The benefits of using certified, virus-tested, true-to-type plant material

The benefits to the primary fruit producers of establishing orchards and vineyards of certified, virus-tested, true-to-type plant material are not well understood. This article summarises the results of a research project which assessed the lifetime economic and non-economic benefits for fresh stone and pome fruit orchards, table and raisin grape vineyards, as well as canning peach orchards in South Africa (Midgley and Vermeulen, 2015; Midgley et al., 2015 and 2016).

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Apple and pear trees are prone to infection with a range of viruses, of which the most important in South Africa are *Apple mosaic virus* (ApMV) and *Apple chlorotic leaf spot virus* (ACLSV). Both viruses can exist in trees for long periods without showing visible symptoms, i.e. they are latent (especially ACLSV). Visible symptoms of ApMV occur with virulent strains of the virus, or in sensitive cultivars, such as Golden Delicious and Granny Smith, and in old orchards. Rapid emergence of visible impacts can be triggered by conditions leading to stress in the orchard, such as drought and disease.

Where trees are affected, fruit tend to be smaller leading to yield reductions and price reductions. Both viruses are spread by grafting with infected plant material. The virus incidence can be managed by planting only certified virus-tested trees, removing infected material from orchards, strict sanitary practices, and using only certified material for re-planting and top-working.

Plum and peach trees, on the other hand, are susceptible to *Prune dwarf virus* (PDV) and *Prunus necrotic ringspot virus* (PNRSV). A wide range of symptoms can occur, including poor yield and fruit quality. Co-infection between PDV and PNRSV may intensify the symptoms. Both viruses can spread by grafting with infected plant material, or using infected seeds to develop rootstocks, while natural spread can occur during pollination by honeybees (although this is a lower risk in peaches than plums).

The viruses can be managed by planting certified virus-tested trees and by preventing spread within and between orchards by removing diseased plants, avoiding the use of commercial beehives recently used in other infected stone fruit orchards, avoiding the propagation of peach rootstocks from uncertified seeds, and using only virus-free material for top-working.

For **grapevines** the most important viruses are *Grapevine leaf-roll associated viruses* (GLRaV's). The GLRaV-3 is the main strain of this virus responsible for Grapevine leafroll disease (GLD) in South Africa. There is a progressive reddening and rolling of the leaves in red cultivars as the season progresses, often beginning in mid-summer when vines are under water stress. Very few of the white cultivars show noticeable symptoms, but may do so if very heavily infected for a long time.

Most vineyards in the Western Cape are infected with GLRaV and the disease spreads very rapidly. If left unmanaged, all plants may become diseased within 10 to 13 years due to the exponential spread.

The GLRaV's can be transmitted by grafting and several insect vectors, such as mealybugs and soft scale insects. GLD can be managed by controlling insect vectors with a combination of systemic and contact insecticides. This is seen as the primary response, together with the planting of certified virus-tested vines. Roguing can be performed based on a visual selection of symptomatic plants in red cultivars. When infection levels are high (>ca.25%) the removal of the entire vineyard can be considered.

Estimates of incidence and impacts in the Western Cape

Limited information is available on the extent of infection and impacts on production in

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South African apple and pear orchards. Infection rates of ApMV in apples are believed to reach 30% (sometimes 100% in old Golden Delicious orchards), yield losses up to 30%, and price reductions of up to 35% due to smaller fruit sizes. For pears, ApMV infection levels are likely to be lower (<1%), although they could also be up to 30%, with yield losses up to 20%, and price reductions up to 35%. ACLSV in apple and pear orchards is generally unknown by industry role players, or considered to have a low incidence and impact, probably due to a lack of visible symptoms.

The incidence of PDV in **plum and peach** trees is considered low (<1%) and that of PNRSV low, but possibly higher than PDF (<10%). However, it is thought that both viruses can spread quickly in plum orchards, since beehives are commonly used for pollination. These pollen transmissible viruses can infect an entire plum orchard within one year. The viruses spread less quickly in peach orchards compared to plum orchards because beehives are not typically used for pollination of peaches.

The usual rate of spread within plum and peach orchards is likely to be 2-30% per year, and between neighbouring orchards 1-5% per year. Yield losses due to PDV and PNRSV in plums can reach 30% or higher, although there are wide differences in estimates; yield losses in peach orchards are not known. Smaller, misshapen and blotchy fruit caused by PNRSV, can reduce prices by around 20%. There appears to be no knowledge on the impacts of PDV infection in stone fruit.

In table grape vineyards the incidence of GLRaV's can be up to 30% and sometimes higher. Yield losses are estimated at approximately 21-30%. The quality of the table grape bunches may be reduced by berries being less pigmented, smaller, and on smaller bunches with poor form. Bunches may have larger off-cuts to improve the bunch form, leading to loss of productivity in packing and yield reductions.

Price reduction could be up to 80%. The price may also be reduced in cases where an early market window is not achieved due to delayed ripening associated with GLRaV infection. The potential loss in raisin grape production and value due to virus infection is not known, although it is thought that the raisins from infected grapevines are smaller, because of a lower sugar content in the berries. The price reduction for smaller raisins could be about 50%.

For all five viruses there is a lack of data supported by laboratory virus tests to support an accurate understanding of the extent of the problem in commercial orchards and vineyards, and in uncertified plant material used by a small minority of deciduous fruit producers. The industry should consider moving away from the term "visually free" by adopting future testing of all plant material for the viruses identified in the Certification Scheme.

Using a modelling approach to assess impacts of viruses and benefits of certified material

Against this background, the long-term (orchard/vineyard lifetime) financial benefit to the producer of using certified virus-tested plant material was estimated by comparing various scenarios under a model. The model of Fuller et al. (2013) for grapevine production in California was used as a basis; see also Fuller et al. (2015). The model was set up for fresh apples, pears, plums and table grapes, for canning peaches, and for raisin (dried) grapes and their key viruses, and is not at this stage cultivar- or area-specific. A wide range of scenarios was modelled to capture the range of possibilities and identify the most critical factors, rather than to depict the current situation in the industry.

To estimate the value of losses incurred by fruit growers as a result of virus-related diseases, and the benefit from using certified virus-tested plant material, we estimated differences in net income from a representative hectare of fruit between several scenarios. For each host-virus combination, we compared scenarios for various aspects of disease pressure: initial disease incidence linked to whether or not the orchard/vineyard was planted using certified virus-tested plant material, rate of disease spread, yield loss in diseased trees/vines, and reduction in price obtained for fruit harvested from diseased trees/vines (reflecting reductions in fruit quality due to the disease). Details of the model are presented in Midgley et al. (2016).

Results of modelling

For ApMV, the cumulative 25-year benefit of planting certified virus-tested trees (not adjusted for inflation) can be up to R2 811,819 per hectare for fresh apples and R1 642,755/ha for fresh pears. For ACLSV it can be up to R3 110,224/ha for apples and R2 061,739/ha for pears. The greater benefit for ACLSV compared to ApMV, relates to the assumption of a slightly higher infection incidence in uncertified planting material, since this virus is latent and not as well controlled using visual assessment methods.

In fresh plums, the cumulative benefit can be up to R1 540,755/ha for PDV and up to R1 736,995/ha for PNRSV. The greater benefit for PNRSV compared to PDV relates to the assumption of a slightly higher yield loss in uncertified trees infected with PNRSV. For both PDV and PNRSV in canning peaches, the cumulative benefit can be up to R627,974/ha.

In the case of table grapes or raisin grapes and GLRaV, infection and spread rates can rapidly reach 100% in a number of scenarios and the cumulative benefit can be up to R2 414,732/ha (table) or R1 957,528/ha (raisin). It is important to note that the results of the modelling study need to be verified with field data from commercial nurseries and orchards/vineyards.

Financial benefits to the producer are maximised primarily where the difference in initial virus incidence between certified and uncertified plants is greatest, and secondarily where the rate of spread is high. A minimum hypothetical difference in infection level at planting between 0,5-1% (certified) and 2-5% (uncertified) already yields benefits, but the benefits are significantly increased as this difference widens. This can be explained by the compound nature of the impacts over the orchard/vineyard lifetime.

The model results show an increase of 34-65% of the financial benefit of using certified virus-tested material, given the expectation that at least one stressful year will be experienced over the orchard/vineyard lifetime giving rise to a doubling of infection impacts. This would be expected to multiply with every additional "stress year".

Currently, most (estimated 90%) apple and pear producers, and around 80% of plum and peach producers are using certified virus-tested material, because they perceive a financial gain from doing so, both in the medium (10 years) and longer term (25 years). Other reasons include that certified material is readily available, it is more likely true-to-type, it is generally also free of pests and other disease-causing agents, and because it gives better yield and fruit quality.

Diseased underperforming trees should be removed and replanted with 'clean' trees; however, in orchards and older than a few years the replacement trees struggle to reach their full potential due to competition with large neighbouring trees. The orchard then loses its uniformity and ease of management. On the other hand, not replacing individual diseased trees means that they require more attention which is costly in terms of labour and chemical inputs, in

Figure 1 *Modelled results for Table Grapes where rate of spread of virus is 20% per annum.*
A and C: Modelled annual net income (blue) and loss from disease (red) as affected by initial incidence of virus in planting material.
B and D: Modelled cumulative net income (blue) and loss from disease (red) as affected by initial incidence of virus in planting material.
A and B: certified virus-tested planting material used (0.5% incidence).
C and D: uncertified planting material used (10% incidence).

Figure 2. Modelled results for Raisin Grapes where rate of spread of virus is 20% per annum.
A and C: Modelled annual net income (blue) and loss from disease (red) as affected by initial incidence of virus in planting material.
B and D: Modelled cumulative net income (blue) and loss from disease (red) as affected by initial incidence of virus in planting material.
A and B: certified virus-tested planting material used (0.5% incidence).
C and D: uncertified planting material used (10% incidence).

addition to the cumulative loss of income. It is far better to establish the orchard with healthy certified trees.

Currently, only about half of table and raisin grape producers are estimated to be using certified virus-tested material. There is a belief that this technology is cost effective within 10 years of establishment, but not over the lifetime of the vineyard due to high levels of disease pressure from infected neighbouring farms. This is partially supported by the results of the scenario based on 0,5% incidence in planted certified vines and a high spread rate of 20% per year. These show a reduction in annual profit from around R292 000 (table) or R311 000 (raisin) in Year 13, to R191 000 (table) or R229 000 (raisin) in Year 25 (Figures 1 and 2).

Uncertified vines (10% starting infection, 20% spread per year) reached 100% infection in Year 14 and had a final annual profit of R48 000 (table) or R112 000 (raisin), since diseased plants still produce marketable fruit. The annual benefit of using certified vines peaked in Year 14 at R241 000 (table) or R197 000 (raisin) and decreased thereafter to R143 000 in Year 25 (table) or R117 000 (raisin) (Figure 1). However, the lifetime cumulative benefit kept increasing to R3 600 000 (table) or R2 991 000 (raisin).

There may be an opportunity cost in not replacing the entire vineyard with fresh plants every 15-20 years in response to market pressures, as indicated by some industry experts. This could be modelled in future.

This study has provided some initial quantified analysis showing that the use of healthy certified virus-tested plant material in the deciduous fruit industry, is the basis for an integrated strategy for managing viruses, together with best practice monitoring and orchard/vineyard management. Given the expected increase in climatic stress in future, brought about by climate change, it is becoming even more important to manage orchard/vineyard stress and at the same time ensure that virus levels are as close to zero as possible at the outset.

Genetic deterioration

The challenge of genetic (cultivar) deviation and reversion (not true-to-type) within some deciduous fruit orchards (particularly apples) is widely acknowledged, but there exists no data on which to base a quantification of the financial and other impacts. Red/blushed apple cultivars known to be prone to deviation include Royal Gala (estimated level 5-50%), Royal Beaut (estimated level 20%), Fuji, Early Red One, Panorama Gold (estimated level 5-20%) and Starking (estimated level 5-15%).

A loss of red fruit colour can reduce the price fetched by approximately 75%. The reverted Panorama Gold has a later harvest date and the fruit is smaller. The income of the producer may be reduced by 80% due to the altered market window. Other benefits of maintaining true-to-type orchards, according to expert opinion, include easier farming with respect to spraying and pruning, predictable farming and peace of mind.

The pear cultivar Early Bon Chrétien (EBC) has reversion rates to the

parent Bon Chrétien (BC) cultivar estimated at between 5% and 50%. BC within a block of EBC has a later harvest date compared to EBC, but maturity levels of EBC and BC are difficult to distinguish, which makes harvesting more difficult and costly. EBC trees are often marked during bloom so that the fruit can be harvested according to labels, which also adds costs. Fruit from the later harvest fetches a much lower price and is sometimes sent for juicing, leading to a financial loss of approximately 71% per bin, according to one estimate.

The stone fruit cultivars do not usually have the challenges associated with genetic deviation and reversion (not true-to-type). Deviation is, however, found in Laetitia and Sungold plums, but there exists no data or expert estimates on which to base a quantification of the possible impacts.

Peach cultivars known to experience deviation fall under the Kakamas types, the primary type used for canning. It is believed that the Kakamas cultivar has changed over the years resulting in an estimated yield loss of 30-40 t/ha. In addition, in one case the shape of the fruit appears to have changed (more pointed end), which leads to easier bruising and incomplete de-pipping by processing machinery. The loss was approximately 30% in this case. Oom Sarel is another peach cultivar that is known to have deviating trees.

Conclusion

At an industry level, all producers together with the nurseries and the plant improvement organisations are collectively responsible for the genetic and phytosanitary status of plant material, and the maintenance of high plant quality over a long time period. Since viruses cannot be treated and cured, and the process involved in supplying clean plant material at the start of the orchard or vineyard lifetime is long and costly, a lack of attention to this will eventually set the deciduous fruit industry back many decades as the quality of trees and vines gradually degenerates. It has been shown over decades of research globally that this leads to reductions in the quality and size of the fruit, the yield, the longevity of the trees/vines, the sensitivity to stress and other adverse environmental factors. Ultimately the producers will pay the cost.

Since the main viruses of plums and grapevines are easily transmitted between farms there is an added imperative for every producer to do everything possible to minimise infections, thereby benefiting not only his own financial success but also that of his neighbours and the production region. Otherwise the efforts of some producers and the plant improvement organisations will become ineffective.

Similarly, and equally concerning, is the gradual loss of income from premium red/blushed apple cultivars, early pear cultivars and canning peach cultivars through genetic deterioration. Focused monitoring of the problem, research, and the continued provision of genetically 'true' plant material and replacement of deviated or reverted trees should remain a key industry priority.

Although the main focus in this study was on viruses it is important that the economic influences of other organisms such as bacteria (for example fireblight in grapes) are also investigated in future.

Acknowledgement and disclosure

This study was funded by SAPO Trust, Stellenbosch. The research outcomes were not influenced or guided by the funder. We thank Prof Gerhard Pietersen for providing valuable comment during the course of the project.

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