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Review Article

Graft-transmissible citrus diseases in P. R. China – research developments

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Abstract

In the P.R. China, ten graft-transmissible pathogens have been identified infecting citrus, including *Candidatus Liberibacter asiaticus*, *Citrus tristeza virus* (CTV), Citrus tatter-leaf virus (CTLV), *Citrus exocortis viroid* (CEVd), *Citrus yellow vein clearing virus* (CYVCV), *Satsuma dwarf virus* (SDV), *Citrus vein enation virus* (CVED), *Citrus psorosis virus* (CPSV), Citrus cachexia viroid (CCaVd), and *Citrus chlorotic dwarf virus* (CCDV). Of these pathogens, the first five cause damage in field citrus trees, whereas the latter five were occasionally detected from the imported citrus materials or field trees. Research progress on HLB, CTV, CYVCV etc. within recent three years are briefly reviewed.

In the P.R. China, ten graft-transmissible pathogens have been identified infecting citrus, including *Candidatus Liberibacter asiaticus*, *Citrus tristeza virus* (CTV), Citrus tatter-leaf virus (CTLV), *Citrus exocortis viroid* (CEVd), *Citrus yellow vein clearing virus* (CYVCV), *Satsuma dwarf virus* (SDV), *Citrus vein enation virus* (CVED), *Citrus psorosis virus* (CPSV), Citrus cachexia viroid (CCaVd) and *Citrus chlorotic dwarf virus* (CCDV) (Fu et al. 2015; Huang et al. 2015; Lin et al. 2013; Lin et al. 2015; Shang et al. 2016; Song, Kurth, et al. 2015; Song, Li, et al. 2015; Wang, Chen, et al. 2015; Wang, Su, et al. 2015; Wang et al. 2013; Wu et al. 2014; Yi and Zhou 2014; Zheng et al. 2014; Zheng and Zhou 2013; Zhou et al. 2017; Zhou et al. 2013). Of these pathogens, the first five cause damage in field citrus trees, whereas the latter five were occasionally detected from the imported citrus materials or field trees.

Since the 1980s, virus-free citrus propagation schemes have been executed in Hunan, Sichuan, and Chongqing at the provincial level. Although some progress has been made, they were all suspended due to a number of reasons. Before the 1980s, HLB-free propagation schemes were also conducted in Guangdong, Guangxi, and Fujian, respectively, but also were suspended.

Due to the fact that over 100 modern virus-free citrus nurseries have been established in 13 provinces through the implementation of a virus-free scheme since 2001, the loss caused by graft-transmissible citrus pathogens, especially for those that are non-vector transmissible such as CTLV, SDV, and CEVd has dramatically decreased. As a result, few research activities have been addressed on those non-vector transmissible pathogens within the last three years, although some damage still can be

observed due to inappropriate budwood distribution and top-grafting larger trees carrying CTLV and/or CEVd.

Since 2012, however, the Huanglongbing (HLB) problem has increased in severity in some of the fast growing citrus provinces such as Guangdong, Jiangxi, and Hunan. For example, over 30 million citrus trees have been removed due to HLB in south Jiangxi within the last three years. So, a series of research projects have focused on the control of HLB. Some progress has been made: 1) putative prophage particles were observed in sweet orange (Fu et al. 2015); 2) the whole genomes of three Chinese isolates of the HLB bacterium were sequenced; bio-information is accumulating quickly, focusing on the prophage genomic region with high genetic variation and recombination events; two HLB origin centres were proposed in the P.R. China (Lin et al. 2013; Lin et al. 2015; Wang et al. 2013; Wang, Su, et al. 2015; Wang, Chen, et al. 2015; Zheng et al. 2014; Zheng and Zhou 2013); 3) transgenic citrus lines against HLB are in field trials for evaluation; 4) a few effective combinations of pesticides have been selected to control citrus psyllids (*Diaphorina citri*); 5) natural thermotherapy of the citrus tree canopy by covering with PVC mulch showed somewhat efficacy to reduce the disease symptoms.

Among the above listed citrus virus pathogens, a few vector-transmissible viruses such as CTV and CYVCV are topics of research due to the difficulty of their control in the field. Because severe stem-pitting isolates of CTV are widely distributed in P.R.China, a few mild isolates with potential cross-protective capability were obtained from screening of thousands of field isolates that are being applied in field trials for efficacy evaluation. Also, progress is being made in understanding the protein-

protein interactions between CTV isolates and their sensitive hosts and vector [brown citrus aphids (*Toxoptera citricida*)] (Shang et al. 2016; Yi and Zhou 2014; Zhou et al. 2013). CYVCV is a newly discovered virus causing severe damage in the lemon industry in the last few years (Huang et al. 2015; Song et al. 2015; Zhou et al. 2017). The citrus whitefly (*Dialeurodes citri*) has been experimentally proved to be the vector of this virus (unpublished data). All viruses above mentioned have been sequenced, and been subjected to phylogenetic analysis. Furthermore, a few types of infectious viral vectors have been constructed. Although viroids are of less importance than other pathogens for the citrus industry, a few new variants such as *Citrus viroid V* and *Citrus viroid I-LSS* were detected and the distribution of the above pathogens has been monitored.

As a lot of attempts have been made for improving the diagnostic methods for these ten pathogens, and some that showed higher efficacy have been being widely applied for quick diagnosis.

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