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ORIGINAL PAPER

Stress-inducible expression of barley *Hva1* gene in transgenic mulberry displays enhanced tolerance against drought, salinity and cold stress

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Abstract Coping with different kinds of biotic and abiotic stresses is the foundation of sustainable agriculture. Although conventional breeding and marker-assisted selection are being employed in mulberry (*Morus indica* L.) to develop better varieties, nonetheless the longer time periods required for these approaches necessitates the use of precise biotechnological approaches for sustainable agriculture. In an attempt to improve stress tolerance of mulberry, an important plant of the sericulture industry, an encoding late embryogenesis abundant gene from barley (HVA1) was introduced into mulberry plants by *Agrobacterium*-mediated transformation. Transgenic mulberry with barley *Hva1* under a constitutive promoter *actin1* was shown to enhance drought and salinity tolerance. Here, we report that overexpression of barley *Hva1* also confers cold tolerance in transgenic mulberry. Further, barley *Hva1* gene under control of a stress-inducible promoter *rd29A* can effectively negate growth retardation under non-stress conditions and confer stress tolerance in transgenic mulberry. Transgenic lines display normal morphology to enhanced growth and an increased tolerance against drought, salt and cold conditions as measured by free proline, membrane stability index and PSII activity. Protein accumulation was detected under stress conditions confirming inductive expression of HVA1 in transgenics. Investigations to assess stress tolerance of these plants under field conditions revealed an overall better performance than the non-transgenic plants. Enhanced expression of stress responsive genes such as *Mi dnaJ* and *Mi 2-cysperoxidin* suggests that *Hva1* can regulate downstream genes associated with providing abiotic stress tolerance. The investigation of transgenic lines presented here demonstrates the acquisition of tolerance against drought, salt and cold stress in plants overexpressing barley *Hva1*, indicating that *Arabidopsis rd29A* promoter can function in mulberry.

Keywords Abiotic stress tolerance · Field evaluation · *Hva1* · Inducible expression · Mulberry · Transgenic plants

Introduction

The detrimental effects of abiotic and biotic stresses with increasing climatic unpredictability and continuous deterioration of arable lands can negatively influence overall homeostasis of plants, thus limiting crop expansion, biomass production and crop productivity worldwide (Bray et al. 2000; Sairam and Tyagi

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