<b>&lt;.0001</b>
Longitude ( $\beta_1$ )	0.0615	0.0127	59	$F = 23.32$	<b>&lt;.0001</b>
Elevation ( $\beta_2$ )	-0.0003	0.0001	59	$F = 11.43$	<b>0.0013</b>

*Note:* assuming that  $\beta_3$  is zero in the model.

<sup>¶</sup>residual from ecosystem zones ( $\varepsilon_j$ ) is integrated into ‘intercept’ (data not shown).

Figure S1





**Figure S2**

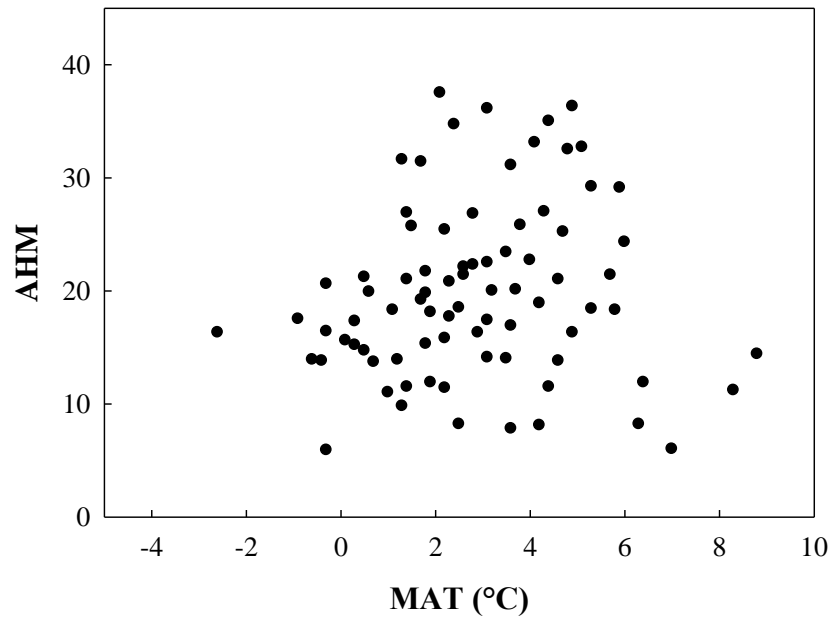


Figure S3

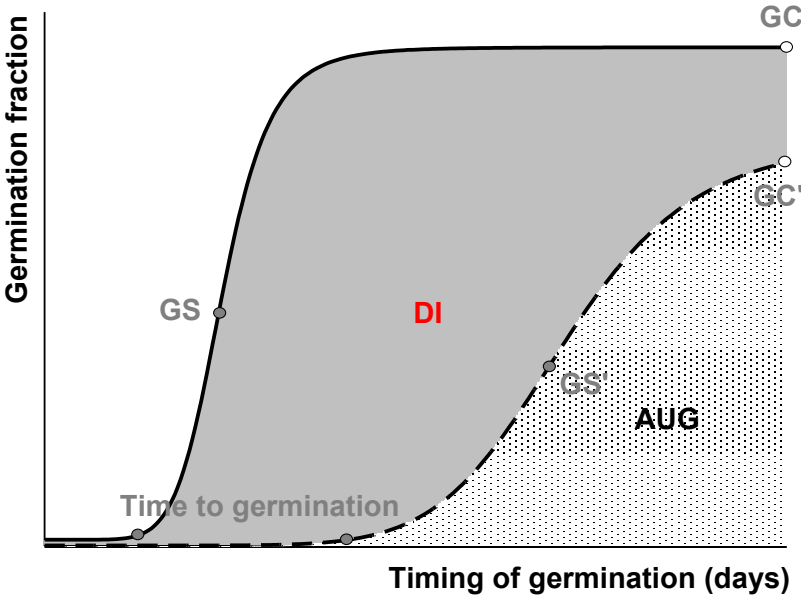


Figure S4

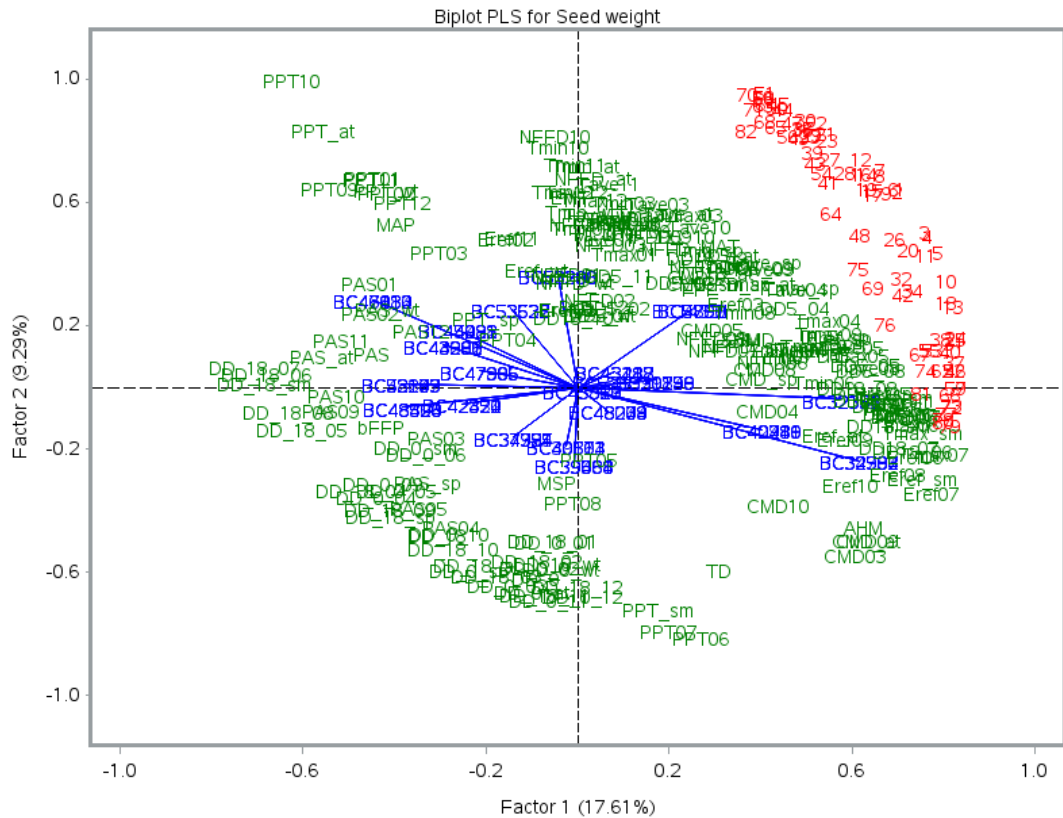
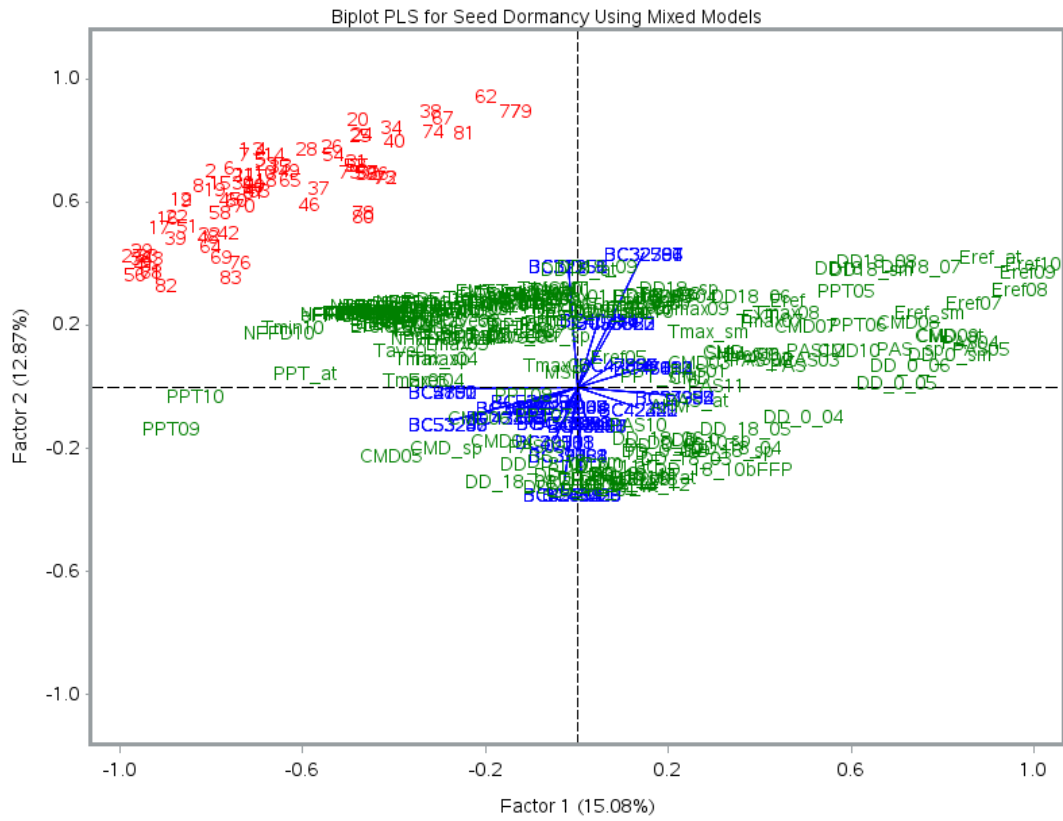
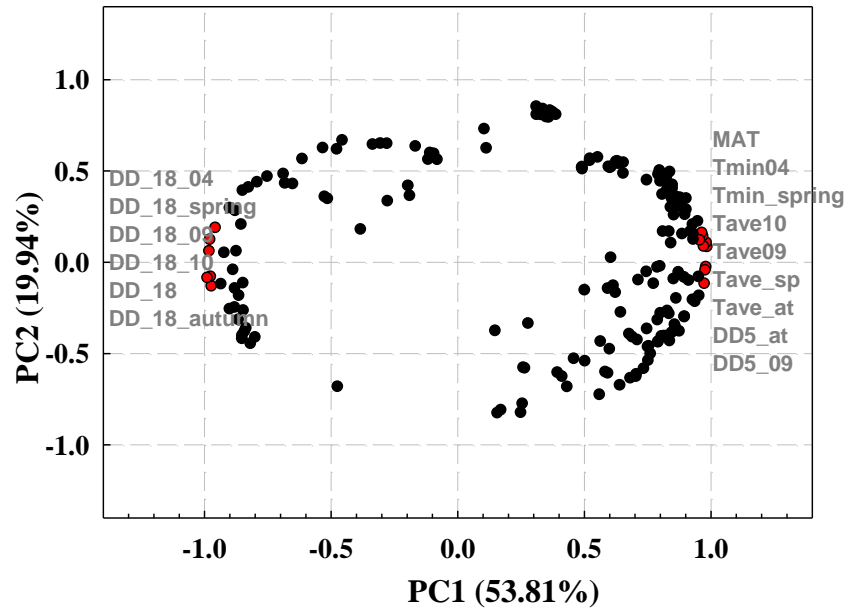
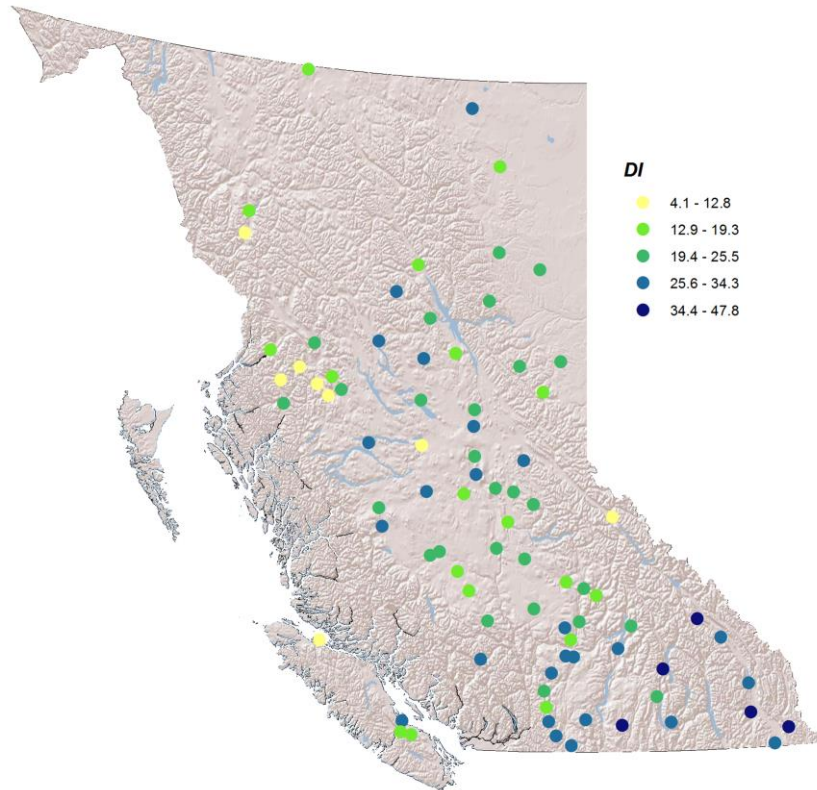


Figure S5



**Figure S6**

a)



b)

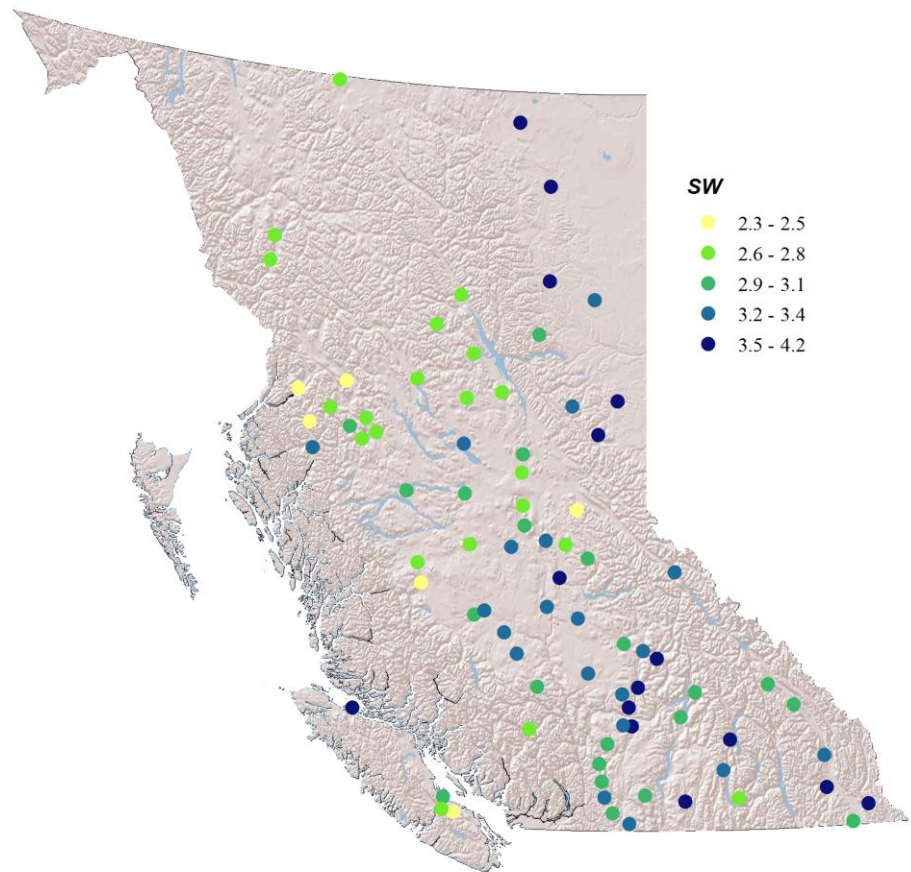


Figure S7

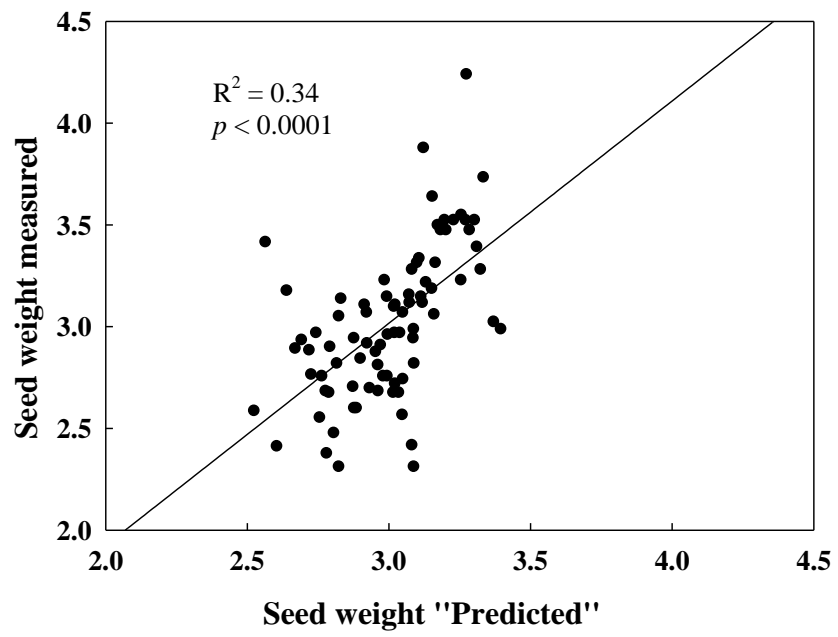


Figure S8

