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Abstract

Susceptibility to temperature-induced dormancy of lettuce (*Lactuca sativa*) seed is influenced both by genotype and maternal environment during seed development. To investigate the nature of environmental susceptibility of seed thermoinhibition and its genetic cause, seeds of the RIL population (PI251246 X Salinas) from multiple production environments were phenotyped for seed germination characteristics at different temperatures. Quantitative trait analysis revealed a major QTL for high temperature germination on chromosome 9 (*qHTG9.1*) which also had a significant QTL by environmental interaction. Using the standard deviations of germination percentages of each RIL when grown in different production environments as the environmental sensitivity parameter for QTL analysis, a major QTL, a.k.a. plastic response QTL, for high temperature germination was identified on chromosome 9 (*qPHTG9.1*). This QTL co-localized with the one obtained for thermoinhibition (*qHTG9.1*). **This result suggests that the main trait locus *qHTG9.1* may not only determine the seed thermoinhibition trait but also underlie environmental sensing during seed development and determine seed germination temperature sensitivity.**

In addition, we utilized a RIL population derived from Salinas x UC96US23 to map QTL for light sensitivity of lettuce seed germination. We found a significant and novel QTL for light sensitivity on Chromosome 7, a.k.a. a dark germination QTL (*qDG7.1*). ***qDG7.1* had a significant epistasis with the *Htg6.1* QTL** which was previously identified from the same mapping population and demonstrated to be due a gene encoding an abscisic acid biosynthetic enzyme, *NCED4* (Huo et al. 2013).

Introduction

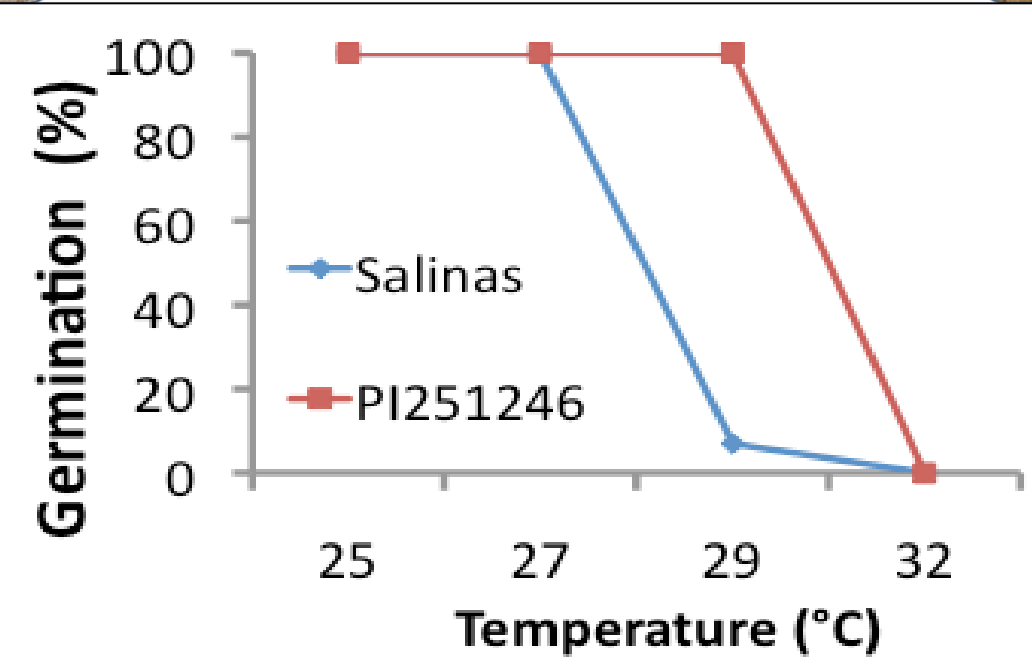


Figure 1. Maximum germination temperatures for *Lactuca sativa* cv. Salinas and PI251246 are 28 and 32°C respectively.

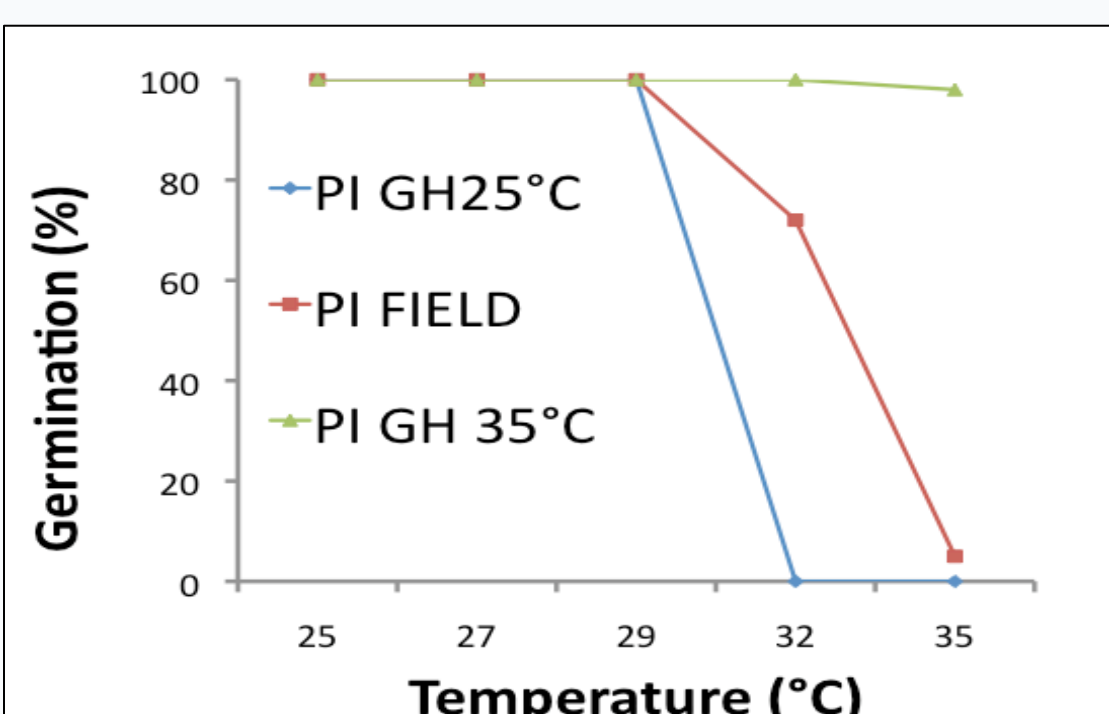


Figure 2. PI251246 shows maternal environmental plasticity with respect to seed germination at high temperature.

Results (QTL for Thermoinhibition)

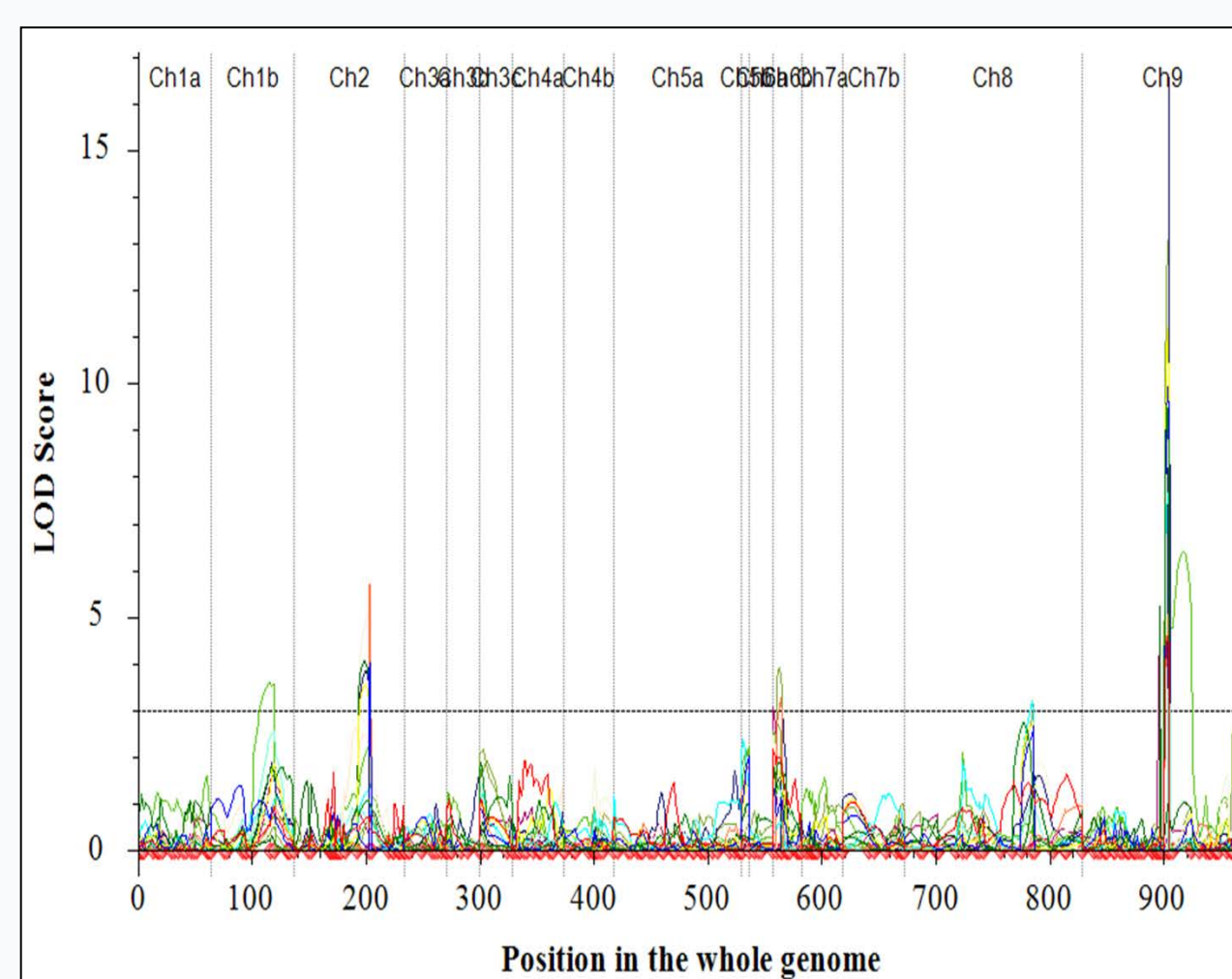


Figure 3. Mean high temperature germination of the same RILs (PI251246 X Salinas) from four locations were used in QTL analysis. A significant QTL was identified on Chromosome 9 with two minor QTL on chromosomes 2 and 6. **The Major High Temperature Germination QTL (*qHTG9.1*) explains 47% of the total phenotypic variance** and is contributed by the PI251246 parent.

Results (QTL for Phenotypic Plasticity)

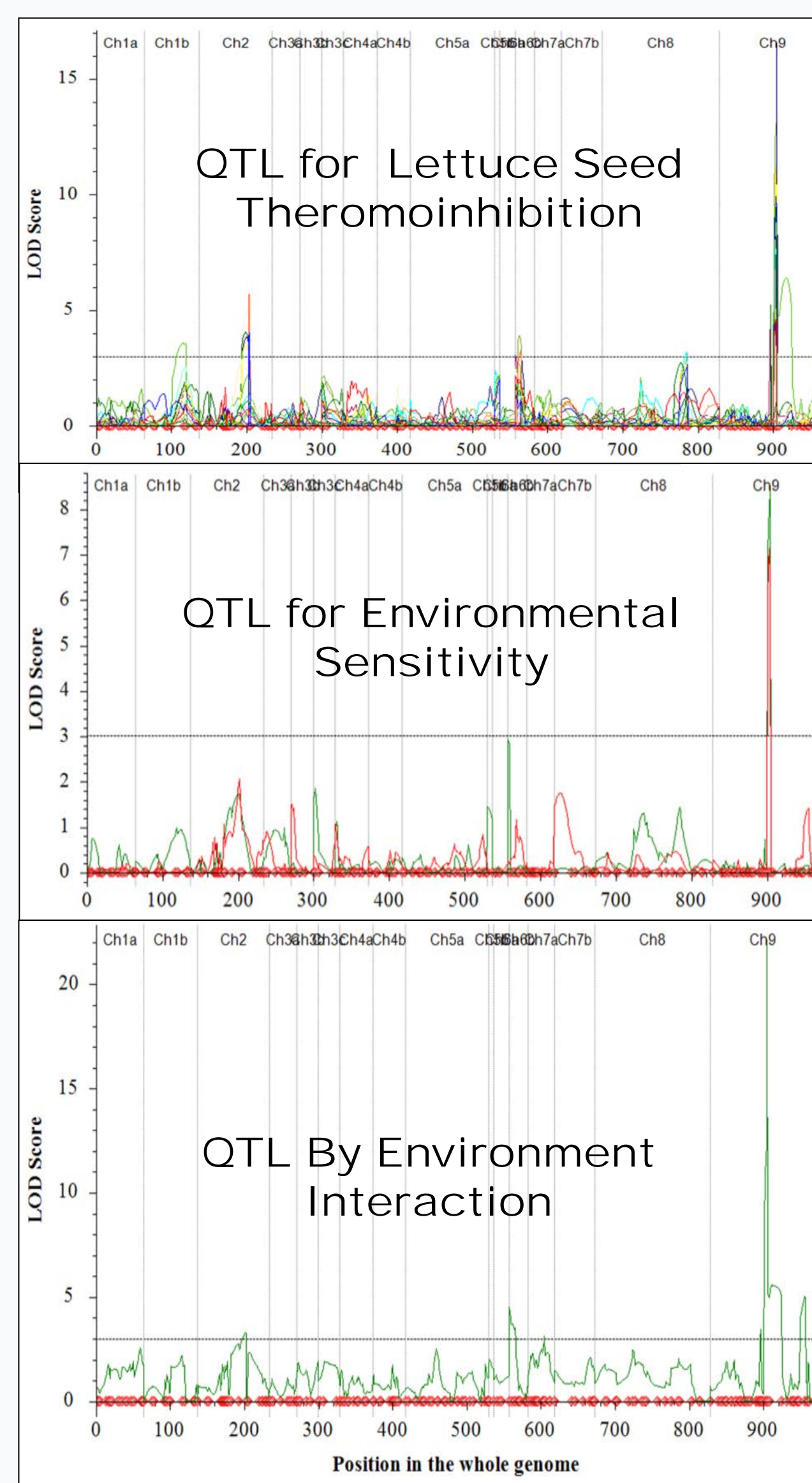


Figure 4. Standard deviation of the high temperature seed germination of RILs from each production location was used as the surrogate for environmental sensitivity in QTL analysis. In addition, QTL by environment analysis was done using the mean seed germination values of RILs from each location. A significant plastic high temperature germination QTL (*qPHTG9.1*) was identified on chromosome 9. **All three QTLs co-localized on Chromosome 9.**

Results (QTL for Photodormancy)

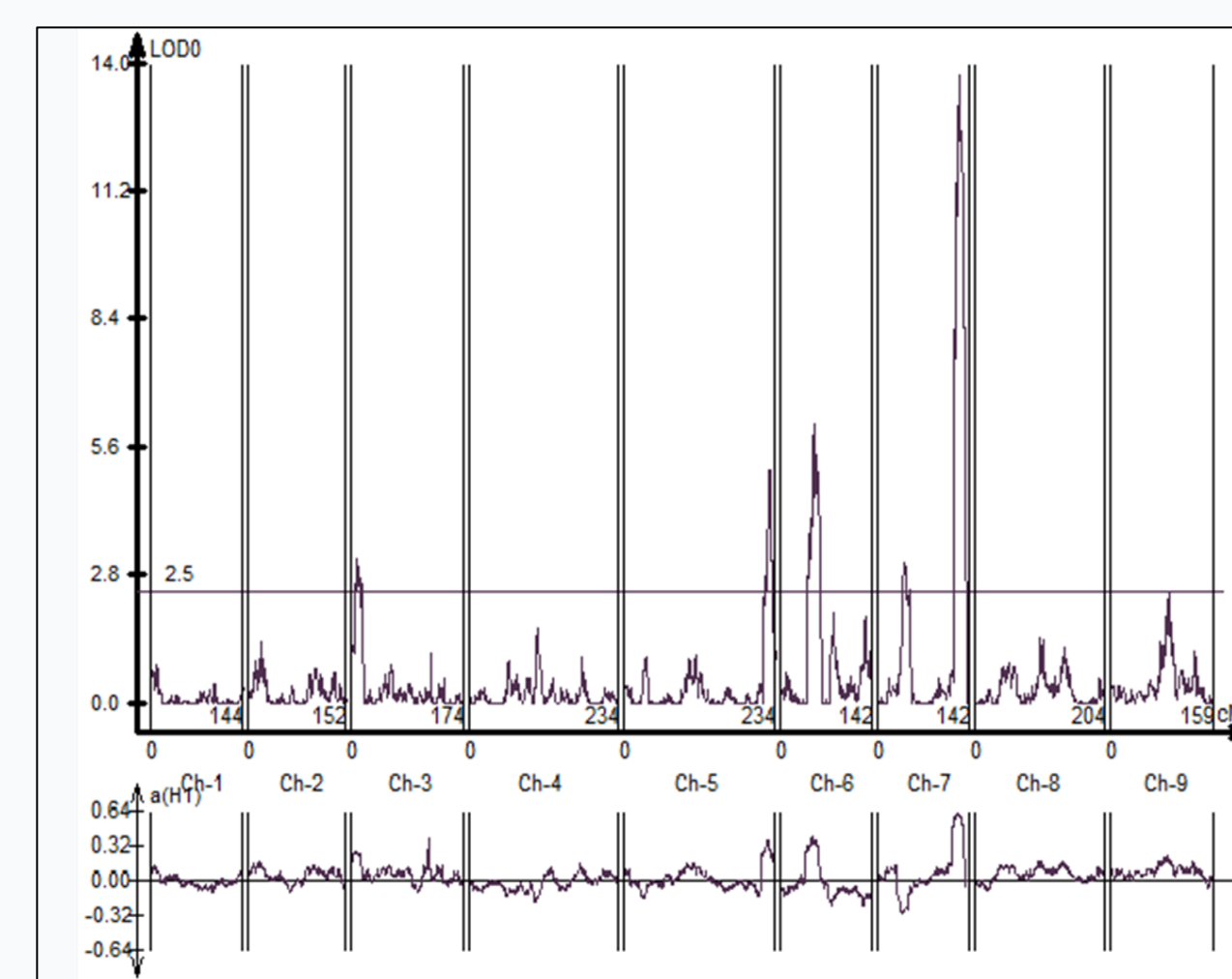


Figure 5. Recombinant inbred lines derived from *Lactuca sativa* cv. Salinas and *Lactuca serriola* (US96UC23) were used in mapping light requirements of lettuce seed germination. Mean seed germination under dark was used in QTL analysis. A significant QTL (*qDG7.1*) was identified on chromosome 7 with two minor QTL on chromosomes 5 and 6. ***qDG7.1* explains 18% of the total phenotypic variance.**

Results (QTL by QTL Interaction)

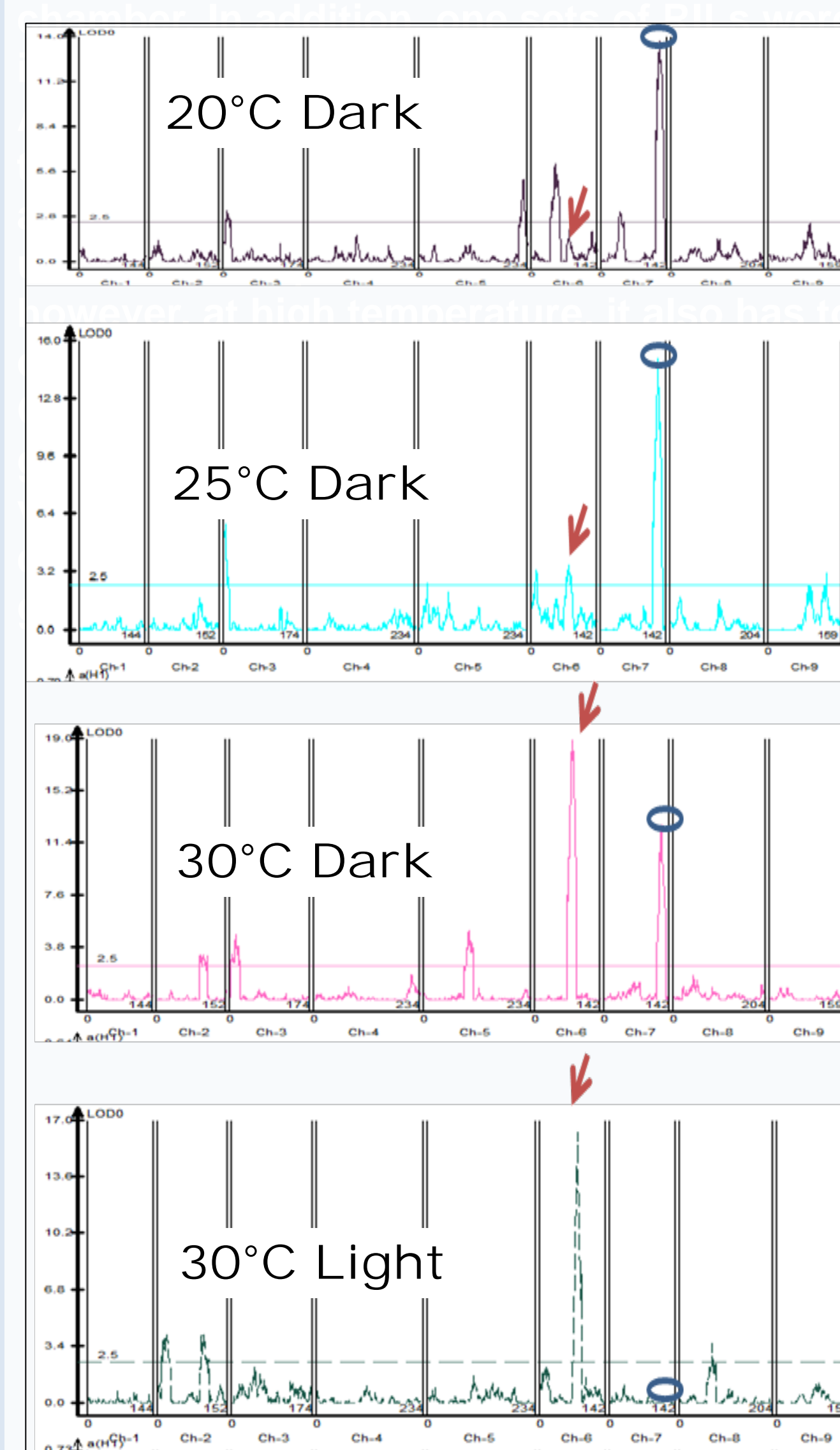


Figure 6. Interaction between thermoinhibition and photodormancy QTLs in the Salinas x US96UC23 mapping population. Examination of QTLs detected for different conditions revealed that *qDG7.1* is present under dark and low temperature treatments. However, **at high temperature and in dark, both *qDG7.1* and *qHTG6.1* are prominent**, while with exposure to light at high temperature, only *qHTG6.1* is significant.

Conclusion

- A QTL on chromosome 9 is responsible for both the thermoinhibition trait and environmental sensitivity (phenotypic plasticity) of this trait.
- The effect of this QTL is expressed differently in different environments.
- This is consistent with the allelic sensitive gene theory of G x E interactions.
- A QTL on chromosome 7 is responsible for photodormancy.
- There is a significant QTL by QTL interaction for photodormancy and thermoinhibition.

Future Directions

- Positional cloning of *qPHTG9.1*.
- Positional cloning of *qDG7.1*.
- Transcriptional studies of genes related to the plastic trait determining the upper temperature limits for seed germination.
- Transcriptional studies of genes related to seed germination under dark conditions.

References

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Acknowledgements

We thank Dr. Richard Michelmore of the Genome Center who provided us the recombinant inbred lines and their genetic maps. This project was supported by Western Regional Seed Physiology Research Group (WRSPRG) and the National Science Foundation (NSF).

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