1 Table S1. Soil characteristics of the experimental soybean fields at Tohoku Agricultural Research Center (TARC), National Agriculture and Food Research Organization

2 (NARO), Morioka, Iwate Prefecture, Japan, in 2015 and 2016.

| | 2015 | 2016 |
|---|-------|-------|
| Soil type | And | dosol |
| Soil pH | 6.4 | 6.7 |
| Available P (mg kg ⁻¹) | 31 | 43 |
| Exchangeable K (mg kg ⁻¹) | 124 | 247 |
| Exchangeable Mg (mg kg ⁻¹) | 823 | 1441 |
| Exchangeable Ca (mg kg ⁻¹) | 4790 | 7325 |
| Cation exchange capacity (cmol kg ⁻¹) | 39.5 | 43.6 |
| Bulk density (g [100 mL] ⁻¹) | 56.6 | 71.9 |
| $\theta_{FC} (mm^3 mm^{-3})$ | 0.470 | 0.585 |
| $\theta_{WP} (mm^3 mm^{-3})$ | 0.193 | 0.239 |

3 θ_{FC} , volumetric soil water content at field capacity (pF = 1.5); θ_{WP} , volumetric soil water content at permanent wilting point (pF = 4.2).

5 Table S2. Aboveground biomass (g m⁻²), seed yield (g m⁻²), harvest index (HI), and yield components (numbers of pods per plant, seeds per pod, nodes per

6 plant, and pods per node, and 100-seed weight, g) of three soybean cultivars (Ryuhou, Enrei, Satonohohoemi) with normal and late sowing dates in 2015 and

| 7 | 2016 in the Tohoku region of northern Japan. | |
|---|--|--|
|---|--|--|

| | | Aboveground | | ш | Number of | Seeds per | Number of | Pods per | 100-seed |
|---------------|--|---|--|---|--|--|---|---|--|
| | | weight | Seed yield | пі | pods | pod | nodes | node | weight |
| Cultivar | Sowing date | (g m ⁻²) | (g m ⁻²) | | (per plant) | | (per plant) | | (g) |
| Ryuhou | Normal | 444 | 270 | 0.61 | 59.1 | 1.62 | 37.5 | 1.56 | 31.4 |
| | Late | 344 | 201 | 0.59 | 46.5 | 1.58 | 32.5 | 1.42 | 28.6 |
| Enrei | Normal | 486 | 257 | 0.53 | 53.6 | 1.57 | 47.8 | 1.13 | 30.6 |
| | Late | 368 | 180 | 0.49 | 41.3 | 1.45 | 35.3 | 1.17 | 26.4 |
| Satonohohoemi | Normal | 599 | 293 | 0.49 | 61.5 | 1.27 | 46.8 | 1.31 | 35.6 |
| | Late | 439 | 224 | 0.50 | 58.8 | 1.03 | 39.9 | 1.48 | 33.3 |
| Ryuhou | Normal | 557 | 333 | 0.60 | 80.7 | 1.47 | 48.5 | 1.66 | 30.8 |
| | Late | 491 | 289 | 0.59 | 73.4 | 1.38 | 48.5 | 1.51 | 29.4 |
| Enrei | Normal | 549 | 319 | 0.58 | 80.1 | 1.45 | 53.7 | 1.49 | 30.0 |
| | Late | 438 | 228 | 0.52 | 72.6 | 1.17 | 45.9 | 1.58 | 27.2 |
| Satonohohoemi | Normal | 618 | 330 | 0.53 | 79.3 | 1.28 | 55.3 | 1.43 | 35.3 |
| | Late | 420 | 162 | 0.39 | 75.0 | 0.60 | 43.3 | 1.73 | 31.9 |
| | Cultivar Ryuhou Enrei Satonohohoemi Ryuhou Enrei Satonohohoemi | CultivarSowing dateRyuhouNormalLateLateEnreiNormalSatonohohoemiNormalRyuhouLateInreiNormalLateLateSatonohohoemiLateEnreiNormalSatonohohoemiLateEnreiNormalLateLateEnreiNormalLateLateSatonohohoemiLateSatonohohoemiNormal | AbovegroundCultivarSowing dateweightCultivarSowing date(g m ⁻²)RyuhouNormal444Late344EnreiNormal486SatonohohoemiLate368RyuhouNormal599Late439557Late491549EnreiNormal549EnreiNormal549SatonohohoemiNormal549SatonohohoemiNormal618SatonohohoemiLate420 | Aboveground weightSeed yield weightCultivarSowing date(g m²)RyuhouNormal444270Iate344201EnreiNormal486257Iate368180SatonohohoemiNormal599293RyuhouNormal557333Iate491289EnreiNormal549319EnreiNormal549319SatonohohoemiNormal549319EnreiNormal548228SatonohohoemiNormal618330SatonohohoemiNormal618330Late420162162 | Aboveground weight Seed yield weight HI Cultivar Sowing date (g m ⁻²) (g m ⁻²) Ryuhou Normal 444 270 0.61 Late 344 201 0.59 Enrei Normal 486 257 0.53 Late 368 180 0.49 Satonohohoemi Normal 599 293 0.49 Late 439 224 0.50 Ryuhou Normal 557 333 0.60 Ryuhou Normal 549 289 0.59 Enrei Normal 549 319 0.58 Enrei Normal 548 228 0.52 Enrei Normal 548 228 0.52 Satonohohoemi Normal 618 330 0.53 Late 420 162 0.39 0.53 | Aboveground weightHNumber of podsCultivarSowing date $(g m^2)$ $(g m^2)$ (per plant)RyuhouNormal4442700.6159.1Late3442010.5946.5EnreiNormal4862570.5353.6EnreiNormal4862570.5353.6SatonohohoemiNormal5992930.4961.5RyuhouNormal5573330.6080.7Late4912890.5973.4EnreiNormal5493190.5880.1EnreiNormal6183300.5379.3SatonohohoemiNormal6183300.5379.3 | Aboveground weightSeed yield weightHNumber of podsSeeds perCultivarSowing date $(g m^{-2})$ <t< td=""><td>Aboveground weight$3eed yield$$HI$Number of podsSeeds perNumber of nodesCultivarSowing date$(g m^2)$$(g m^2)$$(per plant)$$(per plant)$$(per plant)$RyuhouNormal4442700.6159.11.6237.5Late3442010.5946.51.5832.5EnreiNormal4862570.5353.61.5747.8Late3681800.4941.31.4535.3SatonohohoemiNormal5992930.4961.51.2746.8RyuhouNormal5573330.6080.71.4748.5EnreiNormal5492190.5973.41.3848.5EnreiNormal5493190.5880.11.4553.7EnreiNormal5493190.5880.11.4553.7EnreiNormal5493190.5880.11.4553.7SatonohohoemiNormal6183300.5372.61.1745.9SatonohohoemiNormal61830.053.975.00.6043.3</td><td>Aboveground weight${\rm Number of}$Seed sperNumber ofNumber ofPods perCultivarSowing date$(gm^2)$$(gm^2)$$(per plant)$$(per plant)$$(per plant)$$(per plant)$RyuhouNormal4442700.6159.11.6237.51.56Late3442010.5946.51.5832.51.42EnreiNormal4862570.5353.61.5747.81.13Late3681800.4941.31.4535.31.17SatonohohoemiNormal5992930.4961.51.2746.81.31RyuhouNormal5992930.4961.51.2746.81.31Part Part Part Part Part Part Part Part</td></t<> | Aboveground weight $3eed yield$ HI Number of podsSeeds perNumber of nodesCultivarSowing date $(g m^2)$ $(g m^2)$ $(per plant)$ $(per plant)$ $(per plant)$ RyuhouNormal4442700.6159.11.6237.5Late3442010.5946.51.5832.5EnreiNormal4862570.5353.61.5747.8Late3681800.4941.31.4535.3SatonohohoemiNormal5992930.4961.51.2746.8RyuhouNormal5573330.6080.71.4748.5EnreiNormal5492190.5973.41.3848.5EnreiNormal5493190.5880.11.4553.7EnreiNormal5493190.5880.11.4553.7EnreiNormal5493190.5880.11.4553.7SatonohohoemiNormal6183300.5372.61.1745.9SatonohohoemiNormal61830.053.975.00.6043.3 | Aboveground weight ${\rm Number of}$ Seed sperNumber ofNumber ofPods perCultivarSowing date (gm^2) (gm^2) $(per plant)$ $(per plant)$ $(per plant)$ $(per plant)$ RyuhouNormal4442700.6159.11.6237.51.56Late3442010.5946.51.5832.51.42EnreiNormal4862570.5353.61.5747.81.13Late3681800.4941.31.4535.31.17SatonohohoemiNormal5992930.4961.51.2746.81.31RyuhouNormal5992930.4961.51.2746.81.31Part Part Part Part Part Part Part Part |

| Year | Cultimor | Couring data | Days from VE | vs from VE Days from R2 | | Days from VE | |
|------|---------------|--------------|--------------|-------------------------|-------|--------------|--|
| | Cultivar | Sowing date | to R2 | to R5 | to R7 | to R7 | |
| 2015 | Ryuhou | Normal | 49 | 18 | 45 | 111 | |
| | | Late | 39 | 17 | 42 | 98 | |
| | Enrei | Normal | 53 | 22 | 43 | 119 | |
| | | Late | 39 | 20 | 43 | 103 | |
| | Satonohohoemi | Normal | 53 | 22 | 53 | 128 | |
| | | Late | 41 | 20 | 52 | 113 | |
| 2016 | Ryuhou | Normal | 51 | 18 | 47 | 116 | |
| | | Late | 41 | 18 | 46 | 105 | |
| | Enrei | Normal | 54 | 20 | 48 | 122 | |
| | | Late | 43 | 18 | 46 | 107 | |
| | Satonohohoemi | Normal | 55 | 21 | 53 | 129 | |
| | | Late | 44 | 18 | 58 | 120 | |

10 Table S3. Days from emergence (VE) to full flowering (R2), from R2 to the beginning of seed filling (R5), from R5 to the beginning of maturity (R7), and from VE to R7 for three 11 soybean cultivars (Ryuhou, Enrei, Satonohohoemi) with normal and late sowing dates in 2015 and 2016 in the Tohoku region of northern Japan. 14 **Table S4.** Increase in aboveground biomass (ΔAGB, g m⁻²), cumulative intercepted irradiation (CumIR, MJ m⁻²), and radiation use efficiency for dry matter production (RUE, g

15 MJ⁻¹) during reproductive stages (from R2 to R5 and from R5 to 20 days after R5) of three soybean cultivars (Ryuhou, Enrei, Satonohohoemi) with normal and late sowing dates

16 in 2015 and 2016 in the Tohoku region of northern Japan.

| | | | ΔAGW | | C | umIR | RUE | | |
|------|---------------|-------------|----------------------|--------------|-------|----------------------|-----------------------|--------------|--|
| | | | (g m ⁻²) | | (M | IJ m ⁻²) | (g MJ ⁻¹) | | |
| Year | Cultivar | Sowing date | R2-R5 | R5–R5 + 20 d | R2-R5 | R5–R5 + 20 d | R2-R5 | R5–R5 + 20 d | |
| 2015 | Ryuhou | Normal | 196 | 238 | 270 | 212 | 0.73 | 1.13 | |
| | | Late | 163 | 218 | 189 | 204 | 0.86 | 1.07 | |
| | Enrei | Normal | 252 | 238 | 341 | 170 | 0.74 | 1.40 | |
| | | Late | 206 | 214 | 197 | 239 | 1.05 | 0.89 | |
| | Satonohohoemi | Normal | 287 | 173 | 321 | 173 | 0.89 | 1.00 | |
| | | Late | 196 | 189 | 211 | 218 | 0.92 | 0.86 | |
| 2016 | Ryuhou | Normal | 222 | 298 | 265 | 306 | 0.84 | 0.97 | |
| | | Late | 184 | 255 | 217 | 267 | 0.85 | 0.95 | |
| | Enrei | Normal | 307 | 241 | 315 | 271 | 0.98 | 0.89 | |
| | | Late | 199 | 262 | 224 | 248 | 0.89 | 1.06 | |
| | Satonohohoemi | Normal | 320 | 296 | 306 | 272 | 1.05 | 1.09 | |
| | | Late | 156 | 273 | 206 | 273 | 0.75 | 1.00 | |
| | | | | | | | | | |

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19 **Table S5.** Pearson's coefficients of correlation of the relationships between mean temperature and the FASW (fraction of available soil water) during reproductive stages (from

20 R2 to R5 and from R5 to R5 + 20 days) and seed yield (g m⁻²), yield components (numbers of pods per plant, seeds per pod, nodes per plant, and pods per node, and 100-seed

21 weight, g), increase in aboveground biomass (ΔAGB, g m⁻²), cumulative intercepted irradiation (CumIR, MJ m⁻²), and radiation use efficiency for dry matter production (RUE, g

 MJ^{-1}) across three soybean cultivars and two sowing dates in 2015 and 2016 (n = 12) in the Tohoku region of northern Japan.

| | FASW R2–R5 | FASW R5–R5 + 20 days | Seed yield | Number of nodes | Pods per node | Seeds per pod | 100-seed weight | ΔAGB | RUE | CumIR |
|-----------------|---------------|----------------------------|------------|--------------------|------------------|------------------|--------------------|--------|--------|---------|
| Temperature | -0.835 | _ | 0 372 | 0 379 | 0.678 | 0 044 | -0.136 | -0.088 | -0 309 | 0.027 |
| R2-R5 | 0.000 | | 0.072 | 0.079 | 0.070 | 0.011 | 0.150 | 0.000 | 0.009 | 0.027 |
| Significance | *** | _ | ns | ns | * | ns | ns | ns | ns | ns |
| Temperature | _ | -0.873 | 0 585 | 0 506 | 0 527 | 0 134 | -0 229 | 0 179 | 0.073 | 0 1 2 0 |
| R5–R5 + 20 days | _ | -0.075 | 0.000 | 0.500 | 0.527 | 0.134 | 0.22) | 0.179 | 0.075 | 0.120 |
| Significance | - | *** | * | ns | ns | ns | ns | ns | ns | ns |
| FASW | | | 0.264 | 0.008 | 0.419 | 0.476 | 0.202 | 0 175 | 0 516 | 0.002 |
| R2-R5 | _ | _ | -0.364 | -0.098 | -0.416 | -0.476 | 0.295 | 0.175 | 0.316 | -0.093 |
| Significance | - | - | ns | ns | ns | ns | ns | ns | ns | ns |
| FASW | | | 0.2(2 | 0.604 | 0.504 | 0.207 | 0 101 | 0.140 | 0.150 | 0.011 |
| R5–R5 + 20 days | _ | | -0.363 | -0.684 | -0.596 | 0.306 | 0.101 | -0.149 | -0.158 | -0.011 |
| Significance | - | _ | ns | * | * | ns | ns | ns | ns | ns |

23 Significance: ***p < 0.001; *p < 0.05; ns, not significant.



Figure S1. Changes in the canopy cover (%) of three soybean cultivars (Ryuhou, Enrei, Satonohohoemi) growing after normal and late sowing during the (A) 2015 and (B) 2016
seasons in the Tohoku region of northern Japan. DOY, day of the year. Values represent the mean (n = 3).



Figure S2. Changes in daily mean temperature and solar radiation from June to October during the soybean growing season in (A and C) 2015 and (B and D) 2016 in the Tohoku region of northern Japan. DOY, day of the year. R2, beginning of flowering; R5, beginning of seed filling stage; | normal sowing date; is late sowing date; arrows indicate means of the three cultivars.