Genetic insights into drought responses of boreal Scots pine

European Journal of Forest Research

Alper Tuna Kavlak[1*], Harri Mäkinen[1], Olli-Pekka Tikkasalo[1], Hanni Kärkkäinen[3,4], Matti Haapanen[1], Katri Kärkkäinen[2], Sonja Kujala[2]

[1]Natural Resources Institute Finland (Luke), Latokartanonkaari 9, 00790 Helsinki, Finland

[2]Natural Resources Institute Finland (Luke), Paavo Havaksen tie 3, 90570 Oulu, Finland

[3]Natural Resources Institute Finland (Luke), 31600 Jokioinen, Finland

[4]Boreal Kasvinjalostus Oy, Myllytie 10, 31600 Jokioinen, Finland

*Corresponding author: Alper Tuna Kavlak

Email: alper.kavlak@luke.fi

SUPPLEMENTARY MATERIALS

S1. Detailed genomic mixed-model specifications

For Tuusula, the model for observation $i = 1,\ldots,n_{Tuusula}$ was

$$y_i = \mu + \sum_{j=2}^{J} \mathbf{1}\{Block_i = j\}\beta_j^{Block} + u_i + \varepsilon_i,$$

where Block is a fixed effect and J is the number of Block levels (first level is the reference).

For Hankasalmi (two trials combined), the model for observation $i = 1,\ldots,n_{Hankasalmi}$ was

$$y_i = \mu + \sum_{k=2}^{K} 1\{Trial_i = k\}T_k + \sum_{k=1}^{K}\sum_{j=2}^{J_k} 1\{Trial_i = k, Block_i = j\}\gamma_{j(k)}^{Block(Trial)} + u_i + \varepsilon_i,$$

where Trial + Block nested within Trial are the fixed effects. Random terms for both sites were

$$\boldsymbol{u} \sim N(\mathbf{0}, \mathbf{G}\sigma_A^2),\ \varepsilon \sim N(\mathbf{0}, \boldsymbol{I}\sigma_E^2)$$

Here, μ is the intercept; β_j^{Block} are fixed block effects; T_k are fixed trial effects; $\gamma_{j(k)}^{Block(Trial)}$ are fixed block effects nested within trial k; u_i is the random additive genetic effect for tree ii; and ε_i is the residual error. The indicator function $1\{\cdot\}$ equals 1 when the condition in braces is true and 0 otherwise.

Table S1.

Pearson correlations between SPEI variables and annual basal area increment (BAI) Results shown separately for the Tuusula (mesic) and Hankasalmi (sub-xeric) sites. SPEI values are ordered by correlation strength within each site.

Tuusula (mesic)			**Hankasalmi (sub-xeric)**		
SPEI	Month	r (BAI)	SPEI	Month	r (BAI)
SPEI-01	June	**0.736**	SPEI-01	June	**0.826**
SPEI-02	July	0.630	SPEI-12	June	0.708
SPEI-04	September	0.485	SPEI-12	July	0.642
SPEI-03	August	0.453	SPEI-04	July	0.618
SPEI-01	July	0.416	SPEI-24	July	0.568
SPEI-04	July	0.206	SPEI-12	May	0.551
SPEI-03	July	0.179	SPEI-02	July	0.539
SPEI-03	September	0.168	SPEI-06	September	0.490
SPEI-01	September	0.142	SPEI-12	September	0.485

Tuusula (mesic)			Hankasalmi (sub-xeric)		
SPEI-02	August	0.132	SPEI-24	September	0.480
SPEI-06	September	0.117	SPEI-24	June	0.455
SPEI-04	August	0.043	SPEI-03	August	0.426
SPEI-03	June	−0.027	SPEI-04	September	0.400
SPEI-06	July	−0.084	SPEI-24	August	0.397
SPEI-12	September	−0.102	SPEI-12	August	0.355
SPEI-02	June	−0.111	SPEI-24	May	0.337
SPEI-12	August	−0.117	SPEI-01	July	0.321
SPEI-02	September	−0.123	SPEI-06	July	0.320
SPEI-01	August	−0.156	SPEI-03	June	0.238
SPEI-06	August	−0.166	SPEI-03	July	0.207
SPEI-12	July	−0.177	SPEI-06	August	0.201
SPEI-06	June	−0.317	SPEI-02	August	0.171
SPEI-12	June	−0.324	SPEI-03	September	0.132
SPEI-12	May	−0.392	SPEI-04	August	0.112
SPEI-04	June	−0.443	SPEI-06	June	0.089
SPEI-24	September	−0.603	SPEI-04	June	0.031
SPEI-24	August	−0.642	SPEI-02	May	−0.076
SPEI-24	July	−0.706	SPEI-01	August	−0.125

Tuusula (mesic)			Hankasalmi (sub-xeric)		
SPEI-04	May	−0.748	SPEI-02	June	−0.130
SPEI-06	May	−0.763	SPEI-01	September	−0.170
SPEI-02	May	−0.765	SPEI-02	September	−0.272
SPEI-24	May	−0.818	SPEI-03	May	−0.274
SPEI-24	June	−0.833	SPEI-06	May	−0.340
SPEI-01	May	−0.862	SPEI-04	May	−0.419
SPEI-03	May	−0.897	SPEI-01	May	−0.593

Table S2. Within-site Pearson and Spearman correlations between corresponding drought-response traits across the 2019 and 2021 drought events in Tuusula and Hankasalmi.

Site	Trait	2019 vs 2021 comparison	Pearson r	Spearman ρ
Tuusula	Rt	Rt1 vs Rt2	0.032	0.046
Tuusula	Rc	Rc1 vs Rc2	0.052	0.091
Tuusula	Rs	Rs1 vs Rs2	**-0.149**	-0.058
Tuusula	RRs	RRs1 vs RRs2	0.011	0.060
Tuusula	D	D1 vs D2	**-0.131**	-0.074
Hankasalmi	Rt	Rt1 vs Rt2	-0.007	0.002
Hankasalmi	Rc	Rc1 vs Rc2	0.016	-0.024
Hankasalmi	Rs	Rs1 vs Rs2	**-0.281**	**-0.287**
Hankasalmi	RRs	RRs1 vs RRs2	-0.072	**-0.107**

Site	Trait	2019 vs 2021 comparison	Pearson r	Spearman ρ
Hankasalmi	D	D1 vs D2	**-0.236**	**-0.279**

Rt: resistance; Rc: recovery; Rs: resilience; RRs: relative resilience; D: deviation from the full-resilience boundary. Subscripts 1 and 2 refer to the first (2019) and second (2021) drought events, respectively. Rt, Rc, Rs, RRs, and D are dimensionless. Pearson correlations describe linear associations between the corresponding drought-response traits across the 2019 and 2021 drought events, whereas Spearman correlations describe the stability of trait rankings across events. Correlations were calculated separately within each site. Bold values indicate significant correlations at $p < 0.01$.