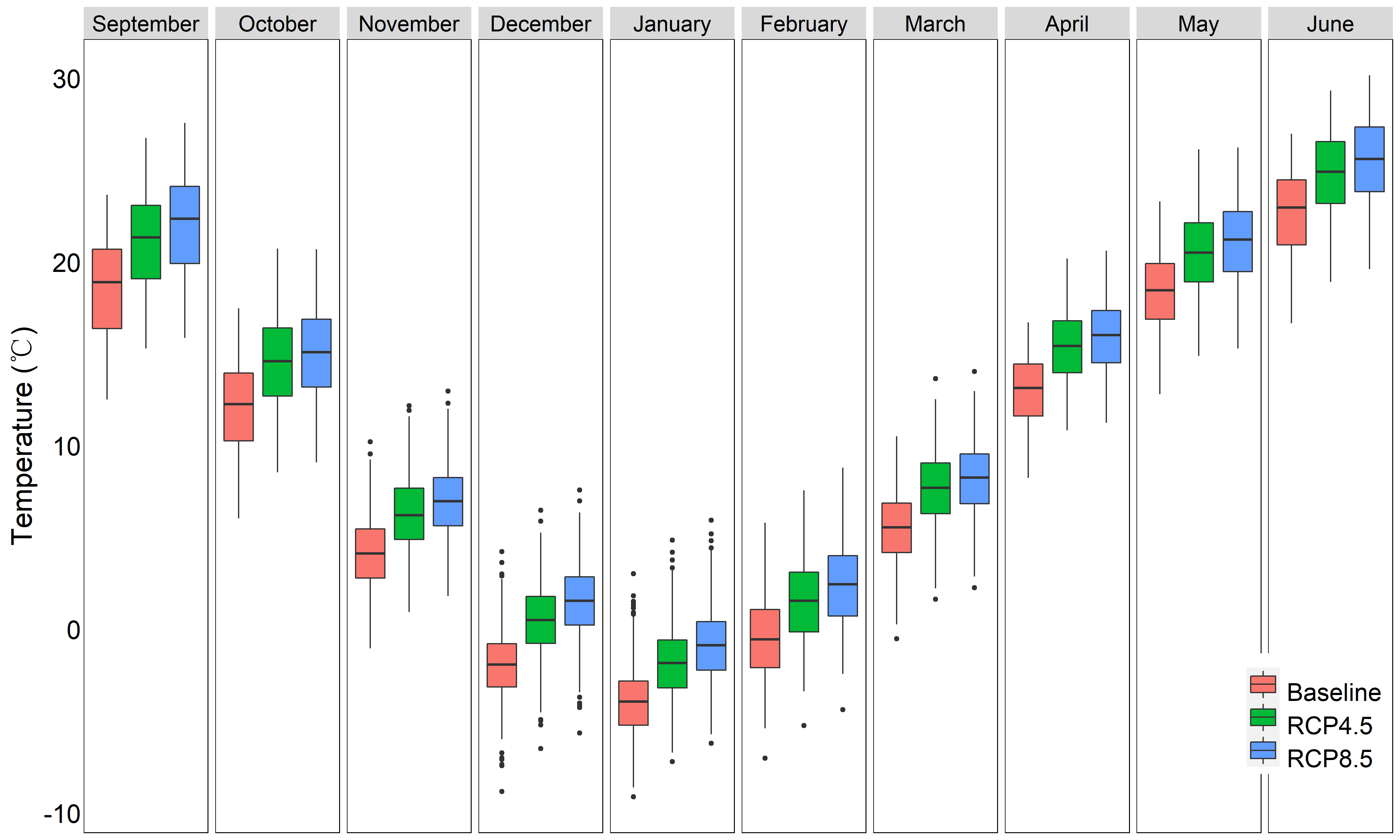
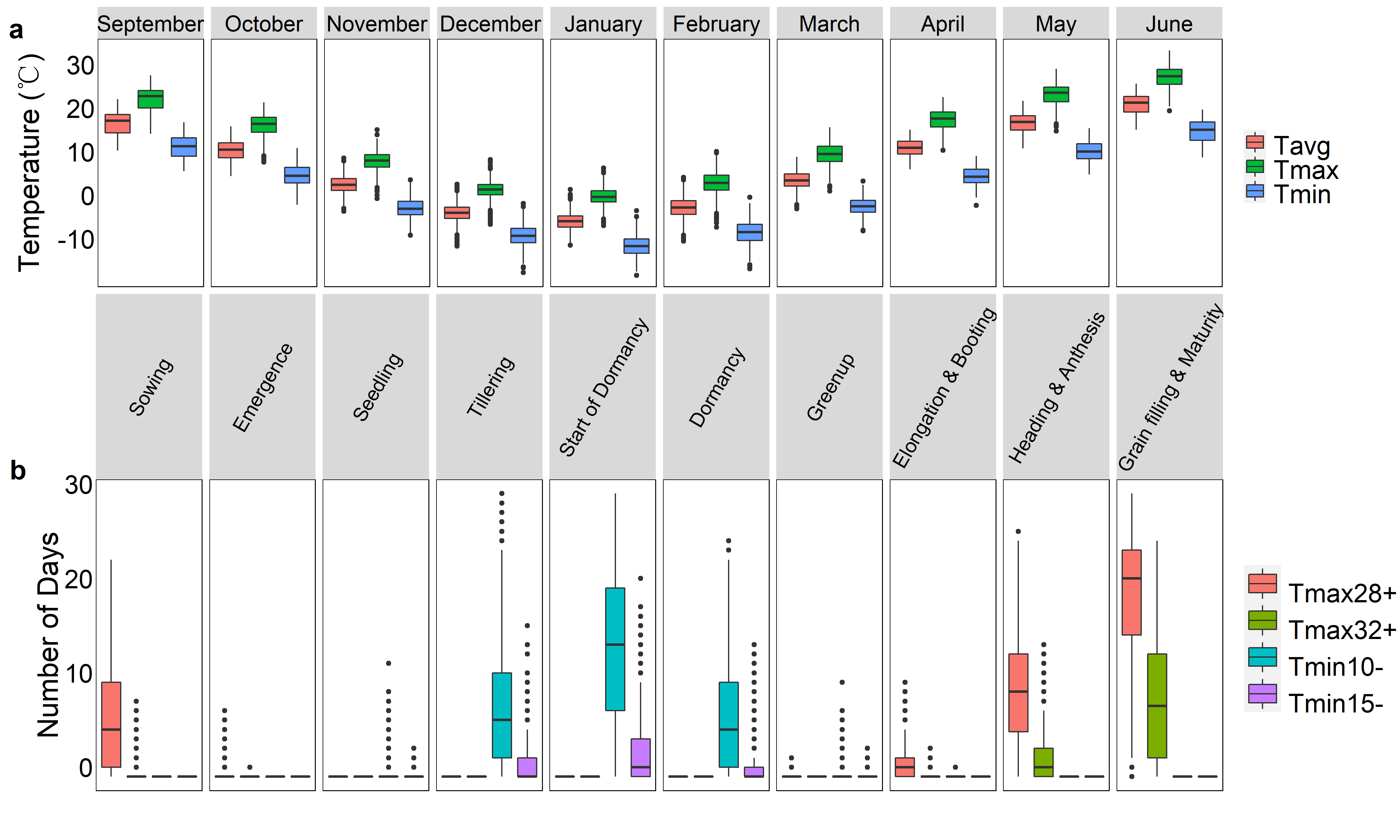
# Supplementary Information

**Multi-locus genotype-based modeling reveals that rising temperatures stabilize the flowering date of winter wheat**

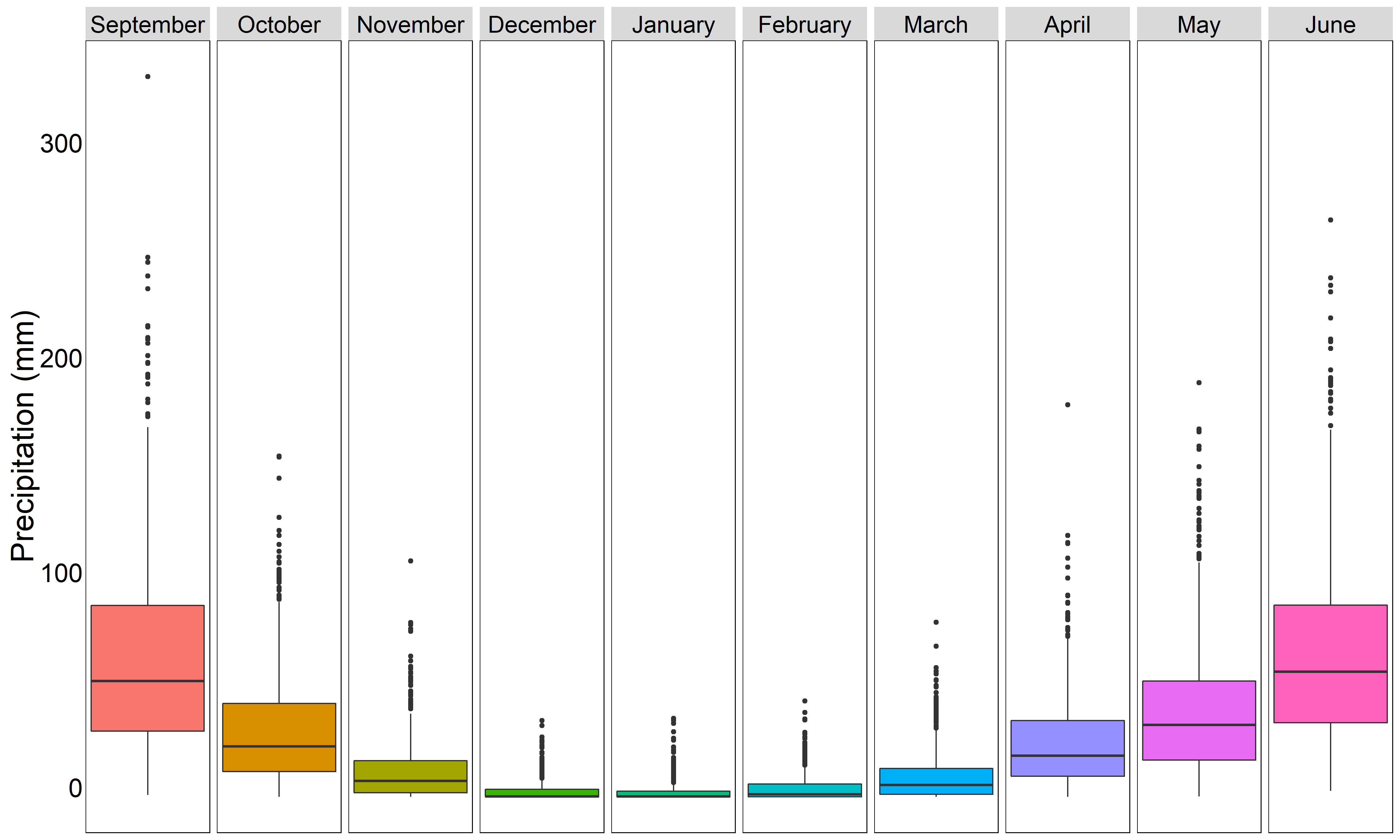
Yong He, Wei Xiong, Pengcheng Hu, Yinglong Xu, Chenyang Hao, Ron DePauw, Bangyou Zheng, Daiqing Huang, Gerrit Hoogenboom, Laura Dixon, Andrew Juan Challinor



**Supplementary Figure 1│Distribution of mean monthly air temperature of wheat growing-season at 16 locations of the Northern China Winter Wheat Region (NCWWR) under baseline (1981–2010), RCP4.5 and RCP8.5 projected climates (2036–2065) of the 16 locations of the Northern China Winter Wheat Region (NCWWR).** Boxes show the median, an upper and lower hinge corresponding to the 25th and 75th percentiles of the distribution (first and third quartiles) and the whiskers, which show data dispersion up to 1.5 times the inter-quantile range; filled black circles are outliers.



**Supplementary Figure 2│Variation in monthly air temperature of growing-season at 16 locations of the Northern China Winter Wheat Region (NCWWR) for the period 1961–2015. a**, Boxplot of averaged monthly temperature (Tavg), maximum temperature (Tmax), and minimum temperature (Tmin). **b**, Boxplot of averaged number of days with daily maximum temperature over 28 °C (Tmax28+), daily maximum temperature over 32 °C (Tmax32+), daily minimum temperature less than -10 °C (Tmin10-), and daily minimum temperature less than -15 °C (Tmin15-) for each month. Boxes in **a** and **b** show the median, an upper and lower hinge corresponding to the 25th and 75th percentiles of the distribution (first and third quartiles) and the whiskers, which show data dispersion up to 1.5 times the inter-quantile range; filled black circles are outliers.



**Supplementary Figure 3│Variation in monthly accumulated precipitation of growing-season at 16 locations of the Northern China Winter Wheat Region (NCWWR) for the period 1961–2015.** Boxes show the median, an upper and lower hinge corresponding to the 25th and 75th percentiles of the distribution (first and third quartiles) and the whiskers, which show data dispersion up to 1.5 times the inter-quantile range; filled black circles are outliers.

Supplementary Table 1. Allelic characterization of varieties for vernalization (*VRN*) and photoperiod (*PDP*) loci

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Variety** | ***Vrn-A1*** | ***Vrn-B1*** | ***Vrn-B3*** | ***Vrn-D1*** | ***Ppd-A1*** | ***Ppd-B1*** | ***Ppd-D1*** |
| CA9722 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Dongfanghong 3 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1b* |
| Zhongyou 206 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Zhongmai 175 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Fengkang 2 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Fengkang 7 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Fengkang 8 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Jing 411 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Jing 9428 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Jingdong 1 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1a* | *Ppd-B1b* | *Ppd-D1a* |
| Jingdong 12 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Jingdong 17 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Jingdong 22 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Jingdong 6 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Jingdong 8 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Jingshuang 10 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Jingshuang 12 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Jingshuang 16 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Jingshuang 9 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Jiahongmai | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1b* |
| Lanhuamai | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Nongda 139 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Nongda 146 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Nongda 183 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1b* |
| Nongda 211 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Nongda 212 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Nongda 311 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1a* | *Ppd-B1b* | *Ppd-D1b* |
| Nongda 3432 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Nongda 36 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1b* |
| Beijing 10 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Beijing 15 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Beijing 8 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Huabei 187 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1a* | *Ppd-B1b* | *Ppd-D1b* |
| Yuandong 822 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Lvhan 328 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Zhoumai 18 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Dabaimang | *vrn-A1* | *vrn-B1* | *vrn-B3* | *Vrn-D1-spring* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1b* |
| Dahongmang | *vrn-A1* | *vrn-B1* | *vrn-B3* | *Vrn-D1-spring* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1b* |
| Dingxian 72 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1b* |
| Xiaokouhong | *vrn-A1* | *vrn-B1* | *vrn-B3* | *Vrn-D1-spring* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1b* |
| Xiaomaimang | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1b* |
| Daimanghongmai | *vrn-A1* | *vrn-B1* | *vrn-B3* | *Vrn-D1-spring* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1b* |
| Yan'an 11 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1b* |
| Zaoyangmai | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1b* |
| Jinmai 8 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1a* | *Ppd-B1b* | *Ppd-D1a* |
| Youmangbai 4 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1b* |
| Youmangbaifu J | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1b* |
| Youmangbaifu L | *vrn-A1* | *vrn-B1* | *vrn-B3* | *Vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1b* |
| Jimai 22 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Zhuoludongmai | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1b* |
| Yannong 19 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Yanda 1817 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1a* | *Ppd-B1b* | *Ppd-D1b* |
| Niuzhijia | *vrn-A1* | *vrn-B1* | *vrn-B3* | *Vrn-D1-spring* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1b* |
| Baiqiumai | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1b* |
| Baiqimai | *vrn-A1* | *vrn-B1* | *vrn-B3* | *Vrn-D1-spring* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1b* |
| Shixin 828 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1a* | *Ppd-B1b* | *Ppd-D1a* |
| Bima 1 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Panshiwumang | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1b* |
| Hongpidongmai | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1a* | *Ppd-B1b* | *Ppd-D1b* |
| Honglaomai | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1b* |
| Hongliang 4 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Hongjinmai | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1b* |
| Hongmai | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1b* |
| Laomai | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Liangxing 99 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Hengguan 35 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *Vrn-D1-spring* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Lunxuan 518 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Lunxuan 987 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Han 6172 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Mingxian 169 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1b* |
| Changfeng 1 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Changzhi 6406 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Shanxibaimai | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Mahuaban | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1b* |
| Zhongmai 998 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Zhongyou 9507 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| PH82-2-2 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Yumai 35 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *Vrn-D1-spring* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Yumai 49 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Yumai 66 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Shanmai 150 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *Vrn-D1-spring* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Jinan 17 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Gaoyou 503 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *Vrn-D1-spring* | *Ppd-A1a* | *Ppd-B1b* | *Ppd-D1a* |
| Taiyuan 136 | *vrn-A1* | *Vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1a* | *Ppd-B1b* | *Ppd-D1a* |
| Qi 79-2060 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1b* |
| Kenong 2009 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Gaocheng 8901 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *Vrn-D1-spring* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Gaoyou 5766 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Gaoyou 5218 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Shiluan 02-1 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Lunxuan 061 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Yuanfeng 175 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Xinong 509 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *Vrn-D1-spring* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Xinong 529 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Henong 58-3 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Shiyou 17 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *Vrn-D1-spring* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Shiyou 20 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Shi 4366 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Jimai 738 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *Vrn-D1-spring* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |
| Jimai U80 | *vrn-A1* | *vrn-B1* | *vrn-B3* | *vrn-D1* | *Ppd-A1b* | *Ppd-B1b* | *Ppd-D1a* |