Looking at citrus chilling injuries from all angles

Frostbite is not a danger to humans only. When citrus fruit gets too cold, it suffers damage that eats into its market value. This multi-factorial research project set out to find ways to take the bite out of factors that cause chilling injuries.

MEDIA REPORTS DURING THE SECOND week of June 2021 trumpeted the good news of the first shipment of South African citrus to the Philippines. This came only a few weeks after an announcement by the Citrus Growers Association of Southern Africa that 2021 would be another record citrus-export year. Estimates were for 158.7 million cartons, compared to 146 million in 2020 and 130 million in 2019. If the 2021 season lives up to expectation, the local industry would see a 22% export growth in only two years.

The successful exporting of fruit rests on many pillars, not least of which is meeting the destination market's phytosanitary requirements. In the case of citrus, this means maintaining cold disinfestation protocols for the European Union (EU), to which about 45% of South Africa's citrus is exported, as well as in the United States and China.

The new markets South Africa is currently developing in the Far East, including the Philippines, Indonesia, Thailand and Vietnam, are likely to follow the lead of the US and China when it comes to cold disinfestation protocols.

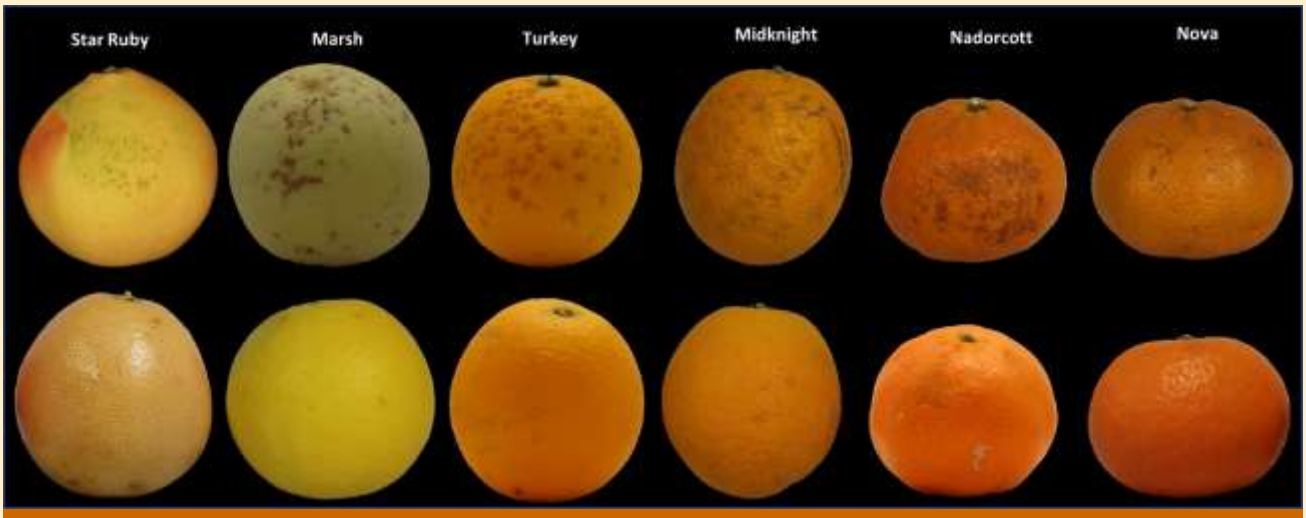


FIGURE 1: Chilling injury symptoms as observed in various cultivars.

The challenge, however, is that citrus fruit may develop necrosis and pitting in the flavedo tissue when stored at temperatures ≤4 °C. These chilling injury (CI) symptoms have a significant impact on the market value of the fruit.

On face value, the local citrus fruit industry finds itself in a catch-22 situation, with the non-negotiable cold disinfestation protocols posing a risk to fruit quality and market values.

However, understanding that factors never exist in isolation, scientists decided to take a broader view. The result was a two-year, multi-faceted project that aimed to identify and quantify pre- and postharvest factors that contribute to the CI susceptibility of different citrus fruit. Armed with this information, postharvest practices would be developed to reduce the fruit's susceptibility and the severity of chilling injuries.

Jointly funded by Citrus Research International (CRI) and the Postharvest Innovation Programme (PHI), the project was led by Professor Paul Cronjé, portfolio manager: citriculture at the CRI and the Department of Horticultural Science at Stellenbosch University, in collaboration with Dr Bahlebi Eiasu. Two MSc (Agric) students were involved in the project, namely, Phillipine Moabelo from the Department of Agronomy at University of Fort Hare, and Jade North-Dewing of CRI from the Department of Horticultural Science at the University of Stellenbosch.

Project scope

The study examined the impact of six variables on these ten citrus cultivars:

- Soft citrus: Nova, Valley Gold and Nadorcott mandarin
- Grapefruit: Star Ruby and Marsh
- Valencia: Turkey and Midknight
- Lemon: Eureka
- Navel: Washington and Cambria

Two MSc (Agric) students were involved in this project. Left: Phillipine Moabelo from the Department of Agronomy, University of Fort Hare. Right: Jade North-Dewing of CRI from the Department of Horticultural Science at the University of Stellenbosch.

PROJECT INFORMATION

Project title: An investigation into aspects affecting chilling injury in Citrus fruit
Principal investigator: Prof. PJR Cronje (PhD)
Duration: 01/01/2019 - 30/06/2021
PHI Programme and Industry Contributions: R751 999 and R751 999
Lead institution: University of Stellenbosch
Beneficiary: The South African citrus industry
Human resource development: 1BSc Agric (3rd year) student & 1 MSc student
Focus area: Shade netting, rind condition, cold chain

Variable 1: Cultivar and production region

The areas in South Africa where citrus is grown, range from sub-tropical to Mediterranean climates. This enables the production of a vast range of citrus cultivars and ensures continuous supply as problems in one region can be offset by favourable conditions in another.

However, when the same cultivars are produced under distinctly different climatic conditions, variations in fruit quality and susceptibility to physiological disorders often occur.

To evaluate the effect of production areas on CI susceptibility, six cultivars from four major production areas were studied.

Variable 2: Fruit maturity

The correct time to harvest, i.e., fruit maturity, is a critical decision in fruit farming. Fruit maturity at harvest often affects rind quality, and the loss of postharvest quality can often be attributed to the incorrect harvest time.

Previous studies have found that citrus fruit harvested very early (immature) or very late (over mature), is of poorer quality and thus likely to be more susceptible to postharvest physiological disorders.

Two cultivars from the same production area were studied over two seasons. Fruit was harvested over 14 weeks at two-weekly intervals to obtain eight sampling periods.

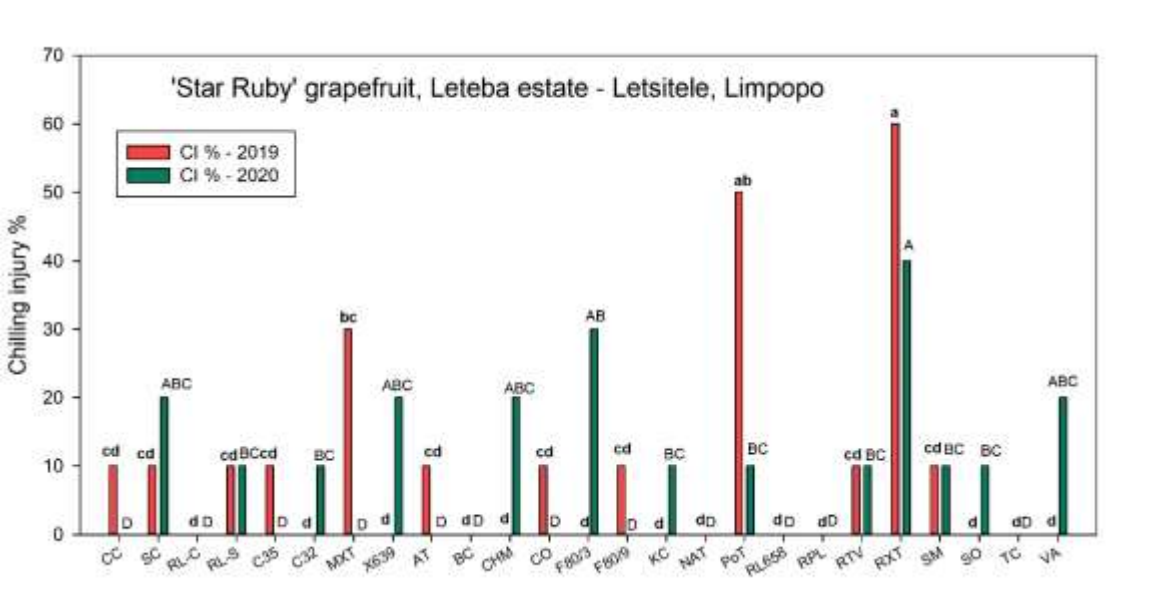


FIGURE 2 & 3: Influence of rootstock on chilling injury of Star Ruby grapefruit and Delta and Midknight Valencia during the 2019 and 2020 seasons (P ≤ 0.05).

Variable 3: Rootstock

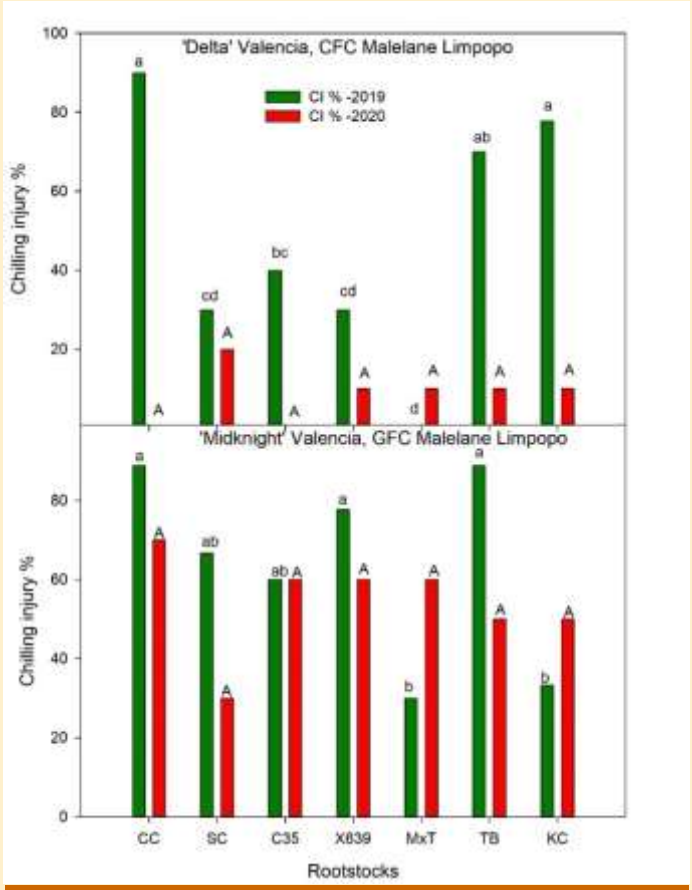
The effect of rootstocks on internal and external citrus fruit quality is well recognised. However, little information is available on the impact rootstocks have on the rind condition and postharvest behaviour of citrus fruit during cold storage. This study aimed to fill the knowledge gap at least as far as several commercially important cultivars are concerned.

The study was carried out in Limpopo. A rootstock research block established in 1997 at Letaba Estates (Limpopo) consisting of Star Ruby grapefruit grafted on 25 different rootstocks, and rootstock blocks at Golden Frontiers Citrus, Malalane (Mpumalanga) consisting of Delta and Midknight Valencia, each grafted on seven different rootstocks, were studied.

Variable 4: Shade netting

Shade netting is commonly used to protect citrus fruit against high temperatures and extreme light intensity. Fruit grown under shade net are less likely to develop sunburn, discolouration and scarring on the rind, compared to those in exposed orchards. Shade netting also increases fruit size and yield, in addition to vegetative development.

However, inconsistent evidence exists about the impact of shade net on internal quality, and nothing more than anecdotal evidence about the effect it has on CI susceptibility. This study used 20% white



Fruit grown under shade net are less likely to develop sunburn, discolouration and scarring on the rind.

permanent shade netting to investigate the internal and external fruit quality of four citrus cultivars grown in the Eastern Cape production area.

Variable 5: Impact of time and temperate on chilling injury development

The incidence of chilling injury in citrus is known to increase with the duration of storage at a threshold temperature. However, the interaction between different storage temperatures and durations on chilling injury development are largely unknown. Cellular damage during cold storage leads to higher metabolic rates, with increased respiration rates following the transfer from cold storage to a warmer temperature.

This study observed fruit respiration rates and chilling injury at various intervals during extended cold storage at -0.6°C, 2°C and 7°C to gain insight into when cellular damage occurs.

The objective was to obtain a better understanding of how the temperature and storage duration interaction affects citrus fruit. An improved understanding of the physiological effects of postharvest treatments may help in predicting the susceptibility of fruit, and thus improve the success of citrus fruit under cold-steri protocols.

Variable 6: Wax coatings

The postharvest treatments applied to citrus fruit destined for the fresh market remove the fruit's natural protective waxy layer, resulting in fruit dehydration, decay and rind disorders. It is, therefore, considered essential to apply a wax coating to fruit destined for export.

Applying a wax coating onto citrus in the packhouse.

Previous studies have found that both the type and the solid content of wax formulations determine their efficacy in reducing CI incidence. Furthermore, the difference in rind anatomy between citrus types could influence water movement across the rind and the response to moisture loss. While a particular wax formulation may effectively reduce CI in one cultivar, it may adversely affect another. Furthermore, the incorrect wax formulation could have detrimental effects on fruit quality and commercial value.This study considered the type and solid content of wax formulations on Nova mandarin and Midknight Valencia from orchards in the Eastern and Western Cape.

Findings and results

This comprehensive project has confirmed that CI is not a simple matter of the temperature at which fruit is stored and transported. There can be no doubt that pre- and postharvest conditions and decisions influence the prevalence and severity of this condition.

Production region has always been suspected to influence CI susceptibility due to the differences in climate. However, this dataset is the first to quantify the influence over two seasons in various cultivars. The study concluded that production area and prevailing climate do contribute to CI susceptibility. As a result, cultivars from certain regions need additional postharvest focus on their packhouse treatments and optimal logistics in the cold chain to reduce CI incidence.

In contrast to the literature, no consistent link between fruit maturity and CI susceptibility was found for the cultivars evaluated. It is possible that South African conditions are not sufficiently extreme compared to Spain and the USA, to reduce the rind's ability to withstand cold temperatures during export.

The study's most significant findings relate to the influence of rootstocks on CI. The information is new and indicates that this previously neglected part of citriculture directly influences chilling injury susceptibly of citrus fruit. These novel results will need follow-up research.

Shade netting is rapidly gaining ground in the local citrus industry, and the concern about added CI susceptibility was the focus of this part of the project. The results indicate that shade netting does not add a high level of

Citrus fruit may develop necrosis and pitting in the flavedo tissue when stored at temperatures ≤4 °C. These chilling injury (CI) symptoms have a significant impact on the market value of the fruit. Top: Satsuma. Middle: Star Ruby Grapefruit Bottom: Oranges.

susceptibly to navels, mandarins or lemons. Furthermore, no drastic and constant reduction in internal quality was found due to shade netting.

Waxing, as a postharvest practice, was shown to make a significant contribution to mitigating CI. It remains the primary management tool in the postharvest environment to reduce CI and all packhouse managers should pay focused attention on effectively applying this chemical coating. In terms of fruit exposure to low temperatures, the results indicate that exporters should strive to reduce the hours that fruit is subjected to temperatures below 4 °C. By reducing the duration, the incidence of CI will be less.

THE PROJECT'S ECONOMIC IMPACT

In 2020, the South African citrus industry's exports were valued at R26.6 billion, which amounts to 0.63% of the country's GDP.

The reduction in fruit quality due to chilling injury can result in total loss of the market value of export citrus fruit. The incidence of this disorder, depending on the export temperature and cultivar, in the commercial exports can reach up to 10%. These high values are prohibitive to sustainable supply of South African citrus to lucrative markets such as China and the USA.

The way forward

This project handed local citrus producers and exporters valuable information on how to combat CI. The requirement to export increasing volumes of fruit at temperatures below 2 °C is problematic and will remain so.

However, by developing commercial handling practices based on the information generated in this study, the commercial impact of chilling injury can be reduced. In fact, changes made by producers, exporters and packhouses have already reduced CI during the 2020 season. ♥