**Genome based meta-QTL analysis of grain weight in tetraploid wheat identifies rare alleles of *GRF4* associated with larger grains**

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*Supplementary Materials*



**Figure S1.** Distributions of thousand-kernel weight (TKW) on the Svevo × Zavitan population across four environments (2014R, 2015A, 2016R\_wet and 2016R\_dry). Arrows point to the mean value for the two parents Svevo (S) and Zavitan (Z).

**Table S1.** QTL parameters for TKW in four environments (see Table 1.)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Chromosome** | **Environment** | **LOD** | **P-value** | **PEVa** | **Subst.effectb** | **Genetic Marker** | **Start on Zavitan** | **End on Zavitan** |
| 1A | 2015A | 3.006 | 0.00093 | 0.059 | 2.731 | IWA2056 | 31274191 | 31274391 |
| 1A | 2016R\_ WET | 4.877 | 0.01429 | 0.069 | 2.76 | IWA8551 | 23748366 | 23748266 |
| 1B | 2015A | 10.85 | 0.01429 | 0.209 | -5.147 | IWB20542 | 373810959 | 373810859 |
| 2A | 2014R | 3.682 | 0.00093 | 0.068 | -2.949 | IWB50818 | 608897808 | 608897908 |
| 2A | 2016R\_ WET | 5.322 | 0.02703 | 0.051 | -3.09 | IWB2683/IWB44472 | 643855130 | 643855230 |
| 2B | 2016R\_ WET | 4.284 | 0.00187 | 0.057 | 2.684 | IWB46299 | 729462816 | 729462877 |
| 3A | 2014R | 5.622 | 0.00093 | 0.111 | 3.757 | IWB53527/IWB52086 | 416199186 | 416199259 |
| 3A | 2016R\_ WET | 7.795 | 0.01429 | 0.101 | 4.363 | IWB16112 | 492095032 | 492094831 |
| 3B | 2015A | 5.471 | 0.01429 | 0.085 | 3.291 | IWB7540 | 787686011 | 787686111 |
| 4B | 2014R | 9.331 | 0.01429 | 0.06 | 2.756 | IWB72369/IWB72367 | 494965971 | 494966071 |
| 4B | 2015A | 3.719 | 0.00093 | 0.131 | 4.081 | IWB72369/IWB72367 | 494965971 | 494966071 |
| 4B | 2016R\_ WET | 7.896 | 0.01429 | 0.179 | 5.799 | IWB72369/IWB72367 | 494965971 | 494966071 |
| 5A | 2014R | 5.052 | 0.01429 | 0.093 | 4.183 | IWB42031/IWB25205 | 622359795 | 622359895 |
| 5A | 2015A | 5.608 | 0.01429 | 0.095 | 3.462 | IWB686 | 611738001 | 611738101 |
| 5B | 2016R\_ WET | 4.565 | 0.0028 | 0.056 | 2.678 | IWB33375 | 383073895 | 383073979 |
| 6A | 2014R | 3.784 | 0.01429 | 0.083 | -3.033 | IWB31050 | 480981917 | 500982017 |
| 6A | 2016R\_DRY | 3.47 | 0.00093 | 0.053 | -2.602 | IWB31050 | 520981917 | 500982017 |
| 6A | 2016R\_ WET | 4.431 | 0.01429 | 0.055 | -3.225 | IWB31050 | 531470572 | 531470672 |
| 6B | 2015A | 4.063 | 0.01429 | 0.061 | 2.77 | IWB72854 | 130241883 | 130241983 |
| 6B | 2016R\_ WET | 4.411 | 0.00093 | 0.053 | 2.606 | IWB19912 | 95059978 | 95060046 |
| 7A | 2016R\_DRY | 3.5 | 0.01429 | 0.082 | -3.028 | IWA7741 | 579644500 | 579644700 |
| 7A | 2016R\_ WET | 3.97 | 0.00093 | 0.049 | -2.492 | IWA6562 | 641817495 | 641817695 |

**a** Proportion of explained variance of the trait.

**b** The adaptive effect of an allele calculated as one-half of the mean difference between homozygotes with and without the allele.

**Table S2.** Mean TKW of parental lines and segregating populations in the 9 independent studies used for the meta-QTL analysis.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Study | Population | Mean TKW (g) of the wild/emmerparent | Mean TKW (g) of the durum/emmer parent | Mean TKW (g) of the population | Type of cross |
| Elouafi and Nachit 2004 | BC1F8 RIL | 28.6 | 32.1 | 29.9 | DW **×** WEW |
| Peleg et al. 2011 | RIL | 42 | 46 | 42 | DW **×** WEW |
| Peng et al. 2003 | F3 | 10 | 30 | - | DW **×** WEW |
| Thanh et al. 2013 | F2 | 19 | 52 (emmer) | - | DEW **×** WEW |
| Faris et al. 2014 | RIL | 28.84 (emmer) | 55.12 | 40.84 | DW **×** DEW |
| Russo et al. 2014 | RIL | 58, 45.5 (emmer) | 74, 54.5 | 58.9, 56.9 | DW **×** DEW |
| Golan et al. 2015  | RIL | 42 | 49.7 | - | DW **×** WEW |
| Tzarfati et al 2014 | RIL | 48, 45 | 56, 51 | - | DW **×** WEW |
| Avni et al. 2018 | RIL | 45.8, 29.7 | 61.8, 56.5 | 49.6, 43.1 | DW **×** WEW |

**Table S3.** Significance of 6A TKW QTL between Svevo and Zavitan alleles in the RIL population. RILs were grouped by their parental allele at the peak QTL marker – IWB31050, significance was determined using a t-test. The table shows mean ± standard error.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Svevo Allele | Zavitan Allele | pv |
| 2016R-WL | 45.5±0.7 | 47.4±0.6 | 0.035 |
| 2016R- WET | 43.8±0.7 | 46.3±0.8 | 0.014 |
| 2014R | 48.1±0.8 | 51.4±0.9 | 0.005 |

**Table S4.** Genotypes used for allelic diversity study with molecular marker for the presence of *GRF4-Az* and *GRF4-Ag*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Label** | **Location** | **Accession** | **Species** | **Improvement status** | **GRF4\_allele** |
| WE-1 | Central Israel | PI 471021 | dicoccoides | wild | - |
| WE-2 | Northern Israel | PI 538673 | dicoccoides | wild | - |
| WE-4 | Central Israel | PI 471038 | dicoccoides | wild | - |
| WE-6 | Qazerin, Syria | PI 466946 | dicoccoides | wild | - |
| WE-7 | Northern Israel | Qazerin (UH 5) | dicoccoides | wild | - |
| WE-8 | Northern Israel | PI 466957 | dicoccoides | wild | - |
| WE-9 | Northern Israel | Nesher (UH 27) | dicoccoides | wild | - |
| WE-10 | Central Israel | PI 471060 | dicoccoides | wild | *GRF4-Az* |
| **WE-11** | **Northern Israel** | **Zavitan** | **dicoccoides** | **wild** | *GRF4-Az* |
| WE-12 | Northern, Israel | PI 467008 | dicoccoides | wild | *GRF4-Az* |
| WE-14 | Central Israel | PI 470962 | dicoccoides | wild | - |
| WE-15 | Central Israel | PI 466950 | dicoccoides | wild | - |
| WE-16 | Central Lebanon | PI 428132 | dicoccoides | wild | - |
| WE-17 | Central Lebanon | PI 352322 | dicoccoides | wild | - |
| WE-18 | Northern Israel | Mt. Hermon (UH 1) | dicoccoides | wild | - |
| WE-19 | Central Israel | Mt. Gerizim (UH 17) | dicoccoides | wild | - |
| WE-20 | Halab, Syria | PI 487264 | dicoccoides | wild | - |
| WE-21 | Iraq | Iraq (UH 41) | dicoccoides | wild | - |
| WE-22 | Central Lebanon | PI 428129 | dicoccoides | wild | - |
| WE-23 | Central Turkey | PI 428066 | dicoccoides | wild | - |
| WE-24 | Diyarbakir, Turkey | PI 428084 | dicoccoides | wild | - |
| WE-25 | Karacadag, Turkey | PI 538666 | dicoccoides | wild | - |
| WE-26 | Diyarbakir, Turkey | PI 428054 | dicoccoides | wild | - |
| WE-29 | Diyarbakir, Turkey | PI 538642 | dicoccoides | wild | - |
| WE-30 | Diyarbakir, Turkey | PI 428072 | dicoccoides | wild | - |
| WE-31 | Central Turkey | PI 428070 | dicoccoides | wild | - |
| WE-32 | Diyarbakir, Turkey | PI 428036 | dicoccoides | wild | - |
| WE-33 | Diyarbakir, Turkey | PI 428025 | dicoccoides | wild | - |
| WE-34 | Diyarbakir, Turkey | PI 538631 | dicoccoides | wild | - |
| G18-16 | Gitit, Israel |  | dicoccoides | wild | *GRF4-Ag* |
| DE-1 | Oman | PI 532302 | dicoccum | domesticated | - |
| DE-2 | India | PI 322232 | dicoccum | domesticated | - |
| DE-3 | Central Turkey | PI 319868 | dicoccum | domesticated | - |
| DE-4 | Central Turkey | PI 319869 | dicoccum | domesticated | - |
| DE-5 | Central Israel | PI 352347 | dicoccum | domesticated | - |
| DE-6 | Southern Turkey | PI 355454 | dicoccum | domesticated | - |
| DE-7 | Central Israel | PI 355496 | dicoccum | domesticated | - |
| DE-8 | Central Israel | PI 352357 | dicoccum | domesticated | - |
| DE-10 | Central Israel | PI 352367 | dicoccum | domesticated | - |
| DE-11 | Southern Turkey | PI 352352 | dicoccum | domesticated | - |
| DE-12 | Central Turkey | PI 182743 | dicoccum | domesticated | - |
| DE-14 | Italy | PI 352361 | dicoccum | domesticated | - |
| DE-15 | Spain | PI 191091 | dicoccum | domesticated | - |
| DE-16 | Spain | PI 276007 | dicoccum | domesticated | - |
| DE-17 | Central Turkey | PI 606325 | dicoccum | domesticated | - |
| DE-18 | Central Turkey | PI 352329 | dicoccum | domesticated | - |
| DE-19 | Ukraine | PI 94741 | dicoccum | domesticated | - |
| DE-20 | Slovenia | PI 377658 | dicoccum | domesticated | - |
| DE-21 | Croatia | PI 264964 | dicoccum | domesticated | - |
| DE-22 | Bosnia and Herzegovnia | PI 434995 | dicoccum | domesticated | - |
| DE-23 | Iran | PI 254158 | dicoccum | domesticated | - |
| DE-24 | Iran | PI 254169 | dicoccum | domesticated | - |
| DE-26 | Central Turkey | PI 470739 | dicoccum | domesticated | - |
| DE-27 | Central Turkey | PI 470738 | dicoccum | domesticated | - |
| DE-28 | Armenia | PI 94661 | dicoccum | domesticated | - |
| DE-29 | Central Turkey | PI 470737 | dicoccum | domesticated | - |
| DE-30 | Georgia | PI 326312 | dicoccum | domesticated | - |
| **DDW** | **Italy** | **Svevo** | **Durum** | **domesticated** | **-** |