Supplementary Figure 1 The phenotype diagram for seed length (SL), seed width (SW) and seed thickness (ST) of parent lines. The letter "G" indicates the female parent Guizao1, and the letter "B" indicates the male parent B13.

Supplementary Table 1 QTLs identified for seed length trait in GB13 RIL across different environments

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| QTL | Chra | Interval | Position (bp) | Position (cM) | LODb | ADDc | PVE (%)d | Env.e | References |
| *qSL-2-1* | 2 | bin143-bin145 | 39848223-39987461 | 130.2 | 2.95 | -0.08 | 4.34 | 19GZ | （Kumawat et al. 2021） |
| *qSL-3-1* | 3 | bin32-bin43 | 4387438-6456915 | 35.3 | 9.37 | 0.15 | 13.57 | 18ZC |  |
|  |  |  |  | 38.4 | 4.61 | 0.09 | 6.61 | 20ZC |  |
|  |  |  |  | 43.1 | 7.49 | 0.11 | 11.93 | 19ZC |  |
|  |  |  |  | 43.1 | 4.03 | 0.09 | 6.03 | 19GZ |  |
|  |  |  |  | 43.1 | 11.45 | 0.11 | 15.91 | CE |  |
|  |  |  |  | 45 | 3.15 | 0.08 | 4.38 | 20GZ |  |
| *qSL-3-2* | 3 | bin51-bin55 | 8784766-17199876 | 49.4 | 6.42 | 0.11 | 9.07 | 20ZC |  |
|  |  |  |  | 49.4 | 10.38 | 0.11 | 14.56 | CE |  |
|  |  |  |  | 50.6 | 7.63 | 0.11 | 12.15 | 19ZC |  |
| *qSL-3-3* | 3 | bin75-bin77 | 31674416-33137748 | 59.2 | 3.51 | 0.08 | 4.86 | 20GZ | （Cui et al. 2020） |
| *qSL-4-1* | 4 | bin39-bin41 | 5744948-5838921 | 34.7 | 3.65 | 0.08 | 4.97 | 20ZC | （Yang et al. 2017） |
| *qSL-4-2* | 4 | bin74-bin76 | 9040807-9546369 | 57.5 | 3.44 | 0.06 | 4.36 | CE | （Salas et al. 2006；Hina et al. 2020） |
| *qSL-4-3* | 4 | bin162-bin164 | 49786918-49996727 | 116.4 | 3.27 | 0.09 | 4.46 | 18ZC | （Cui et al. 2020） |
| *qSL-5-1* | 5 | bin100-bin102 | 34370060-34917661 | 90.3 | 2.94 | 0.06 | 3.9 | 19ZC |  |

Supplementary Table 1 continued

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| QTL | Chra | Interval | Position (bp) | Position (cM) | LODb | ADDc | PVE (%)d | Env.e | References |
| *qSL-6-1* | 6 | bin1-bin2 | 1-989938 | 0 | 4.12 | 0.09 | 5.79 | 20GZ |  |
| *qSL-6-2* | 6 | bin31-bin33 | 4933392-5729762 | 38.1 | 2.72 | 0.05 | 3.51 | CE | （Xu et al. 2011；Hina et al. 2020） |
| *qSL-8-1* | 8 | bin147-bin149 | 39509026-42016655 | 128.1 | 2.81 | 0.08 | 3.84 | 18ZC |  |
| *qSL-11-1* | 11 | bin106-bin108 | 27762029-28460697 | 104.7 | 4.08 | -0.09 | 5.66 | 20GZ | （Cui et al. 2020） |
| *qSL-11-2* | 11 | bin134-bin135 | 33570965-33658063 | 139.7 | 3.58 | 0.08 | 5.04 | 20GZ | （Niu et al. 2013） |
| *qSL-13-1* | 13 | bin115-bin117 | 27473391-27671175 | 90 | 2.55 | 0.08 | 3.47 | 18ZC |  |
|  |  |  |  | 90 | 3.03 | 0.07 | 4.12 | 20ZC |  |
|  |  |  |  | 90 | 3.54 | 0.06 | 4.47 | CE |  |
| *qSL-17-1* | 17 | bin8-bin10 | 1909481-2137276 | 16.2 | 3.03 | 0.07 | 4.09 | 20ZC |  |
| *qSL-17-2* | 17 | bin49-bin51 | 7320307-8459319 | 54.2 | 3.44 | 0.06 | 4.36 | CE |  |
| *qSL-18-1* | 18 | bin19-bin21 | 2460215-2936665 | 13 | 4.58 | 0.09 | 6.45 | 20GZ |  |
| *qSL-18-2* | 18 | bin29-bin30 | 3254606-3692649 | 18.5 | 4.77 | 0.1 | 6.69 | 20GZ | （Xu et al. 2011） |
| *qSL-20-1* | 20 | bin153-bin162 | 41990737-44864841 | 129.5 | 2.71 | 0.05 | 3.22 | CE | （Kumawat et al. 2021） |
|  |  |  |  | 139.7 | 2.68 | 0.06 | 3.56 | 19ZC |

aChromosome. bThe log of odds (LOD) value at the peak likelihood of QTL. dPhenotypic variation explained. eEnvironment.

Supplementary Table 2 QTLs identified for seed width trait in GB13 RIL across different environments

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| QTL | Chra | Interval | Position (bp) | Position (cM) | LODb | ADDc | PVE (%)d | Env.e | References |
| *qSW-2-1* | 2 | bin97-bin101 | 14922813-15587115 | 93.9 | 2.74 | -0.04 | 3.14 | CE | （Niu et al. 2013；Yang et al. 2017） |
|  |  |  |  | 100.8 | 3.4 | -0.07 | 4.93 | 19GZ |
| *qSW-2-2* | 2 | bin157-bin159 | 41365389-41705254 | 141.4 | 3.34 | -0.06 | 4.53 | 18ZC | （Hina et al. 2020） |
| *qSW-4-1* | 4 | bin19-bin19 | 2707907-4097410 | 24.2 | 3.75 | -0.07 | 5.19 | 19GZ | （Yang et al. 2017） |
| *qSW-4-2* | 4 | bin77-bin79 | 9159728-10115048 | 64.4 | 2.97 | 0.06 | 3.78 | 18ZC |  |
|  |  |  |  | 64.4 | 3.24 | 0.04 | 3.7 | CE |  |
| *qSW-9-1* | 9 | bin14-bin16 | 3371562-3979304 | 24.9 | 2.76 | 0.04 | 3.43 | CE | （Hina et al. 2020） |
| *qSW-10-1* | 10 | bin29-bin31 | 3306301-3873671 | 20.5 | 2.7 | -0.05 | 3.34 | 19ZC | （Xu et al. 2011） |
| *qSW-11-1* | 11 | bin95-bin100 | 15151676-18213414 | 100.1 | 5.14 | -0.05 | 6.34 | CE |  |
|  |  |  |  | 101 | 5.23 | -0.08 | 7.48 | 20GZ |  |
|  |  |  |  | 101.7 | 2.9 | -0.06 | 3.89 | 18ZC |  |
| *qSW-11-2* | 11 | bin108-bin110 | 28193727-29598942 | 106.1 | 4.73 | -0.07 | 6.8 | 20GZ |  |
| *qSW-12-1* | 12 | bin95-bin97 | 33432791-35013253 | 93.7 | 4.35 | 0.05 | 6.4 | CE |  |
| *qSW-12-2* | 12 | bin103-bin109 | 35464404-36328576 | 106 | 4.37 | 0.06 | 5.79 | 19ZC |  |
|  |  |  |  | 111.1 | 2.83 | 0.05 | 3.69 | 20ZC |  |
|  |  |  |  |  | 4.36 | 0.05 | 5.39 | CE |  |
| *qSW-14-1* | 14 | bin118-bin120 | 32052002-32660037 | 116.2 | 3.12 | -0.04 | 3.86 | CE |  |
| *qSW-14-2* | 14 | bin148-bin150 | 42605675-42819236 | 129.3 | 3.97 | -0.05 | 4.88 | CE |  |
| *qSW-15-1* | 15 | bin16-bin18 | 3955219-4264223 | 22.8 | 2.87 | 0.05 | 3.81 | 19ZC | （Yang et al. 2017） |
| *qSW-15-2* | 15 | bin24-bin26 | 4706262-5531628 | 28 | 2.9 | 0.06 | 3.97 | 19GZ |  |

Supplementary Table 2 continued

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| QTL | Chra | Interval | Position (bp) | Position (cM) | LODb | ADDc | PVE (%)d | Env.e | References |
| *qSW-15-3* | 15 | bin29-bin31 | 5944971-7199234 | 34.2 | 3.59 | 0.06 | 4.74 | 19ZC |  |
| *qSW-17-1* | 17 | bin40-bin42 | 4938708-5526049 | 44.2 | 2.79 | 0.04 | 3.52 | CE |  |
| *qSW-18-1* | 18 | bin237-bin239 | 55133917-55281850 | 152.4 | 3.72 | 0.05 | 4.91 | 19ZC |  |
|  |  |  |  |  | 3.24 | 0.04 | 3.91 | CE |  |
|  |  |  |  | 153 | 4.03 | 0.07 | 5.62 | 18ZC |  |
| *qSW-18-2* | 18 | bin250-bin252 | 56079924-56416403 | 158 | 5.28 | 0.08 | 7.3 | 18ZC |  |
|  |  |  |  |  | 3.68 | 0.05 | 4.86 | 19ZC |
| *qSW-20-1* | 20 | bin37-bin39 | 3056426-3144885 | 44.8 | 4.78 | -0.07 | 6.77 | 20GZ | （Yang et al. 2017） |
| *qSW-20-2* | 20 | bin46-bin53 | 5369281-12095409 | 47.5 | 6.24 | -0.07 | 8.64 | 19ZC |  |
|  |  |  |  | 49.1 | 5.3 | -0.08 | 7.46 | 18ZC |  |
|  |  |  |  | 51.5 | 8.29 | -0.1 | 11.8 | 19GZ |  |
| *qSW-20-3* | 20 | Bin64-bin68 | 27890104-31573673 | 55.3 | 15.04 | -0.14 | 21.93 | 20ZC |  |
|  |  |  |  | 55.3 | 15.24 | -0.1 | 20.89 | CE |  |
|  |  |  |  | 55.9 | 6.63 | -0.09 | 9.22 | 18ZC |  |
|  |  |  |  | 55.9 | 7.89 | -0.08 | 10.79 | 19ZC |  |
| *qSW-20-4* | 20 | bin84-bin86 | 34383022-34599659 | 64.2 | 2.65 | -0.05 | 3.8 | 19ZC |  |
|  |  |  |  | 64.2 | 4.56 | -0.09 | 7.3 | 20ZC |  |
|  |  |  |  | 64.2 | 3.86 | -0.05 | 5.81 | CE |  |
| *qSW-20-5* | 20 | bin142-bin146 | 38972351-41472016 | 114.1 | 5.15 | 0.08 | 7.04 | 18ZC | （Xu et al. 2011） |
|  |  |  |  | 121.6 | 2.67 | 0.04 | 3.42 | CE |  |

aChromosome. bThe log of odds (LOD) value at the peak likelihood of QTL. dPhenotypic variation explained. eEnvironment.

Supplementary Table 3 QTLs identified for seed thickness trait in GB13 RIL across different environments

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| QTL | Chra | Interval | Position (bp) | Position (cM) | LODb | ADDc | PVE (%)d | Env.e | References |
| *qST-4-1* | 4 | bin14-bin16 | 3371562-3979304 | 20.3 | 6.71 | 0.08 | 9.6 | 20ZC |  |
| *qST-4-2* | 4 | bin31-bin33 | 4820821-5222780 | 28.5 | 5.39 | 0.07 | 7.4 | 20ZC |  |
| *qST-4-3* | 4 | bin77-bin83 | 9546370-12316836 | 63.6 | 5.44 | 0.08 | 8.61 | 19GZ |  |
|  |  |  |  | 65.2 | 4.7 | 0.04 | 6.1 | CE |  |
|  |  |  |  | 66 | 3.18 | 0.06 | 4.86 | 18ZC |  |
| *qST-4-4* | 4 | bin131-bin133 | 46448812-46832786 | 87.1 | 2.76 | -0.04 | 3.33 | CE | （Niu et al. 2013） |
| *qST-5-1* | 5 | bin29-bin31 | 5480651-5715897 | 44.6 | 2.76 | -0.08 | 4.39 | 19GZ |  |
| *qST-5-2* | 5 | bin155-bin158 | 41674961-42084084 | 134.9 | 2.89 | -0.04 | 3.69 | CE | （Niu et al. 2013） |
|  |  |  |  | 135.1 | 3.13 | -0.06 | 4.52 | 20GZ |
|  |  |  |  | 135.6 | 3.06 | -0.06 | 4.67 | 18ZC |
| *qST-6-1* | 6 | bin4-bin6 | 1104402-1376019 | 3.5 | 2.7 | 0.05 | 3.88 | 20GZ | （Xu et al. 2011） |
| *qST-7-1* | 7 | bin154-bin161 | 35395660-36554645 | 136.4 | 4.06 | 0.06 | 5.75 | 20ZC |  |
|  |  |  |  | 139.9 | 5.37 | 0.05 | 6.99 | CE |  |
|  |  |  |  | 140.8 | 2.69 | 0.05 | 3.85 | 20GZ |  |

Supplementary Table 3 continued

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| QTL | Chra | Interval | Position (bp) | Position (cM) | LODb | ADDc | PVE (%)d | Env.e | References |
| *qST-11-1* | 11 | bin108-bin110 | 28193727-29598942 | 106.1 | 4.57 | -0.07 | 6.7 | 20GZ |  |
| *qST-11-2* | 11 | bin134-bin135 | 33570965-33658063 | 139.1 | 5.99 | 0.09 | 8.92 | 20GZ |  |
| *qST-13-1* | 13 | bin115-bin117 | 27473391-27671175 | 90 | 2.92 | 0.04 | 3.82 | CE | （Hina et al. 2020） |
| *qST-13-2* | 13 | bin132-bin134 | 29638488-30044281 | 99.5 | 4.16 | 0.04 | 5.38 | CE |  |
| *qST-13-3* | 13 | bin143-bin149 | 31125816-32078884 | 103.2 | 3.74 | 0.06 | 5.52 | 19ZC |  |
|  |  |  |  | 104.6 | 3.27 | 0.06 | 5.09 | 19GZ |
|  |  |  |  | 105.1 | 3.5 | 0.04 | 4.56 | CE |
| *qST-13-4* | 13 | bin210-bin212 | 41247693-41446366 | 164.9 | 3.42 | 0.06 | 5.21 | 18ZC |  |
| *qST-15-1* | 15 | bin30-bin32 | 6130184-7229125 | 35.1 | 2.97 | 0.05 | 4.33 | 19ZC |  |
| *qST-20-1* | 20 | bin38-bin44 | 3056426-4919680 | 44.8 | 2.71 | -0.05 | 3.68 | 20GZ |  |
|  |  |  |  | 46.8 | 4.07 | -0.04 | 5.4 | CE |
| *qST-20-2* | 20 | bin67-bin69 | 28731837-32801623 | 55.9 | 5.77 | -0.05 | 7.55 | CE |  |
| *qST-20-3* | 20 | bin81-bin82 | 34185019-34291632 | 62.9 | 2.84 | -0.05 | 4.15 | 19ZC |  |
|  |  |  |  | 63.4 | 3.92 | -0.04 | 5.22 | CE | （Xu et al. 2011） |

aChromosome. bThe log of odds (LOD) value at the peak likelihood of QTL. dPhenotypic variation explained. eEnvironment.

Supplementary Table 4 QTLs identified for 100-seed weight trait in GB13 RIL across different environments

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| QTL | Chra | Interval | Position (bp) | Position (cM) | LODb | ADDc | PVE (%)d | Env.e | References |
| *qHSW-1-1* | 1 | bin12-bin14 | 1696769-1911204 | 9.9 | 2.74 | -0.48 | 3.68 | 18ZC |  |
| *qHSW-3-1* | 3 | bin39-bin41 | 5378498-5821215 | 43.1 | 2.69 | 0.33 | 3.77 | 19ZC |  |
|  |  |  |  | 43.1 | 4.82 | 0.35 | 6.07 | CE |  |
| *qHSW-3-2* | 3 | bin53-bin55 | 9825422-17199876 | 50.1 | 3.2 | 0.37 | 4.41 | 20ZC |  |
|  |  |  |  | 50.1 | 5.43 | 0.37 | 6.81 | CE |  |
|  |  |  |  | 50.6 | 3.68 | 0.38 | 5.12 | 19ZC |  |
| *qHSW-3-3* | 3 | bin66-bin68 | 28943719-29501827 | 56.4 | 3.11 | 0.42 | 4.88 | 19GZ |  |
| *qHSW-4-1* | 4 | bin39-bin41 | 5744948-5838921 | 34.7 | 6.94 | 0.56 | 9.81 | 20ZC |  |
| *qHSW-4-2* | 4 | bin75-bin78 | 9159728-9824768 | 57.5 | 3.25 | 0.37 | 4.68 | 19ZC |  |
|  |  |  |  | 57.5 | 4.18 | 0.33 | 5.28 | CE |  |
|  |  |  |  | 64.4 | 3.75 | 0.59 | 5.34 | 18ZC |  |
| *qHSW-4-3* | 4 | bin152-bin154 | 48442371-48908321 | 104.7 | 2.85 | 0.51 | 4.09 | 18ZC | （Teng et al. 2009；Kato et al. 2014） |
| *qHSW-6-1* | 6 | bin4-bin6 | 1104402-1376019 | 3.5 | 5.09 | 0.55 | 7.18 | 20GZ |  |
| *qHSW-11-1* | 11 | bin72-bin74 | 11002248-11089313 | 71.9 | 2.93 | -0.51 | 4.15 | 18ZC |  |
| *qHSW-11-2* | 11 | bin108-bin110 | 28193727-29598942 | 106.1 | 4.98 | -0.54 | 6.91 | 20GZ |  |
| *qHSW-11-3* | 11 | bin131-bin134 | 32796587-33617864 | 129.5 | 2.56 | 0.32 | 3.33 | 20ZC |  |
|  |  |  |  | 133.1 | 2.99 | 0.42 | 4.9 | 19GZ |  |
|  |  |  |  | 133.1 | 3.41 | 0.31 | 4.41 | CE |  |
|  |  |  |  | 139.1 | 5.76 | 0.59 | 8.26 | 20GZ |  |

Supplementary Table 4 continued

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| QTL | Chra | Interval | Position (bp) | Position (cM) | LODb | ADDc | PVE (%)d | Env.e | References |
| *qHSW-13-1* | 13 | bin115-bin116 | 27473391-27540372 | 89.1 | 3.79 | 0.4 | 5.19 | 20ZC |  |
|  |  |  |  | 90 | 2.91 | 0.39 | 4.34 | 19GZ |  |
|  |  |  |  | 90.1 | 5.69 | 0.38 | 7.21 | CE |  |
| *qHSW-13-2* | 13 | bin132-bin134 | 29638488-30044281 | 97.9 | 3.13 | 0.29 | 4.11 | CE | （Teng et al. 2009） |
| *qHSW-13-3* | 13 | bin233-bin235 | 43433420-45874162 | 188.9 | 4.47 | 0.43 | 6.27 | 19ZC |  |
| *qHSW-14-1* | 14 | bin148-bin150 | 42605675-42819236 | 128.5 | 3.02 | -0.27 | 3.52 | CE |  |
| *qHSW-15-1* | 15 | bin24-bin26 | 4706262-5531628 | 28 | 2.83 | 0.39 | 4.21 | 19GZ |  |
| *qHSW-16-1* | 16 | bin186-bin188 | 36238318-36478110 | 113.9 | 2.77 | -0.4 | 3.81 | 20GZ |  |
| *qHSW-17-1* | 17 | bin40-bin42 | 4938708-5526049 | 44.2 | 3.36 | 0.39 | 5.06 | 19ZC |  |
| *qHSW-17-2* | 17 | bin51-bin53 | 7579564-9011168 | 60.6 | 4.53 | 0.34 | 5.69 | CE | （Teng et al. 2009；Kato et al. 2014） |
| *qHSW-18-1* | 18 | bin29-bin30 | 3254606-3692649 | 18.2 | 3.2 | 0.43 | 4.41 | 20GZ |  |
| *qHSW-20-1* | 20 | bin26-bin28 | 2146582-2308673 | 39 | 3.33 | -0.55 | 4.74 | 18ZC | （Han et al. 2012；Kato et al. 2014） |
| *qHSW-20-2* | 20 | bin42-bin43 | 4610581-4735006 | 45.9 | 2.79 | -0.39 | 4.25 | 19GZ |  |
| *qHSW-20-3* | 20 | bin68-bin73 | 31482024-33222868 | 55.9 | 4.06 | -0.47 | 6.12 | 19GZ |  |
|  |  |  |  | 55.9 | 5.7 | -0.38 | 7.21 | CE |  |
|  |  |  |  | 56.1 | 3.42 | -0.38 | 4.68 | 20ZC |  |
|  |  |  |  | 56.8 | 2.52 | -0.31 | 3.31 | 19ZC |  |
| *qHSW-20-4* | 20 | bin103-bin105 | 35549932-35683070 | 83.6 | 2.6 | 0.48 | 3.49 | 18ZC |  |
| *qHSW-20-5* | 20 | bin123-bin125 | 36748229-36956101 | 96.6 | 2.77 | 0.49 | 3.72 | 18ZC | （Kato et al. 2014） |

aChromosome. bThe log of odds (LOD) value at the peak likelihood of QTL. dPhenotypic variation explained. eEnvironment.