SATI
SOUTH AFRICAN TABLE GRAPE INDUSTRY

RESEARCH REPORT

2012/13 – 2015/16 LEVY CYCLE

2017

CONTENTS / INHOUD

SATI
South African Table Grape Industry

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REPORT: R&D COMMITTEE CHAIR

Economic growth is fueled by innovation, and research is the catalyst that inspires scientists to achieve innovative success. This is why it is essential for the South African Table Grape Industry (SATI) to continue to invest in research and the transfer of technology to ensure competitiveness and growth in a challenging and demanding global table grape market.

The creation of a progressive, equitable and sustainable table grape industry does not come without a myriad of challenges and opportunities.

Agriculture faces many challenges, some of which are unique to the local table grape industry, and others which overlap with those faced by other industries (e.g. climate change and the consequent changes in pest and disease pressures). Overlapping challenges have provided the perfect opportunity for SATI to partner with other industry associations like Winetech, Hortgro Science, Dried Fruit Technical Services (DFTS) and government (including the Agricultural Research Council and the Department of Science and Technology, through the Post-Harvest Innovation Fund). SATI has also been working with South Africa's official perishable produce export certification agency (PPECB).

One of the main objectives for SATI Research is to align projects with the diversity of producer needs, as well as the continued demands of changing markets, all within the framework of SATI's strategic objectives and budget. To achieve this, the SATI team worked closely with industry. Workshops held in each of the five diverse production regions created a platform to exchange valuable information about short and long-term challenges that require research or technology transfer.

SATI endeavours to ensure that knowledge, technology and processes developed from this research are transferred back to established and emerging producers as well as other role players in the table grape industry. We want to equip them to become both sustainable and successful entrepreneurs.

SATI's Research and Development Committee prides itself in having fine-tuned the research process during the 2012 – 2016 cycle. Not only was there a more functional balance between short-term and long-term projects, but also a structured outlook on the following segments of the industry. The focus has been on the following:

- Pest and disease management;
- Post-harvest and cold chain management;
- Natural resource management;
- Crop production; and
- Cultivar development.

The process was further streamlined by implementing technical committees for each of these sections and structuring the Research and Development Committee to include specialised members involved in production, technical aspects, training and the industry. The implementation of a streamlined process resulted in an excellent project completion percentage, within time and budget limits.

The 2012 - 2016 (levy) cycle will be remembered for a persisting drought in many regions of South Africa and the consequence of this will still be felt for at least two to three years after the drought has broken. This changed the focus and prompted the Research and Development Committee to pay attention to the impact of climate change and the way industry manages natural resources, especially water.

A significant strategic intervention during the 2012 - 2016 levy cycle was a change in the structure of the Agricultural Research Council (ARC) Breeding and Evaluation Programme. An agreement was reached with the ARC, which will now allow SATI (industry) to drive the evaluation of cultivars bred by the ARC. This intervention provides exciting opportunities in terms of specialised breeding for the diverse climates of South Africa's table grape industry. This will strengthen both the ARC and SATI's ability to become leaders in the field of cultivar development. Special attention was also given to market access research and this is reflected in year-on-year expenditure across the four years.
Technology transfer platforms and positive feedback from levy payers prove that the restructured research process starts to reap positive results. The challenge will be to continually improve and re-adjust.
Some challenges have been identified on the road ahead. These include:

- Climate change is a constant challenge both in terms of the availability of water for farming as well as damage to crops by new pests and diseases with the associated threat to market access. This again stresses the demand for eco-friendly biological pesticides to steer away from any chemical residues on grapes.
- Food safety will stay one of the major objectives in agriculture and needs to be on the radar of research.
- Food and fruit wastage is at a problematic 40% (of what is being produced), before it even reaches the market. New technologies and business models need to address this increasing problem, especially in developing countries.
- Funding, and the lack thereof will always be a challenge. This goes hand in hand with the shortage of researchers and students available to participate in projects. Agricultural role players and government need to put a higher margin on the priority of research.
- The lack of cross-pollination between researchers can result in a decline of vision and creativeness.
- Transformation plays a very important role as it not only steers the research process towards a wider scope of inputs but also adapts to the needs of upcoming farmers.
- It is important to continuously adapt to suitable technology transfer platforms that cater for all the role players in need of table grape technology transfer.

As chairperson of the SATI Research and Development committee, I would like to express my appreciation to all who participated and gave of their time and knowledge to ensure we remain focused on the needs of our levy payers, in accordance with the competitive nature of the international table grape industry.

Going forward, I believe we need to strengthen our partnerships and focus on keeping South Africa a preferred country of origin for table grapes with the best eating quality.

Eurica Scholtz

October 2017

INTRODUCTION

SATI's Research and Technology Transfer Programme strives to identify research needs, and develop knowledge and technology tools that are relevant to the industry.

To ensure alignment with industry needs, SATI hosts annual research workshops in each region, where producers are invited to participate and to share their research needs. Through this process, SATI can identify research needs that are relevant to the industry, as well as identify key topics for knowledge and technology exchange.

Funding is split across six research themes:

CULTIVAR DEVELOPMENT

The breeding and evaluation of new table grape cultivars specifically suited for cultivation under South African conditions; and the assessment and performance of rootstock cultivars.

NATURAL RESOURCE MANAGEMENT

Research to support the sustainable management and efficient use of soil and water resources in table grape production.

CROP PRODUCTION

Research aimed at addressing challenges and developing innovations in the cultivation of table grapes.

Photo Credit: T Platt (Stellenbosch University)

DISEASE MANAGEMENT

Research which aims to minimise diseases to encourage optimal grapevine performance, by focusing on the quality of grapevine material and management practices to reduce the spread of grapevine diseases. Emphasis is also placed on disease management strategies that are safe for the environment and, as far as possible, reduce maximum residue limits (MRLs).

PEST MANAGEMENT

Research which aims to minimise the presence of pests in table grapes safely before and after harvest, with a special focus on management strategies that are safe for the environment, as far as possible, to reduce MRLs and optimise, retain and maintain market access.

POST-HARVEST QUALITY MANAGEMENT

Research which focuses on optimising the handling and storage of table grapes across the cold chain, to ensure that table grapes that arrive in the export market are of good quality and quality claims from the export market are minimised.

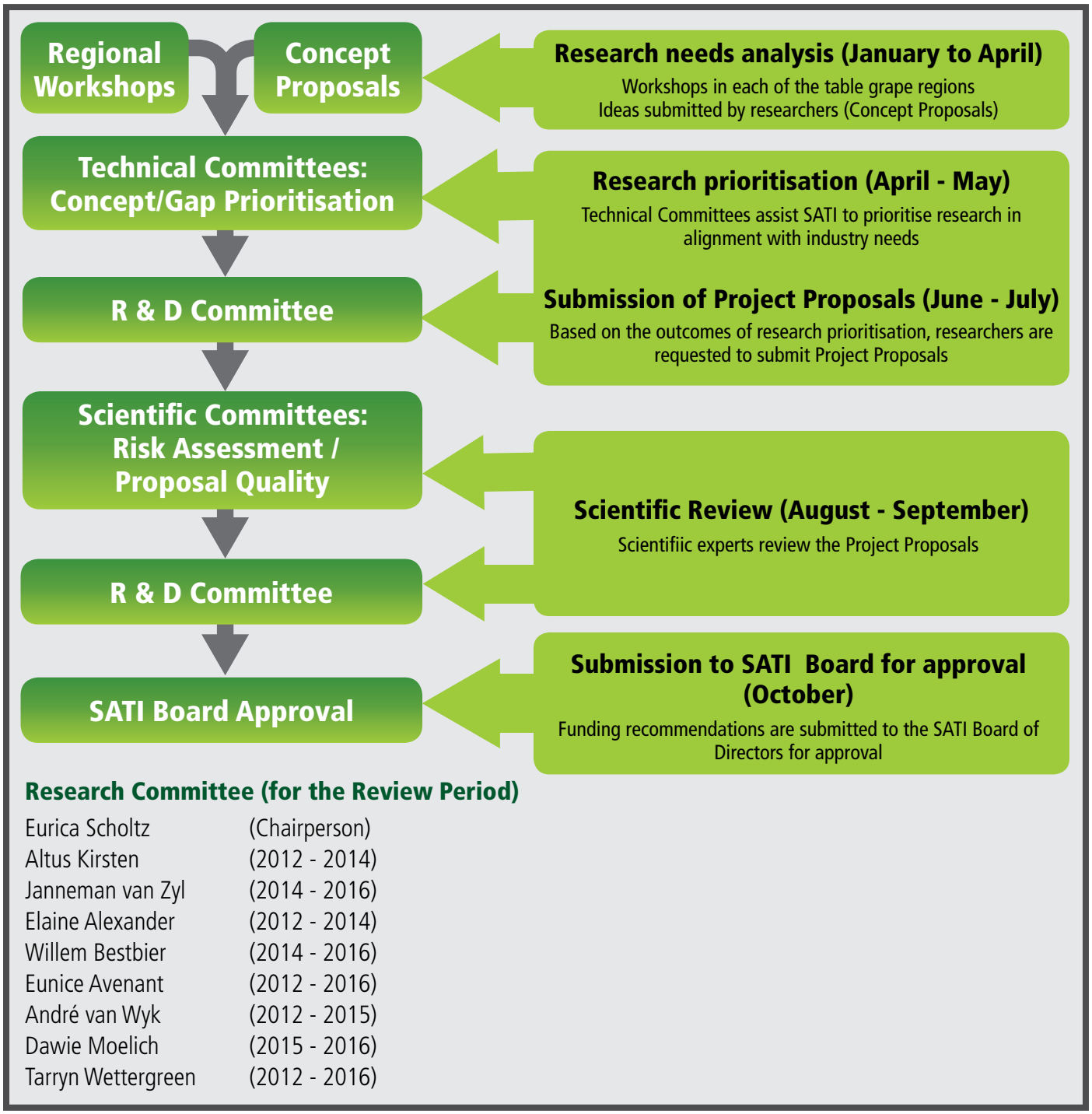
Photo Credit: E Avenant (Stellenbosch University)

STRUCTURE AND PROCESS

The **SATI Research Committee** is a subcommittee of the SATI Board with the primary responsibility of ensuring that the SATI research portfolio is carried out within the framework of the SATI Strategic Plan. Additionally, it is the responsibility of the committee to ensure systems and processes implemented by the **SATI Research and Technology Transfer Manager** are fair, and research funds align with producer needs.

Two committee types, which play an advisory role to SATI, have been established. The **Technical Committees** assist SATI to prioritise research needs, while **Scientific Review Committees** assist in assessing the science of project proposals.

The following diagram (Figure 1) illustrates the structures and processes SATI utilises to identify which projects to fund.



Research Committee (for the Review Period)

Eurica Scholtz	(Chairperson)
Altus Kirsten	(2012 - 2014)
Janneman van Zyl	(2014 - 2016)
Elaine Alexander	(2012 - 2014)
Willem Bestbier	(2014 - 2016)
Eunice Avenant	(2012 - 2016)
André van Wyk	(2012 - 2015)
Dawie Moelich	(2015 - 2016)
Tarryn Wettergreen	(2012 - 2016)

Figure 1: SATI's funding process

RESEARCH FUNDING

Funds available for research projects varied considerably between 2012 and 2016 due to the varying levy income, which was influenced by export volumes (Table 2).

Table 2: Number of projects funded each year between 2012/13 and 2015/16.

2012/13:	10
2013/14:	14
2014/15:	14
2015/16:	22

During the 2012/13 financial year, SATI spent roughly R2.5 million on research projects. By the 2015/16 financial year, SATI was able to nearly double that expenditure (Table 3).

Approximately R13.6 million was spent on research during the 2012/13 – 2015/16 levy cycle. Table 3 gives the breakdown of expenditure as follows: percentage split per research discipline per year, percentage split per research discipline for the entire levy cycle, the total cost (in rand) per year and total expenditure for the levy cycle.

Table 3: Research and development expenditure between 2012 and 2016

Research discipline	Expenditure per year*				2012 – 2016 (%)
	2012/13	2013/14	2014/15	2015/16	
Crop production	0%	0%	3%	3%	2%
Cultivar development	80%	60%	66%	35%	56%
Post-harvest quality	4%	0%	0%	22%	8%
Pest management	6%	11%	10%	26%	15%
Disease management	10%	17%	11%	7%	11%
Natural resource management	0%	12%	9%	7%	7%
Total expenditure in millions	**R 2.51**	**R 3.24**	**R 2.96**	**R 4.87**	**R 13.58**

*SATI's financial year starts 1 November and ends on 31 October each year.

Projects that support market access cut across three of the research themes (post-harvest quality management, pest management, and disease management).

Figure 4 shows the distribution of funds spent on market access research for each of the funding years. As a consequence of the increase in the funds allocated to research across the four years, and as a consequence of the decrease in the percentage of funds allocated to cultivar development, SATI was able to channel more funding into market access projects by the end of the levy cycle.

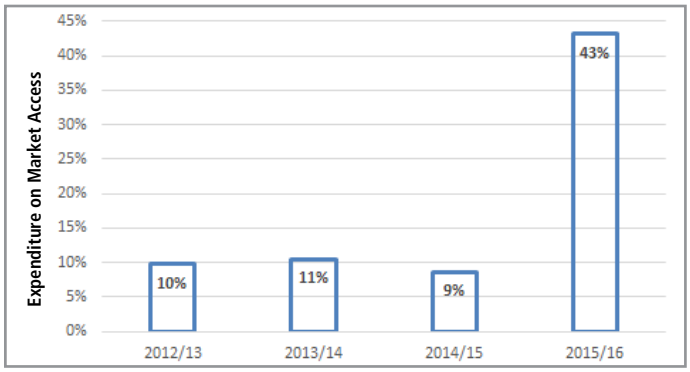


Figure 4: Distribution of funds spend on market access

STUDENTS

In total, 26 students will have received postgraduate qualifications from participating in SATI-funded research projects during the 2012 - 2016 levy cycle. Table 5 gives a breakdown of the number of students that were registered each year during the levy cycle.

Table 5: Number of registered students per year per post-graduate qualification

	2012/13	2013/14	2014/15	2015/16
Hons	-	2	1	-
MSc	2	3	5	6
PhD	1	5	6	9
Postdoctoral studies	-	1	2	3
Total	**3**	**11**	**14**	**18**

KEY RESEARCH INTERVENTIONS

Cold Treatment Protocol (China):
Industry raised concerns that the duration and below freezing temperature (at which table grapes were required to be shipped to China) were negatively affecting the quality of table grapes on arrival in the Far East. An opportunity arose for the shipment protocol of table grapes to China to be amended, but SATI needed to initiate a research project with the aim of proving the efficacy of a higher temperature protocol to disinfest table grapes against FCM. The outcome of the project is that the protocol for shipping table grapes to China has been amended to allow for higher shipping temperatures (refer to page 16 for the full project summary). This creates a market opportunity to increase table grape exports from South Africa to China to about R 2.5 billion over the next five years (SATI press release 4 November 2016).

Cultivar Development:
The ARC's breeding programme, which is co-funded by SATI, is ideally positioned to provide affordable cultivars, assessed under South African conditions. During 2015 SATI approached the ARC with a proposal to partner more strongly – the ARC drives the breeding, and the (table grape) industry (SATI) drives the evaluation. The ARC agreed, and an "industry-driven" cultivar evaluation started under the leadership of Anthony Hill (a table grape producer from the Hex River Region) and Phyllis Burger (head researcher of the ARC Infruitec-Nietvoorbij table grape breeding programme) in 2016.

CULTIVAR DEVELOPMENT

The breeding and evaluation of new table grape cultivars specifically suited for cultivation under South African conditions; and the assessment and performance of rootstock cultivars.

Photo credit: P Burger (ARC)

Photo credit: J Avenant (ARC)

There are three distinct phases in cultivar development - breeding, evaluation and commercialisation. Breeding and evaluation are funded in partnership with the ARC. The accumulated objective of these projects is to breed cultivars that are in demand by producers and targeted export markets.

BREEDING OF NEW TABLE GRAPE CULTIVARS

Project leader: P Burger (ARC Infruitec-Nietvoorbij)
Project duration: Ongoing

This project has two components: (1) breeding seeded grapes, and (2) screening seeded and seedless grape seedlings to select individual plants for further evaluation. Although the primary focus of the ARC's table grape breeding programme is breeding of seedless grapes, the breeders purposefully also breed seeded grapes, with the aim to use them as breeding parents. Progenies developed from the seeded grapes are screened for desirable breeding characteristics, while the seedless progenies are screened for commercial use. Progenies that do not meet the requirements for either breeding or commercial use are discarded. Desirable characteristics include crunchy texture, large berry size, crack resistance, good storage ability, excellent flavour, disease resistance, loose bunches, even berry size and dark flesh colour.

This project continues to progress well. Although not concluded, good progress is made in the development of disease resistance to downy and powdery mildew.

Photo credit: P Burger (ARC)

BREEDING OF SEEDLESS GRAPES BY EMBRYO RESCUE

Project Leader: P Burger (ARC Infruitec-Nietvoorbij)
Project Duration: Ongoing

The focus of this project is to develop a range of white, red and black seedless grape cultivars, from seedless crosses by using *in vitro* embryo rescue, that ripen for the entire duration of the South African table grape season. Desirable characteristics include crunchy texture, large berry size, crack resistance, good storage ability, excellent flavour, disease resistance, loose bunches, even berry size and good natural colouration.

THE EVALUATION AND SCREENING OF NEW TABLE GRAPE SELECTIONS AND CULTIVARS

Project leader: A Nieuwenhuys (ARC Infruitec-Nietvoorbij)
Project duration: Ongoing

Grapevine plants that meet initial screening requirements are escalated to this project, with the aim of assessing them for commercial potential. The grapevines (selections) escalated to this project are grafted onto rootstocks for the first time. Commercial criteria which are further assessed are productivity, storage ability and market potential. Selections which show promise are escalated to the next phase of evaluation, which is more intensive. Vineyard treatments include applications of gibberellic acid (GA_3) and forchlorfenuron (CPPU) to assess the effects of an application on the selections. Grapes are placed in cold storage for five weeks, after which they are evaluated based on their taste and appearance, the occurrence of any visual defects and quality of the juice of the grapes. This helps to screen their storage ability and market potential.

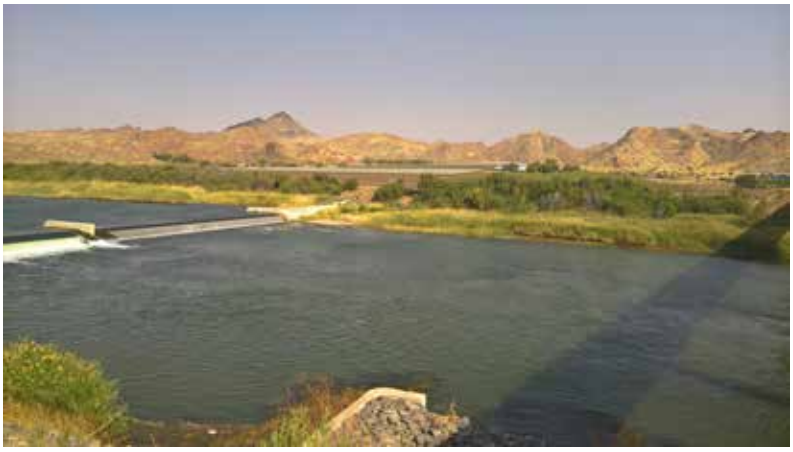
VITICULTURAL EVALUATION OF NEW TABLE GRAPE SELECTIONS AND CULTIVARS

Project leader: J Avenant (ARC Infruitec-Nietvoorbij)
Project duration: Ongoing

The focus of this project is the scientific evaluation of ARC-bred selections and cultivars so that production guidelines can be developed. This includes assessing selection and cultivar productivity, susceptibility to field cracking, grape quality, the intensity of inputs required (the lower, the better) and storage ability. Different viticultural practices such as pruning systems, manual bunch preparation actions, as well as plant bioregulator applications, including gibberellic acid (GA_3), forchlorfenuron (CPPU) and ethephon, are evaluated.

NATURAL RESOURCE MANAGEMENT

Research to support the sustainable management and efficient use of soil and water resources in table grape production.



DETERMINING THE WATER FOOTPRINT OF TABLE GRAPES TO IMPROVE WATER RESOURCE MANAGEMENT OF THE SOUTH AFRICAN TABLE GRAPE INDUSTRY

Project leader: E Avenant (Stellenbosch University)
Project duration: 2013 - 2017
Students to be qualified: G Kangueehi (PhD)

The primary focus of this project is to estimate the "blue" water footprint (freshwater use) for all table grape production regions of South Africa, as well as to provide data regarding actual grapevine water consumption at different phenological stages. This is being done by conducting a field trial in the Hex River Valley on Crimson Seedless to collect plant-based measurements (including vegetative growth, yield and grape quality, photosynthetic rate, transpiration rate, stomatal conductance and stem water potential). In the field trial, water used for irrigation is being calculated based on irrigation data supplied by the producers, water meter readings obtained from water meters installed in the blocks, soil water measurements and climate data received from the automatic weather station (AWS) nearest to the blocks. Water use by the grapevine through evapotranspiration will be calculated by using weather station data, published crop factors and FruitLook data. Through the sap flow measurements in two of the experimental blocks in the field trial, accurate measurements of the water used by grapevines are obtained.

In addition to the field trial, a water footprint case study of representative table grape production units from the other four table grape production areas in South Africa is being done, using a "water footprint questionnaire". In the case study, the total annual blue water consumption along the production chain will be determined for the table grapes by accounting for all processes utilising water from the start of the growing season until the grapes are packed.

Preliminary results indicate that total water use for irrigation (per ha per season) varies from 4 598 m^3 to 10 560 m^3 in the Hex River Valley, 12 301 m^3 to 18 634 m^3 in the Lower Orange River region and 4 710 m^3 to 8402 m^3 in the Northern Provinces. Regarding water use for spraying, the highest volumes used were in the Northern Provinces (30.1 m^3). Regarding "pack-store water use" there was vast variations. No pre-cooling was done in the Western Cape sites, while sites in the Orange River region and Northern Province used this technique. Results of the case study indicated differences in the blue water footprint of table grapes between regions, which can be linked to differences between regions in terms of climate (temperature and rainfall), as well as the length of the grapevine growing season.

CONFRONTING CLIMATE CHANGE INITIATIVE

Project leader: A Blignaut (Blue North)
Project duration: 2014 - 2017

The Confronting Climate Change Initiative is a strategic project which is funded in collaboration with Hortgro Science, Winetech, the Citrus Growers' Association and the Western Cape Department of Agriculture. The objectives of this project have been to develop a comprehensive online carbon calculator and an associated information platform. The online tool that has been developed (http://www.climatefruitandwine.co.za/) and provides the opportunity for producers to calculate their carbon emissions using an audited calculator. It is regularly updated with the newest developments relating to a carbon tax and shares "real-life" examples (case studies) of the implications of on-farm changes to reduce carbon emissions.

The benefits of using this tool are:

- Better managed and more sustainable businesses (user benefit);
- Enhanced industry competitiveness (industry benefit); and
- Regulatory and Standards readiness and compliance.

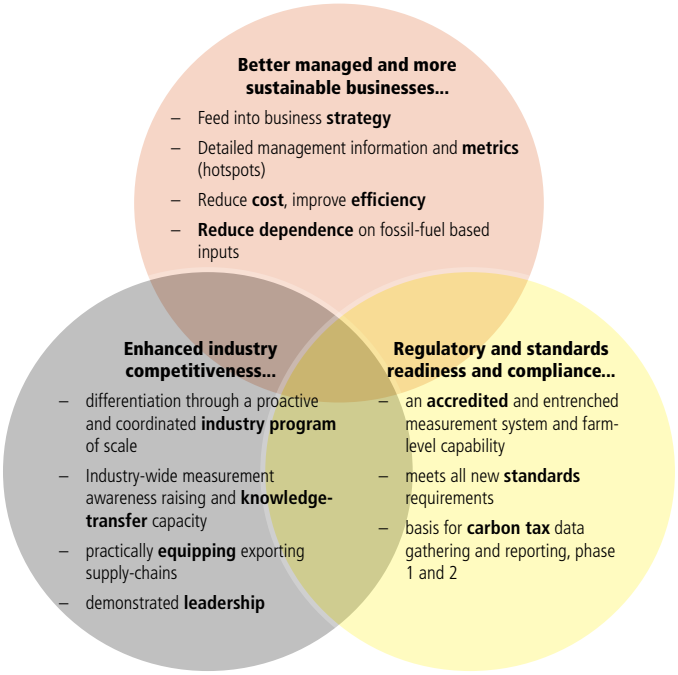


Figure 5: Benefits of using the online carbon calculator

PREPARATION OF VINEYARD SOILS IN SOUTH AFRICA: A SYNOPSIS OF 50 YEARS OF RESEARCH INFORMATION

Project leader: J van Zyl (Stellenbosch University)
Project duration: 2016 - 2017

Research regarding soil preparation of vineyards has been conducted over many years, and different generations of researchers, and consequently the knowledge is fragmented among many articles, journals, and experts. In short, a divide has developed between available knowledge and the end-users of the knowledge. It is imperative that all the available information is compiled correctly in one place, considering the role of soil preparation in the establishment of a vineyard and the huge costs involved. The objective of the project, therefore, is to comprehensively review all literature about the preparation of vineyard soils in South Africa and internationally to compile the existing information in a practical condensed handbook suitable for use by wine and table grape farmers, technical advisers and students.

Photo Credit: P Raath

Photo Credit: P Raath

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CROP PRODUCTION

Research aimed at addressing challenges and developing innovations in the cultivation of table grapes.

THE EVALUATION OF ROOTSTOCKS FOR TABLE GRAPES

Project leader: J Avenant (ARC Infruitec-Nietvoorbij)
Project duration: 1998 - 2016

To provide decision-making support for producers, the scientific evaluation of rootstocks has aimed to identify the most suitable rootstock/scion combinations. Criteria used to assess performance were scion growth, yield achieved, and the quality of grapes produced. This was done by assessing for high yield/high-quality combinations, matching rootstock and scion combinations to soil type and the economic viability and sustainability of the soil, rootstock and scion combinations. The outcomes of this project are being developed into commercial guidelines in a technology transfer project, which will be completed in 2018.

UNDERSTANDING TABLE GRAPE BERRY GROWTH AND COMPOSITION

Project leader: P Raath (Stellenbosch University*)
Project duration: 2011 - 2013
Students qualified: N Sonnekus (MSc)

The judgment of inherent table grape quality remains an elusive concept. This leads to the frustration that producers and exporters experience when apparently good quality grapes are rejected on arrival in the market because of quality deterioration during transport and cold storage. The objectives of this project were, therefore, to provide basic information as the first steps in building knowledge relating to table grape berry growth and composition. This can be used to evaluate the intrinsic quality of a specific table grape population. The ultimate goal is to predict each population's risk of post-harvest deterioration during export. This was done by quantifying and describing changes in berry composition throughout its development. This can be used to establish the relationship between the sugar and acid ratio and shelf life. The study was performed on Prime and Crimson Seedless, both grafted onto Ramsey, in the Paarl region of South Africa.
Research results for both cultivars showed that berry size does not play a major role in the occurrence of post-harvest defects. However, some small differences were observed. Medium-size berries were, for example, more prone to exhibit loose berries in both cultivars. Large berries obtained a higher percentage berry crack in both cultivars. Greater berry decline was found with later harvesting dates, especially for the Crimson Seedless where the second harvest took place 24 hours after rainfall. Berry size also did not affect the sugar and acid ratio of either of the two cultivars. The study, therefore, showed that post-harvest defects were not influenced by sugar and acid ratio but rather by harvest time. Environmental conditions before harvesting also impacted on post-harvest shelf life.

*Pieter Raath was employed at Stellenbosch University at the time the project was initiated.

RETURN FERTILITY OF TABLE GRAPES AS AFFECTED BY DIFFERENT APPLICATION METHODS OF PLANT BIOREGULATORS FOR THINNING AND BERRY SIZING

Project leader: E Avenant (Stellenbosch University)
Project duration: 2014 – 2016
Students qualified: L van der Vyfer (MSc)

Gibberellic acid (GA_3) is the most commonly used plant bioregulator in table grape production for bunch thinning and berry sizing. There are several reports from industry which describe an observed decrease in bud fertility which is ascribed to GA_3 treatment, but very few published research results are available to support these observations. The aim of this project was, therefore, to identify GA_3 application methods (volumes) for effective thinning and sizing treatments of table grapes without negatively affecting fertility.

The trial was conducted on the cultivar Prime Seedless in the Berg River region. GA_3 treatments for thinning and sizing were applied at the recommended concentrations and phenological stages for Prime Seedless. Different GA_3 application methods (application volumes) were evaluated both for thinning and berry sizing treatments. The Prime experimental block had an acceptable level of fertility before the trial started.

Based on the results after two treatment seasons, the following is recommended regarding GA_3 application methods and volumes for effective thinning and sizing treatments of table grapes without negatively affecting fertility:

Lower spray application volumes for berry sizing, (250 L/ha) and (ESS 72 L/ha) were associated with a decrease in fertility, while with 500 L/ha no negative effect on fertility was found. Therefore, repetition of the trial is needed to verify these results and to investigate whether the 500 L/ha spray application volume could be used instead of the current standard industry practice of using 1000 L/ha for the majority PBRs and other spray applications. Using an application volume of 500 L/ha instead of 1000 L/ha will have several practical and economic benefits (e.g. more hectares being sprayed with a one tank mix, decreasing the water footprint, reducing the carbon footprint).

Practical implementation of Treatment 2 (chemical thinning with a standard GA_3 spray application, followed by a GA_3 dipping treatment for berry sizing) in commercial table grape production requires the availability of sufficient labour. This is already practically applied by several producers in the industry in situations where they experienced a decline in fertility after GA_3 spray applications. The trial will be repeated with external funding to validate results.

DISEASE MANAGEMENT

Research which aims to minimise diseases to encourage optimal grapevine performance, by focusing on the quality of grapevine material and management practices to reduce the spread of grapevine diseases. Emphasis is also placed on disease management strategies that are safe for the environment and, as far as possible, reduce the maximum residue limits (MRLs).

Photo Credit: Y Petersen (ARC)

Photo Credit: Y Petersen (ARC)

Photo Credit: Y Petersen (ARC)

IMPROVING PRUNING WOUND PROTECTION AGAINST TRUNK DISEASE PATHOGENS

Project leader: L Mostert (Stellenbosch University)
Project duration: 2010 – 2013
Students qualified: GJ Makatini (MSc), C Mutawila (PhD)

Research has shown that Trichoderma is an effective biocontrol treatment to protect grapevines against trunk disease infections which originate from pruning wounds. It is well established that winter pruning wounds are an important portal of infection for grapevine trunk diseases, but less is known about the role of sucker wounds. The aims of this work were to develop an improved understanding of the efficacy of Trichoderma based products, create a better understanding of the mechanisms of control, and investigate the role of sucker wounds in trunk disease epidemiology.

Photo Credit: L Mostert (Stellenbosch University)

Field trials were established to assess the best method, timing and formulation for Trichoderma application. Glasshouse trials were established to assess the susceptibility of sucker wounds to trunk diseases. Additionally, field surveys were also conducted to establish if sucker wounds become infected under commercial conditions. The effectivity of Trichoderma to protect sucker wounds against trunk diseases was assessed in a field trial.

Results showed that it is best to apply Trichoderma six hours after pruning. Application with a backpack sprayer and paintbrush gave the best results in comparison with a gator application. Several additives were tested to improve the formulation of the Trichoderma product but were not significantly better than the Trichoderma and water mixture. Studies in the glasshouse, as well as during the field trials, showed that sucker wounds are susceptible to trunk disease pathogens. A survey of sucker wounds from both wine and table grape cultivars in different regions in the Western Cape also showed that trunk disease pathogens naturally infected the sucker wounds. A field trial demonstrated the potential for the use of Trichoderma products for the protection of sucker wounds from infection of trunk disease pathogens. *In vitro* tests indicated that fungicides interact with Trichoderma and may affect its effectivity.

XYLOPHILUS AMPELINUS: IDENTIFICATION AND ANALYSIS OF TYPE III SYSTEM EFFECTOR GENES

Project leader: Y Petersen (ARC Infruitec-Nietvoorbij)
Project duration: 2012 - 2015
Students qualified: NPP Nyembe (MSc)

Research conducted at ARC Infruitec-Nietvoorbij has made considerable progress in acquiring fundamental knowledge relating to the genetic makeup of *X. ampelinus* (bacterial blight). Recent research has focused on the identification and verification in *X. ampelinus* of a key pathogenicity mechanism found in many Gram-negative plant and animal bacteria known as the Type III secretion system (T3SS). Type III secretion system-dependent effectors (T3Es) have been shown to act as triggers that suppress the immune system of plants. The importance of understanding this is to enable the breeding of bacterial blight resistance into grapevines. The aim of the project was, therefore, to identify and subsequently start the characterisation of the *X. ampelinus* T3E repertoire for resistance breeding. The project identified 46 candidate effector genes in the *X. ampelinus* genome and of the subset studied further, showed that while some of these genes were not active as effectors, deleting individual effector genes from the genome did not noticeably reduce virulence, indicating that those particular T3Es may be dispensable for pathogenesis. Some of the outcomes of this project are being incorporated into bacterial blight resistance breeding for grapevines.

QUANTIFICATION OF SOIL-BORNE PATHOGENS IN GRAPEVINE NURSERIES

Project leader: L Mostert (Stellenbosch University)
Project duration: 2013 - 2016
Students qualified: S Langenhoven (Hons. and MSc), M Bester (Postdoctoral student)

The "take percentage" of plants in grapevine nurseries varies from 40% to 50%. This low success rate could potentially be ascribed to grafting incompatibilities, the presence of soil-borne diseases, quality of planting material and environmental factors, amongst other things. The aim of this project was to create a

better understanding of soil-borne pathogens (specifically *Cylindrocarpen, Phytophthora* and *Pythium*) and their interaction with rotation crops. Additionally, this project aimed to further develop PCR techniques for identification of *Cylindrocarpen, Phytophthora* and *Pythium* from soil samples.

The project has shown that two of the rotation crops evaluated (Tricale and forage radish) as well as the weeds corn spurry, rye grass, winter grass, Cape marigold and Johnson grass, harbour black foot and crown and root rot. In contrast, results showed that canola, white mustard and lupins do not harbour black foot and crown and root rot. An additional outcome is that a quantitative polymerase chain reaction (qPCR) protocol was developed for the identification of three fungi (*Dactylonectriall Ilyonectria, Phytophthora* and *Pythium irregulare*) in the soil.

Photo Credit: L Mostert (Stellenbosch University)

IDENTIFICATION OF POTENTIAL *XYLOPHILUS AMPELINUS* INOCULUM SOURCES IN VINEYARDS, WITH SPECIAL REFERENCE TO SOIL AND PLANT DEBRIS, AS WELL AS THE ASSESSMENT OF POPULATION DYNAMICS

Project leader: Y Petersen (ARC Infruitec-Nietvoorbij)
Project duration: 2016 - 2018
Students to be qualified: NPP Nyembe (PhD)

Through research conducted at ARC Infruitec-Nietvoorbij in recent years, considerable progress is being made towards understanding the pathogen through setting up genetic systems to facilitate the study of the pathogens' disease-causing ability, as well as gene identification via genome sequencing. However, for a sustainable management system for bacterial blight to be implemented in South African vineyards, the genomic studies need to be complemented by a thorough knowledge of the ecology and epidemiology (including the occurrence and life-cycle of the pathogen) of the organism and the disease it causes. Uncovering potential inoculation sources in South African vineyards (vines, soil and plant debris) and determining their importance in relation to the initiation and spread of bacterial blight, would permit the design of control measures for a pathogen at its source.

Unlike fungal diseases, bacterioses are notoriously difficult to treat or eradicate once an outbreak occurs. Reducing or eliminating the bacterial inoculum at its primary source may prove more effective as a sustainable control measure for bacterial blight of grapevine. Hence, this project aims to build upon and expand previous *X. ampelinus* research to encompass the epidemiological aspects of bacterial blight that will allow for a more targeted approach to disease control. The primary objective of this project is to determine the potential of soil and plant debris to serve as sources of *X. ampelinus* inoculum. Since there are no known successful protocols for detection and enumeration of this bacterium in soil and plant debris, a method involving quantitative real-time PCR will be investigated to assist with achieving the primary objective.

INVESTIGATION INTO THE EFFICACY OF *TRICHODERMA* SPP, COLONISATION OF GRAPEVINE NURSERY PLANTS

Project leader: L Mostert (Stellenbosch University)
Project duration: 2016 - 2018
Students to be qualified: W van Jaarsveld (MSc), R Pierron (Postdoctoral student)

Research has shown that grapevine nursery plants get infected by black foot pathogens present in the soil. *Trichoderma* spp. has the potential to be used to control the infection of black foot pathogens and has the added benefit of growth promotion. The efficacy of *Trichoderma* spp. towards the different fungal pathogens causing black foot has not been determined. Various *Trichoderma* products are available for grapevine pruning wound application, but these have not been tested for root application. *In vitro* and field testing is necessary to be able to determine their efficacies. Currently, there are no registered *Trichoderma* products for grapevine root application. Visual observations of *Trichoderma* spp. growth in roots has not been done and would aid in selecting effective *Trichoderma* isolates. *Trichoderma* spp. activates plant host defense genes, which prime the plant against pathogen attack. The activation of grapevine defense genes by *Trichoderma* spp. has only recently been established for grapevine cell cultures and needs to be expanded to test *in planta*. Understanding the efficacy of root colonisation and host defense activation of rootstocks is essential as the first step in evaluating the use of *Trichoderma* spp. in nurseries and new vineyards.

Photo Credit: E Allsopp (ARC)

Photo credit: B Dlamini (Stellenbosch University)

Photo Credit: N Parry

PEST MANAGEMENT

Research which aims to minimise the presence of pests in table grapes safely before and after harvest, with special focus on management strategies that are safe for the environment, as far as possible, reduce MRLs and optimise, retain and maintain market access.

MOLECULAR ANALYSIS AND BIODIVERSITY SURVEY OF FRUIT FLIES ASSOCIATED WITH DECIDUOUS FRUITS AND VINES, WITH A FOCUS ON ECONOMICALLY IMPORTANT SPECIES

Project leader: P Addison (Stellenbosch University)
Project duration: 2012 - 2014
Students qualified: M Karsten (PhD)

Research in the field of biological invasions has increased dramatically in the last two decades, especially due to the impact of human activity such as transport, travel and international trade. Different stages of invasion have been proposed, each stage posing different barriers that must be overcome by the organism for it to become established. For the prevention of new invasions and the formulation of a successfully integrated pest management programme (IPM), knowledge of insect community assemblages, movement patterns and the ability to identify the pest species rapidly in the field are important. In this project, we made use of multiple agriculturally important fruit fly species, *Ceratitis capitata, C. rosa* and *Bactrocera invadens (B. dorsalis)*, in the Tephritidae family in different stages of the invasion process using different research methods. This was done to investigate seasonal variation in fruit fly abundance in orchards and natural vegetation in the Western Cape to determine whether natural vegetation is used as possible refugia. The researchers also want to determine the suitability of Loop-mediated isothermal AMPlification of DNA (LAMP) to identify *Bactrocera invadens (B. dorsalis)* rapidly in the field. They also want to investigate the population genetic structure, using molecular and morphological markers, to estimate gene flow and dispersal ability of *C. rosa* in South Africa.

Results showed that *C. capitata* was the most abundant species captured and Biolure® the most effective lure. The largest number of individuals of either species (C. rosa and C. capitata) were captured in austral autumn (March-May) in both orchards and natural habitat with low capture rates throughout the rest of the year. Orchards and natural habitats were significantly different with higher trap catches always found in orchards. LAMP showed to be marginally adept to identify *B. invadens (B. dorsalis),* but further work is required to refine this technique. Based on microsatellite markers and geometric morphometrics, results indicate that there is no population structure in *C. rosa* within South Africa. This indicates that there are high levels of connectivity between different pest-occupied sites within the country and suggests that area-wide pest management should be undertaken on a much larger, preferably country-wide scale. The results are discussed in the framework of invasion biology as well as integrated pest management. In conclusion, when investigating biological invasions, information from an organism's biology and ecology, as well as molecular biology, can be valuable to inform decision-making regarding prevention and mitigation of pest species.

DISPERSAL CAPACITY OF *BACTROCERA DORSALIS*

Project leader: C Weldon (Pretoria University)
Project duration: 2013 – 2017

Students to be qualified: S Mnguni (BSc.Hons), C Dufourd (PhD), L Makumbe (PhD)

This project aims to create a better understanding of the movement of *Bactrocera invadens** in relation to some variables. This has been achieved by using sterile *B. dorsalis* in mark-release-capture experiments to determine the effects of fly maturity, sex and availability of host fruit on dispersal, as well as laboratory experiments on activity over a range of temperatures.

Results from the field indicate that females fly further than males, and this is particularly pronounced when females are released amongst non-host plants. Younger males disperse further than older males released from the same point at the same time. *B. dorsalis* is largely inactive at temperatures lower than 20˚C. The frequency and duration of walking and flight increases between 24-32˚C. At a temperature of 36˚C, the duration of resting begins to increase, which may indicate the onset of thermal stress. Tethered flight on "flight mills" verified the observation that flight was optimal between 24-32˚C. These tests also found that older females flew further and faster than males.

Fly age, sex and the proximity of host plants influence the distance that *B. dorsalis* travel from the point of origin. Based on observations of spontaneous and tethered flight in the laboratory, higher dispersal ability of younger male flies may result from higher numbers of short flights when temperatures are within the range of 24-32˚C. However, within the same temperature range, females are stronger fliers.

* It is now recognised that *B. invadens* is a synonym for the Oriental fruit fly, *Bactrocera dorsalis*.

FOLIAR APPLICATION OF ENTOMOPATHOGENIC NEMATODES FOR THE CONTROL OF VINE MEALYBUG (*PLANOCOCCUS FICUS*) IN VINEYARDS

Project leader: N Stokwe (ARC Infruitec-Nietvoorbij)
Project duration: 2015 - 2018
Students to be qualified: Thomas Platt (MSc)

The grapevine mealybug, *Planococcus ficus* (Hemiptera: *Pseudococcidae)*, is the dominant mealybug on grapevines in South Africa. It causes direct damage to wine and table grapes and it is also the primary vector of grapevine leafroll virus. The risk of developing resistance to insecticides and consumer demands for sustainably produced, residue-free fruit have led to a search for alternative control methods.

Photo Credit: T Platt (Stellenbosch University)

Currently, mealybug management relies heavily on chemical control. Success is hampered by the inability of the chemicals to come into direct contact with the mealybugs because of their wax secretions and cryptic habits. Chemical control before budding is often not possible because vineyards are waterlogged and post-harvest chemical control is harmful to natural enemies. Entomopathogenic nematodes (EPNs) belonging to the families Heterorhabditidae and Steinernematidae have been shown to be effective against grapevine mealybugs in laboratory studies. Application of EPNs to grapevines after harvest or in autumn when leaves have fallen would provide an environmentally acceptable alternative to insecticide applications before budding for mealybug control. The project aims to investigate the use of EPNs to control grapevine mealybug on the leaves, cordon arms and stems of grapevines, with the goal of incorporating the use of EPNs in an integrated pest management (IPM) system for mealybug.

RING NEMATODE *(CRICONEMOIDES XENOPLAX)* DISTRIBUTION, CHARACTERISATION AND CULTURE METHODS

Project leader: A Malan (Stellenbosch University)
Project duration: 2015 - 2017
Students to be qualified: M Odendaal (MSc)

The ring nematode, *Criconemoides xenoplax*, has become a serious pest in South African stone fruit and grapevine soils. Limited knowledge and understanding exist about the occurrence, morphology and molecular characterisation of ring nematode in South Africa.

The overall aim of the project is to gather basic information relating to the ring nematode, by characterising ring nematodes from different areas in terms of their morphological and molecular differences. A technique to culture the ring nematode for use in future research projects will also be investigated. Commercial grapevine rootstocks will be screened for susceptibility to ring nematode. Soil samples representative of the different grapevine and stone fruit areas will be collected. Ring nematode counts will be done, and nematodes will be sampled for morphological, morphometrical and molecular studies.

Five commercial grapevine rootstocks were inoculated with 2000 ring nematodes per plant. After six months, the plants were removed from the pots, and the soil washed, using a sugar flotation technique.

The highest number of ring nematodes were obtained from Richter 99 and Richter 110, indicating them to be the most susceptible. Ramsey showed the least reproduction of ring nematode, with the lowest final nematode counts. Thus far, ring nematode has been recorded in all areas sampled in the Western Cape. Greenhouse trials need to be repeated and statistically analysed to determine the difference in susceptibility between the commercial rootstocks. Morphological and morphometrical analysis still needs to be done on samples collected from the different stone fruit areas concerned.

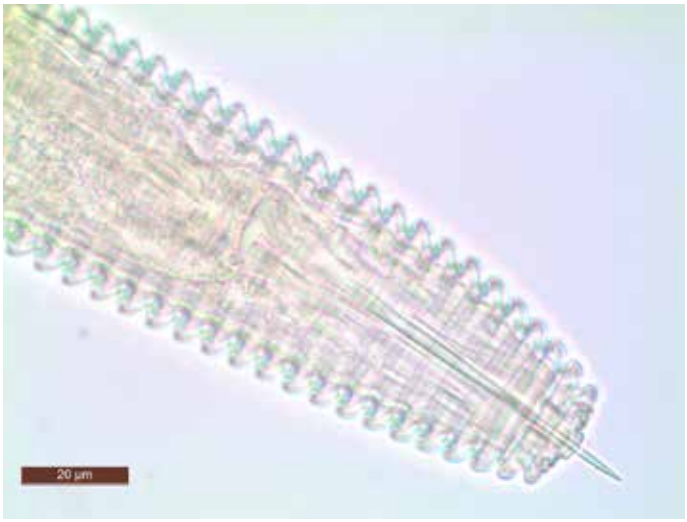

Photo Credit: M Odendaal (Stellenbosch University)

EVALUATION OF COLD AS A DISINFESTATION TREATMENT FOR FALSE CODLING MOTH

***(Thaumatotibia leucotreta)* [Lepidoptera: Tortricidae]) with table grapes as a test medium**

Project leader: A Ware (Agri-Biotech Research Consultancies CC)
Project duration: Jan 2015 to Aug 2015

Market access and market retention are essential components for the continual growth and prosperity of the South African fruit industry. To achieve this, table grapes must adhere to strict international quality specifications.

False codling moth (FCM) is indigenous to sub-Saharan Africa. Some countries importing South African table grapes might require the application of a post-harvest disinfestation treatment to export consignments. A cold treatment protocol (-0.6$_3$C for 22 days) has been the standard FCM post-harvest disinfestation treatment and is based on research done by Myburgh (1965) and with treatment efficacy validation by Hofmeyr and Hofmeyr (2005). However, this protocol is considered detrimental to grape quality, and a higher temperature for disinfestation is desirable. This research examines the possibility of using a less damaging cold treatment for disinfestation of FCM using table grapes as a test medium. The aim of this study was, therefore, to investigate if FCM can be disinfested from table grape consignments at higher temperatures. Results showed that there were no survivors from more than 35000 individuals treated for 20 days at 0.8°C or more than 30000 individuals subjected to -0.6°C for 18 days. These results support the adoption of these cold treatment options in international fruit trade protocols.

USING BIOCONTROL AGAINST TWO SPORADIC PESTS IN VINEYARDS AND ORCHARDS

Project leader: P Addison (Stellenbosch University)
Project duration: 2016 – 2019
Students to be qualified: F du Preez (MSc), B Dlamini (PhD)

The common method of controlling banded fruit weevil (BFW) and the *Phlyctinus callosus* (Coleoptera: Curculionidae) involves the use of pyrethroids applied on the tree trunks and foliage. Entomopathogenic nematodes (EPNs) from two families (Heterorhabditidae and Steinernematidae) can be incorporated into an integrated pest management (IPM) system to control *P. callosus* which is a key pest of grapes, apples and nectarines in South Africa.

Due to the sporadic nature of katydids in vineyards, no chemical pesticides have been registered for this pest and current chemical control measures are mostly ineffective. However, previous research has identified possible biological control agents, including entomopathogenic fungi (EPFs) and parasitic wasps, which can be incorporated into an IPM program.

S. yingalemense shows good control against *P. callosus* in preliminary laboratory trials at 100IJs/insect. However, more EPNs must be tried before the pathogen can be incorporated into an integrated pest management system to improve the control of *P. callosus.* Trials against katydids will commence early in the growing season as soon as immature insects are monitored in the field.

INTEGRATED MANAGEMENT OF THE CONTROL OF FALSE CODLING MOTH *(THAUMATOTIBIA LEUCOTREATA)*

Project leader: P Addison
Project duration: 2016 – 2018
Students to be qualified: VM Steyn

This project aims to investigate the use of biological control and mating disruption as alternate control methods for false codling moth (FCM). With regard to the objective of biological control, soil surveys will be conducted in the Western Cape to establish what pathogens (nematodes and fungi) are present in the region. Species and strains of pathogens will be tested in laboratory bioassays against FCM larvae, pupae and eggs. Strains that show the most promise will be further tested in the field by means of applying the biologicals on the orchard floor that is artificially infested with larvae and pupae to allow for assessment.

With regard to the objective of mating disruption, several similar blocks will be treated with increasing levels of dispenser densities, along a grid of traps. After releasing sterile FCM, the level of disruption experienced (in the form of FCM caught in treated/ untreated blocks) will be recorded. The data obtained will be analysed in accordance with Miller et al.'s (2006) guidelines, and dosage–response profiles will be drawn to identify the disruption mechanism involved and to calculate the optimal dose required.

Photo credit: J Fouche (Nexus Ag)

Photo Credit: A Daniels (ARC)

POST-HARVEST MANAGEMENT

Research which focuses on optimising the handling and storage of table grapes across the cold chain, to ensure that table grapes that arrive in the export market are of good quality and quality claims from the export market are minimised.

RE-EVALUATION OF THE TABLE GRAPE SHIPPING PROTOCOL

Project leader: MEK Ncgobo (PPECB*)
Project duration: 2012 - 2014

Recently, there has been a significant increase in dispensation requests to pre-cool table grapes to higher pulp temperatures than the recommended statutory temperature of -0.5°C. The practice is such that the grapes are cooled to these elevated pulp temperatures and then shipped under normal shipping protocols where the reefer containers/ships are set at set-point of -0.5°C delivery air temperatures (DAT). The request is usually to load grapes at pulp temperatures between plus 2.5°C to plus 5°C. The reasons for the requests include the early arrival in markets to take advantage of good market prices and the poor stem conditions which are claimed to be associated with forced air cooling grapes to -0.5°C.

The objective of this project was therefore to investigate whether the current statutory temperature could be raised to high pulp temperatures of up to about 5°C and shipped at the current shipping protocol of -0.5°C without negatively affecting the outturn quality of table grapes.

During the commercial trial, pre-cooling table grapes to -0.5°C resulted in poor stem conditions than cooling grapes to elevated pulp temperatures of 2.5°C and 5°C. However, this observation was not true under the small-scale simulation trial, indicating that the forced air cooling process needs to be optimised to avoid negative effects on stem quality. Forced air cooling grapes to higher pulp temperatures and shipping under the current regime of -0.5°C seem to have a potential for a short-term solution. Generally, all grapes had a good quality upon arrival and regardless of the target pulp temperature. However, cooling grapes to higher pulp temperatures before shipping may result in the shorter shelf life of grapes, especially during seasons of low quality. Hence the seasonal conditions need to be considered when adopting such cooling practices.

DETECTION OF POST-HARVEST PATHOGEN PROFILES LINKED TO MARKET-END LOSSES IN LOCAL AND EXPORT MARKETS AND FUTURE CONTROL STRATEGIES FOR THE TABLE GRAPE INDUSTRY

Project leader: L Korsten
Project duration: 2014 - 2017
Students to be qualified: N Botha (MSc), L Louw (MComm), P Carmichael (PhD), N Siyoum (Postdoctoral student).

In extended supply chains, table grapes may become more susceptible to post-harvest pathogens as they are distributed, and the berries mature. Post-harvest pathogens from genera with a broad range of species (i.e. *Penicillium*) and wide host specificities are not well studied. A general lack of information relating to the pathogenic role and status of these organisms on table grapes exists. Although numerous species have been isolated from berries, no evidence or traceability exists to indicate the link between pathogen inoculum levels, prevalence, associated losses and cost to the grower.

Furthermore, post-harvest losses are regularly identified through visual inspections and attributed to the more common pathogens making it inaccurate. A supply chain approach to reduction of post-harvest losses is required.

This study aims to identify the causal agents of post-harvest decay on table grapes in the local and export chain from South Africa (SA) to the United Kingdom (UK) and the development of more effective end-market disease control approaches. To achieve this, the source of table grape pathogens including *B.cinerea* was monitored from three different agro-climatic sites, to investigate the prevalence and concentration from flowering to market-ready fruit. Also, symptomatic fruit and the air were sampled from three farms, pack-houses and three of the most prominent local fresh produce markets, as well as the export supply chain from SA to the UK. The economic impact of losses was also investigated and the link made between pathogens present, losses and costs.

The study will provide insights into losses and waste as a result of the presence of the pathogens studied throughout production and marketing. Preliminary results indicate that Penicillium species are especially prevalent in the local fresh produce markets. The six most dominant species in the table grape export chain were: *Penicillium glabrum* (13.32%), *P. commune* (10.44%), *P. polonicum* (10.08%), *P. thomii* (9.83%), *P. expansum* (8.72%), and *P. digitatum* (6.88%). The latter two are well known post-harvest pathogens on pears and citrus and in this study were found to be highly aggressive on different table grape varieties.

NON-DESTRUCTIVE QUANTIFICATION AND PREDICTION OF TABLE GRAPE EXTERNAL AND INTERNAL QUALITY

Project leader: U L Opara
Project duration: 2016 - 2018
Students to be qualified: A Daniels (PhD)

The evaluation of table grape quality is mostly done by visual inspection of whole bunches and destructive chemical tests. The focus of this research will thus be to determine the feasibility of evaluating specific quality parameters of whole table grape berries and bunches, quickly and easily, using non-destructive infrared (IR) spectroscopic methods.

Two white table grape cultivars (Regal Seedless and Thompson Seedless) were harvested at two ripeness levels (16-18°Brix and 19-22°Brix) from four different commercial vineyards in the Western Cape. Whole bunches and berries were tested with the available near-infrared (NIR) and sensor technologies (handheld,

laboratory and industrial) for multi-parameter evaluation to establish optimal spectral measuring strategies. Reference values (such as total soluble solids (TSS), titratable acidity (TA) and pH plus a visual assessment of browning incidence and severity was generated. IR microscopy to characterise external quality defects on berry surface during storage was applied. Preliminary quantitative prediction models for TSS, TA and pH were constructed of whole bunches scanned. The most prominent browning phenotypes on whole table grape bunches were established. Spectra and images of the browning defects were obtained from the IR microscopy work.

Photo Credit: A Daniels (ARC)

DETAILED TEMPERATURE PROFILING OF SELECTED FORCED-AIR COOLING FACILITIES AND THE COLD CHAIN, TO IDENTIFY PROBLEM AREAS WITH THE VIEW TO AVOID FREEZING AND CHILLING DAMAGE AND BROWNING OF STEMS OF TABLE GRAPES SUBJECTED TO COMMERCIAL COLD STERI REGIMES

Project leader: D Moelich
Project duration: 2015 - 2017

Detailed measurements were conducted on several commercial table grape consignments, in 12 to 18 monitoring positions per shipment, in cooling tunnels or inside reefer containers, during pre-selected phases of the cold treatment export chain.

The objective was to identify "cold spots" which may be injurious to the grape stem or grape pulp, according to published and industry (PPECB) benchmarks. Temperature data loggers were used to measure air and pulp temperature in predetermined positions, in layers at the base and top of table grape pallets. Data from various cold chain phases were then screened to identify when air or pulp temperature entered into ranges which were regarded as damaging (freezing) or ranges of uncertainty, last-mentioned falling between specific threshold/benchmark levels. For easier reference, these benchmarks were used to define a "red zone" and a "yellow zone" temperature range. These colour zones indicated the published freezing point or a temperature range wherein the effect on storage quality is uncertain, yet regarded as risky, according to industry/PPECB norms.

The Ph 3 data recorded in the land-based facility showed that in the coldest positions in grape pallet cooling stacks, temperatures occasionally (one out of five runs) entered the red zone for grape stems (<2°C), indicating that grape stem quality can be compromised in localised positions, in consignments.

The Ph 4 data recorded during the sea voyage, confirmed a practice used by some shipping lines, namely stepwise adjustment of set-points. This resulted in air temperatures reaching lowest levels soon (1-4h) after loading of the container, followed by and a further low temperature period spanning four to five days after loading. These low temperatures are likely capable of damaging grape stems in localised positions, such as the side of cartons on the base layers of pallets, closest to the air inlet.

Data recorded during specific phases of the cold treatment handling chain confirmed that temperatures which are regarded as potentially damaging to table grapes stem condition were reached in localised positions in the shipping container, in positions which are not routinely monitored by the container probes or the routinely used temperature-logger (Temptale). This occurred when shipping lines used consecutive two- or three step set-points during the sea voyage, in their efforts to maintain the pulp temperature protocol. The recently relaxed cold treatment protocol to China is likely to create leeway, allowing that shipping lines can avoid this practice, in future. This relaxed protocol will be monitored, during the 2016/2017 season. It was observed that the implementation of the cold treatment protocol, which includes a mandatory 72h pre-cooling period at specifically approved cold treatment facilities, increased the duration between harvest and marketing by between seven and ten days, compared to grapes destined to non-regulated markets. The longer duration of the cold treatment handling chain is, therefore, a further challenge for the maintenance of table grape quality to regulated markets.

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