|  |  |  |
| --- | --- | --- |
| **System Component** | **Quantity** | **Description** |
| Straight wall container | 4 | Plastic storage container (190.5mm height x 812.8mm length x 381mm width; W.W. Grainger, Lake Forest, IL ) |
| Binder clips | 600 | Small spring tight metal binder clip (19.05mm; Staples, Framingham, MA) |
| Blue blotter germination paper | 300 sheets | Steel blue seed germination blotter (482.6mm x 304.8mm; Anchor Paper, Minneapolis, MN) |
| Brown germination paper | 300 sheets | Brown germination paper (482.6mm x 304.8mm; Anchor Paper Co., Minneapolis, MN) |
| Plastic labels | 300 | Plant tag Slip 'N Lock thermal transfer perforated loop labels (25.4mm x 177.8mm; A.M. Leonard, Piqua, OH) |
| Fabric cutter | 1 | Rotary cutter with 45mm perforated wheel (Fiskars, Helsinki, Finland) |
| Plastic container | 2 | Plastic storage container (266.7mm height x 692.15mm length x 431.8mm width; Rubbermaid, Atlanta, GA ) |
| Forceps | 4 | Stainless steel forceps (114.3mm; W.W. Grainger, Lake Forest, IL ) |
| Data logger | 1 | Track-It RH/Temp Data Logger w/display (Monarch Instument, Amherst, NH) |
| Acrylic sheet | 4 | Transparent acrylic sheet (482.6mm x 304.8mm; Lowes, Mooresville, NC) |
| Canon EOS Rebel T5i | 1 | 18.0MP DSLR camera, 18-55mm IS STM lens (Canon, Tokyo, Japan) |
| Oben BE-117 ball head mount | 1 | Ball head with quick mount (Gradus Group LLC, New York, NY) |
| Laptop | 1 | Dell Latitude 7470 (Dell, Round Rock, TX) |
| USB cable | 1 | USB-A to mini USB cable |
| Aluminum frame | 1 | 80/20 T-slotted extrusion (80/20 Inc. Columbia City, IN) |
| Softbox light | 2 | 700W 5500k photography studio softbox (B&H Photo, New York, NY) |

Table S1: A list of imaging system components.

Table S2: Validation correlations between 23 RSA traits extracted from ARIA 2.0 using 298 heuristically segmented and CAE segmented root images.

|  |  |
| --- | --- |
| **Trait** | **R** |
| TRL | 0.97 |
| PRL | 0.98 |
| SRL | 0.97 |
| MED | 0.98 |
| MAX | 0.96 |
| LED | 0.75 |
| PER | 0.98 |
| DIA | 0.71 |
| VOL | 0.78 |
| Area | 0.86 |
| TRLUpper | 0.94 |
| TRLLower | 0.86 |
| CVA | 0.97 |
| DEP | 0.99 |
| WID | 0.98 |
| NWA | 0.96 |
| RHZO | 0.98 |
| LRB | 0.85 |
| NLR | 0.80 |
| IRB | 0.84 |
| Area | 0.92 |
| TRAUpper | 0.92 |
| TRALower | 0.90 |
| Mean | 0.91 |

Table S3: RSA traits at 6d, 9d and 12d when grouped into country of origin, growth habit type and diversity of genetic background.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  | **Root** | **Shoot** | **Seed** |
|  | **Day** | **n** | **TRL** | **TRL\_GR** | **PRL** | **VOL** | **WID** | **WDR** | **CVA** | **RHZO** | **LRB** | **LRA** | **LED** | **Weight** | **Weight** | **Weight** |
| China | 6 | 78 | 70.5 | 23.5 | 21.0 | 89.6 | 6.0 | 0.31 | 65.8 | 1161 | 38.1 | 85.4 | 1.73 | - | - | - |
| Japan | 6 | 8 | 58.6 | 19.5 | 19.9 | 81.5 | 5.2 | 0.27 | 55.4 | 967 | 32.7 | 85.3 | 1.54 | - | - | - |
| Korea | 6 | 3 | 75.7 | 25.2 | 21.4 | 111.1 | 6.9 | 0.34 | 77.7 | 1245 | 37.8 | 85.2 | 1.99 | - | - | - |
| Other | 6 | 9 | 67.2 | 22.4 | 21.0 | 87.1 | 5.6 | 0.29 | 59.9 | 1107 | 38.8 | 85.4 | 1.69 | - | - | - |
| Russia | 6 | 11 | 73.0 | 24.3 | 21.1 | 101.6 | 6.2 | 0.32 | 68.0 | 1212 | 37.6 | 85.3 | 1.80 | - | - | - |
| USA | 6 | 6 | 69.6 | 23.2 | 21.2 | 98.5 | 6.2 | 0.32 | 68.1 | 1149 | 38.2 | 85.2 | 1.88 | - | - | - |
| China | 9 | 78 | 220.9 | 49.4 | 35.9 | 156.4 | 16.3 | 0.50 | 299.0 | 3791 | 72.8 | 86.9 | 2.66 | - | - | - |
| Japan | 9 | 8 | 177.6 | 40.0 | 34.4 | 136.1 | 13.8 | 0.45 | 244.6 | 3027 | 65.7 | 86.5 | 2.34 | - | - | - |
| Korea | 9 | 3 | 238.2 | 56.5 | 37.9 | 216.1 | 18.2 | 0.52 | 352.5 | 4057 | 74.6 | 87.6 | 3.19 | - | - | - |
| Other | 9 | 9 | 214.1 | 48.7 | 36.0 | 156.5 | 15.9 | 0.48 | 290.2 | 3651 | 77.3 | 86.8 | 2.56 | - | - | - |
| Russia | 9 | 11 | 231.9 | 53.1 | 36.6 | 171.3 | 17.5 | 0.52 | 328.4 | 4019 | 72.1 | 87.3 | 2.71 | - | - | - |
| USA | 9 | 6 | 211.2 | 47.3 | 37.4 | 169.1 | 16.2 | 0.48 | 311.5 | 3617 | 75.7 | 86.7 | 2.62 | - | - | - |
| China | 12 | 78 | 340.8 | 40.3 | 47.6 | 213.4 | 21.3 | 0.51 | 512.1 | 5720 | 104.4 | 89.0 | 2.89 | 0.09 | 0.21 | 13.7 |
| Japan | 12 | 8 | 277.5 | 31.3 | 45.9 | 207.9 | 18.3 | 0.47 | 424.6 | 4559 | 99.3 | 88.8 | 2.59 | 0.08 | 0.20 | 12.6 |
| Korea | 12 | 3 | 389.8 | 45.5 | 49.7 | 258.2 | 24.3 | 0.54 | 627.3 | 6666 | 117.8 | 89.1 | 2.82 | 0.11 | 0.27 | 19.2 |
| Other | 12 | 9 | 329.5 | 38.8 | 47.8 | 217.7 | 20.9 | 0.50 | 502.9 | 5573 | 113.0 | 89.0 | 2.65 | 0.08 | 0.21 | 13.1 |
| Russia | 12 | 11 | 378.2 | 47.1 | 48.7 | 253.9 | 23.7 | 0.55 | 588.8 | 6437 | 109.1 | 89.1 | 2.96 | 0.10 | 0.23 | 14.6 |
| USA | 12 | 6 | 319.2 | 36.3 | 49.2 | 240.9 | 20.4 | 0.48 | 504.8 | 5332 | 113.4 | 89.1 | 2.66 | 0.10 | 0.25 | 16.5 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Determinate | 6 | 25 | 72.2 | 24.1 | 21.2 | 95.3 | 6.2 | 0.32 | 67.2 | 1181 | 38.4 | 85.6 | 1.83 | - | - | - |
| Indeterminate | 6 | 71 | 67.8 | 22.6 | 20.8 | 88.6 | 5.9 | 0.30 | 64.2 | 1127 | 36.8 | 85.2 | 1.68 | - | - | - |
| Semi-determinate | 6 | 19 | 73.5 | 24.5 | 21.1 | 94.6 | 6.1 | 0.31 | 66.5 | 1194 | 40.2 | 85.7 | 1.78 | - | - | - |
| Determinate | 9 | 25 | 229.2 | 51.8 | 36.1 | 167.9 | 16.5 | 0.50 | 306.3 | 3913 | 74.3 | 86.6 | 2.68 | - | - | - |
| Indeterminate | 9 | 71 | 212.4 | 47.6 | 36.0 | 152.3 | 16.1 | 0.49 | 297.0 | 3669 | 71.5 | 86.9 | 2.62 | - | - | - |
| Semi-determinate | 9 | 19 | 226.3 | 51.4 | 35.9 | 170.2 | 16.3 | 0.50 | 299.2 | 3817 | 75.3 | 87.2 | 2.69 | - | - | - |
| Determinate | 12 | 25 | 358.5 | 41.5 | 47.5 | 225.7 | 21.4 | 0.51 | 513.8 | 5968 | 107.9 | 88.9 | 2.82 | 0.10 | 0.25 | 16.4 |
| Indeterminate | 12 | 71 | 329.2 | 39.5 | 48.0 | 216.8 | 21.2 | 0.51 | 516.0 | 5580 | 105.3 | 89.1 | 2.81 | 0.09 | 0.21 | 13.4 |
| Semi-determinate | 12 | 19 | 351.5 | 40.8 | 47.0 | 223.4 | 21.6 | 0.53 | 514.1 | 5798 | 105.7 | 89.1 | 2.98 | 0.09 | 0.22 | 12.7 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Diverse | 6 | 4 | 70.9 | 23.6 | 21.0 | 103.2 | 6.4 | 0.33 | 69.5 | 1165 | 38.9 | 85.3 | 1.87 | 0.11 | 0.25 | 16.0 |
| Elite | 6 | 2 | 67.1 | 22.4 | 21.6 | 89.2 | 5.8 | 0.29 | 65.3 | 1117 | 36.9 | 85.0 | 1.90 | 0.09 | 0.24 | 17.5 |
| Landrace | 6 | 109 | 69.7 | 23.2 | 20.9 | 90.6 | 6.0 | 0.31 | 65.1 | 1150 | 37.7 | 85.4 | 1.72 | 0.09 | 0.22 | 13.8 |
| Diverse | 9 | 4 | 216.1 | 47.9 | 37.6 | 180.4 | 16.8 | 0.49 | 325.7 | 3698 | 76.2 | 86.7 | 2.62 | 0.11 | 0.25 | 16.0 |
| Elite | 9 | 2 | 201.3 | 46.1 | 37.0 | 146.4 | 15.0 | 0.45 | 283.1 | 3454 | 74.8 | 86.6 | 2.63 | 0.09 | 0.24 | 17.5 |
| Landrace | 9 | 109 | 218.7 | 49.2 | 35.9 | 158.0 | 16.2 | 0.50 | 298.7 | 3754 | 72.6 | 86.9 | 2.65 | 0.09 | 0.22 | 13.8 |
| Diverse | 12 | 4 | 332.2 | 38.2 | 49.9 | 265.6 | 21.7 | 0.51 | 545.0 | 5580 | 114.5 | 89.2 | 2.74 | 0.11 | 0.25 | 16.0 |
| Elite | 12 | 2 | 293.3 | 32.4 | 47.9 | 191.6 | 17.6 | 0.43 | 424.5 | 4836 | 111.3 | 89.0 | 2.52 | 0.09 | 0.24 | 17.5 |
| Landrace | 12 | 109 | 340.4 | 40.4 | 47.7 | 218.7 | 21.4 | 0.51 | 515.8 | 5721 | 105.6 | 89.0 | 2.85 | 0.09 | 0.22 | 13.8 |

Table S4: Descriptive statistics for 6 root and shoot traits of 115 maturity group II genotypes of soybean at 6d, 9d and 12d, obtained from BLUP values for each genotype.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Day** | **Trait** | **TRL (cm)** | **PRL (cm)** | **LRB** | **WID (cm)** | **Area (cm2)** | **LED** | **Shoot (g)** | **Root (g)** |
| **6** | Mean | 68.79 | 20.84 | 37.45 | 5.91 | 6.06 | 1.72 |  |  |
| Median | 68.79 | 21.01 | 37.45 | 5.90 | 6.06 | 1.71 |  |  |
| Maximum | 217.69 | 37.16 | 108.00 | 22.35 | 23.68 | 2.05 |  |  |
| Std Deviation | 39.95 | 5.61 | 20.14 | 3.38 | 3.63 | 0.11 |  |  |
| ANOVA (Genotype) | \*\*\* | \*\*\* | \*\*\* | \*\*\* | \*\*\* | \*\*\* |  |  |
| Heritability | 94% | 89% | 88% | 90% | 94% | 80% |  |  |
| CVg | 22% | 8% | 19% | 21% | 22% |  |  |  |
| **9** | Mean | 213.01 | 34.90 | 70.91 | 15.77 | 18.28 | 2.50 |  |  |
| Median | 208.53 | 35.62 | 70.00 | 15.55 | 17.51 | 2.60 |  |  |
| Maximum | 545.16 | 78.31 | 330.00 | 33.03 | 49.53 | 4.08 |  |  |
| Std Deviation | 93.02 | 8.14 | 25.99 | 5.78 | 8.18 | 0.43 |  |  |
| ANOVA (Genotype) | \*\*\* | \*\*\* | \*\*\* | \*\*\* | \*\*\* | \*\*\* |  |  |
| Heritability | 93% | 82% | 86% | 93% | 93% | 69% |  |  |
| CVg | 20% | 7% | 14% | 19% | 22% |  |  |  |
| **12** | Mean | 333.86 | 45.64 | 102.98 | 20.66 | 27.29 | 2.63 | 0.22 | 0.09 |
| Median | 328.29 | 47.62 | 98.00 | 21.31 | 26.10 | 2.62 | 0.22 | 0.09 |
| Maximum | 1860.31 | 72.62 | 232.00 | 33.33 | 122.72 | 3.73 | 0.49 | 0.19 |
| Std Deviation | 130.25 | 9.89 | 39.70 | 6.04 | 11.40 | 0.35 | 0.07 | 0.03 |
| ANOVA (Genotype) | \*\*\* | \*\*\* | \*\*\* | \*\*\* | \*\*\* | \*\*\* | \*\*\* | \*\*\* |
| Heritability | 91% | 80% | 85% | 93% | 91% | 66% | 1.00 | 1.00 |
| CVg | 21% | 8% | 14% | 17% | 22% |  | 0.27 | 0.24 |
| \* | < 0.05 |  |  |  |  |  |  |  |  |
| \*\* | < 0.01 |  |  |  |  |  |  |  |  |
| \*\*\* | < 0.001 |  |  |  |  |  |  |  |  |

Table S5: Validation correlation between GiARoot software and ARIA 2.0.

|  |  |
| --- | --- |
| **Trait** | **R2** |
| TRL | 0.996 |
| PER | 0.904 |
| DEP | 0.994 |
| WID | 0.945 |
| CVA | 0.998 |
| Area | 0.996 |
| WDR | 0.929 |
| SOL | 0.766 |
| BSH | 0.659 |
| LED | 0.974 |
| Mean | 0.916 |

Table S6. Root angle diversity among the three genotypes. A Kolmogorov-Smirnov test was used to detect p-value statistical differences in directionality on root branching angle at each of the three time points.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Genotype** | | |
| **Day** | **A** | **B** | **C** |
| **d6/d9** | 0.02202 | 0.04774 | 0.87495 |
| **d9/d12** | 0.06863 | 0.98005 | 0.72851 |
| **d6/d12** | 0.00004 | 0.06548 | 0.38231 |
|  |  |  |  |
|  | **Day** | | |
| **Genotype** | **d6** | **d9** | **d12** |
| **A/B** | 0.00625 | 0.06328 | 0.99997 |
| **B/C** | 0.78103 | 0.99128 | 0.85781 |
| **A/C** | 0.00008 | 0.16646 | 0.96162 |

Table S7: Correlations (r) between plant dry weight taken at 12d and root traits at 9d for 115 maturity group II genotypes of soybean

|  |  |  |
| --- | --- | --- |
|  | **Dry Weight** | |
| **Root Trait** | **Shoot** | **Root** |
| Shoot Weight | - | 0.86 |
| Root Weight | 0.86 | - |
| TRL | 0.61 | 0.76 |
| PRL | 0.41 | 0.48 |
| SRL | 0.61 | 0.75 |
| MSL | 0.38 | 0.51 |
| TRLUpper | 0.63 | 0.67 |
| TRLLower | 0.62 | 0.74 |
| NWA | 0.60 | 0.75 |
| PER | 0.51 | 0.67 |
| DEP | 0.35 | 0.42 |
| WID | 0.55 | 0.65 |
| DIA | 0.68 | 0.71 |
| LRB | 0.52 | 0.60 |
| NLR | 0.45 | 0.52 |
| IRB | 0.47 | 0.55 |
| MED | 0.48 | 0.57 |
| MAX | 0.57 | 0.73 |
| CVA | 0.57 | 0.66 |
| Rhzo | 0.56 | 0.72 |
| Area | 0.72 | 0.84 |
| PRA | 0.35 | 0.51 |
| TRAUpper | 0.72 | 0.82 |
| TRALower | 0.45 | 0.60 |
| VOL | 0.62 | 0.64 |
| WDR | -0.37 | -0.45 |
| SOL | -0.14 | -0.16 |
| BSH | 0.10 | 0.24 |
| LED | 0.19 | 0.20 |
| LSLPL | -0.04 | -0.02 |