

## Article

# Berry texture QTL and candidate gene analysis in grape (*Vitis vinifera* L.)

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(PerB). The high-density linkage map was constructed using whole-genome resequencing based on 151 F

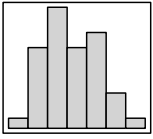
<sup>1</sup> individuals originating from intraspecific hybridization between the firm-flesh cultivar 'Red Globe' and soft-flesh cultivar 'Muscat Hamburg'. The total length of the consensus map was 1613.17 cM, with a mean genetic distance between adjacent bin markers of 0.59 cM. Twenty-seven quantitative trait loci (QTLs) for berry MesF, PPH, and PerB were identified in linkage groups (LGs) 1, 3, 4, 6, 8, 9, 10, 11, 14, 16, and 17, including twelve QTLs that were firstly detected in LGs 6, 11, and 14. Fourteen promising candidate genes were identified from the stable QTL regions in LGs 10, 11, 14, and 17. In particular, *VvWARK2* and *VvWARK8* refer to chromosome 17 and are two promising candidate genes for MesF and PPH, as the *VvWARK8* gene may increase pectin residue binding with WARK for high berry firmness maintenance and the allele for *VvWARK2* carrying the 'CC' and 'GA' genotypes at Chr17:1836764 and Chr17:1836770 may be associated with non-hard texture grape cultivars. In addition, real-time quantitative polymerase chain reaction (RT-qPCR) verification revealed that the promising candidate transcription factor genes *VvMYB4*-like, *VvERF113*, *VvWRKY31*, *VvWRKY1*, and *VvNAC83* may regulate cell wall metabolism candidate gene expression for grape berry texture changes.

## Introduction

Grape (*Vitis vinifera* L.), which belongs to family Vitaceae, is an economically important fruit tree cultivated worldwide. Grape berry texture has high agronomic relevance because of its relationships with the quality parameters and marketing requirements of table, raisin, and wine grapes [1], and the flesh firmness and peel

found two stable QTLs associated with berry firmness near SSR

















the present study ( $n=151$ ). The female parent 'Red Globe' has a firm-flesh texture after maturation, and the male parent 'Muscat Hamburg' has a soft-flesh texture after maturation. Intraspecific hybridization was conducted in May 2011, and hybrid seeds were collected in October 2011. The offspring and parents were cultivated at Shenyang Agricultural University with commercial vineyard management and pruning. Genomic DNA (gDNA) was extracted from young leaves of the parents and offspring. Clusters were harvested from each plant at maturity from 2017 to 2019, 30 similarly sized berries were used for texture evaluation immediately, and 10 berries were frozen with liquid nitrogen for the following experiment after sampling.

### **Grape berry texture determination**

The berry mesocarp (flesh) firmness (MesF), pericarp (peel) puncture hardness (PPH), and pericarp brittleness (PerB) were determined using a texture analyzer (TA. XT Express, Stable Micro System, Godalming, UK) according to a previous method, with some modifications [64]. MesF indicated the average force (g) required to puncture the berry flesh, PPH indicated the force (g) used from the probe touching the peel until the peel is punctured and PerB indicated the displacement distance (mm) from the probe touching the peel to puncture peel. Berry puncture determination



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