Postharvest pathology – prepacking pointers (W. du Plooy)

Orchard sanitation: Sanitation is of crucial importance just before picking season starts. This practice is key for reducing fungal spore load, as well as keeping FCM and fruit fly under control. Orchard sanitation involves removing all fallen, decayed and injured fruit (including those on the trees) from the orchard and then burying or macerating the fruit. For macerating, the fruit should be cut into fine pieces and allowed to dry in the sun away from the orchards and packhouses. Fallen and injured fruit removed from the orchard can also be used as animal feed. Remember to follow the FMS guidelines and examine a sample of the sanitation fruit if you export to the EU. The FMS can be found on the CRI website under "Member downloads" and all changes will be communicated via the CRI *Cutting Edges*.

Skirt trees for sour rot and brown rot control: Ensure that trees are adequately skirted before they start bearing. This prevents low-hanging fruit, especially for heavily laden trees where fruit will be touching the ground or be within range of water splash. The practice will reduce the risk of Phytophthora brown rot infection during the rainfall season as well as sour rot (Galactomyces spp.) infection. Keep in mind that no pre-harvest fungicides are available to adequately control sour rot, so orchard sanitation and skirting are crucial. Remove dead wood from all citrus trees to reduce the spore load of the latent citrus pathogens.

Prevent injuries: Ensure that picking teams are trained to focus on preventing injuries. Avoid snap picking, unless pickers have mastered the technique, and the fruit is not to be exported. Injuries are the number one cause of postharvest decay. Keep in mind that some markets may be stricter on the stem-end length, so ensure pickers cut the stem end as short as possible, without damaging the rind.

Packhouse sanitation: Thoroughly clean the entire packhouse building and line before any fruit is brought to the packhouse in the new season. Use an appropriate sanitiser to clean everywhere from the roof to the floor, including walls and hard-to-reach nooks and crannies.

- Never allow any fruit – and more importantly, any fungicide-treated fruit – to lie around in the packhouse at any stage during the packing process.
- Spray the packhouse regularly with sanitisers, and immediately after finding even just a single rotten fruit.
- Constantly monitor concentrations of sanitisers in dump tanks, sprays, rinses, etc., and ensure that these sanitisers are being used according to the correct specifications (e.g., pH).
- Wash equipment such as trailers and/harvesting bins with a suitable sanitiser before they leave for the orchard.
- Ensure that packed cartons are cooled as soon as possible to prevent decay development.
- Store retention samples for each consignment and check them regularly for waste and other developing factors, such as pitting, rind breakdown and latent pathogens. Keep track of other defects such as damage by wind, thrips and mechanical damage.

Rudolph Strydom

Irma Raspel

Vernon Jacobs

Selection of fungicides: For many packhouses, the chemicals that will be used during the upcoming season are being sourced and negotiated. Decide on a chemical programme that is in line with decay control and export market regulations. Make use of the CRI Postharvest Factsheets that are available online at www.citrusres.com under "Member downloads". If using a new product, ensure that it is safe for use (possible phytotoxicity; MRL restrictions) and that it is applied correctly. Also, keep in mind the cleaning protocol that must be followed if you need to strip the line of residues that has been used but is no longer allowed. See *Cutting Edge No. 314*, published by CRI, available on www.citrusres.com. Considering the increased cold-temperature shipping and FMS protocols, it is important that packhouses use thiabendazole (TBZ) for all fruit being exported. TBZ applied in the wax provides protection against chilling injury and helps control latent pathogen infections. A high solid wax (20–22%) will also aid in preventing chilling injury.

False codling moth

Reliable pre-harvest monitoring systems

Study shows five-data-tree monitoring system and a newly developed system using a 100-fruit sample from sanitation fruit, to be statistically reliable and accurate. By

Tamryn Marsberg, Sean Moore, Mellissa Peyper, Luke Cousins, Marcel van der Merwe, Guy Sutton, Sonnica van Niekerk and Vaughan Hattingh

Pre-harvest monitoring for FCM infestation in citrus orchards is important in assessing FCM risk and the need for additional control measures. Particularly within a systems approach, it is important that such a system is reliable and accurate.

This study determined that both the originally used five-data-tree monitoring system and a newly developed system using a 100-fruit sample from sanitation fruit, are statistically reliable and accurate. The advantage of the new system is that it avoids a clash between the activities of the orchard monitoring and sanitation teams.

Context

Pre-harvest infestation monitoring for FCM in citrus orchards is an important component of an effective FCM management strategy. This is particularly so within a systems approach for FCM, as has been implemented for export of citrus to the European Union (Moore et al., 2016; Hattingh et al., 2020). The systems approach requires monitoring of fruit infestation in orchards for at least 12 weeks before harvest (Moore et al., 2016; Hattingh et al., 2020). At the time of this study, the exercise was done by collecting fallen fruit under selected data trees and assessing them for FCM infestation. If infestation exceeded the set threshold, corrective actions or colder shipping conditions were required.

This study aimed to determine how accurately and reliably this monitoring system reflected true orchard infestation and to explore development of a better method. Accuracy and reliability of pre-harvest infestation monitoring are critical to ensure the efficacy of the systems approach.

Materials and methods

Trial sites

The study was conducted over two seasons (2021–22) in Navel orange orchards in the Sundays River Valley, Eastern Cape (**Figures 1** and **2**). In 2021, seven orchards with a history of high FCM infestation were selected. In 2022, seven new orchards with historically low infestation levels were chosen, so that monitoring systems could be tested under different pest pressures.

Trial layout and monitoring

Each orchard was divided into four quadrants, with five marked data trees per quadrant (**Figure 3**). Fallen fruit were collected twice weekly from these trees for the 12 weeks leading up to harvest (**Figure 4**). They were then dissected to check for FCM larvae or damage (larva exited fruit). On the same days, sanitation teams collected all fallen fruit from the rest of the orchard. These fruit were assessed in the same way as the quadrant fruit, but separately. Infestation levels were expressed as the number of infested fruit per tree per week.

Data analysis

The study tested whether infestation data from the sets of five data trees accurately represented infestation in the orchard as a whole. The study also determined whether a sample of fruit from the sanitation fruit could alternatively be used to do this. Statistical models were used to compare infestation trends, determine the best sample sizes for accurate estimates, and assess how infestation varied over time. The analyses also examined whether infestation was randomly or unevenly distributed within orchards. All statistical models were performed in R version 4.4.0 (R Core Team, 2024).

Results

Over the two seasons, a total of 134 952 fallen fruit were collected, cut and inspected for FCM (Figure 5).

In the first season there was a strong, positive relationship between infestation recorded from the sets of five data trees and the entire orchard ($p < 0.001$). This confirmed that the five-data-tree monitoring method provided a reliable estimate of orchard infestation levels. The average infestation per tree per week for data trees was 0.22, whereas for the whole orchard it was 0.13 infested fruit per tree per week. Therefore, data trees slightly overestimated infestation compared to the entire orchard, an advantage for ensuring compliance with infestation thresholds and, hence, market access security. In the second season, overall infestation levels were exceptionally low, between 29 and 333 times below the threshold of 0.1 infested fruit per tree per week. Although the majority of fruit under data trees recorded zero infestation, this was not problematic, as it still provided a reliable indication that orchards remained compliant with the systems approach threshold.

Statistical modelling showed that a 100-fruit sample per orchard per week provided a good estimate for the actual infestation level in the entire orchard. In most cases, infestation in the first 100-fruit sample taken from an orchard was equal to or higher than the orchard as a whole. In cases where the infestation threshold of 0.1 infested fruit per tree per week was exceeded, it was correctly detected in 100% of the first 100-fruit samples taken.

Spatial analysis showed that in both seasons, FCM infestation in orchards was only slightly clustered. Towards the end of the season, during the last four weeks before harvest, FCM infestation became more randomly distributed throughout the orchard.

Across both seasons, infestation levels tended to decline over time, with only a slight increase shortly before harvest. This suggested that monitoring every two weeks instead of weekly should be adequate, including during the last four weeks before harvest.

Tamryn Marsberg

Sean Moore

Mellissa Peyper

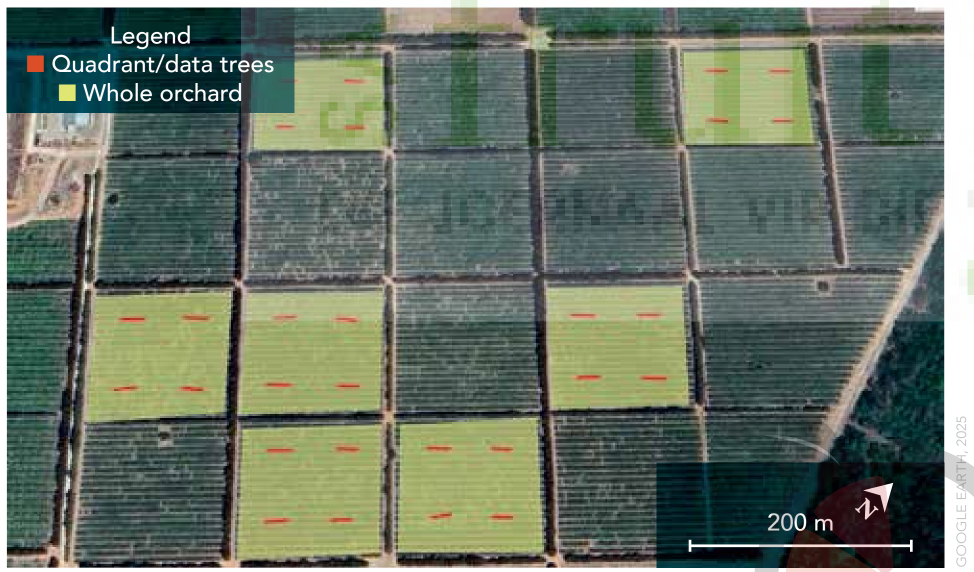

Figure 1. Pre-harvest infestation study site for 2021

Figure 2. Pre-harvest infestation study site for 2022

> Pre-harvest infestation monitoring for FCM in citrus orchards is an important component of an effective FCM management strategy.

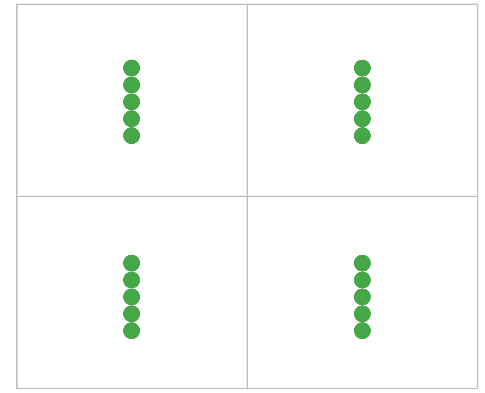

Figure 3. Quadrant layout with five marked data trees per quadrant

Figure 4. Fallen fruit collected from the whole orchard

Luke Cousins

Marcel van der Merwe

Further insight

During two seasons, more than 134 000 fallen fruit were collected and inspected for FCM infestation. As this study included all fallen fruit from all study orchards over a 12-week period, the results provided a complete and accurate picture of infestation levels in each orchard and therefore gave us a highly reliable comparison between infestation indicated by the monitoring systems, and actual infestation in the orchards.

The originally used five-data-tree method gave a good estimate of orchard infestation levels. Although data trees recorded slightly higher infestation, possibly due to shelter effects within orchards, the method reliably detected when the threshold of 0.1 infested fruit per tree per week was exceeded. Even if data trees were not optimally positioned, i.e., not positioned where fruit drop in the orchard was observed to be highest, threshold exceedance was detected in over 98% of cases, showing that infestation was relatively evenly distributed and random tree selection would not compromise the efficacy of the system.

MELISSA PEYPER

Figure 5. Left: The whole-orchard fruit dissection crew. Right: The tree fruit dissection crew.

Guy Sutton

Sonnica van Niekerk

Vaughan Hattingh

However, using data trees can conflict with orchard sanitation practices, which are crucial for reducing FCM populations. The risk is that orchard sanitation teams might remove fruit from underneath data trees, before monitors evaluate infestation of such fruit. To address this, a new system was developed, sampling a portion of the total sanitation fruit instead of using fixed data trees. Consequently, the sanitation team and the monitoring team would now be cooperating, rather than potentially conflicting with each other.

Statistical analysis showed that sampling 100 fruit per orchard was sufficiently sensitive to reliably detect when the threshold was exceeded, even in large orchards, and was practical to apply. Random selection of fruit for sampling and inspection is required within the systems approach. But non-adherence, especially in the last four weeks before harvest, would not meaningfully undermine the accuracy of the system.

Infestation levels remained consistent through most of the season, rising slightly only in the last four weeks before harvest. This indicated that fortnightly sampling is sufficient, including two checks in the final month before harvest.

Overall, the study confirmed that the inspection of a randomly selected 100-fruit sample every two weeks for several weeks leading up to harvest is effective and reliable for pre-harvest monitoring of FCM infestation in citrus orchards (Figure 6).

This research has been published in an international peer-reviewed scientific journal (Moore et al., 2025).

This study confirmed that two pre-harvest monitoring systems for FCM infestation are highly accurate and reliable, including a 100-fruit sanitation sampling method used in the FCM systems approach. Furthermore, the 100-fruit sanitation sampling method reduces data loss caused by sanitation practices and strengthens SA's systems approach towards maintaining access to export markets.

Key Findings

- The five-data-tree fallen fruit sampling system was highly reliable for indicating FCM infestation threshold exceedance in the orchard.
- Sampling 100 sanitation fruit per orchard also provided a highly reliable indication of FCM infestation threshold exceedance in the orchard.
- The second method aligns with standard orchard sanitation practices, reducing labour and data loss.
- Fortnightly monitoring provides sufficient data for accurate estimation of FCM infestation status.

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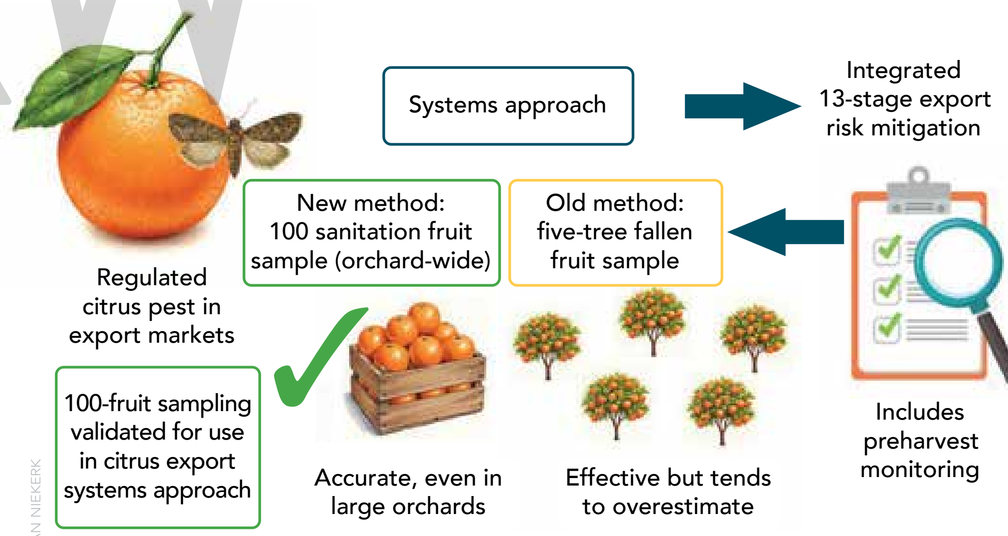
Tamryn Marsberg[1], Sean Moore[1, 2] Mellissa Peyper[1], Luke Cousins[1], Marcel van der Merwe[2, 3] Guy Sutton[2], Sonnica van Niekerk[1] and Vaughan Hattingh[4]

1 Citrus Research International, P.O. Box 5095, Walmer, Gqeberha, 6065 South Africa

2 Centre for Biological Control, Department of Zoology and Entomology, Rhodes University, P.O. Box 94, Makhanda, 6140, South Africa

3 Department of Biochemistry and Microbiology, Rhodes University, P.O. Box 94, Makhanda 6140, South Africa

4 Citrus Research International, Department of Horticultural Sciences, Stellenbosch University, Stellenbosch 7600, SA.



SONNICA VAN NIEKERK

Figure 6. Graphical representation of the improved pre-harvest monitoring system for FCM