

## Supplementary data:

# Wheat kernel dimensions: how do they contribute to kernel weight at an individual QTL level?

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**Table 1.** Unconditional QTL with significant additive effects for thousand-kernel weight and kernel dimensions in the WJ population.

| Trait <sup>a</sup>   | QTL <sup>b</sup>             | Interval <sup>c</sup>        | En. <sup>d</sup>          | LOD <sup>e</sup>         | PVE% <sup>f</sup>        | Add <sup>g</sup>              |                   |
|----------------------|------------------------------|------------------------------|---------------------------|--------------------------|--------------------------|-------------------------------|-------------------|
| TKW                  | <i>QTrw-WJ-1A.2</i>          | <i>Xbarc176.1-Xwmc333</i>    | E3/E4                     | 6.75/6.46                | 8.10/7.91                | 1.39/1.41                     |                   |
|                      | <i>QTrw-WJ-1A.1</i>          | <i>Xksun104-Xwmc781</i>      | E3                        | 2.62                     | 4.30                     | 0.91                          |                   |
|                      | <i>QTrw-WJ-2B.2</i>          | <i>Xwmc617.1-Xmag3798</i>    | E2/P                      | 2.75/2.93                | 2.25/3.11                | 0.73/0.76                     |                   |
|                      | <i>QTrw-WJ-2D-2.1</i>        | <i>Xwmc181.1-PPQ29.1</i>     | E2                        | 3.78                     | 2.90                     | -0.90                         |                   |
|                      | <i>QTrw-WJ-3B.3</i>          | <i>Xcfd3374.1-Xcfd3374.2</i> | E1/E2/P                   | 5.63/3.05/2.78           | 4.58/2.26/2.67           | 1.20/0.74/0.71                |                   |
|                      | <i>QTrw-WJ-3D.2</i>          | <i>BE7905.1-BE7905.2</i>     | E3/P                      | 2.59/2.87                | 2.06/1.97                | -0.65/-0.64                   |                   |
|                      | <i>QTrw-WJ-4A.5</i>          | <i>Xpsp3029-Xwmc161</i>      | E1/E2/E3/E4/P             | 6.20/3.01/3.02/3.85/5.61 | 5.29/2.36/2.59/4.00/4.55 | 1.27/0.75/0.69/0.89/0.87      |                   |
|                      | <b><i>QTrw-WJ-5B.4</i></b>   | <i>Xisrr854.1-Xwmc73</i>     | E1/E2/E4/P                | 4.22/5.98/5.97/5.61      | 3.35/4.22/4.75/4.00      | -1.09/-1.09/-1.03/-0.91       |                   |
|                      | <b><i>QTrw-WJ-5D-2.2</i></b> | <i>Xbarc133-Xcfe242.1</i>    | E3/E4                     | 3.64/3.68                | 2.93/5.57                | -0.73/-1.04                   |                   |
|                      | <i>QTrw-WJ-6A.5</i>          | <i>Xcfe273.2-Xcfe273.1</i>   | E1/E2/E3/E4/P             | 6.57/6.16/2.94/6.13/6.98 | 5.94/5.46/2.32/5.77/4.82 | -1.34/-1.14/-0.66/-1.06/-0.95 |                   |
|                      | <b><i>QTrw-WJ-7A.2a</i></b>  | <i>Xgwm473-Xedm16.1</i>      | E2/E4                     | 4.44/3.57                | 4.42/4.22                | -1.05/-0.93                   |                   |
|                      | <b><i>QTrw-WJ-7A.2b</i></b>  | <i>Xbarc176.2-Xcfe261</i>    | E3/P                      | 5.27/3.97                | 6.30/4.29                | -1.10/-0.91                   |                   |
|                      | <b><i>QTrw-WJ-7A.3</i></b>   | <i>ww160.2-Xbarc49.2</i>     | E1/E4/P                   | 2.91/3.38/6.28           | 2.20/2.56/4.24           | 0.84/0.72/0.91                |                   |
|                      | <b><i>QTrw-WJ-7B-2.3</i></b> | <i>Xbarc65-Xcfe75</i>        | E1/E2/P                   | 3.90/2.87/3.59           | 3.50/3.09/2.74           | 1.72/1.35/1.16                |                   |
|                      | KL                           | <i>QKI-WJ-1A.1</i>           | <i>Xedm80.4-Glu-a1</i>    | E1                       | 6.84                     | 11.99                         | 0.012             |
|                      |                              | <i>QKI-WJ-1B.2</i>           | <i>Xwmc134-Glu-b1</i>     | E1/P                     | 3.52/4.91                | 3.48/4.28                     | 0.006/0.007       |
|                      |                              | <i>QKI-WJ-1D-2.3</i>         | <i>Glu-d1-Xbarc346.1</i>  | E2/E4/P                  | 3.18/4.13/6.23           | 3.88/6.20/7.60                | 0.008/0.010/0.009 |
|                      |                              | <i>QKI-WJ-2A.1</i>           | <i>Xdupw210-Xgwm382.1</i> | E2                       | 2.52                     | 4.03                          | -0.007            |
|                      |                              | <i>QKI-WJ-2D-2.3</i>         | <i>Xcfd267-Xcfd44</i>     | E1/E3/P                  | 5.78/2.93/4.98           | 4.81/2.61/4.89                | 0.008/0.006/0.006 |
|                      |                              | <i>QKI-WJ-2D-2.1</i>         | <i>PPQ29.1-Xmag633</i>    | E1                       | 3.29                     | 3.97                          | -0.006            |
| <i>QKI-WJ-3B.5</i>   |                              | <i>Xbarc164-Xcfd53</i>       | E1/E2/E3/E4/P             | 6.86/6.23/4.32/6.81/7.32 | 7.71/8.18/3.94/7.97/7.21 | 0.009/0.010/0.007/0.010/0.007 |                   |
| <i>QKI-WJ-5A-1.2</i> |                              | <i>Xbarc165-Xcwm216</i>      | E3/P                      | 4.40/5.87                | 4.26/9.03                | 0.008/0.008                   |                   |
| <i>QKI-WJ-5B.4</i>   |                              | <i>Xisrr854.1-Xwmc73</i>     | E1/E3/E4/P                | 3.49/7.19/3.82/8.33      | 3.51/5.97/4.64/6.36      | -0.006/-0.010/-0.008/-0.007   |                   |
| <i>QKI-WJ-6A.1a</i>  |                              | <i>Xcfe87.1-Xswes123.2</i>   | P                         | 3.07                     | 2.41                     | 0.004                         |                   |
| <i>QKI-WJ-6A.1b</i>  |                              | <i>Xcfe273.2-Xcfe273.1</i>   | P                         | 3.29                     | 2.57                     | -0.004                        |                   |
| <i>QKI-WJ-6D.1</i>   |                              | <i>Xcfa2114-Xswes123.1</i>   | E3                        | 3.60                     | 4.87                     | -0.008                        |                   |

**Table 1** (contd.)

| Trait <sup>a</sup>    | QTL <sup>b</sup>       | Interval <sup>c</sup>        | En. <sup>d</sup>         | LOD <sup>e</sup>    | PVE% <sup>f</sup>       | Add <sup>g</sup>            |                             |
|-----------------------|------------------------|------------------------------|--------------------------|---------------------|-------------------------|-----------------------------|-----------------------------|
| KW                    | <i>QKw-WJ-1A.2</i>     | <i>Glu-a1-Xwmc333</i>        | E3/P                     | 3.08/3.94           | 3.98/3.15               | 0.007/0.004                 |                             |
|                       | <i>QKw-WJ-1D-2.1</i>   | <i>Glu-d1-Xbarc346.1</i>     | E2                       | 4.05                | 4.44                    | 0.006                       |                             |
|                       | <i>QKw-WJ-2A.1</i>     | <i>Xgwm382.3-Xbarc212</i>    | E4                       | 5.04                | 5.30                    | 0.005                       |                             |
|                       | <i>QKw-WJ-2B.1</i>     | <i>Xcfe230-Xwmc617.1</i>     | E1                       | 2.84                | 3.41                    | 0.004                       |                             |
|                       | <i>QKw-WJ-2D-2.1</i>   | <i>Xcfd168.1-STSO1</i>       | E2                       | 3.34                | 2.85                    | -0.004                      |                             |
|                       | <i>QKw-WJ-3A.1</i>     | <i>Xswes185-Xmag896.1</i>    | E3                       | 4.77                | 4.62                    | -0.006                      |                             |
|                       | <i>QKw-WJ-3B.2</i>     | <i>Xcfe3374.1-Xcfe3374.2</i> | E1/P                     | 3.82/2.73           | 3.62/3.08               | 0.004/0.003                 |                             |
|                       | <i>QKw-WJ-3B.1</i>     | <i>Xcfe3374.3-Xbarc164</i>   | E3                       | 2.63                | 2.39                    | 0.004                       |                             |
|                       | <i>QKw-WJ-3D.1</i>     | <i>BE7905.1-BE7905.2</i>     | E2                       | 3.37                | 2.92                    | -0.004                      |                             |
|                       | <i>QKw-WJ-5A-3.3</i>   | <i>Xwmc524-Xcfe29</i>        | E2/E4/P                  | 5.43/3.55/5.17      | 7.83/5.62/5.17          | 0.006/0.004/0.004           |                             |
|                       | <i>QKw-WJ-5D-2.1</i>   | <i>Xbarc133-Xcfe242.1</i>    | P                        | 4.20                | 6.68                    | -0.005                      |                             |
|                       | <i>QKw-WJ-6A.4</i>     | <i>Xcfe273.2-Xcfe273.1</i>   | E1/E3/E4/P               | 3.33/3.79/3.95/6.93 | 3.45/4.09/4.02/6.56     | -0.004/-0.006/-0.004/-0.004 |                             |
|                       | <i>QKw-WJ-7B-1.1</i>   | <i>Xcfe233-Xissr844.2</i>    | E4                       | 2.51                | 3.96                    | 0.004                       |                             |
|                       | <i>QKdr-WJ-1D-2.1a</i> | <i>Xswes226.1-Xwmc429.4</i>  | E2                       | 2.52                | 2.97                    | 0.040                       |                             |
|                       | <i>QKdr-WJ-1D-2.1b</i> | <i>Xwmc429.4-Xwmc429.3</i>   | E3                       | 3.27                | 4.32                    | -0.037                      |                             |
|                       | KDR                    | <i>QKdr-WJ-2A.4</i>          | <i>Xgwm382.3-Xgwm558</i> | E1/E2/E4/P          | 2.84/2.90/3.26/3.67     | 3.95/2.96/4.19/4.02         | -0.030/-0.030/-0.026/-0.024 |
|                       |                        | <i>QKdr-WJ-2D-2.3</i>        | <i>Xcfd267-cfd44</i>     | E1/E2/P             | 3.55/2.80/4.37          | 3.97/3.44/4.36              | 0.030/0.027/0.025           |
| <i>QKdr-WJ-3A.3</i>   |                        | <i>Xmag896.2-Xmag896.1</i>   | E1/E3/P                  | 4.57/8.36/7.28      | 4.22/7.42/5.88          | 0.033/0.047/0.028           |                             |
| <i>QKdr-WJ-3B.3</i>   |                        | <i>Xbarc164-Xcfe53</i>       | E3/E4/P                  | 2.79/6.72/4.78      | 2.47/6.63/4.00          | 0.027/0.031/0.032           |                             |
| <i>QKdr-WJ-5A-1.4</i> |                        | <i>Xbarc165-Xcwm216</i>      | E1/E3/E4/P               | 6.70/4.05/4.00/7.51 | 14.94/13.49/14.96/15.08 | 0.057/0.042/0.050/0.045     |                             |
| <i>QKdr-WJ-5A-3.3</i> |                        | <i>Xwmc524-Xcfe29</i>        | E2/E4/P                  | 4.21/4.11/3.13      | 8.62/5.00/4.54          | -0.042/-0.027/-0.024        |                             |
| <i>QKdr-WJ-5B.1a</i>  |                        | <i>Xmag467-Xcfe74</i>        | E2                       | 2.55                | 3.80                    | -0.028                      |                             |
| <i>QKdr-WJ-5B.1b</i>  |                        | <i>Xissr854.1-wmc73</i>      | E4                       | 2.89                | 3.56                    | -0.024                      |                             |
| <i>QKdr-WJ-6B.2</i>   |                        | <i>Xswes131.4-Xswes131.3</i> | E3/P                     | 5.72/3.94           | 5.48/3.45               | -0.040/-0.021               |                             |
| <i>QKdr-WJ-6D.1</i>   |                        | <i>Xissr844.1-Xissr817</i>   | E4                       | 2.88                | 3.28                    | -0.024                      |                             |

<sup>a</sup>TKW, thousand-kernel weight; KL, kernel length; KW, kernel width; KDR, kernel diameter ratio.

<sup>b</sup>The assignment of a QTL name is named according to the following rules: italic upper case 'Q' denotes 'QTL'; letters following it are the abbreviation of the corresponding trait; the next upper case letters sandwiched the two dashes '-' indicates the population in which the corresponding QTL was detected; next, a numeral plus an upper case letter, 'A', 'B' or 'D', indicates the wheat chromosome on which the corresponding QTL was detected; if a break occurred on a chromosome, a dash '-' plus a numeral are placed as suffixes to distinguish different segments of the corresponding chromosome; the last numeral after a period denotes the number of environments in which the corresponding QTL was detected; and if the name of two different QTL for the same trait look the same, a lower case letter is used to distinguish them. An unconditional QTL that still showed significance in conditional analysis in a trial, in which it did not show significance in unconditional analysis, is marked by bold typeface.

<sup>c</sup>Flanking markers of the QTL.

<sup>d</sup>Environments in which the corresponding QTL was detected; for additional details, see the notes in table 1. In addition, P represents the pooled environment in which the average data were calculated from the above four trials.

<sup>e</sup>LOD value of the corresponding putative additive QTL.

<sup>f</sup>Phenotypic variance explained by the corresponding putative additive QTL.

<sup>g</sup>Additive effect of the corresponding putative additive QTL; positive values indicate Weimai 8 alleles that increase the value of the corresponding trait, and conversely, negative values indicate Weimai 8 alleles decrease it.

**Table 2.** Unconditional QTL with significant additive effects for thousand-kernel weight and kernel dimensions in the WY population.

| Trait <sup>a</sup>  | QTL <sup>b</sup>                        | Interval <sup>c</sup>          | En. <sup>d</sup>             | LOD <sup>e</sup>         | PVE% <sup>f</sup>         | Add <sup>g</sup>                   |                             |
|---------------------|-----------------------------------------|--------------------------------|------------------------------|--------------------------|---------------------------|------------------------------------|-----------------------------|
| TKW                 | <b>QTKw-WY-2A.1</b>                     | <i>Xissr848–Xgwm372</i>        | E1                           | 3.95                     | 6.72                      | –1.32                              |                             |
|                     | <i>QTKw-WY-2A.3</i>                     | <i>Xcfd2263–Xpsp3029.1</i>     | E3/E4/P                      | 4.05/5.34/6.39           | 8.01/9.93/12.60           | 1.15/1.47/1.29                     |                             |
|                     | <b>QTKw-WY-2B-1.3</b>                   | <i>Xcinau119.1–Xcinau119.2</i> | E1/E3/P                      | 2.67/2.76/4.22           | 8.36/9.21/14.79           | –1.46/–1.23/–1.40                  |                             |
|                     | <i>QTKw-WY-6B.2</i>                     | <i>Lr9–Xcwm104</i>             | E1/P                         | 2.95/2.80                | 7.44/7.15                 | –1.38/–0.97                        |                             |
|                     | <i>QTKw-WY-6B.1</i>                     | <i>Xgwm88.2–Xswes131.2</i>     | E2                           | 2.65                     | 6.05                      | 0.95                               |                             |
|                     | <i>QTKw-WY-6D.2</i>                     | <i>Xcfe127–Xswes123.1</i>      | E1/E2                        | 3.02/2.88                | 5.48/5.98                 | –1.18/–0.94                        |                             |
|                     | <b>QTKw-WY-7B.1a</b>                    | <i>Xcau12.4–ww121</i>          | E3                           | 3.38                     | 10.23                     | –1.29                              |                             |
|                     | <i>QTKw-WY-7B.1b</i>                    | <i>Xwmc338–Xswes209.1</i>      | E4                           | 2.87                     | 5.11                      | –1.13                              |                             |
|                     | <i>QTKw-WY-7D.1</i>                     | <i>Xissr814.2–Xswm5.1</i>      | E4                           | 3.16                     | 5.69                      | –1.15                              |                             |
|                     | KL                                      | <i>QKI-WY-3A.1</i>             | <i>Xme3em1.1–Xbarc1040</i>   | P                        | 3.11                      | 4.00                               | –0.007                      |
|                     |                                         | <i>QKI-WY-6A.1a</i>            | <i>Xwmc580.2–Xwmc580.1</i>   | E3                       | 3.98                      | 6.95                               | –0.011                      |
|                     |                                         | <i>QKI-WY-6A.1b</i>            | <i>Xme3em2. –Xpsp3152</i>    | P                        | 3.32                      | 4.28                               | –0.006                      |
|                     |                                         | <i>QKI-WY-6B.4</i>             | <i>Xswes180.1–Xmag3469</i>   | P                        | 5.78/5.12/5.64/4.51       | 10.87/11.64/10.58/7.78             | –0.012/–0.014/–0.013/–0.009 |
|                     |                                         | <i>QKI-WY-6B.2</i>             | <i>Xbarc146–Xgwm88.1</i>     | E3/P                     | 7.94/5.25                 | 12.95/6.80                         | –0.013/–0.008               |
|                     |                                         | <i>QKI-WY-6D.3</i>             | <i>Xswes123.6–Xswes123.2</i> | E1/E2/P                  | 3.38/3.43/5.43            | 5.90/6.70/7.08                     | –0.009/–0.010/–0.008        |
|                     |                                         | <i>QKI-WY-6D.1</i>             | <i>Xswes123.9–Xcfe87.2</i>   | E3                       | 4.35                      | 7.79                               | –0.011                      |
|                     |                                         | <i>QKw-WY-1A.1a</i>            | <i>Be470813.3–Xbarc176</i>   | P                        | 5.28                      | 11.89                              | 0.005                       |
| <i>QKw-WY-1A.1b</i> |                                         | <i>Glu-a1–Xgdm93</i>           | E2                           | 4.02                     | 10.08                     | –0.007                             |                             |
| <i>QKw-WY-1A.1c</i> |                                         | <i>Xcfe26.3–Xcwm109.5</i>      | E4                           | 2.82                     | 17.29                     | 0.008                              |                             |
| KDR                 | <i>QKw-WY-1A.2</i>                      | <i>ww114.2–Xwmc120</i>         | E3/P                         | 3.62/4.46                | 7.43/9.17                 | 0.005/0.004                        |                             |
|                     | <i>QKw-WY-4B-1.1</i>                    | <i>Xgwm66.2–Xgwm66.1</i>       | E2                           | 2.95                     | 5.61                      | –0.006                             |                             |
|                     | <i>QKw-WY-5D.1</i>                      | <i>Xbarc130–Xbarc144</i>       | E3                           | 4.63                     | 11.01                     | –0.006                             |                             |
|                     | <i>QKw-WY-6A.1</i>                      | <i>Xswes123.2–Xcfe179.2</i>    | E1                           | 2.65                     | 6.29                      | 0.005                              |                             |
|                     | <i>QKw-WY-6B.1a</i>                     | <i>Xwmc473–Xbarc146</i>        | P                            | 2.59                     | 4.71                      | 0.003                              |                             |
|                     | <i>QKw-WY-6B.1b</i>                     | <i>Xwmc737–Xcwm29.1</i>        | E2                           | 4.11                     | 9.09                      | 0.006                              |                             |
|                     | <i>QKdr-WY-1A.1a</i>                    | <i>Glu-a1–Xgdm93</i>           | E2                           | 2.66                     | 6.19                      | 0.042                              |                             |
|                     | <i>QKdr-WY-1A.1b</i>                    | <i>ww127.3–ww114.2</i>         | E3                           | 3.72                     | 5.36                      | –0.035                             |                             |
|                     | <i>QKdr-WY-1A.1c</i>                    | <i>Xbarc28.1–Xcfe257.4</i>     | P                            | 4.42                     | 7.05                      | –0.032                             |                             |
|                     | <i>QKdr-WY-1D.2</i>                     | <i>Xmag3478–Xme3em2.4</i>      | E2/P                         | 4.72/3.31                | 8.91/5.20                 | –0.055/–0.032                      |                             |
|                     | <i>QKdr-WY-2A.2</i>                     | <i>Xwmc453–Xbarc212</i>        | E1/P                         | 5.20/2.69                | 8.96/5.16                 | –0.050/–0.031                      |                             |
|                     | <i>QKdr-WY-2D.1</i>                     | <i>Xbarc228–Xwmc181.1</i>      | E3                           | 3.01                     | 4.53                      | 0.034                              |                             |
|                     | <i>QKdr-WY-6A.1</i>                     | <i>Xcwm17.1–Xmag3273</i>       | P                            | 3.27                     | 4.05                      | –0.025                             |                             |
|                     | <i>QKdr-WY-6B.1</i>                     | <i>Xswes123.2–Xcfe179.2</i>    | E1                           | 5.52                     | 17.78                     | –0.060                             |                             |
|                     | <i>QKdr-WY-6B.5</i>                     | <i>Xwmc517.3–Xbarc153</i>      | E2                           | 2.83                     | 7.78                      | 0.045                              |                             |
|                     | <i>QKdr-WY-6D.3</i>                     | <i>Xbarc146–Xgwm88.1</i>       | E1/E2/E3/E4/P                | 2.84/3.22/9.53/4.51/5.94 | 5.24/5.25/13.97/7.69/7.60 | –0.037/–0.043/–0.066/–0.052/–0.039 |                             |
|                     | <i>QKdr-WY-7B.1</i>                     | <i>Xswes123.6–Xswes123.2</i>   | E2/E4/P                      | 4.91/3.65/5.81           | 7.42/6.34/7.71            | –0.049/–0.044/–0.038               |                             |
| <i>QKdr-WY-7D.1</i> | <i>BF–Xwmc76</i><br><i>Xcfd4–Xgwm44</i> | E4<br>E3                       | 3.93<br>4.54                 | 7.64<br>6.56             | 0.044<br>0.039            |                                    |                             |

See table 1 in electronic supplementary material for title descriptions.