**Table S1.** Field management methods and soil texture in eight environments

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Environment | Year | Location | Sowing  date | Seeding density  (Plants/ha) | Soil type | Fertilizer  N: P2O5: K2O  (kg/ha) | Chemical herbicides |
|
| E1 | 2013 | Harbin | 10 May | 2.22×105 | Meadow black soil | 60:90:75 | 90% Acetochlor emulsifiable concentrates 2000 ml |
| E2 | 2013 | Keshan | 10 May | 2.80×105 | Chernozem soil | 75:90:75 | 90% Acetochlor emulsifiable concentrates 2000 ml |
| E3 | 2014 | Harbin | 10 May | 2.22×105 | Meadow black soil | 60:90:75 | 90% Acetochlor emulsifiable concentrates 2000 ml |
| E4 | 2014 | Harbin | 20 May | 2.22×105 | Meadow black soil | 60:90:75 | 90% Acetochlor emulsifiable concentrates 2000 ml |
| E5 | 2015 | Harbin | 10 May | 2.22×105 | Meadow black soil | 60:90:75 | 90% Acetochlor emulsifiable concentrates 2000 ml |
| E6 | 2015 | Harbin | 10 May | 3.08×105 | Meadow black soil | 60:90:75 | 90% Acetochlor emulsifiable concentrates 2000 ml |
| E7 | 2015 | Keshan | 10 May | 2.58×105 | Chernozem soil | 75:90:75 | 90% Acetochlor emulsifiable concentrates 2000 ml |
| E8 | 2015 | Keshan | 10 May | 3.51×105 | Chernozem soil | 75:90:75 | 90% Acetochlor emulsifiable concentrates 2000 ml |

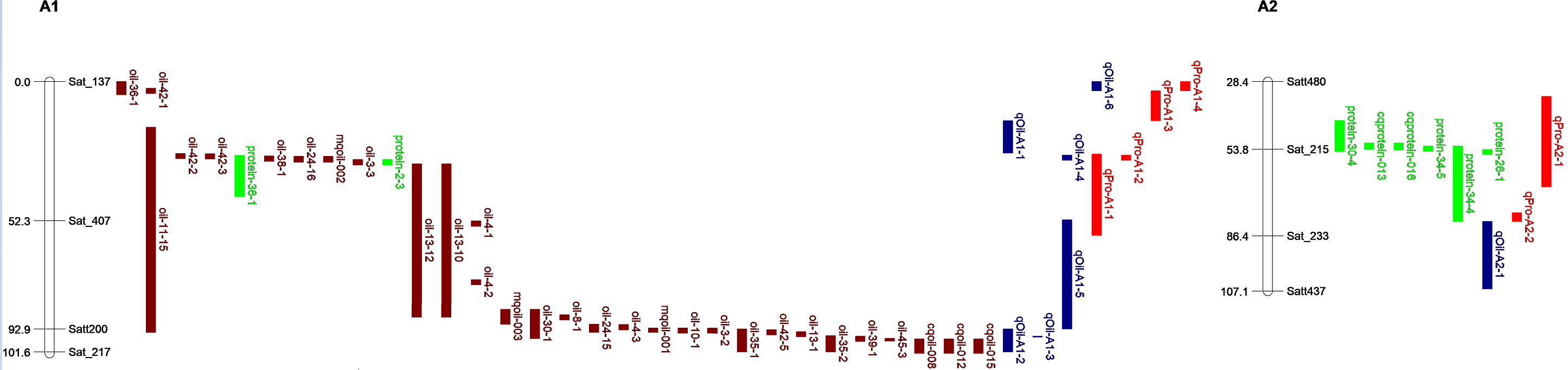
**Table S2.** Protein and oil content of four parents in eight environments

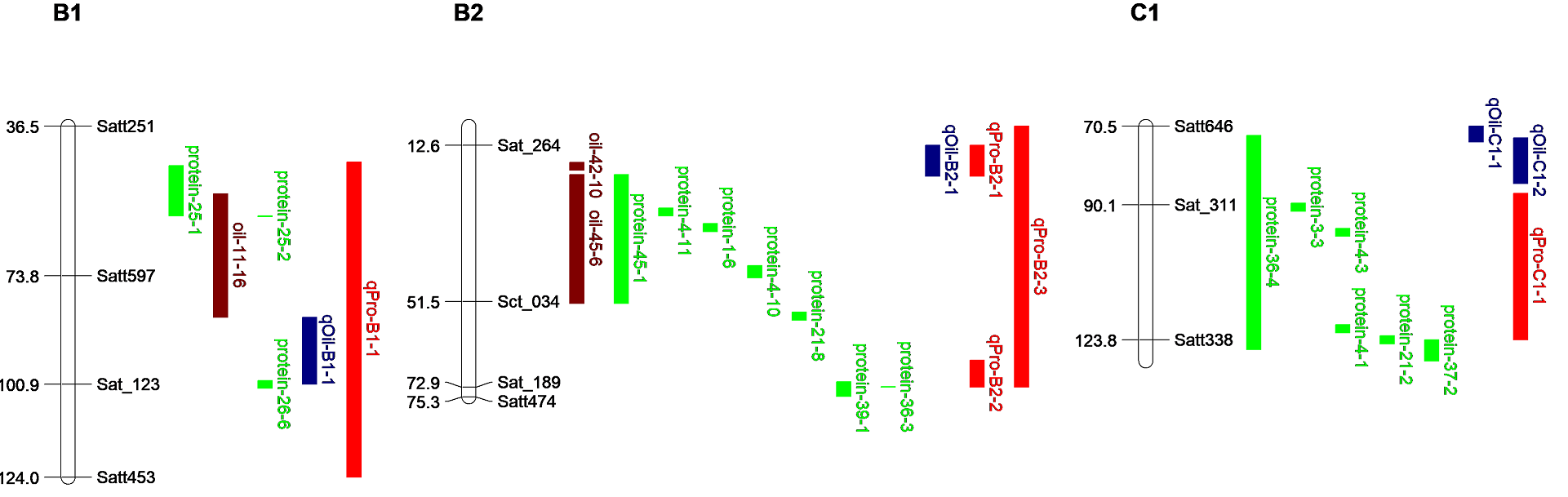
|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Environment | Year | Location | Protein content (g/kg) | | | | Oil content (g/kg) | | | |
| P1 | P2 | P3 | P4 | P1 | P2 | P3 | P4 |
| E1 | 2013 | Harbin | 426.20 | 416.90 | 413.90 | 419.00 | 200.40 | 202.60 | 210.50 | 196.50 |
| E2 | 2013 | Keshan | 426.40 | 447.70 | 432.00 | 466.80 | 156.30 | 186.10 | 160.20 | 169.40 |
| E3 | 2014 | Harbin | 423.10 | 421.90 | 422.50 | 451.10 | 213.80 | 205.10 | 197.50 | 190.90 |
| E4 | 2014 | Harbin | 420.70 | 413.10 | 406.70 | 426.30 | 196.40 | 202.60 | 189.40 | 190.30 |
| E5 | 2015 | Harbin | 429.00 | 411.00 | 399.00 | 439.00 | 203.70 | 202.70 | 218.80 | 198.20 |
| E6 | 2015 | Harbin | 438.00 | 429.00 | 453.00 | 447.00 | 197.70 | 202.50 | 196.00 | 202.60 |
| E7 | 2015 | Keshan | 430.00 | 409.00 | 395.00 | 433.00 | 190.80 | 198.50 | 209.70 | 191.90 |
| E8 | 2015 | Keshan | 427.00 | 412.00 | 422.00 | 435.00 | 194.10 | 187.10 | 194.50 | 198.20 |

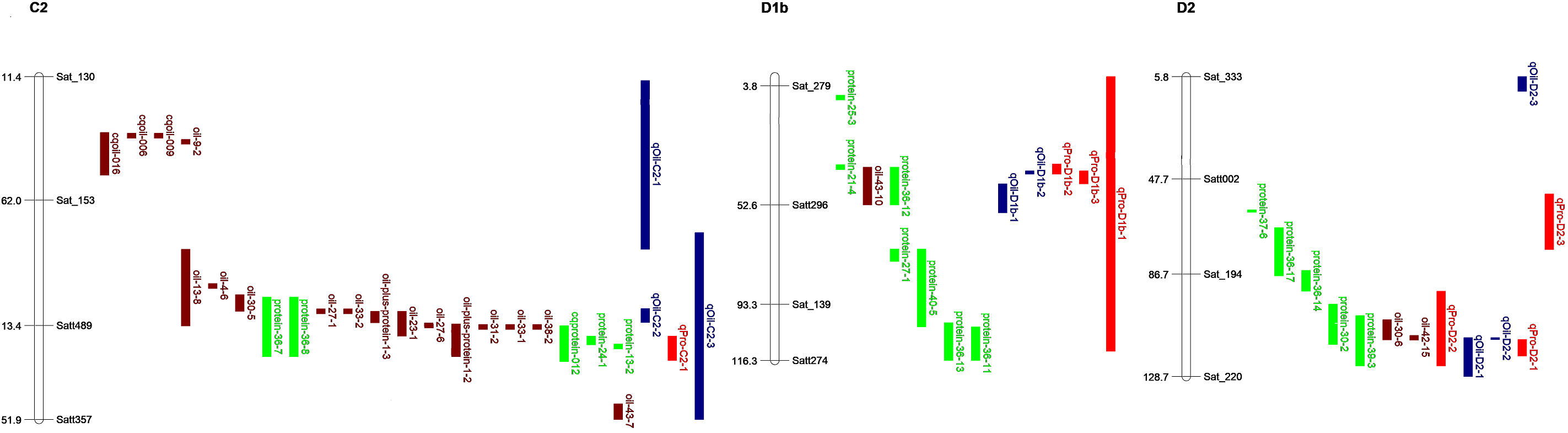
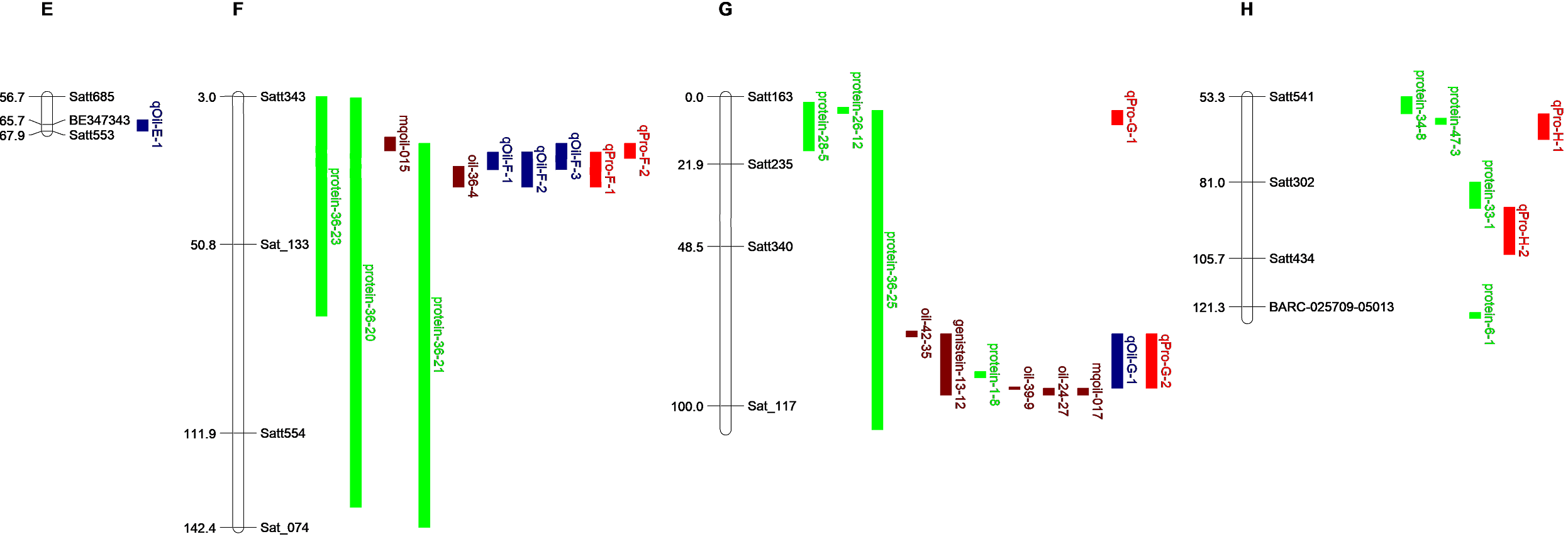
E, environment; E1, Harbin in 2013; E2, Keshan in 2013; E3, the first sowing date in Harbin in 2014; E4, the second sowing date in Harbin in 2014; E5, 2.22×105 plants/ha in Harbin; E6, 3.08×105 plants/ha in Harbin; E7, 2.58×105 plants/ha in Keshan; E8, 3.51×105plants/ha in Keshan. P1, Kenfeng14; P2, Kenfeng15; P3, Heinong48; P4, Kenfeng19

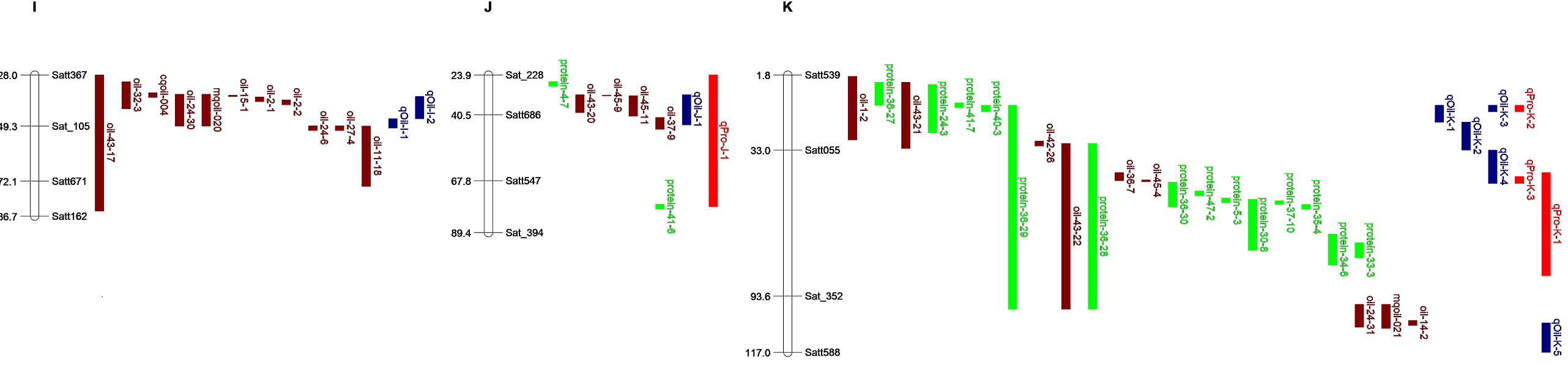
**Table S3.** Quantitative trait loci (QTL) with positive additive effect alleles in four-way parents

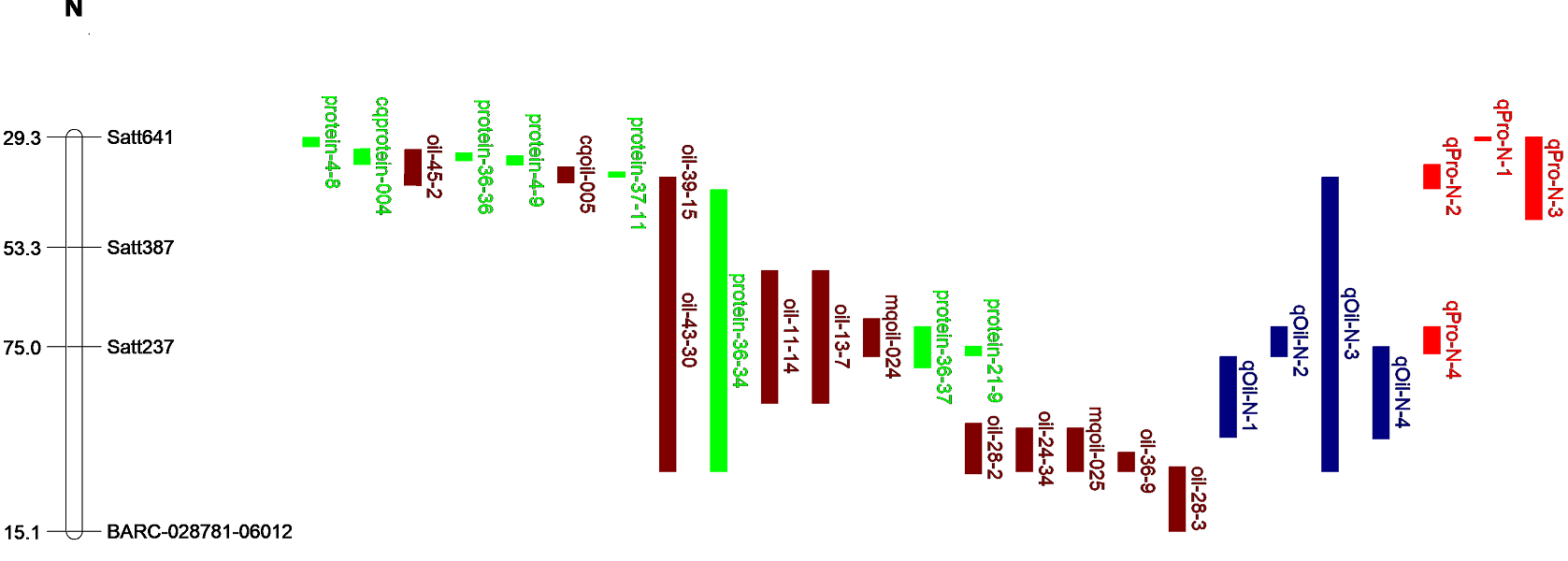
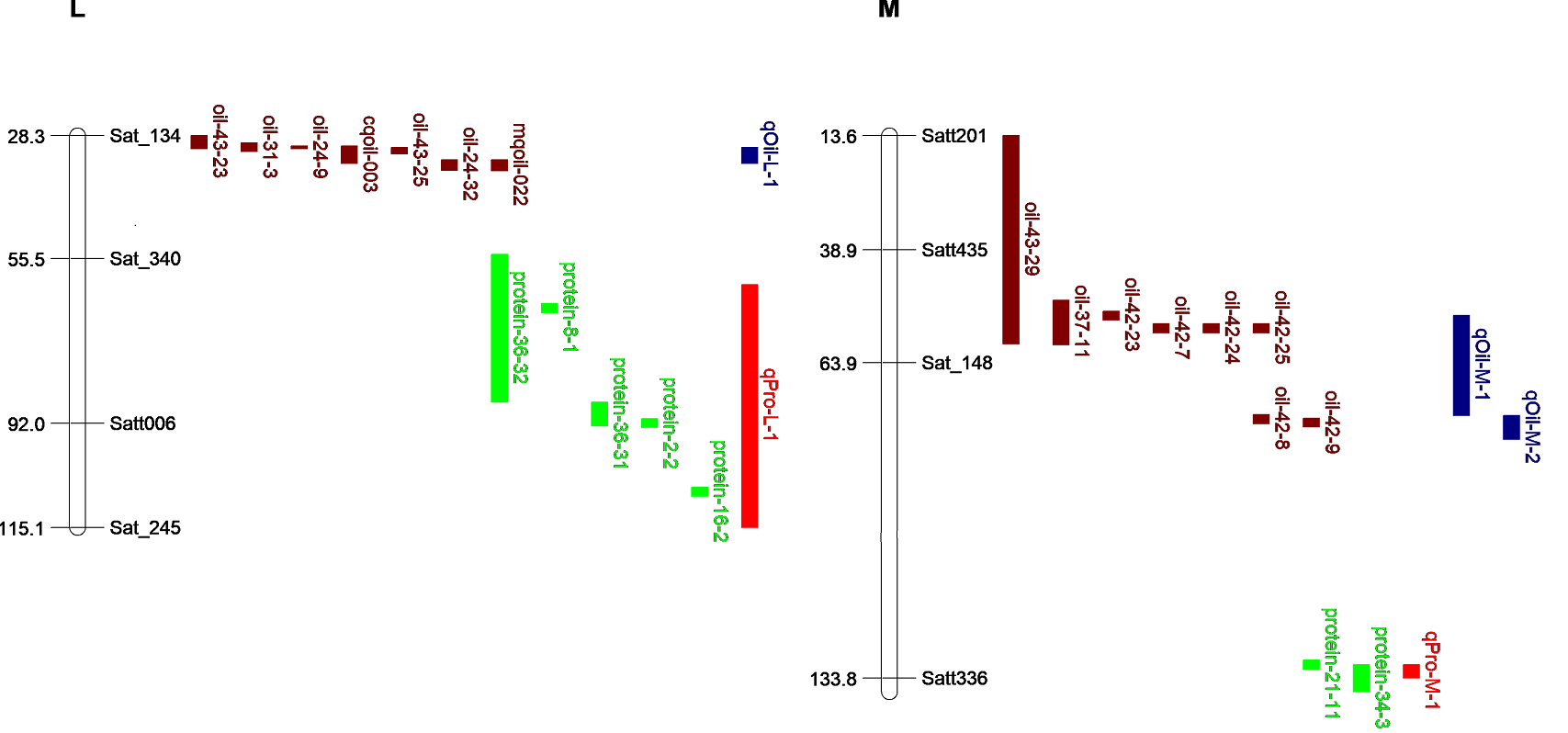
|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Trait | Parent name | QTL | | | | |
| protein | Kenfeng14 | qPro-A2-2 | qPro-B1-1 | qPro-D2-1 | qPro-D2-2 | qPro-D2-3 |
|  | qPro-F-1 | qPro-F-2 | qPro-H-1 | qPro-K-3 | qPro-M-1 |
|  | qPro-N-1 |  |  |  |  |
| Kenfeng15 | qPro-B1-1 | qPro-B2-1 | qPro-B2-2 | qPro-D1b-1 | qPro-D1b-2 |
|  | qPro-H-1 | qPro-K-1 | qPro-K-2 | qPro-K-3 | qPro-N-1 |
|  | qPro-N-3 | qPro-N-4 |  |  |  |
| Heinong48 | qPro-A1-3 | qPro-A2-2 | qPro-B2-1 | qPro-B2-3 | qPro-D1b-1 |
|  | qPro-D1b-2 | qPro-D1b-3 | qPro-D2-2 | qPro-D2-3 | qPro-F-2 |
|  | qPro-G-1 | qPro-G-2 | qPro-H-1 | qPro-H-2 | qPro-J-1 |
|  | qPro-N-4 |  |  |  |  |
| Kenfeng19 | qPro-A1-1 | qPro-A1-2 | qPro-A1-4 | qPro-A2-1 | qPro-B2-1 |
|  | qPro-B2-2 | qPro-B2-3 | qPro-C2-1 | qPro-D1b-2 | qPro-D2-1 |
|  | qPro-D2-2 | qPro-D2-3 | qPro-F-2 | qPro-G-1 | qPro-G-2 |
|  | qPro-H-2 | qPro-L-1 | qPro-M-1 | qPro-N-1 | qPro-N-2 |
|  | qPro-N-3 | qPro-N-4 |  |  |  |
| oil | Kenfeng14 | qOil-A1-1 | qOil-A1-2 | qOil-A1-3 | qOil-A1-4 | qOil-A1-5 |
|  | qOil-B2-1 | qOil-C1-1 | qOil-C1-2 | qOil-C2-1 | qOil-C2-2 |
|  | qOil-D2-1 | qOil-D2-2 | qOil-D2-3 | qOil-F-3 | qOil-I-1 |
|  | qOil-I-2 | qOil-J-1 | qOil-K-2 | qOil-K-4 | qOil-M-2 |
|  | qOil-N-1 | qOil-N-2 | qOil-N-3 | qOil-N-4 |  |
| Kenfeng15 | qOil-A1-2 | qOil-A2-1 | qOil-C2-2 | qOil-C2-3 | qOil-D1b-2 |
|  | qOil-D2-1 | qOil-D2-2 | qOil-D2-3 | qOil-E-1 | qOil-G-1 |
|  | qOil-I-2 | qOil-K-3 | qOil-K-5 | qOil-L-1 | qOil-N-4 |
| Heinong48 | qOil-A1-4 | qOil-C1-2 | qOil-C2-1 | qOil-F-2 | qOil-G-1 |
|  | qOil-K-1 | qOil-K-3 | qOil-K-4 | qOil-K-5 |  |
| Kenfeng19 | qOil-A1-3 | qOil-E-1 | qOil-F-2 | qOil-F-3 | qOil-I-1 |
|  | qOil-I-2 | qOil-N-3 |  |  |  |











**Fig. S1.** Integrated linkage map of quantitative trait loci (QTLs) for protein and oil content detected in the present study and previous reports (in SoyBase) based on the positions of markers in the public map. These QTLs are distributed on the left chromosome, and the size of the QTL interval is represented by the length of the QTL. Red represents protein QTLs found in the four-way recombinant inbred line (FW-RIL); blue represents oil QTLs found in FW-RIL; brown represents oil QTLs reported previously; green represents protein QTLs reported previously. The chromosome unit is cM.