



**COLLEGE of  
BIOLOGICAL SCIENCE**

DEPARTMENT OF MOLECULAR  
AND CELLULAR BIOLOGY

***Announcement:***

*All interested members of the university community are invited to attend the Final Oral Examination for the degree of **Doctor of Philosophy** of*

**YASHU SONG**

**on Friday, June 3, 2022 at 9:30 a.m. (online)**

**Thesis Title:** Investigation of the global gene expression changes in major wine grapes infected with grapevine leafroll-associated virus 3

**Examination Committee:**

Dr. Ray Lu, Dept. of Molecular and Cellular Biology (Exam Chair)  
Dr. Baozhong Meng, Dept. of Molecular and Cellular Biology  
Dr. Tariq Akhtar, Dept. of Molecular and Cellular Biology  
Dr. Dirk Steinke, Dept. of Integrative Biology  
Dr. Jonathan Griffiths, London Research and Development Centre – Vineland Station, Agriculture and Agri-Food Canada (External Examiner)

**Advisory Committee:**

Dr. Baozhong Meng (Co-Advisor)  
Dr. Robert Hanner (Co-Advisor)  
Dr. Tariq Akhtar

**Abstract:** Grapevine leafroll-associated virus 3 (GLRaV-3) is one of the most important viruses affecting global grape and wine production. GLRaV-3 is the chief agent associated with grapevine leafroll disease (GLRD), the most prevalent and economically destructive grapevine viral disease complex. Molecular response of grapevine to GLRaV-3 infection is poorly characterized, limiting the understanding of GLRaV-3 pathogenesis and viral-associated symptomatic development. In this research, we used RNA Sequencing (RNA-Seq) to profile the global gene expression change of Cabernet Franc, a premium red wine grape, analyzing leaf and berry tissues at three key different developmental stages. We have identified 1,457 differentially expressed genes (DEGs) in leaves and 1,181 DEGs in berries. Expressional profiles of a subset of DEGs were validated through RT-qPCR, including those involved in photosynthesis (VvPSBP1), carbohydrate partitioning (VvSUT2, VvHT5, VvGBSS1, and VvSUS), flavonoid biosynthesis (VvUFGT, VvLAR1, and VvFLS), defense response (VvPR-10.3, VvPR-10.7), and mitochondrial activities (ETFB, TIM13, NDUFA1). GLRaV-3 infection altered source-sink relationship between leaves and berries. Photosynthesis and photosynthate assimilation were inhibited in mature leaves while increased in young berries. The expression of genes involved in anthocyanin biosynthesis increased in GLRaV-3-infected leaves, correlating with interveinal tissue reddening, a hallmark of GLRD symptoms. Notably, we identified changes in gene expression that suggest a compromised sugar export and increased sugar retrieval in GLRaV-3-infected leaves.

Genes associated with mitochondria were down-regulated in both leaves and berries of Cabernet Franc infected with GLRaV-3. Results of the present study suggest that GLRaV-3 infection may disrupt mitochondrial function of grapevine leaves, leading to repressed sugar export and accumulation of sugar in photosynthetic tissues. The excessive sugar accumulation in GLRaV-3-infected leaves would trigger downstream GLRD symptom development and negatively impact berry quality. We propose a working model to account for the molecular events underlying the pathogenesis of GLRaV-3 and symptom development. During the course of this research, a refined total RNA extraction protocol suitable for dark-skinned ripe berries and *novel* reference genes suitable for grapevine associated RT-qPCR analysis were identified.

**Curriculum Vitae:** Yashu obtained her B.Sc. with honours in Biology at Western University in June of 2014. Following this, Yashu completed her Master of Bioinformatics at the University of Guelph. In January 2018, Yashu began her Ph.D. in Molecular and Cellular Biology under the supervision of Dr. Baozhong Meng and Dr. Robert Hanner at the University of Guelph.

**Awards:** International Graduate Tuition Scholarship (IGTS) (2018 – 2021), University of Guelph.

**Publications:** Song, Y.; Hanner, R.H.; Meng, B. RNA-Seq Analysis Unveils Complex Virus-Host Interactions in Grapevine ‘Cabernet Franc’. (*\*Manuscript, submitted, processed for peer review*)

Song, Y.; Hanner, R.H.; Meng, B. Genome-wide screening of novel RT-qPCR reference genes for study of GLRaV-3 infection in wine grapes and refinement of an RNA isolation protocol for grape berries. *Plant Methods* 2021, 17, 110, doi:10.1186/s13007-021-00808-4.

Song, Y.; Hanner, R.H.; Meng, B. Probing into the effects of grapevine leafroll-associated viruses on the physiology, fruit quality and gene expression of grapes. *Viruses* 2021, 13, 593, doi:10.3390/v13040593.

Diaz-Lara, A.; Klaassen, V.; Stevens, K.; Sudarshana, M.R.; Rowhani, A.; Maree, H.J.; Chooi, K.M.; Blouin, A.G.; Habili, N.; Song, Y.; et al. Characterization of grapevine leafroll-associated virus 3 genetic variants and application towards RT-qPCR assay design. *PLoS One* 2018, 13, e0208862, doi:10.1371/journal.pone.0208862.