Identification of novel genomic regions for root nodulation and adverse climate resistance in soybeans.

Abstract

The soybean (*Glycine max*) is a crucial annual legume valued for its high protein and oil content, making it an important economic crop worldwide. Its high protein content necessitates substantial nitrogen, which is supplied through symbiotic nitrogen fixation (SNF) with Bradyrhizobia bacteria in root nodules. This biological process converts atmospheric nitrogen into ammonia, providing a sustainable alternative to chemical fertilizers, which are often costly and environmentally detrimental. Climate change has adversely affects soil conditions, root growth, water and nutrient absorption, and nodulation. Elucidating the genetic basis of soybean–rhizobia-mediated nitrogen fixation can enhance nitrogen availability in agricultural systems. Genome-wide association studies (GWAS) have emerged as an effective method for identifying genetic regions linked to phenotypic variation. In this study, nodulation traits were evaluated in 238 mid- to late-maturing soybean accessions. Soybean seeds were germinated on brown germination paper, and 7-day-old seedlings were inoculated with *Bradyrhizobium japonicum* before transferring to blue blotting paper. After 28 days, root images were captured, and 24 nodulation traits were analyzed using a newly developed YOLO-based pipeline. The YOLO model was trained and validated on the high-performance computing platform, run:ai (https://www.run.ai/), using two graphics processing units (NVIDIA A40 GPU) with a memory of 90 GB. Phenotypic data from the YOLO based pipeline and SNP markers from the Illumina Infinium SoySNP50K iSelect SNP BeadChip were subjected to GWAS using the TASSEL 5.0 mixed linear model and FarmCPU. This analysis identified 158 significant Single Nucleotide Polymorphims (SNPs) associated with nodulation traits and climate resistance, comprising 112 from TASSEL and 46 from FarmCPU, with the maximum SNPs on chromosome 14. The identified loci provide valuable genetic targets for enhancing nodulation and improving SNF efficiency. These findings can facilitate the development of soybean cultivars with improved symbiotic nitrogen fixation, resistance to adverse climatic conditions and promoting sustainable agricultural practices.