Supplement

Table S1. Influence of temperature and autumn period on leaf elongation, estimated by a non-linear asymptotic model. Leaf elongation is expressed as estimated average logistic rate constants (lrc) and estimated asymptote (asym). Confidence intervals (95%) are presented in brackets (lower, upper).

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Temp. °C | Early period | | | | Intermediate period | | | | Late periode | | | |
| Population | lrc |  | Asym | | lrc |  | Asym | | lrc | | Asym | |
| PRG southern | 6 | -2.47 | (-2.49, -2.46) | 229 | (229, 231) | -2.75 | (-2.92, -2.58) | 234 | (217, 254) | -3.08 | (-3.09, -3.06) | 253 | (253, 255) |
| 9/3\* | -2.30 | (-2.39, -2.21) | 196 | (183, 210) | -2.19 | (-2.21, -2.17) | 219 | (219, 221) | -2.87 | (-2.88, -2.85) | 275 | (275, 277) |
| 12 | -1.39 | (-1.54, -1.24) | 227 | (205, 250) | -1.53 | (-1.61, -1.45) | 220 | (207, 234) | -2.00 | (-2.03, -1.98) | 252 | (252, 254) |
| PRG northern | 6 | -2.33 | (-2.55, -2.12) | 195 | (174, 218) | -2.62 | (-2.64, -2.60) | 208 | (208, 210) | -2.93 | (-3.04, -2.82) | 228 | (207, 253) |
| 9/3\* | -2.20 | (-2.37, -2.04) | 223 | (196, 252) | -2.39 | (-2.56, -2.21) | 238 | (218, 260) | -2.65 | (-2.68, -2.62) | 241 | (242, 244) |
| 12 | -1.09 | (-1.10, -1.08) | 213 | (213, 215) | -1.82 | (-1.84, -1.81) | 243 | (243, 245) | -2.11 | (-2.21, -2.01) | 288 | (271, 308) |
| Timothy southern | 6 | -2.63 | (-2.78, -2.48) | 220 | (205, 237) | -3.02 | (-3.25, -2.80) | 235 | (216, 257) | -2.94 | (-2.97, -2.91) | 219 | (219, 221) |
| 9/3\* | -2.40 | (-2.56, -2.24) | 213 | (198, 230) | -2.71 | (-2.91, -2.51) | 232 | (205, 262) | -2.91 | (-3.13, -2.69) | 276 | (250, 303) |
| 12 | -1.58 | (-1.61, -1.56) | 219 | (218, 220) | -1.94 | (-1.96, -1.92) | 254 | (254, 256) | -2.21 | (-2.23, -2.18) | 240 | (240, 242) |
| Timothy northern | 6 | -2.77 | (-2.98, -2.56) | 218 | (205, 233) | -2.88 | (-3.10, -2.67) | 201 | (176, 229) | -2.84 | (-2.85, -2.82) | 222 | (222, 224) |
| 9/3\* | -2.52 | (-2.66, -2.38) | 203 | (189, 219) | -2.76 | (-2.87, -2.64) | 236 | (220, 253) | -2.82 | (-2.92, -2.72) | 260 | (242, 281) |
| 12 | -1.73 | (-1.82, -1.64) | 204 | (186, 225) | -1.94 | (-2.01, -1.86) | 242 | (229, 258) | -2.21 | (-2.32, -2.11) | 266 | (250, 284) |

\*day/night

Table S2. Model comparison (10 best models) for biomass production. Abbreviations: D=Daylength, T=temperature treatment; Po=population; Sp=species; df=degrees of freedom; AICc=Akaike’s information criterion corrected for small sample size; ∆AICc= difference in AICc-value to best model.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Intercept | T | D | Po | Sp | T×D | T×Po | T×Sp | D×Po | D×Sp | Po×Sp | T×D×Po | T×D×Sp | T×Po×Sp | D×Po×Sp | T×D×Po×Sp | | R2 | df | AICc | ∆AICc |
| 5.844 | + | + | + | + | + | + |  | + | + | + | + |  |  |  |  | 0.784 | | 23 | 430.88 | 0 |
| 5.887 | + | + | + | + | + |  |  |  | + | + |  |  |  |  |  | 0.773 | | 15 | 430.98 | 0.106 |
| 5.784 | + | + | + | + | + | + |  | + | + | + | + |  |  | + |  | 0.787 | | 25 | 431.49 | 0.609 |
| 5.798 | + | + | + | + | + | + | + | + | + | + | + |  |  |  |  | 0.787 | | 25 | 431.86 | 0.985 |
| 5.841 | + | + | + | + | + |  | + |  | + | + |  |  |  |  |  | 0.775 | | 17 | 431.93 | 1.056 |
| 5.738 | + | + | + | + | + | + | + | + | + | + | + |  |  | + |  | 0.789 | | 27 | 432.49 | 1.609 |
| 5.861 | + | + | + | + | + |  |  | + | + | + |  |  |  |  |  | 0.774 | | 17 | 433.80 | 2.927 |
| 5.754 | + | + | + | + | + | + | + | + | + | + | + |  | + |  |  | 0.788 | | 27 | 434.32 | 3.437 |
| 5.802 | + | + | + | + | + |  |  | + | + | + |  |  |  | + |  | 0.777 | | 19 | 434.43 | 3.554 |
| 5.816 | + | + | + | + | + |  | + | + | + | + |  |  |  |  |  | 0.776 | | 19 | 434.79 | 3.913 |

Table S3. Parameter estimates for biomass production. Abbreviations: SD=shortest daylength, MD=intermediate daylength, LD=longest daylength. Reference value (intercept) represents treatment LD, treatment 12°C, population northern and species perennial ryegrass.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Estimate | SE | t value | P-value |
| Intercept | 5.880 | 0.096 | 60.980 | ˂0.000 |
| Treatment MD | -0.944 | 0.124 | -7.583 | ˂0.000 |
| Treatment SD | -1.773 | 0.124 | -14.243 | ˂0.000 |
| Treatment 6°C | -0.912 | 0.111 | -8.191 | ˂0.000 |
| Treatment 9/3°C | -0.678 | 0.111 | -6.088 | ˂0.000 |
| Species timothy | -0.637 | 0.091 | -7.006 | ˂0.000 |
| Population southern | -0.290 | 0.111 | -2.602 | 0.010 |
| Treatment MD × treatment 6°C | 0.313 | 0.136 | 2.297 | 0.022 |
| Treatment SD × treatment 6°C | 0.513 | 0.136 | 3.761 | ˂0.000 |
| Treatment MD × treatment 9/3°C | 0.523 | 0.136 | 3.834 | ˂0.000 |
| Treatment SD × treatment 9/3°C | 0.418 | 0.136 | 3.064 | 0.002 |
| Treatment 6°C × population southern | 0.040 | 0.111 | 0.364 | 0.716 |
| Treatment 9/3°C × population southern | 0.072 | 0.111 | 0.646 | 0.518 |
| Treatment MD × population southern | -0.026 | 0.111 | -0.229 | 0.819 |
| Treatment SD × population southern | -0.129 | 0.111 | -1.156 | 0.248 |
| Treatment MD × species timothy | 0.188 | 0.111 | 1.690 | 0.092 |
| Treatment SD × species timothy | -0.189 | 0.111 | -1.696 | 0.091 |
| Species timothy× population southern | 0.272 | 0.091 | 2.987 | 0.003 |

Table S4. Model comparison (10 best models) for Fv/Fm (maximum quantum yield of PSII) after pre-acclimation treatment. For Abbreviations see table S1.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Intercept | Pp | Po | Sp | T | D×Po | D×Sp | D×T | Po×Sp | Po×T | Sp×T | D×Po×Sp | D×Po×T | D×Sp×T | Po×Sp×T | D×Po×Sp×T | | R2 | df | AICc | ∆AICc |
| 0.742 | + | + | + | + | + | + | + |  | + | + |  | + | + |  |  | 0.575 | | 28 | -3136.74 | 0 |
| 0.742 | + | + | + | + | + | + | + | + | + | + |  | + | + |  |  | 0.575 | | 29 | -3134.97 | 1.768 |
| 0.742 | + | + | + | + | + | + | + | + | + | + | + | + | + |  |  | 0.577 | | 31 | -3133.43 | 3.308 |
| 0.741 | + | + | + | + | + | + | + | + | + | + |  | + | + | + |  | 0.577 | | 31 | -3132.60 | 4.140 |
| 0.742 | + | + | + | + | + | + | + | + | + | + | + | + | + | + |  | 0.579 | | 33 | -3131.02 | 5.712 |
| 0.740 | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | 0.583 | | 37 | -3127.28 | 9.459 |
| 0.741 | + | + | + | + |  | + | + |  | + | + |  |  | + |  |  | 0.544 | | 22 | -3112.47 | 24.270 |
| 0.741 | + | + | + | + |  | + | + | + | + | + |  |  | + |  |  | 0.544 | | 23 | -3110.70 | 26.037 |
| 0.742 | + | + | + | + | + | + | + |  | + | + |  |  | + |  |  | 0.544 | | 24 | -3108.32 | 28.413 |
| 0.741 | + | + | + | + |  | + | + | + | + | + |  |  | + | + |  | 0.546 | | 25 | -3108.32 | 28.414 |

Table S5. Model comparison (10 best models) for NPQ (non-photochemical quenching of chlorophyll fluorescence) after pre-acclimation treatment. For Abbreviations see table S1.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Intercept | D | Po | Sp | T | D×Po | D×Sp | D×T | Po×Sp | Po×T | Sp×T | D×Po×Sp | D×Po×T | D×Sp×T | Po×Sp×T | D×Po×Sp×T | | R2 | df | AICc | ∆AICc |
| 1.849 | + | + | + | + | + | + | + | + | + | + | + | + | + |  |  | 0.555 | | 31 | 235.98 | 0 |
| 1.837 | + |  | + | + |  | + | + |  |  | + |  |  |  |  |  | 0.575 | | 15 | 236.00 | 0.011 |
| 1.818 | + |  | + | + |  | + | + |  |  | + |  |  | + |  |  | 0.577 | | 19 | 236.07 | 0.084 |
| 1.868 | + | + | + | + | + | + | + | + | + | + | + | + |  |  |  | 0.577 | | 27 | 236.34 | 0.352 |
| 1.852 | + | + | + | + |  | + | + | + |  | + |  |  |  |  |  | 0.579 | | 17 | 237.15 | 1.165 |
| 1.832 | + | + | + | + |  | + | + | + |  | + |  |  | + |  |  | 0.583 | | 21 | 237.25 | 1.263 |
| 1.807 | + | + | + | + | + | + | + | + | + | + |  | + | + |  |  | 0.544 | | 29 | 237.27 | 1.289 |
| 1.864 | + | + | + | + | + | + | + | + |  | + | + |  |  |  |  | 0.544 | | 21 | 237.32 | 1.334 |
| 1.843 | + | + | + | + | + | + | + | + |  | + | + |  | + |  |  | 0.544 | | 25 | 237.36 | 1.370 |
| 1.826 | + | + | + | + | + | + | + | + | + | + |  | + |  |  |  | 0.546 | | 25 | 237.65 | 1.664 |

Table S6. Model comparison (10 best models) for фPSII (Current quantum yield of PSII) after pre-acclimation treatment. For Abbreviations see table S1.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Intercept | D | Po | Sp | T | D×Po | D×Sp | D×T | Po×Sp | Po×T | Sp×T | D×Po×Sp | D×Po×T | D×Sp×T | Po×Sp×T | D×Po×Sp×T | | R2 | df | AICc | ∆AICc |
| -1.591 | + | + | + | + | + | + | + |  |  | + |  |  |  |  |  | 0.721 | | 18 | 315.17 | 0 |
| -1.611 | + | + | + | + | + | + | + | + |  | + |  |  |  |  |  | 0.722 | | 19 | 315.19 | 0.025 |
| -1.625 | + | + | + | + | + | + | + |  |  |  |  |  |  |  |  | 0.718 | | 16 | 315.27 | 0.101 |
| -1.646 | + | + | + | + | + | + | + | + |  |  |  |  |  |  |  | 0.720 | | 17 | 315.31 | 0.142 |
| -1.614 | + | + | + | + | + | + | + | + |  | + | + |  |  |  |  | 0.724 | | 21 | 315.99 | 0.824 |
| -1.649 | + | + | + | + | + | + | + | + |  |  | + |  |  |  |  | 0.721 | | 19 | 316.08 | 0.912 |
| -1.580 | + | + | + | + | + | + |  |  |  | + |  |  |  |  |  | 0.716 | | 14 | 316.09 | 0.926 |
| -1.615 | + | + | + | + | + | + |  |  |  |  |  |  |  |  |  | 0.714 | | 12 | 316.11 | 0.939 |
| -1.601 | + | + | + | + | + | + |  | + |  | + |  |  |  |  |  | 0.717 | | 15 | 316.11 | 0.946 |
| -1.635 | + | + | + | + | + | + |  | + |  |  |  |  |  |  |  | 0.715 | | 13 | 316.14 | 0.974 |

Table S7. Model comparison (10 best models) for qp (photochemical quenching of chlorophyll fluorescence) after pre-acclimation treatment. For Abbreviations see table S1.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Intercept | D | Po | Sp | T | D×Po | D×Sp | D×T | Po×Sp | Po×T | Sp×T | D×Po×Sp | D×Po×T | D×Sp×T | Po×Sp×T | D×Po×Sp×T | | R2 | df | AICc | ∆AICc |
| 0.524 | + | + | + | + | + | + | + |  |  | + |  |  | + |  |  | 0.774 | | 22 | -1063.91 | 0 |
| 0.519 | + | + | + | + | + | + | + | + |  | + |  |  | + |  |  | 0.774 | | 23 | -1063.66 | 0.257 |
| 0.539 | + | + | + | + | + | + | + | + | + | + |  |  | + | + |  | 0.778 | | 27 | -1063.60 | 0.315 |
| 0.514 | + |  | + | + |  | + | + |  |  | + |  |  | + |  |  | 0.771 | | 19 | -1063.44 | 0.480 |
| 0.533 | + | + | + | + | + | + | + |  | + | + |  |  | + |  |  | 0.775 | | 24 | -1062.79 | 1.126 |
| 0.528 | + | + | + | + | + | + | + | + | + | + |  |  | + |  |  | 0.776 | | 25 | -1062.54 | 1.378 |
| 0.511 | + | + | + | + |  | + | + |  |  | + |  |  | + |  |  | 0.771 | | 20 | -1062.11 | 1.805 |
| 0.526 | + | + | + | + |  | + | + | + | + | + |  |  | + | + |  | 0.776 | | 25 | -1061.97 | 1.948 |
| 0.506 | + | + | + | + |  | + | + | + |  | + |  |  | + |  |  | 0.772 | | 21 | -1061.90 | 2.019 |
| 0.518 | + | + | + | + | + | + | + | + |  | + | + |  | + |  |  | 0.775 | | 25 | -1061.66 | 2.253 |

Table S8. Parameter estimates for maximum quantum yield of PSII (Fv/Fm) after pre-acclimation treatment. Abbreviations: SD=shortest daylength, MD=intermediate daylength, LD=longest daylength. Reference value (intercept) represents treatment LD, treatment 12°C, population northern and species perennial ryegrass.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Estimate | SE | t value | P-value |
| Intercept | 0.742 | 0.003 | 266.39 | ˂0.000 |
| Treatment MD | 0.007 | 0.004 | 1.68 | 0.093 |
| Treatment SD | -0.015 | 0.004 | -3.89 | ˂0.000 |
| Treatment 6°C | -0.042 | 0.004 | -10.44 | ˂0.000 |
| Treatment 9/3°C | -0.006 | 0.004 | -1.58 | 0.115 |
| Species timothy | -0.008 | 0.003 | -2.63 | 0.009 |
| Population southern | 0.002 | 0.003 | 0.48 | 0.634 |
| Treatment MD × population southern | 0.002 | 0.005 | 0.55 | 0.586 |
| Treatment SD × population southern | 0.001 | 0.005 | 0.24 | 0.809 |
| Treatment MD × species timothy | -0.003 | 0.005 | -0.69 | 0.490 |
| Treatment SD × species timothy | -0.010 | 0.005 | -2.25 | 0.025 |
| Treatment MD × treatment 6°C | 0.042 | 0.006 | 7.40 | ˂0.000 |
| Treatment SD × treatment 6°C | 0.047 | 0.006 | 8.31 | ˂0.000 |
| Treatment MD × treatment 9/3°C | -0.006 | 0.006 | -1.05 | 0.295 |
| Treatment SD × treatment 9/3°C | 0.004 | 0.006 | 0.80 | 0.424 |
| Treatment 6°C × population southern | 0.017 | 0.005 | 3.58 | ˂0.000 |
| Treatment 9/3°C × population southern | -0.019 | 0.005 | -4.09 | ˂0.000 |
| Treatment 6°C × species timothy | 0.018 | 0.005 | 3.80 | ˂0.000 |
| Treatment 9/3°C × species timothy | -0.014 | 0.005 | -2.95 | 0.003 |
| Treatment MD × treatment 6°C × population southern | -0.021 | 0.006 | -3.22 | 0.001 |
| Treatment SD × treatment 6°C × population southern | -0.016 | 0.006 | -2.53 | 0.012 |
| Treatment MD × treatment 9/3°C × population southern | 0.017 | 0.006 | 2.56 | 0.011 |
| Treatment SD × treatment 9/3°C × population southern | 0.013 | 0.006 | 2.01 | 0.045 |
| Treatment MD × treatment 6°C × species timothy | -0.011 | 0.006 | -1.66 | 0.098 |
| Treatment SD × treatment 6°C × species timothy | -0.011 | 0.006 | -1.66 | 0.097 |
| Treatment MD × treatment 9/3°C × species timothy | 0.024 | 0.006 | 3.70 | ˂0.000 |
| Treatment SD × treatment 9/3°C × species timothy | 0.024 | 0.006 | 3.70 | ˂0.000 |

Table S9. Parameter estimates for coefficient of the non-photochemical quenching of chlorophyll fluorescence (NPQ) after pre-acclimation. Abbreviations: SD=shortest daylength, MD=intermediate daylength, LD=longest daylength. Reference value (intercept) represents treatment LD, treatment 12°C, population northern and species perennial ryegrass.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Estimate | Std error | t value | P-value |
| Intercept | 1.786 | 0.066 | 27..21 | ˂0.000 |
| Treatment MD | 0.368 | 0.093 | 3.96 | ˂0.000 |
| Treatment SD | -0.183 | 0.093 | -1.97 | 0.050 |
| Treatment 6°C | -0.469 | 0.096 | -4.61 | ˂0.000 |
| Treatment 9/3°C | 0.111 | 0.094 | 1.18 | 0.238 |
| Species timothy | 0.185 | 0.076 | 2.45 | 0.015 |
| Population southern | 0.063 | 0.076 | 0.84 | 0.403 |
| Treatment MD × population southern | -0.032 | 0.108 | -0.29 | 0.769 |
| Treatment SD × population southern | -0.136 | 0.108 | -1.27 | 0.207 |
| Treatment MD × species timothy | -0.124 | 0.108 | -1.15 | 0.249 |
| Treatment SD × species timothy | -0.244 | 0.108 | -2.28 | 0.023 |
| Treatment MD × treatment 6°C | 0.518 | 0.133 | 3.89 | ˂0.000 |
| Treatment SD × treatment 6°C | 0.672 | 0.133 | 5.05 | ˂0.000 |
| Treatment MD × treatment 9/3°C | -0.198 | 0.132 | -1.49 | 0.136 |
| Treatment SD × treatment 9/3°C | -0.011 | 0.132 | -0.08 | 0.936 |
| Treatment 6°C × population southern | 0.197 | 0.109 | 1.81 | 0.071 |
| Treatment 9/3°C × population southern | -0.151 | 0.109 | -1.40 | 0.163 |
| Treatment 6°C × species timothy | 0.496 | 0.109 | 4.57 | ˂0.000 |
| Treatment 9/3°C × species timothy | 0.061 | 0.109 | 0.56 | 0.574 |
| Treatment MD × treatment 6°C × population southern | -0.314 | 0.153 | -2.06 | 0.040 |
| Treatment SD × treatment 6°C × population southern | -0.057 | 0.153 | -0.37 | 0.708 |
| Treatment MD × treatment 9/3°C × population southern | 0.149 | 0.153 | 0.98 | 0.330 |
| Treatment SD × treatment 9/3°C × population southern | 0.155 | 0.153 | 1.02 | 0.308 |
| Treatment MD × treatment 6°C × species timothy | -0.055 | 0.153 | -0.36 | 0.718 |
| Treatment SD × treatment 6°C × species timothy | -0.150 | 0.1553 | -0.99 | 0.325 |
| Treatment MD × treatment 9/3°C × species timothy | 0.271 | 0.153 | 1.77 | 0.077 |
| Treatment SD × treatment 9/3°C × species timothy | 0.269 | 0.152 | 1.76 | 0.078 |

Table S10. Parameter estimates for coefficient of the Current quantum yield of PSII (фPSII) after pre-acclimation. Abbreviations: SD=shortest daylength, MD=intermediate daylength, LD=longest daylength. Reference value (intercept) represents treatment LD, treatment 12°C, population northern and species perennial ryegrass.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Estimate | Std error | t value | P-value |
| Intercept | -1.591 | 0.057 | -27.94 | ˂0.000 |
| Treatment MD | -0.266 | 0.076 | -3.52 | ˂0.000 |
| Treatment SD | -1.055 | 0.075 | -13.97 | ˂0.000 |
| Treatment 6°C | 0.276 | 0.068 | 4.05 | ˂ 0.000 |
| Treatment 9/3°C | 0.101 | 0.068 | 1.49 | 0.138 |
| Species timothy | -0.265 | 0.062 | -4.30 | ˂0.000 |
| Population southern | -0.056 | 0.048 | -1.15 | 0.249 |
| Treatment MD × population southern | 0.132 | 0.068 | 1.94 | 0.052 |
| Treatment SD × population southern | 0.163 | 0.068 | 2.41 | 0.016 |
| Treatment MD × species timothy | -0.268 | 0.068 | -3.95 | ˂0.000 |
| Treatment SD × species timothy | -0.305 | 0.068 | -4.50 | ˂0.000 |
| Treatment MD × treatment 6°C | -0.150 | 0.083 | -1.81 | 0.071 |
| Treatment SD × treatment 6°C | 0.021 | 0.083 | 0.25 | 0.802 |
| Treatment MD × treatment 9/3°C | -0.097 | 0.083 | -1.17 | 0.243 |
| Treatment SD × treatment 9/3°C | 0.124 | 0.083 | 1.50 | 0.133 |
| Treatment 6°C × species timothy | 0.072 | 0.068 | 1.06 | 0.290 |
| Treatment 9/3°C × species timothy | 0.139 | 0.068 | 2.06 | 0.040 |

Table S11. Parameter estimates for coefficient of the photochemical quenching of chlorophyll fluorescence (qp) after pre-acclimation. Abbreviations: SD=shortest daylength, MD=intermediate daylength, LD=longest daylength. Reference value (intercept) represents treatment LD, treatment 12°C, population northern and species perennial ryegrass.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Estimate | Std error | t value | P-value |
| Intercept | 0.524 | 0.017 | 30.37 | ˂0.000 |
| Treatment MD | -0.095 | 0.025 | -3.89 | ˂0.000 |
| Treatment SD | -0.348 | 0.024 | -14.26 | ˂0.000 |
| Treatment 6°C | 0.134 | 0.023 | 5.82 | ˂0.000 |
| Treatment 9/3°C | 0.029 | 0.023 | 1.26 | 0.207 |
| Species timothy | -0.107 | 0.023 | -4.73 | ˂0.000 |
| Population southern | -0.020 | 0.013 | -1.48 | 0.139 |
| Treatment MD × population southern | 0.039 | 0.019 | 2.10 | 0.037 |
| Treatment SD × population southern | 0.040 | 0.019 | 2.13 | 0.033 |
| Treatment MD × species timothy | -0.037 | 0.032 | -1.14 | 0.254 |
| Treatment SD × species timothy | 0.040 | 0.032 | 1.25 | 0.213 |
| Treatment MD× treatment 6°C | -0.085 | 0.032 | -2.62 | 0.009 |
| Treatment SD × treatment 6°C | -0.045 | 0.032 | -1.41 | 0.160 |
| Treatment MD × treatment 9/3°C | 0.001 | 0.032 | 0.04 | 0.969 |
| Treatment SD × treatment 9/3°C | 0.041 | 0.032 | 1.27 | 0.205 |
| Treatment 6°C × species timothy | 0.071 | 0.032 | 2.20 | 0.028 |
| Treatment 9/3°C × species timothy | 0.147 | 0.032 | 4.57 | ˂0.000 |
| Treatment MD × treatment 6°C × species timothy | -0.041 | 0.045 | -0.90 | 0.367 |
| Treatment SD × treatment 6°C × species timothy | -0.088 | 0.045 | -9.94 | 0.053 |
| Treatment MD× treatment 9/3°C × species timothy | -0.133 | 0.045 | -2.92 | 0.004 |
| Treatment SD × treatment 9/3°C × species timothy | -0.158 | 0.045 | -3.50 | ˂0.000 |

Table S12. Model comparison (10 best models) for freezing tolerance of perennial ryegrass. Abbreviations: D=daylength; F= pre-determined freezing temperatures; Po=population; T=Temerature treatment; df=degrees of freedom; AICc=Akaike’s information criterion corrected for small sample size; ∆AICc=difference in AICc-value to best model.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Intercept | D | F | Po | T | D×F | D×Po | D×T | F×Po | F×T | Po×T | D×F×Po | D×F×T | D×Po×T | F×Po×T | D×F×Po×T | R2 | df | AICc | ∆AICc |
| 25.50 | + | 1.862 | + | + | + |  | + | + |  |  |  |  |  |  |  | 0.610 | 14 | 791.38 | 0 |
| 24.49 | + | 1.782 | + | + | + |  | + | + | + |  |  |  |  |  |  | 0.611 | 16 | 792.71 | 1.333 |
| 28.50 | + | 2.069 | + | + | + | + | + | + |  |  |  |  |  |  |  | 0.610 | 16 | 794.04 | 2.664 |
| 39.04 | + | 2.838 | + | + | + | + |  | + |  |  |  |  |  |  |  | 0.609 | 12 | 795.01 | 3.629 |
| 25.49 | + | 1.858 | + | + | + |  | + | + |  | + |  |  |  |  |  | 0.610 | 16 | 795.12 | 3.745 |
| 27.29 | + | 1.977 | + | + | + | + | + | + | + |  |  |  |  |  |  | 0.611 | 18 | 795.68 | 4.296 |
| 24.15 | + | 1.761 | + | + | + |  | + | + | + | + |  |  |  |  |  | 0.611 | 18 | 796.60 | 5.220 |
| 35.46 | + | 2.575 | + | + | + | + |  | + | + |  |  |  |  |  |  | 0.609 | 14 | 796.81 | 5.429 |
| 29.72 | + | 2.146 | + | + | + | + | + | + |  |  | + |  |  |  |  | 0.610 | 18 | 797.73 | 6.354 |
| 28.54 | + | 2.075 | + | + | + | + | + | + |  | + |  |  |  |  |  | 0.610 | 18 | 797.79 | 6.410 |

Table S13. Table S. Model comparison (10 best models) for freezing tolerance of timothy. For abbreviations see table S11.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Intercept | D | F | Po | T | D×F | D×Po | D×T | F×Po | F×T | Po×T | D×F×Po | D×F×T | D×Po×T | F×Po×T | D×F×Po×T | | R2 | df | AICc | ∆AICc |
| 12.88 | + | 1.024 | + | + |  |  | + | + | + | + |  |  |  | + |  | 0.559 | | 18 | 1175.2 | 0 |
| 12.95 | + | 1.021 | + | + |  | + | + | + | + | + |  |  |  | + |  | 0.560 | | 20 | 1177.2 | 1.995 |
| 14.72 | + | 1.159 | + | + | + | + | + | + | + | + |  |  |  | + |  | 0.560 | | 22 | 1177.4 | 2.194 |
| 13.83 | + | 1.103 | + | + | + |  | + | + | + | + |  |  |  | + |  | 0.560 | | 20 | 1177.4 | 2.224 |
| 13.79 | + | 1.101 | + | + |  |  | + | + | + |  |  |  |  |  |  | 0.557 | | 14 | 1178.6 | 3.422 |
| 14.38 | + | 1.131 | + | + |  | + | + |  | + | + |  |  | + |  |  | 0.560 | | 21 | 1179.0 | 3.823 |
| 14.50 | + | 1.155 | + | + |  |  | + |  | + |  |  |  |  |  |  | 0.556 | | 13 | 1179.1 | 3.932 |
| 15.58 | + | 1.232 | + | + | + | + | + | + | + |  |  |  |  |  |  | 0.558 | | 18 | 1179.5 | 4.295 |
| 16.03 | + | 1.261 | + | + | + | + | + |  | + | + |  |  | + |  |  | 0.560 | | 23 | 1179.6 | 4.413 |
| 13.79 | + | 1.091 | + | + |  | + | + | + | + |  |  |  |  |  |  | 0.557 | | 16 | 1179.6 | 4.418 |

Table S14. Parameter estimates (logit-transformed) of a logistic model for freezing tolerance for perennial ryegrass. Abbreviations: SD=shortest daylength, MD=intermediate daylength, LD=longest daylength. Reference value (intercept) represents northern-adapted population at 12°C and LD.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Predictor | Estimate | SE | z-value | p-value |
| Intercept | 26.22 | 2.56 | 10.25 | ˂0.000 |
| Population southern | 2.06 | 0.84 | 2.45 | 0.014 |
| Treatment 6°C | 3.82 | 0.59 | 6.52 | ˂0.000 |
| Treatment 9/3°C | 3.79 | 0.58 | 6.49 | ˂0.000 |
| Treatment MD | -10.84 | 2.60 | -4.17 | ˂0.000 |
| Treatment SD | -18.62 | 2.59 | -7.19 | ˂0.000 |
| Freezing | 1.91 | 0.19 | 10.02 | ˂0.000 |
| Treatment MD × freezing | -0.60 | 0.20 | -2.95 | 0.003 |
| Treatment SD × freezing | -0.86 | 0.20 | -4.22 | ˂0.000 |
| Treatment 6°C × MD | 3.43 | 0.84 | 4.10 | ˂0.000 |
| Treatment 9/3°C × MD | 1.90 | 0.78 | 2.44 | 0.015 |
| Treatment 6°C × SD | 2.96 | 0.81 | 3.64 | ˂0.000 |
| Treatment 9/3°C × SD | 2.01 | 0.76 | 2.59 | 0.010 |
| Populations southern × freezing | 0.37 | 0.07 | 5.33 | ˂0.000 |

Table S15. Parameter estimates (logit-transformed) of a logistic model for freezing tolerance for timothy. Abbreviations: SD=shortest daylength, MD=intermediate daylength, LD=longest daylength. Reference value (intercept) represents northern-adapted population at 12°C and LD.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Predictor | Estimate | SE | z-value | p-value |
| Intercept | 12.88 | 1.19 | 10.80 | ˂0.000 |
| Population southern | 1.52 | 1.27 | 1.19 | 0.233 |
| Treatment 6°C | 0.03 | 1.68 | 0.02 | 0.983 |
| Treatment 9/3°C | 2.99 | 1.92 | 1.56 | 0.120 |
| Treatment MD | -0.09 | 0.35 | -0.25 | 0.800 |
| Treatment SD | -4.52 | 0.51 | -8.94 | ˂0.000 |
| Freezing | 1.02 | 0.09 | 10.79 | ˂0.000 |
| Population southern × freezing | 0.25 | 0.12 | 2.09 | 0.037 |
| Treatment 6°C × freezing | -0.29 | 0.12 | -2.48 | 0.013 |
| Treatment 9/3°C × freezing | -0.02 | 0.14 | -0.14 | 0.886 |
| Treatment 6°C × MD | -0.10 | 0.47 | -0.22 | 0.828 |
| Treatment 9/3°C × MD | 1.83 | 0.49 | 3.73 | ˂0.000 |
| Treatment 6°C × SD | 0.32 | 0.66 | 0.49 | 0.626 |
| Treatment 9/3°C × SD | 0.82 | 0.66 | 1.23 | 0.217 |
| Populations southern × Treatment 6°C | -1.13 | 1.73 | -0.65 | 0.513 |
| Populations southern × Treatment 9/3°C | -5.41 | 1.85 | -2.92 | 0.004 |
| Populations southern × Treatment 6°C × freezing | -0.10 | 0.15 | -0.72 | 0.475 |
| Populations southern × Treatment 9/3°C × freezing | -0.42 | 0.15 | -2.80 | 0.005 |