Post-harvest fungicide resistance management in the citrus packhouse

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Introduction

The largest portion of South African citrus is exported to distant markets around the globe, which means prolonged shipping periods of the fruit. Protecting fruit from decay during transit is, therefore, of major importance. The most important post-harvest spoilage diseases of citrus are blue and green mould, as well as sour rot. To control these diseases, a number of fungicides are registered, each unique in its target disease as well as curative and protective abilities. The choice of and number of post-harvest chemicals used is, unfortunately, not dictated by efficacy of the fungicide. The residue allowed on the fruit in the export market is becoming the determining factor. Besides the increased risk of decay, the risk of the pathogens becoming resistant against the remaining post-harvest fungicides is a reality. Managing decay and preventing fungicide resistance is becoming a multi-facet challenge, where good post-harvest practices and sanitation is of increasing importance.

The fungicides

Fungicides are classed into different, so called FRAC groups, depending on their mode of action. Cross resistance is possible in a target pathogen against fungicides that are in the same FRAC group. Fungicides in different FRAC groups differ in their ability to cause resistance in pathogens. All pathogens are also not equally prone to become resistant against a fungicide. (FRAC is the abbreviation for Fungicide Resistance Action Committee and is a specialized technical group and an initiative of CropLife International, which works to prolong the effectiveness of fungicides liable to encounter resistance problems. Details can be obtained at www.frac.info.)

Resistance in fungicides is known in the green mould pathogen, *Penicillium digitatum* while resistance against the sour rot pathogen, *Galactomycis citri-auranti,* is uncommon.

Repeated treatment of a set of fruit with the same fungicide or FRAC group with a time delay of days in-between, increases the risk of resistance. Drenching and treating the fruit with the same fungicide again after degreening a few days later, is an example. Applying the fungicide in the bath and then again in the wax, without a significant time delay, is not a risk if it is done correctly. Poor packhouse and pre-packhouse practices and hygiene are also risk factors, even if fruit is exposed to the fungicide only once.

The post-harvest fungicides and their characteristics are as follows:

Imazalil: Belongs to FRAC group 3 and is the primary fungicide for the control of green and blue mould. Imazalil has very good curative as well as protective abilities and sporulation inhibition. The resistance risk is classified as medium. Resistance in P. digitatum is known. Fortunately, resistant populations are mostly not very well adapted and is out competed by wild populations in time. However, repeated pressure on a population can result in a resistant population to adapt and become dominant. Resistance management is important to protect this primary green mould fungicide. Important characteristics of imazalil: Where used in a fungicide bath, imazalil dissociates and become water insoluble if the pH for the solution exceeds pH 6.00. Application bath pH should be between pH 3.00 and pH 6.00. The higher the pH, the higher the residue loading.

Pyrimethanil: Belongs to FRAC group 9 and is second to imazalil the most effective fungicide to control green mould with good curative and protective ability. It is inferior to imazalil regarding sporulation inhibition. Pyrimethanil is classified as a medium risk fungicide for resistance and resistance is known in *P. digitatum* populations. Important characteristics of pyrimethanil: The pyrimethanil alone formulation is a suspended concentrate (SC) and the active will settle out if not constantly mixed. Pyrimethanil residue loading increases if applied at increased heat, especially on lemons.

Guazatine: Belongs to FRAC group M7 and is the primary fungicide for the control of sour rot. It also controls green mould, but is not included for this purpose. Guazatine targets multi-sites and is classified as "a low risk group without any signs of resistance developing".

Thiabendazole: Belongs to FRAC group 1 and although registered against blue and green mould, the main target is stem-end-rot. It is also included to protect the fruit against cold damage and other peel defects. It is classified as a high risk fungicide for resistance development and it is widely accepted that resistance is common in *P. digitatum* populations. Important characteristics: The thiabendazole formulation is a suspended concentrate (SC), and the active will settle out of mixture if not constantly agitated.

Propiconazole: Belongs to FRAC group 3 and is registered for the control of sour rot. It also controls green mould. The curative ability against both diseases is inferior to imazalil and guazatine, but if

used timely after harvest, gives good control of both diseases. It belongs to the same FRAC group as imazalil and cross resistance is a possibility.

Fludioxonil: Belongs to FRAC group 12 and is registered to control green and blue mould. It is a contact fungicide with limited curative ability, but if applied as a wax treatment, controls green mould sporulation well. It is classified as a low to medium risk fungicide for resistance development and resistance management is required. Natural resistance was detected in citrus packhouses in the USA. Important characteristics: The fludioxonil formulation is a suspended concentrate (SC) and the active will settle out of mixture if not constantly agitated.

The choice of fungicide in the packhouse

Post-harvest fungicide resistance management strategies are focused to prolong the efficacy against P. digitatum ensuring long term green mould control. Part of this strategy is the choice of fungicide and where to apply it.

Until recently, common practice was to treat the fruit in the drench with pyrimethanil (FRAC group 9), guazatine (FRAC group M7) and thiabendazole (FRAC group 1) and after degreening, treated in the fungicide bath and/or wax with imazalil (FRAC group 3) and thiabendazole (FRAC group 2). Besides thiabendazole, which is not part of the green mould control strategy, fungicides from different FRAC groups were used pre- and post-degreening. From a resistance management view, this was the ideal.

This situation changed when the European Union (EU) removed guazatine from the list of allowed chemicals, although a CODEX MRL is still available. Although the target of guazatine is sour rot and not green mould, the result is an increase in sour rot with the absence of a fungicide for its control and increased secondary green mould infections on treated fruit, putting green mould fungicides under resistance pressure. An alternative fungicide, propiconazole (FRAC group 3) was registered for the control of sour rot on fruit destined for the EU market. Propiconazole is in the same FRAC group as imazalil, increasing the risk of cross resistance if used in the place of guazatine in the drench. The solution was a combination fungicide (propiconazole + pyrimethanil) for cross protection with another FRAC group in packhouses that degreen. Propiconazole has a CODEX MRL on oranges and not on lemons and soft citrus, which are the most susceptible to sour rot. A few packhouses packing lemons and soft citrus for only the EU or CODEX do use either propiconazole or guazatine. Most packhouses, however, pack for both markets resulting in omitting sour rot control by fungicides, and rely only on sanitizers to control sour rot (no curative or protective action). This resulted in increased sour rot and also secondary green mould incidence, increasing the risk of resistance in *P. digitatum* against imazalil and pyrimethanil.

Residue transfer from the packline to fruit, and the detection of traces of these residues during residue analysis, also prevent packhouses from using different fungicides on different sets of fruit or fruit destined for different markets. Beside the official maximum residue limits (MRL) set by the export countries, some retailers also set their own secondary standards limiting the number of actives allowed on the fruit and setting MRL standards at halve or up to a third of the official MRL. These secondary standards are not based on sound scientific findings and is used as a marketing tool. Unfortunately, these lucrative markets dictates practices and chemical use in the packhouse, increasing the resistance risk against fungicides further as chemical usage in packhouses is unfortunately dictated by the most sensitive market.

Fludioxonil (FRAC group 12) was registered as an alternative for the control of green mould. Although inferior to the generally used fungicides regarding curative ability, it is effective if applied timely and has good sporulation inhibition ability if applied in wax. Fludioxonil is in an alternative FRAC group and can be used if resistance becomes an issue and furthermore it is regarded as a reduced risk fungicide.

Good packhouse practices to ensure prolonged fungicide efficacy

The more the pressure mounts to limit the number of chemicals as well as to lower the MRLs on fruit, the more relevant the implementation of good packhouse practices as well as pre-packhouse practices becomes in order to ensure efficacy of the remaining fungicides and mould free fruit on the market.

Post-harvest fungicide management and packhouse sanitation is only a few of the packhouse manager's multiple responsibilities. Setting up a checklist of do's and don'ts and a standard operating procedure and a well-trained workforce will definitely ease the manager's task. The quality, origin and handling of the fruit, inoculum presence and pressure as well as the timely and optimum application of post-harvest sanitizers and fungicides dictates the success of decay control and therefore also prolong fungicide efficacy. The pathogens causing fruit decay are microscopic and even the visually most hygienic packhouse with good programs in place often have increased inoculum hot spots that cannot be visually detected. An independent packhouse hygiene service is available in some citrus producing areas that can be highly recommended as an aid to packhouses.

Currently, there is a tremendous boom in late mandarins and lemons. Late mandarins are, for instance, picked in a specific time frame and packhouses should be geared to handle the maximum volumes of fruit expected. A delay in the ability to timely process the fruit will result in increased decay problems which will lead to higher inoculum pressure in the packhouse and increased resistance pressure on the chemicals. Lucrative markets and the physical nature of some varieties also result in less than desired skirting CONTINUED ON PAGE 77

supply, tree capacity in nurseries has more than doubled to accommodate the increased demand, and most nurseries are still fully booked. Nurseries make trees almost exclusively on order and the delay in provision of trees is largely linked to the time it takes to make a tree (18-24 months). Experienced growers plan their developments and required tree delivery dates and accordingly order trees well in advance to ensure that they have space and rootstocks booked in their nursery of choice.

Figure 3. Expansion of rootstock seed orchards at the Citrus Foundation Block.

Nurseries often experience growers changing their orders, and instead of the cultivar originally ordered, they might opt for something else. This unexpected demand might potentially lead to short supply, as growers often order what others are ordering, leading to a rapid increase in demand. Supply of open cultivars will only be constrained by budwood availability. However, CFB will not supply buds from privately owned and managed cultivars without the cultivar agent's written approval, and the agents will not grant approval if contracts with the grower and the nursery are not in place and/or fees are not paid. Nurseries should therefore not place budwood orders for a private cultivar with CFB if their client's 'paperwork' with the agent is not in order. This can lead to frustration and unnecessary delays and growers should therefore not leave these arrangements too late.

Growers and developers should understand that it takes 2 years to make a citrus tree. Often developers (particularly newcomers) want trees to plant now and since (almost) no trees are made on speculation by nurseries, none is available and they sense there is a "shortage". Plan early, and order space/rootstocks in nurseries according to your development plan. Please also include nurseries and the CFB in the planning phases of large developments.

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of trees. Producers are well aware of the dangers regarding brown and sour rot infection of low hanging fruit, but often overlook the practical implications of the pickers' picking bags that will unavoidably rest on the ground when picking low hanging fruit. This result in contamination of the bags and carry over of soil and sand to the bins, increasing injuries and fruit infection.

To conclude

The choice of fungicides and order of fungicide application protects their long-term efficacy. Fruit protection and decay prevention begins in the orchard, long before harvest. An integrated approach in the prevention of decay, which includes, in addition to the correct choice and sequence of fungicide application, orchard management, sanitation of the drench and fungicide solutions, sanitation of fruit, and packline with appropriate sanitizers.

A few key words in fungicide resistance prevention or Good Packhouse Practices include: minimal fruit injury; timely post-harvest fungicide application; effective fruit and pack line sanitation; effective fungicide application – residue loading; effective drying and waxing of fruit; not exceeding packing capacity of the packhouse; etc.

The packhouse manager largely operates in isolation, with the chemical representatives and visits by CRI personnel his only external extension inputs. The popularity and high attendance rate of the annual CRI Packhouse Workshops clearly demonstrates the hunger for information. The packhouse manager should communicate as wide as possible. He should implement external scientifically proven inputs selectively to his advantage for the optimum protection of the fruit against post-harvest decay and the fungicides against resistance. The effect of changes in pre-packhouse and packhouse practices on the potential increase in post-harvest decay potential should be a key consideration prior to implementation of any new practices.