A-133

Is photoperiod-sensitive E4 locus effective for soybean yield enhancement by future warming in cool climates of Japan?

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Improving phenological traits of soybean cultivars can be important adaptive options to climate change in the northern regions of Japan. Previously, we showed that yield responses to elevated temperature differed significantly between cultivars of different maturity groups. A late maturing cultivar (Enrei) showed a positive yield response to elevated temperature but no response for an early maturing one (Yukihomarre). The greater response for Enrei was mostly explained by increased pod number due to a prolonged period from the beginning of flowering (R1) to the beginning of pod filling (R3) by high temperature, but the genetic factors for this difference remain unclear. The two varieties differ in the alleles at the photoperiod sensitivity locus E4, which encodes Phytochrome A genes; Enrei has dominant E4 alleles but Yukihomare has recessive e4 alleles. Therefore, we hypothesized that E4 alleles, in conjunction with a longer photoperiod, prolong the period from R1 to R3 and thereby increase pod number and seed yield at elevated temperature. To test this, Enrei and an its near-isogenic line with e4 alleles (NIL-e4, early-maturing) were grown under three temperature regimes, T1 (ambient), T2 (2.0 °C above ambient), T3 (4.6 °C above ambient), in temperature gradient chambers. Compared to T1, pod number and seed yield increased at T2 and T3 in Enrei but not in the NIL-e4. In T2 and T3, the period from R1 to R3 was prolonged in Enrei but not in the NIL-e4. Days from R1 to R3 were significantly and positively correlated with pod number in only Enrei. These data supported our hypothesis, and we concluded that E4 alleles are effective for yield enhancement in future warming in the cool regions of Japan. Our results underline the importance of modifying photoperiod-sensitive locus for adaptation of soybean production to future global warming.