**Table S1** QTLs identified for seed vigor-related traits under artificial aging in the Zhou8425B/Chinese Spring population

| **Trait** | **Environment** | **QTL** | **Position** | **Marker interval** | **LOD** | **PVE** | **Add** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| MGT | ZK2014 | *QaMGT.cas-5AS.1* | 33 | *IWB20588~IWA5368* | 2.21  | 9.7  | -0.062  |
|  |  | *QaMGT.cas-6BL.2* | 183 | *IWB57192~IWB44671* | 2.02  | 3.6  | -0.040  |
|  |  | *QaMGT.cas-7AL.1* | 177 | *IWB7519~IWB20876* | 2.80  | 6.4  | -0.052  |
|  |  | *QaMGT.cas-7AL.2* | 243 | *IWA4993~IWB12039* | 2.60  | 4.7  | 0.044  |
|  | ZZ2014 | *QaMGT.cas-1AL.3* | 180 | *IWA4518~IWB8643* | 2.16  | 3.8  | 0.043  |
|  |  | *QaMGT.cas-2DS.2* | 51 | *IWB12962~IWB11197* | 2.30  | 7.0  | 0.058  |
|  |  | *QaMGT.cas-4AS* | 30 | *IWB70645~IWA5858* | 2.64  | 8.9  | 0.065  |
|  |  | *QaMGT.cas-5BL.1* | 135 | *IWB230~IWB43739* | 2.25  | 4.1  | 0.044  |
|  | ZZ2015 | *QaMGT.cas-2DS.2* | 46 | *IWB21991~IWB75065* | 2.54  | 5.4  | 0.062  |
|  |  | *QaMGT.cas-3BL.2* | 166 | *IWB53203~IWB1543* | 2.03  | 3.8  | -0.052  |
|  |  | *QaMGT.cas-5DS* | 20 | *IWB60953~IWB44516* | 2.17  | 3.9  | 0.053  |
|  | BJ2016 | *QaMGT.cas-3DL* | 91 | *IWB52937~IWB17930* | 2.82  | 4.6  | 0.062  |
|  |  | *QaMGT.cas-4AS* | 44 | *IWB3572~IWB11606* | 2.92  | 8.1  | 0.081  |
|  |  | *QaMGT.cas-4AL.3* | 139 | *IWB21713~IWB28717* | 3.02  | 5.2  | 0.065  |
|  | Average | *QaMGT.cas-1AL.2* | 109 | *IWB8121~IWB35745* | 2.66  | 4.2  | -0.029  |
|  |  | *QaMGT.cas-2DS.2* | 51 | *IWB12962~IWB11197* | 4.38  | 10.8  | 0.047  |
|  |  | *QaMGT.cas-4AS* | 28 | *IWB12389~IWB70645* | 5.97  | 9.2  | 0.043  |
|  |  | *QaMGT.cas-5BL.4* | 199 | *IWB36613~IWB24418* | 3.37  | 5.0  | 0.032  |
| 　 | 　 | *QaMGT.cas-7AL.2* | 243 | *IWA4993~IWB12039* | 2.89  | 4.6  | 0.031  |
| MGR | ZK2014 | *QaMGR.cas-2DS.2* | 48 | *IWB21991~IWB75065* | 2.65  | 4.6  | -0.006  |
|  |  | *QaMGR.cas-5AS.1* | 33 | *IWB20588~IWA5368* | 4.45  | 19.4  | 0.012  |
|  |  | *QaMGR.cas-6BL.2* | 167 | *IWA4246~IWB57728* | 2.75  | 4.9  | 0.007  |
|  |  | *QaMGR.cas-7AL.2* | 243 | *IWA4993~IWB12039* | 2.31  | 4.0  | -0.006  |
|  | ZZ2014 | *QaMGR.cas-2DS.2* | 51 | *IWB12962~IWB11197* | 2.05  | 6.3  | -0.007  |
|  |  | *QaMGR.cas-3BS* | 12 | *IWB11728~IWA5347* | 2.15  | 3.8  | -0.005  |
|  |  | *QaMGR.cas-4AS* | 30 | *IWB70645~IWA5858* | 2.88  | 10.0  | -0.008  |
|  |  | *QaMGR.cas-5BL.1* | 135 | *IWB230~IWB43739* | 2.10  | 3.8  | -0.005  |
|  | ZZ2015 | *QaMGR.cas-2AL* | 187 | *IWB973~IWB29535* | 2.11  | 5.4  | -0.007  |
|  |  | *QaMGR.cas-2DS.2* | 47 | *IWB21991~IWB75065* | 2.35  | 5.0  | -0.007  |
|  |  | *QaMGR.cas-3BL.2* | 166 | *IWB53203~IWB1543* | 2.03  | 4.0  | 0.006  |
|  |  | *QaMGR.cas-5DS* | 20 | *IWB60953~IWB44516* | 2.07  | 3.9  | -0.006  |
|  | BJ2016 | *QaMGR.cas-2DS.1* | 27 | *IWB5774~IWB41295* | 2.15  | 3.9  | -0.007  |
|  |  | *QaMGR.cas-3DL* | 91 | *IWB52937~IWB17930* | 2.90  | 5.0  | -0.008  |
|  |  | *QaMGR.cas-4AS* | 33 | *IWB63157~IWB9651* | 3.39  | 10.7  | -0.012  |
|  |  | *QaMGR.cas-4AL.3* | 139 | *IWB21713~IWB28717* | 3.25  | 5.8  | -0.009  |
|  | Average | *QaMGR.cas-1AL.2* | 109 | *IWB8121~IWB35745* | 3.79  | 6.5  | 0.005  |
|  |  | *QaMGR.cas-2DS.2* | 51 | *IWB12962~IWB11197* | 2.61  | 6.5  | -0.005  |
|  |  | *QaMGR.cas-3AS.2* | 83 | *IWB41434~IWB63999* | 3.03  | 5.1  | -0.004  |
|  |  | *QaMGR.cas-3DL* | 73 | *IWB52937~IWB17930* | 2.18  | 3.8  | -0.004  |
|  |  | *QaMGR.cas-4AS* | 28 | *IWB12389~IWB70645* | 4.68  | 7.6  | -0.005  |
| 　 | 　 | *QaMGR.cas-5BL.4* | 199 | *IWB36613~IWB24418* | 2.04  | 3.1  | -0.003  |
|  |  |  |  |  |  | (Contined) |
|  |  |  |  |  |  |  |
| **Trait** | **Environment** | **QTL** | **Position** | **Marker interval** | **LOD** | **PVE** | **Add** |
| GI | ZK2014 | *QaGI.cas-1DS* | 54 | *IWB31245~IWB26128* | 2.00  | 7.3  | -2.711  |
|  |  | *QaGI.cas-2DL* | 97 | *IWB43924~IWB28458* | 2.20  | 5.4  | -2.362  |
|  |  | *QaGI.cas-3AS.3* | 112 | *IWA7022~IWA5151* | 3.61  | 5.6  | 2.377  |
|  |  | *QaGI.cas-3DL* | 57 | *IWB34976~IWB25194* | 2.01  | 3.1  | -1.785  |
|  |  | *QaGI.cas-5BL.3* | 165 | *IWB71831~IWB7308* | 2.16  | 4.3  | 2.088  |
|  |  | *QaGI.cas-6AS* | 32 | *IWB48751~IWB47853* | 2.64  | 4.2  | 2.045  |
|  |  | *QaGI.cas-6BL.1* | 107 | *IWB17986~IWA3289* | 2.01  | 3.0  | 1.724  |
|  |  | *QaGI.cas-6BL.2* | 159 | *IWA4869~IWB28256* | 2.84  | 4.4  | 2.250  |
|  | ZZ2014 | *QaGI.cas-2AS* | 98 | *IWB17323~IWB53010* | 2.01  | 3.6  | -1.736  |
|  |  | *QaGI.cas-4AL.1* | 60 | *IWB27577~IWA4079* | 3.99  | 7.5  | -2.495  |
|  | ZZ2015 | *QaGI.cas-2DS.2* | 45 | *IWB21991~IWB75065* | 2.28  | 4.6  | -1.883  |
|  |  | *QaGI.cas-5DS* | 20 | *IWB60953~IWB44516* | 2.01  | 3.6  | -1.662  |
|  | BJ2016 | *QaGI.cas-3AS.1* | 35 | *IWB7136~IWA8100* | 2.70  | 4.1  | -2.861  |
|  |  | *QaGI.cas-3DL* | 91 | *IWB52937~IWB17930* | 4.39  | 6.6  | -2.754  |
|  |  | *QaGI.cas-4AL.2* | 79 | *IWB830~IWB1522* | 3.81  | 8.0  | -3.261  |
|  |  | *QaGI.cas-4AL.3* | 139 | *IWB21713~IWB28717* | 4.04  | 6.3  | -2.680  |
|  |  | *QaGI.cas-5AS.2* | 55 | *IWB8074~IWB7316* | 2.23  | 4.3  | -2.211  |
|  |  | *QaGI.cas-5BL.3* | 159 | *IWB60911~IWB71831* | 2.04  | 2.9  | -1.840  |
|  | Average | *QaGI.cas-2DS.1* | 28 | *IWB41295~IWB60488* | 3.69  | 8.2  | -1.751  |
|  |  | *QaGI.cas-2DS.2* | 51 | *IWB12962~IWB11197* | 2.24  | 6.1  | -1.497  |
|  |  | *QaGI.cas-3AS.2* | 82 | *IWB41434~IWB63999* | 2.23  | 3.8  | -1.178  |
|  |  | *QaGI.cas-3AS.3* | 112 | *IWA7022~IWA5151* | 2.04  | 3.2  | 1.073  |
|  |  | *QaGI.cas-3AL* | 155 | *IWA4851~IWA6783* | 2.04  | 3.3  | 1.263  |
|  |  | *QaGI.cas-3BS* | 12 | *IWB11728~IWA5347* | 2.35  | 3.7  | -1.217  |
|  |  | *QaGI.cas-3BL.1* | 118 | *IWB7963~IWB12064* | 2.26  | 3.5  | -1.150  |
|  |  | *QaGI.cas-3DL* | 86 | *IWB52937~IWB17930* | 2.75  | 5.6  | -1.427  |
|  |  | *QaGI.cas-4AL.3* | 128 | *IWB23723~IWB49186* | 2.11  | 4.6  | -1.293  |
| 　 | 　 | *QaGI.cas-6BL.2* | 159 | *IWA4869~IWB28256* | 4.21  | 7.0  | 1.702  |
| GR | ZK2014 | *QaGR.cas-2DL* | 97 | *IWB43924~IWB28458* | 2.16  | 5.3  | -2.769  |
|  |  | *QaGR.cas-3AS.3* | 112 | *IWA7022~IWA5151* | 3.62  | 5.7  | 2.818  |
|  |  | *QaGR.cas-6AS* | 32 | *IWB48751~IWB47853* | 2.88  | 4.6  | 2.529  |
|  |  | *QaGR.cas-6BL.2* | 159 | *IWA4869~IWB28256* | 2.51  | 3.9  | 2.495  |
|  | ZZ2014 | *QaGR.cas-3DL* | 91 | *IWB52937~IWB17930* | 2.85  | 4.7  | -2.371  |
|  |  | *QaGR.cas-4AL.1* | 60 | *IWB27577~IWA4079* | 3.00  | 5.3  | -2.527  |
|  |  | *QaGR.cas-6BL.2* | 159 | *IWA4869~IWB28256* | 2.52  | 4.1  | 2.378  |
|  |  | *QaGR.cas-7BL* | 166 | *IWB2239~IWB6699* | 2.32  | 3.7  | -2.101  |
|  | ZZ2015 | *QaGR.cas-3BL.1* | 122 | *IWB60906~IWB32722* | 2.03  | 6.6  | -2.772  |
|  | BJ2016 | *QaGR.cas-3AS.1* | 35 | *IWB7136~IWA8100* | 2.95  | 4.5  | -1.636  |
|  |  | *QaGR.cas-3DL* | 91 | *IWB52937~IWB17930* | 3.71  | 5.7  | -1.388  |
|  |  | *QaGR.cas-4AL.2* | 79 | *IWB830~IWB1522* | 3.77  | 8.1  | -1.788  |
|  |  | *QaGR.cas-4AL.3* | 139 | *IWB21713~IWB28717* | 3.35  | 5.3  | -1.343  |
|  | Average | *QaGR.cas-2DS.1* | 28 | *IWB41295~IWB60488* | 3.07  | 6.7  | -0.926  |
|  |  | *QaGR.cas-3BL.1* | 118 | *IWB7963~IWB12064* | 2.16  | 3.4  | -0.658  |
|  |  |  |  |  |  | (Contined) |
| **Trait** | **Environment** | **QTL** | **Position** | **Marker interval** | **LOD** | **PVE** | **Add** |
|  |  | *QaGR.cas-3DL* | 87 | *IWB52937~IWB17930* | 2.88  | 5.6  | -0.835  |
| 　 | 　 | *QaGR.cas-6BL.2* | 159 | *IWA4869~IWB28256* | 4.31  | 7.2  | 1.009  |
| Z | ZK2014 | *QaZ.cas-2DS.2* | 48 | *IWB21991~IWB75065* | 2.08  | 3.7  | -0.017  |
|  |  | *QaZ.cas-5AS.2* | 54 | *IWB8074~IWB7316* | 3.12  | 6.3  | 0.023  |
|  |  | *QaZ.cas-7AL.2* | 243 | *IWA4993~IWB12039* | 2.09  | 3.8  | -0.018  |
|  | ZZ2014 | *QaZ.cas-3AS.3* | 109 | *IWB9676~IWB58700* | 2.05  | 3.8  | 0.014  |
|  |  | *QaZ.cas-3BS* | 10 | *IWB11728~IWA5347* | 2.38  | 5.1  | -0.017  |
|  |  | *QaZ.cas-4AS* | 30 | *IWB70645~IWA5858* | 3.32  | 11.5  | -0.025  |
|  |  | *QaZ.cas-5BL.2* | 146 | *IWB71849~IWB73643* | 2.00  | 4.3  | -0.015  |
|  |  | *QaZ.cas-6BL.2* | 185 | *IWB57192~IWB44671* | 2.47  | 5.2  | 0.017  |
|  | ZZ2015 | *QaZ.cas-1BL* | 76 | *IWB22510~IWB27264* | 2.11  | 3.9  | 0.016  |
|  |  | *QaZ.cas-1DS* | 59 | *IWB59650~IWB10694* | 2.13  | 3.5  | -0.015  |
|  |  | *QaZ.cas-2DS.2* | 46 | *IWB21991~IWB75065* | 3.30  | 6.6  | -0.020  |
|  |  | *QaZ.cas-3BL.2* | 167 | *IWB53203~IWB1543* | 3.22  | 6.4  | 0.020  |
|  | BJ2016 | *QaZ.cas-3DL* | 91 | *IWB52937~IWB17930* | 3.57  | 6.2  | -0.030  |
|  |  | *QaZ.cas-4AS* | 43 | *IWB3572~IWB11606* | 2.09  | 6.4  | -0.030  |
|  |  | *QaZ.cas-4AL.2* | 71 | *IWB52955~IWB830* | 2.64  | 4.6  | -0.025  |
|  |  | *QaZ.cas-4AL.3* | 139 | *IWB21713~IWB28717* | 2.06  | 3.5  | -0.022  |
|  | Average | *QaZ.cas-1AL.2* | 108 | *IWB10475~IWB12600* | 3.80  | 5.8  | 0.012  |
|  |  | *QaZ.cas-3AS.2* | 84 | *IWB63999~IWA3939* | 4.39  | 6.9  | -0.013  |
|  |  | *QaZ.cas-4AS* | 49 | *IWA1137~IWB2177* | 4.20  | 10.3  | -0.016  |
| 　 | 　 | *QaZ.cas-5AL* | 181 | *IWA3704~IWB48788* | 3.64  | 5.5  | 0.012  |
| FCGR | ZK2014 | *QaFCGR.cas-1AL.1* | 49 | *IWB36443~IWB55507* | 2.04  | 3.4  | 1.160  |
|  |  | *QaFCGR.cas-2DS.2* | 51 | *IWB12962~IWB11197* | 2.33  | 5.8  | -1.511  |
|  |  | *QaFCGR.cas-3AS.3* | 112 | *IWA7022~IWA5151* | 4.03  | 6.6  | 1.615  |
|  |  | *QaFCGR.cas-3DL* | 56 | *IWA5030~IWB34976* | 2.31  | 3.6  | -1.198  |
|  |  | *QaFCGR.cas-6BL.2* | 159 | *IWA4869~IWB28256* | 3.27  | 5.3  | 1.551  |
|  | ZZ2014 | *QaFCGR.cas-2DS.2* | 50 | *IWB12962~IWB11197* | 2.48  | 4.0  | -1.207  |
|  |  | *QaFCGR.cas-4AL.1* | 60 | *IWB27577~IWA4079* | 3.38  | 6.0  | -1.469  |
|  | ZZ2015 | *QaFCGR.cas-2DS.2* | 39 | *IWB42663~IWB21362* | 2.58  | 7.9  | -1.545  |
|  |  | *QaFCGR.cas-3BL.1* | 122 | *IWB60906~IWB32722* | 2.32  | 7.0  | -1.461  |
|  |  | *QaFCGR.cas-5DS* | 20 | *IWB60953~IWB44516* | 2.02  | 3.6  | -1.042  |
|  |  | *QaFCGR.cas-6BS* | 79 | *IWB45294~IWB9751* | 2.51  | 4.7  | 1.197  |
|  | BJ2016 | *QaFCGR.cas-3AS.1* | 35 | *IWB7136~IWA8100* | 2.69  | 4.1  | -1.852  |
|  |  | *QaFCGR.cas-3DL* | 91 | *IWB52937~IWB17930* | 4.96  | 7.5  | -1.901  |
|  |  | *QaFCGR.cas-4AL.2* | 79 | *IWB830~IWB1522* | 3.43  | 7.2  | -2.004  |
|  |  | *QaFCGR.cas-4AL.3* | 139 | *IWB21713~IWB28717* | 4.71  | 7.4  | -1.879  |
|  |  | *QaFCGR.cas-5AS.2* | 55 | *IWB8074~IWB7316* | 2.18  | 4.2  | -1.414  |
|  |  | *QaFCGR.cas-7BL* | 166 | *IWB2239~IWB6699* | 2.18  | 3.1  | -1.221  |
|  | Average | *QaFCGR.cas-2DS.2* | 51 | *IWB12962~IWB11197* | 4.99  | 13.6  | -1.401  |
|  |  | *QaFCGR.cas-3BS* | 12 | *IWB11728~IWA5347* | 2.15  | 3.4  | -0.731  |
|  |  | *QaFCGR.cas-3DL* | 82 | *IWB52937~IWB17930* | 3.74  | 8.3  | -1.099  |
|  |  | *QaFCGR.cas-4B* | 112 | *IWB72706~IWB36208* | 2.46  | 3.8  | -0.768  |
| 　 | 　 | *QaFCGR.cas-6BL.2* | 159 | *IWA4869~IWB28256* | 3.91  | 6.4  | 1.029  |

LOD, logarithm of odds score; PVE, percentage of phenotypic variance explained by the QTL; ADD, additive effect of resistance allele; L, long chromosome arms; S, short chromosome arms; ZK, Zhoukou; ZZ, Zhengzhou; BJ, Beijing; MGT, mean germination time; MGR, mean germination rate; GI, weighted germination index; GR, germination ratio; Z, the synchrony index; FCGR, first count germination ratio.