**Appendix A**

**Table A1 The initial seed germination percentage, hard (water-impermeable) seed percentage and thousand-seed weight (TSW) of the tested species.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Species | Family | Seed  collection time | Seed  collection site | Initial seed  germination (%) | Hard seed (%) | TSW (g) |
| *Elymus dahuricus* | Poaceae | September, 2016 | Maqu, China | 85.67 ± 0.88 | — | 4.76 ± 0.08 |
| *E. nutans* | Poaceae | September, 2016 | Maqu, China | 96.67 ± 0.67 | — | 4.31 ± 0.05 |
| *E. sibiricus* | Poaceae | September, 2016 | Maqu, China | 90.67 ± 1.20 | — | 4.49 ± 0.11 |
| *Ephedra intermedia* | Ephedraceae | July, 2016 | Minqin, China | 80.67 ± 0.88 | — | 6.24 ± 0.17 |
| *Festuca sinensis* | Poaceae | August, 2016 | Tongde, China | 98.67 ± 0.33 | — | 1.07 ± 0.02 |
| *Hedysarum multijugum* | Fabaceae | September, 2016 | Minqin, China | 96.67 ± 1.20 | 3.33 ± 1.33 | 5.63 ± 0.09 |
| *Lepidium apetalum* | Brassicaceae | July, 2016 | Minqin, China | 97.67 ± 0.33 | — | 0.19 ± 0.01 |
| *Lolium multiflorum* | Poaceae | July, 2016 | Zhuanglang, China | 98.67 ± 0.67 | — | 4.53 ± 0.12 |
| *L. perenne* | Poaceae | July, 2016 | Zhuanglang, China | 89.00 ± 1.73 | — | 2.34 ± 0.04 |
| *Medicago sativa* | Fabaceae | July, 2016 | Yuzhong, China | 99.67 ± 0.33 | 0.67 ± 0.67 | 2.31 ± 0.01 |
| *Onobrychis viciifolia* | Fabaceae | July, 2016 | Yuzhong, China | 84.00 ± 1.15 | 4.00 ± 1.15 | 22.99 ± 0.18 |
| *Poa crymophila* | Poaceae | August, 2016 | Tongde, China | 87.33 ± 1.45 | — | 0.19 ± 0.01 |
| *Sorghum bicolor* | Poaceae | August, 2016 | Jiuquan, China | 98.00 ± 1.15 | — | 26.28 ± 0.25 |
| *Trifolium pratens* | Fabaceae | August, 2016 | Zhuanglang, China | 98.67 ± 0.67 | 2.67 ± 0.67 | 1.79 ± 0.02 |
| *T. repens* | Fabaceae | August, 2016 | Zhuanglang, China | 96.00 ± 1.15 | 2.00 ± 1.15 | 0.69 ± 0.01 |

**Appendix B Thermal times of tested species predicted by thermal time models based on five distributions at suboptimal temperatures.**

**Appendix C Scatter plots of thermal time against residuals (RT) for five distributions used in thermal time models of the tested species at suboptimal temperatures.**

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\萌发率-观测值、预测值\披碱草\披碱草-亚适温\披碱草-亚适温-积温.tif**

**Figure B1 Thermal time of *E. dahuricus* seeds predicted by thermal time models based on five distributions at suboptimal temperatures.**

Circles show the observed mean thermal times. The red dashed lines show the predicted thermal time, which was fitted by the thermal time model based on the five distributions. The same as below.

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\残差图\披碱草\披碱草-亚适温\披碱草-亚适温-积温（无）.tif**

**Figure C1 Scatter plots of thermal time against residuals (RT) for five distributions used in thermal time models of *E. dahuricus* seeds at suboptimal temperatures.**

The red dashed lines are quadratic polynomials fitted to the residuals for better visualization of trends. The same as below.

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\萌发率-观测值、预测值\垂穗披碱草\垂穗披碱草-亚适温\垂穗披碱草-亚适温-积温.tif**

**Figure B2 Thermal time of *E. nutans* seeds predicted by thermal time models based on five distributions at suboptimal temperatures.**

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\残差图\垂穗披碱草\垂穗披碱草-亚适温\垂穗披碱草-亚适温-积温(无).tif**

**Figure C2 Scatter plots of thermal time against residuals (RT) for five distributions used in thermal time models of *E. nutans* seeds at suboptimal temperatures.**

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\萌发率-观测值、预测值\老芒麦\老芒麦-亚适温\老芒麦-亚适温-积温.tif**

**Figure B3 Thermal time of *E. sibiricus* seeds predicted by thermal time models based on five distributions at suboptimal temperatures.**

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\残差图\老芒麦\老芒麦-亚适温\老芒麦-亚适温-积温（无）.tif**

**Figure C3 Scatter plots of thermal time against residuals (RT) for five distributions used in thermal time models of *E. sibiricus* seeds at suboptimal temperatures.**

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\萌发率-观测值、预测值\中麻黄\中麻黄-亚适温\中麻黄-亚适温-积温.tif**

**Figure B4 Thermal time of *E. intermedia* seeds predicted by thermal time models based on five distributions at suboptimal temperatures.**

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\残差图\中麻黄\中麻黄-亚适温\中麻黄-亚适温-积温（无）.tif**

**Figure C4 Scatter plots of thermal time against residuals (RT) for five distributions used in thermal time models of *E. intermedia* seeds at suboptimal temperatures.**

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\萌发率-观测值、预测值\中华羊茅\中华羊茅-亚适温\中华羊茅-亚适温-积温.tif**

**Figure B5 Thermal time of *F. sinensis* seeds predicted by thermal time models based on five distributions at suboptimal temperatures.**

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\残差图\中华羊茅\中华羊茅-亚适温\中华羊茅-亚适温-积温（无）.tif**

**Figure C5 Scatter plots of thermal time against residuals (RT) for five distributions used in thermal time models of *F. sinensi* seeds at suboptimal temperatures.**

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\萌发率-观测值、预测值\红花岩黄耆\红花岩黄耆-亚适温\红花岩黄耆-亚适温-积温.tif**

**Figure B6 Thermal time of *H. multijugum* seeds predicted by thermal time models based on five distributions at suboptimal temperatures.**

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\残差图\红花岩黄耆\红花岩黄耆-亚适温\红花岩黄耆-亚适温-积温（无）.tif**

**Figure C6 Scatter plots of thermal time against residuals (RT) for five distributions used in thermal time models of *H. multijugum* seeds at suboptimal temperatures.**

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\萌发率-观测值、预测值\腺独行菜\腺独行菜-亚适温\腺独行菜-亚适温-积温.tif**

**Figure B7 Thermal time of *L. apetalum* seeds predicted by thermal time models based on five distributions at suboptimal temperatures.**

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\残差图\腺独行菜\腺独行菜-亚适温\腺独行菜-亚适温-积温(无).tif**

**Figure C7 Scatter plots of thermal time against residuals (RT) for five distributions used in thermal time models of *L. apetalum* seeds at suboptimal temperatures.**

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\萌发率-观测值、预测值\多花黑麦草\多花黑麦草-亚适温\多花黑麦草-亚适温-积温.tif**

**Figure B8 Thermal time of *L. multiflorum* seeds predicted by thermal time models based on five distributions at suboptimal temperatures.**

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\残差图\多花黑麦草\多花黑麦草-亚适温\多花黑麦草-亚适温-积温（无）.tif**

**Figure C8 Scatter plots of thermal time against residuals (RT) for five distributions used in thermal time models of *L. multiflorum* seeds at suboptimal temperatures.**

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\萌发率-观测值、预测值\多年生黑麦草\多年生黑麦草-亚适温\多年生黑麦草-亚适温-积温.tif**

**Figure B9 Thermal time of *L. perenne* seeds predicted by thermal time models based on five distributions at suboptimal temperatures.**

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\残差图\多年生黑麦草\多年生黑麦草-亚适温\多年生黑麦草-亚适温-积温（无）.tif**

**Figure C9 Scatter plots of thermal time against residuals (RT) for five distributions used in thermal time models of *L. perenne* seeds at suboptimal temperatures.**

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\萌发率-观测值、预测值\紫花苜蓿\紫花苜蓿-亚适温\紫花苜蓿-亚适温-积温.tif**

**Figure B10 Thermal time of *M. sativa* seeds predicted by thermal time models based on five distributions at suboptimal temperatures.**

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\残差图\紫花苜蓿\紫花苜蓿-亚适温\紫花苜蓿-亚适温-积温（无）.tif**

**Figure C10 Scatter plots of thermal time against residuals (RT) for five distributions used in thermal time models of *M. sativa* seeds at suboptimal temperatures.**

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\萌发率-观测值、预测值\红豆草\红豆草-亚适温\红豆草-亚适温-积温.tif**

**Figure B11 Thermal time of *O. viciifolia* seeds predicted by thermal time models based on five distributions at suboptimal temperatures.**

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\残差图\红豆草\红豆草-亚适温\红豆草-亚适温-积温(无).tif**

**Figure C11 Scatter plots of thermal time against residuals (RT) for five distributions used in thermal time models of *O. viciifolia* seeds at suboptimal temperatures.**

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\萌发率-观测值、预测值\冷地早熟禾\冷地早熟禾-亚适温\冷地早熟禾-亚适温-积温.tif**

**Figure B12 Thermal time of *P. crymophila* seeds predicted by thermal time models based on five distributions at suboptimal temperatures.**

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\残差图\冷地早熟禾\冷地早熟禾-亚适温\冷地早熟禾-亚适温-积温（无）.tif**

**Figure C12 Scatter plots of thermal time against residuals (RT) for five distributions used in thermal time models of *P. crymophila* seeds at suboptimal temperatures.**

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\萌发率-观测值、预测值\高粱\高粱-亚适温\高粱-亚适温-积温.tif**

**Figure B13 Thermal time of *S. bicolor* seeds predicted by thermal time models based on five distributions at suboptimal temperatures.**

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\残差图\高粱\高粱-亚适温\高粱-亚适温-积温（无）.tif**

**Figure C13 Scatter plots of thermal time against residuals (RT) for five distributions used in thermal time models of *S. bicolor* seeds at suboptimal temperatures.**

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\萌发率-观测值、预测值\白三叶\白三叶-亚适温\白三叶-亚适温-积温.tif**

**Figure B14 Thermal time of *T. repens* seeds predicted by thermal time models based on five distributions at suboptimal temperatures.**

**D:\兰大\试验\模型试验\积温模型\数据\图表整理\残差图\白三叶\白三叶-亚适温\白三叶-亚适温-积温（无）.tif**

**Figure C14 Scatter plots of thermal time against residuals (RT) for five distributions used in thermal time models of *T. repens* seeds at suboptimal temperatures.**