EPIDEMIOLOGY OF VIRUSES

INFECTING HOP (*Humulus lupulus* L.)

IN AUSTRALIA

By

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ABSTRACT

The objectives of this study were to quantify the rate and means of spread of hop mosaic *carlavirus* (HpMV), hop latent *carlavirus* (HpLV), and *Prunus* necrotic ringspot *ilarvirus,* apple (PNRSV-A) and intermediate (PNRSV-I) serotypes in Australian-bred cultivars of hop (*Humulus lupulus* L.), and to determine if viruses posed a significant constraint to the yield and quality of hop products from these cultivars.

Significant reductions in yield and levels of brewing organic acids were associated with virus infection in 'Opal' and 'Pride of Ringwood'. Infection by HpLV + HpMV + PNRSV-A and HpLV + HpMV + PNRSV-I, had the most significant impact on yield and levels of bittering compounds in 'Opal'. Yield of cones (ripe flowers) was reduced by 48 %, and 53 %, respectively, alpha acid content by 23 %, and 33 %, respectively, beta acid content by 15 % and 14 %, and the alpha to beta acid ratio by 35 % and 41 %, respectively. Infection by HpMV and PNRSV-I had the most significant impact on yield of cones and levels of bittering compounds in 'Pride of Ringwood'. Yield of cones was reduced by 55 % and 51 % respectively, and alpha acid content by 19 % and 15 %, respectively. Virus infection in 'Pride of Ringwood' caused no significant reduction in beta acid content. No significant reductions in yield of cones and levels of brewing organic acids were associated with viruses or combinations of viruses in 'Victoria', or from infection by HpLV, HpMV, PNRSV-I, and HpLV + PNRSV-I in 'Nugget'.

Significant differences in virus incidence were consistently demonstrated between cultivars. 'Victoria' gardens planted with elite (virus-tested) material became almost totally re-infected with PNRSV within eight years. Mechanical inoculation of PNRSV into a range of hop cultivars suggested 'Victoria' was more susceptible than traditional ones. In contrast, the spread rate of HpLV, HpMV, and PNRSV was consistently slower in 'Opal' gardens, and this was found to be the most field resistant cultivar to infection by all three viruses.

PNRSV was detected by double antibody sandwich enzyme-linked immunosorbent assay (DAS-ELISA) in chronically infected 'Victoria' plants throughout the growing season. Testing of a range of tissues from 'Victoria' plants suggested a symmetrical distribution of PNRSV within the plant. Similar testing of 'Nugget', 'Pride of Ringwood', and 'Opal' plants suggested an asymmetrical distribution of PNRSV within the plant. The longer period of elevated virus levels in all tissues in 'Victoria' may increase the probability of virus transmission and be responsible for the accelerated transmission of PNRSV in this cultivar. The asymmetric virus distribution in 'Nugget', 'Pride of Ringwood', and 'Opal' suggested that accurate virus testing relies upon sampling from several bines from each string.

Spatial analysis of PNRSV epidemics by ordinary run and radial correlation analyses in 'Victoria' gardens in Myrtleford, Victoria and Bushy Park, Tasmania associated PNRSV transmission with mechanical mowing of basal growth. Transmission was reduced in field trials by preventing basal growth contact between infected and virus-free plants along rows early in the season. This demonstrated that plant contact early in the season increases the probability of transmitting PNRSV to virus-free plants by decreasing the distance infective virions have to travel to infect new plants. Glasshouse trials also confirmed PNRSV to be transmitted by contact and simulated slashing between infected and virus-free plants. Root grafting was also successful at transmitting PNRSV between infected and virus-free plants. The presence of root grafts in Tasmanian hop gardens was suggested by injection of the translocatable herbicide marker, glyphosate. However, quantification of the extent to which root grafts contribute to transmission of all three viruses requires further work.

Spatial analysis of *carlavirus* epidemics showed different distributions between 'Victoria' gardens in Myrtleford and Bushy Park. Random distributions of both HpLV and HpMV at Myrtleford suggested transmission by alatae aphid vectors. Autocorrelated along row distributions of both viruses at Bushy Park suggested transmission by either mechanical transmission through basal growth mowing, and/or aphid vectors (alatae or apterous) directed along rows from basal growth bridges formed through basal growth mowing between rows. A significant positive association between HpLV and HpMV was consistently demonstrated in several cultivars. This may suggest transmission by common aphid vector species, transencapsidation, or the possibility that infection by one virus makes the plant more susceptible to infection by the other.

In most hop cultivars grown in Australia the slow rate of virus transmission and significant effect of some viruses on yield of cones and levels of brewing organic acids suggested the continued use of a virus certification scheme for planting stock is warranted. However, in 'Victoria', the usefulness of certification schemes is uncertain because of the rapid spread of viruses in this cultivar and its tolerance to infection.