HISTORY OF PLANT PATHOLOGY IN SOUTH AFRICA

Teresa A Coutinho · Michael J Wingfield

BRIZA ACADEMIC BOOKS

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LEGENDS TO FIGURES ON FRONT COVER (CREDIT GIVEN IN BRACKETS):

Left (Top to Bottom):

- Galls formed by *Uromycladium morrisii* on *Acacia saligna* (Alan Wood)
- Symptoms of powdery scab of potato (Jacquie van der Waals)
- Symptoms of Fusarium wilt of banana (Altus Viljoen)
- Symptoms of citrus canker on the fruit (Alberto Gochez)

Right:

- Symptoms caused by grapevine leaf roll (Johan Burger)

LEGENDS TO FIGURES ON TITLE PAGE (CREDIT GIVEN IN BRACKETS):

Top (L to R):

- Symptoms of citrus canker on the fruit (Alberto Gochez)
- Galls formed by *Uromycladium morrisii* on *Acacia saligna* (Alan Wood)
- Myrtle rust symptoms (Jolanda Roux)

Bottom (L to R):

- Symptoms caused by the potato leaf roll virus (Jacquie van der Waals)
- Symptoms of Fusarium wilt of banana (Altus Viljoen)
- Symptoms of powdery scab of potato (Jacquie van der Waals)

HISTORY OF PLANT PATHOLOGY IN SOUTH AFRICA

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DEDICATION

This book is dedicated to our FABI and University of Pretoria colleague, Professor Theresa (Terry) Aveling. She was a passionate and committed plant pathologist and stalwart member of the Southern African Society for Plant Pathology throughout her career. Terry passed away in December 2019 after a courageous battle with CoViD-19. She will be missed by her friends, colleagues and students.

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FOREWORD

This book covering the history of Plant Pathology in South Africa and also covering the Southern African Society for Plant Pathology (SASPP) has appropriately been produced during the United Nations 2020 International Year of Plant Health. While it is focused on the history of plant pathology in South Africa, it also captures much of the history of the society that served as a catalyst for the discipline in general. Although it is difficult to identify the starting point of a discipline in a country, we learn from this book that the first reports of plant disease date back to 1875 and thus about 140 years. The SASPP is obviously much younger, having been established in 1962. My comments here focus strongly on my relationship with the SASPP, yet they pertain as much to the field of plant pathology.

I was not present at the birth of the SASPP. At that time, I was a third-year plant pathology student. My first contact with the society came at the 1966 Pietermaritzburg congress where I met for the first time with awe-inspiring, formally-dressed, serious, stern participants, strictly observing the timing of programme presentations. I remember them painstakingly moulding the first draft of the society constitution and its wording, which needed to be in both English and Afrikaans. I recall being most impressed! But, while I wasn't part of the society when it was first established, I must be one of its longest-standing members. I presume that this is why I have been requested to contribute the foreword for this important book.

The SASPP has come a long way since the days when we travelled by night-train to meetings in Pretoria. Typically, two staff members of each plant pathology department in South Africa had permission to attend and our presentations had to be approved by the director of the region. It is important to remember that our University departments at that time fell under the jurisdiction of both the University and the government Department of Agricultural Technical Services. These were also the days when a large South African oil company would be pleased to support our conference with a cheque for R5.00; clearly then a considerable sum!

This book is a tribute to plant pathologists in South Africa. It is also a testament to the many larger-than-life people who contributed, very often under trying and even primitive circumstances, to our field. As a society and country, we can be justly proud of our plant pathologists, many of them internationally recognised, that have and continue to emerge from our universities and research institutes. It is good and fitting to see their lives and contributions encapsulated in these pages. The book also records the history of plant pathology's sub-disciplines and details the many important diseases on which South African pathologists have worked. This has all been achieved in an effort to broaden our knowledge regarding plant pathogens, the diseases that they cause, and to establish improved methods for their management and control.

An important aspect of this book is its focus on congresses that the SASPP has organised. In reminiscing about how the form and expression of these meetings has morphed in over half a century, I stand in awe of the quality of today's impressive oral PowerPoint or Keynote type presentations. Likewise, the computer-generated posters that have replaced hand-drawn graphics with Letraset letters glued to them. Gone are the products of the Kodak Instamatic cameras, slides and overhead projectors. Yes, we have come a long way - good science, highly regarded scientists as members, excellent students, a very efficiently run and streamlined society, and evermore convivial and informative congresses.

For approximately 140 years and for the SASPP's almost 60 years, South Africa has been blessed, not only with excellent scientists but also with great leaders and leadership: hard-working, intelligent, altruistic people who have given selflessly of their time and expertise from their already busy lives. This is well-illustrated by the publication of this book, particularly by those who compiled it, but also by those who so freely and expertly contributed to its contents. It is another token of a grand and mature discipline. We have every reason to be proud to be South African plant pathologists and members of the SASPP.

So, from me to the society and to South African plant pathologists: I now look forward to writing the foreword to the centenary volume. Thank you for the memories. *Ad multos annos!*

Frits HJ Rijkenberg

Emeritus Professor, University of KwaZulu-Natal, Pietermaritzburg
Fellow and Honorary Member of the SASPP

PREFACE

The reasons we embarked on the endeavour to produce this book were three-fold. These were to celebrate 140 years of plant pathology in South Africa, 50 years of congresses of the Southern African Society for Plant Pathology (SASPP) and to recognise the United Nations International Year of Plant Health 2020. Initially, the intention was to record the history of the SASPP, the archive of which exists in many boxes, which over the years have been moved from one region of the country to another following the changing leadership teams (councils). In 2016, Frits Rijkenberg consolidated the entire collection and retained only essential documents. What was somewhat disturbing is the fact that, once computers became part of our daily lives, records were no longer retained as hard copies but rather on disks. Accessing some of the more recent information was consequently difficult and, in some cases, impossible. We hope that readers will understand these constraints that have inevitably resulted in some gaps in information.

The first part of the book focuses on the history of plant pathology. This is the second attempt by members of the society to document this topic. In 1997, the council of SASPP decided to record the history of plant pathology for the period 1945 to 1995. Deon van der Westhuizen undertook this task and 40 pages were written. We were, unfortunately, unable to trace that document.

Efforts were made to trace any evidence of plant diseases or plagues prior to 1652 and the arrival of Jan van Riebeeck. Here we had the assistance of Riaan Rifkin, an anthropologist. We have good evidence that plant diseases had an impact on the Company Gardens established by the early Dutch settlers, and later on in the first farms established in the Cape Colony. The plant gatherers or hunters in the 18^{th} and 19^{th} centuries are known to have collected diseased plant material of native vegetation which, in many cases, was sent to collections in Europe. Once the South African government was established in the early 1900s, plant pathology was included as part of 'economic botany'. Universities were established and plant pathology was taught as a discipline.

Over the years, many plant diseases have led to significant economic losses in South Africa. In one case the disease known as citrus canker was eradicated. There is also the interesting example of the rust pathogen *Uromycladium morrisii* being intentionally introduced as a biological control agent for an aggressive invasive *Acacia* species. Independent research institutes were established by industries linked to agriculture and forestry. The Agricultural Research Council (ARC) was established, as was the South African Plant Improvement Organisation (SAPO). There have been a number of South African plant pathologists who, during their lifetime, were leaders in their fields nationally and/or internationally and who have made a significant contribution to the discipline in South Africa. These included, for example, Illtyd B Pole-Evans, Ethel M Doidge, James E Vanderplank, Susarah Truter, Peter Knox-Davies, Walter (Wally) Marasas, Joszef (Jo) Darvas and Jan (Ballie) Kotzé.

The second part of this book records the history of the South Africa's plant pathology society. This was established in 1962 and was known as the South African Society for Plant Pathology and Microbiology (SASPPM). In 1981 it separated into the respective disciplines of microbiology and plant pathology. In 1994, the society expanded its activities beyond the borders of South Africa, and the name was changed to the Southern African Society for Plant Pathology (SASPP). From 1962 until 2007, congresses were held annually and spread over three days. This was changed from 2009 onwards, when congresses were held every two years, with a duration of three days. A decision was also made that the local branches would hold plant pathology 'events' in the years when a congress was not held. In 2015, the congress was extended by an additional day with the intention that the gala dinner and awards ceremony would mark the close of the congress.

Congresses of the SASPP have always been special occasions, including not only the presentations but also quiz evenings, workshops and then the unforgettable social events. More often than not, the social events are what many participants recall most clearly. These include turning a perfectly pleasant parrot into an inebriated bird unable to remain on its perch, to "skinny dipping" in the ocean. The SASPP congresses were and still remain special events that have played an important part of the history of plant pathology in South Africa. We believe that they will continue long into the future and that they will define a subject area crucially important to the health and well-being of the citizens of the country.

In order to maintain a relatively uniform content, we have edited material supplied to us for the various sections of this book, in some cases quite extensively. Occasionally, this also involved removing text. We hope the authors that have supplied us with such material will understand why we needed to make this decision. Likewise, for some sections, it was necessary to rely on information provided on the internet. In the majority of these cases, the content was verified by the organisation being discussed and sometimes this was modified by them. A plant pathologist involved in that particular field was then consulted to include additional information on the aspects related to plant pathology. The website consulted is cited as the source below the information included in the book. As plant pathologists we have all contributed to the growth of the discipline in numerous ways. We have tried not to be exclusionary or elitist in compiling this history. If your name or that of a colleague does not appear in this book, this should NOT imply that your or their involvement in the history of plant pathology and/or in was insignificant. We will surely have made errors and omissions, for which we apologise in advance, but also take responsibility for our failures. There will surely be an updated version in the future and such omissions will be rectified.

ACKNOWLEDGEMENTS

Writing this book was more difficult than we thought it might be when the task begun. But it has also been more rewarding than we could ever have imagined. Our decision was to write it as a dialogue. There are no references cited in the text but a bibliography is provided at the end of the book to acknowledge the publications that were consulted.

After considerable debate, we chose not to use the professional titles of the many plant pathologists named in this book. And we mostly did not use first names for even those colleagues very well known to members of the South African Plant Pathology community. This decision was made because titles change over time, some were not known to us and likewise first names and nicknames were inconsistently available. We recognise that this approach might be a little informal but hope that readers will appreciate our decision.

We are incredibly grateful to our various colleagues, who spent long hours writing some of the sections. Without their contributions, compiling this book would not have been possible. They are credited here rather than in the sections, for which they provided all or parts of the text. We hope that they will forgive us for editorial changes that we have chosen to make. Likewise, that readers will understand why there are some inconsistencies in writing style. We are thus grateful to the following plant pathologists and colleagues who contributed material for this history:

- Riaan Rifkin, an anthropologist, for the section pre-1652 (1.0)
- Melanie Arendse and Mike Holtzhauzen for the section on plant pathology in government 1992-2020 (3.0)
- Ida Wilson for the sections on plant pathology in the commercial sector (15.0)
- Riana Jacobs-Venter for the section on plant pathology in the Agricultural Research Council (5.0)
- Altus Viljoen for the section on plant pathology at Stellenbosch University (6.2) and with Diane Mostert for the section on Fusarium wilt of banana (25.6)
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- Joanna Dames for the section on plant pathology at Rhodes University (6.7)
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- Khosi Ramachela for the section on plant pathology at North-West University (6.9)
- Thierry Regnier for the section on plant pathology at the Tshwane University of Technology (6.10)
- Brenda Wingfield for the section on molecular plant pathology (10.0)
- Sandra Lamprecht for the section on the annual soilborne disease symposia (11.1)
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- Sanette Thiart for the section on the potato certification scheme (14.3)
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- Bradley Flett and Neil McLaren for the section on maize pathology (22.0)
- Lise Korsten for the section on mushroom pathology (23.0)
- John Rheeder for the section on mycotoxin research (24.0)
- Jolanda Roux for the section on myrtle rust (25.9)
- Chris Spies for the section on diseases caused by *Phytophthora* species (25.10)
- Alan Wood and Mike Morris for the section on the development of a biological control agent for the Port Jackson Willow (26.0)
- Jacquie van der Waals for the section on James Edward Vanderplank (27.4)

Our special thanks go to Rianie van der Linde, one of the remarkable information specialists at the University of Pretoria. She assisted us in locating difficult-to-find information, which involved liaising with curators of numerous archives hosted by different institutions or the Government. We are likewise deeply grateful to Zakkie Pretorius and Frits Rijkenberg for reviewing some sections of this book and their many helpful comments and suggestions. Thanks to Morné Booj-Liewes and Namhla Tshisela for editing the final draft.

AN IMPORTANT NOTE:

Until 1994, South Africa had four provinces, viz. Transvaal, Natal, Cape and the Orange Free State. The Transvaal was subsequently sub-divided into Gauteng, North West, Mpumalanga and Limpopo. The names of Natal and the Orange Free State provinces were changed to KwaZulu-Natal and Free State, respectively. The Cape was sub-divided into Eastern, Western and Northern Cape provinces. These changes impacted on the names of some universities. The University of Natal is now known as the University of KwaZulu-Natal and incorporates the University of Durban-Westville. The University of the Orange Free State is now the University of the Free State. North-West University was previously known at the Potchefstroom University for Christian Higher Education. The Rand Afrikaans University became the University of Johannesburg. In the text of this book, past (prior to 1994) and present names are used.

SECTION I: HISTORY OF PLANT PATHOLOGY

1.0 Pre-1652

For the greater part of their history, the earliest occupants of southern Africa, the San, subsisted solely by gathering wild plant food and hunting wild animals. Closely following the arrival of Khoi livestock farmers in the arid parts of the Western Cape some 2000 years ago, the first Bantu-speaking people from central and eastern Africa, had migrated into the eastern parts of South Africa. Along this east-west divide, the San hunter-gatherers, Khoi herdsmen and the Bantu-speaking agro-pastoralists interacted and traded in various economic commodities. Large semi-permanent farming communities were quickly established by the newly-arriving Bantu inhabitants, who initially cultivated millet and sorghum, and some fruit and vegetables. Since most of these agricultural crops were brought with them from the north during their southward migration, either as seed or propagation material, these must also have included various plant pests and pathogens. There is, however, no record of losses incurred which may have led to famines in the region.

2.0 1652-1900

When Johan Anthoniszoon (Jan) van Riebeeck founded the settlement in the Cape in 1652, progress in terms of agriculture was slow. The Company's Garden was established as a 'refreshment station' in April of that year. Vegetables and fruit-bearing plants, including grapevines, were initially grown. Later a herb and medicinal garden was established together with various ornamental plants, amongst which were roses, oak and pine trees. Interestingly, in 2008 the oak trees and numerous other woody ornamental trees and shrubs in the Garden were shown to be infected with *Armillaria mellea*, which was probably introduced from Europe when the Garden was established. Diseases of other crops, fruit and vegetables were likely to have been introduced on propagating material bought from Europe and the East.

In 1655 maize was introduced, and later in 1672 sugarcane was planted. Fruit such as avocado was introduced between 1652 and 1700; mango trees were planted in the Garden in 1653, but failed to establish because of the unfavourable climatic conditions. However, there is speculation that mangoes were introduced into KwaZulu-Natal before the 17th century. A total of 1162 orange trees were planted in the Garden and were obtained from St Helena, probably originating from Portugal. Barley and wheat were also planted during the mid-1650s. There is some evidence that smut and mildew were problems in wheat (referred to as plagues) as early as 1678, and the first rust epidemic on this host was documented in 1726.

It was not until Simon van der Stel arrived as governor of the region (1679) and discovered the Stellenbosch valley, that farms were formally established. His farm, Constantia, was founded on the foothills of Table Mountain. In terms of pathology, it has a fascinating history. In 1859 powdery mildew, caused by *Uncinula necator* (*Oidium tuckeri*) together with the pest *Phylloxera vastatrix*, were responsible for devastating losses of the vineyards on Constantia. The then owner, Hendrik Cloete, treated the vines with sulphur and had some success combating the disease.

In the first years of the 18th century, expansion of land used for farming steadily increased inland and along the coast. It was not until the latter half of that century that plant collectors arrived from Europe.

The first recorded collector was Jan Andries Auge (1711-c.1805), the gardener appointed by Ryk Tulbagh, the Governor of the Dutch Cape Colony from 1751-1771. Mr Auge undertook many excursions into the interior to collect plants. These specimens, of which there were more than 200, were sent to Carl Linnaeus. Carl Peter Thunberg (1743-1829) visited Mr Auge in 1772 and with him as his guide journeyed inland. They collected over 3000 plant species of which more than 1000 were new to science. They also collected 14 fungi and 39 lichens; the first significant collection recorded from South Africa. Thunberg is credited with collecting the first plant pathogen on an indigenous host in South Africa, the ascomycete *Corynelia uberata* on a yellow wood tree (*Podocarpus* sp.). No further collection excursions were untaken for the next 35 years.

In 1761, Christiaan Hendrik Persoon, the "Father of Mycology" was born in Stellenbosch. He left South Africa in 1775 for Europe and devoted his life to the study of fungi. The earliest of his works was *Abbildungen der Schwämme* (Illustrations of the fungi), published in three parts in 1790, 1791 and 1793. Between 1805 and 1807, Persoon published two volumes of *Synopsis plantarum*, a popular work describing 20 000 species of plants. However, his pioneering research was on the fungi. The *Synopsis methodica fungorum*, which he wrote in 1801, was the beginning for the nomenclature of the Uredinales, Ustilaginales and the Gasteromycetes. He died in Paris in 1836.

In 1810, William John Burchell (1781-1863) undertook numerous excursions inland and collected 56 fungi and 90 lichens, but his specimens were never traced. Among these specimens were what he termed 'fungillus' on leaves and bark of flowering plant species. James Niven (1776-1827), who collected specimens for Hibbert, the Empress Josephine and others between 1798 and 1812, recorded the first rust on an indigenous host, the gall-forming fungus *Aecidium resinicolum*, which he found on a species of *Rafnia* (family Leguminoseae). Based on his specimens, the fungus was described as a new species by Rudolfi in 1829. Numerous other plant collectors visited the country throughout the rest of the 19th century. Between 1822 and 1880 a number of leaf fungi, mostly rusts, were collected, some of which are in the South African Museum in Cape Town (now called Iziko South African Museum). These included *Uromyces ixiae*, *U. freesiae* and *U. ecklonii*. John Medley Wood (1827-1915), in 1882, reported an outbreak of *Hemileia vastatrix* in the coffee plantations on the KwaZulu-Natal (Natal) coast. In 1881, Peter MacOwan (1830-1909) was appointed Director of the Cape Town Botanical Gardens and curator of the Cape government Herbarium. His focus was on "economic botany" and some of his reports were published in the *Agricultural Journal of the Cape Colony*, while others were filed. Amongst these reports are the first papers written in South Africa on subjects connected with plant pathology, e.g., the fungus enemies of apples and pears, and some on diseased trees in forestry plantations. Plant Pathology as a science thus formally began in 1887 in South Africa. Between 1897 and 1910, two entomologists, Charles Pugsley Lounsbury (1872-1955) and Claude Fuller (1876-1968), published a number of papers on plant diseases in the *Agricultural Journal of the Cape of Good Hope*, the *Natal Agricultural Journal* and *Mining Record*.

3.0 Plant Pathology in Government

1901-1983

In 1903, the Transvaal Department of Agriculture was established. The agrostologist and botanist Joseph Burtt Davy (1870-1940) had to deal with numerous enquiries about plant diseases which he referred to Kew. Coffee rust, first reported in Natal (later known as KwaZulu-Natal), was now destroying the plantations in the Transvaal (later known as Limpopo and Mpumalanga). Davy appointed the plant pathologist Illtyd Buller Pole-Evans (refer to section 28.2) after consulting Harry Marshall Ward, the chair of botany at Cambridge University. He took up the position in 1905 and initially focused on the cereal rust problem. He collected 200 fungal specimens, which formed the nucleus of the mycological herbarium in Pretoria. At that time there were three mycological herbaria in South Africa. These included the Albany Museum in Grahamstown, the South African Museum in Cape Town that housed the incomplete set of MacOwan's fungi, and the Natal Herbarium that housed Medley Wood's collections. Ethel M Doidge (refer to section 28.3) was appointed as Pole-Evans' assistant in 1908.

In 1910, the Union of South Africa was formed and a separate Division of Plant Pathology and Mycology was established for the investigation and control of plant diseases in all of the then four provinces. In

1911, Paul A van der Bijl (1888-1939) (refer to section 27.1) was appointed, followed by Averil Bottomley (1889-1984) in 1913. Doidge (refer to section 27.3) was appointed as the principal pathologist in the mycological section of the newly-created Division of Plant Industry in 1929 and remained in this position until she retired in 1942.

In 1915, after Medley Wood's death, a phytopathological laboratory associated with the Natal Herbarium was established and Paul A van der Bijl was appointed as head. In 1917 Victor A Putterill (1919-1954) was appointed as a fruit inspector in the Division of Plant Pathology and Mycology. The next year he became the head of the newly-established mycological laboratory in Cape Town, and in 1926 became the chief fruit inspector in the region. His interest was primarily in postharvest pathology. In 1926 Vincent A Wager (1904-1989) joined the division and remained there until 1940. In that year until 1969 he was employed in the Natal Herbarium. He published mainly on fungal pathogens of agricultural and horticultural crops. Eric E Schaefer joined the division in 1934 and provided additional plant pathological support. Between 1940 and 1960 Patrick HB Talbot, a purely systematic mycologist, was employed. In 1946 Gerald JMA Gorter was appointed. He published prolifically on fungal pathogens, and is best recognised for the lists he provided on the plant pathogens present in South Africa, published in 1977, 1979 and 1981. Talbot was succeeded by Gideon CA van der Westhuizen, a plant pathologist, in 1947. In 1963 he was appointed as the head of the Mycology section of the Plant Protection Research Institute (PPRI) and retired in 1984.

When the Republic of South Africa was formally proclaimed in 1961, restructuring resulted in the formation of the Plant Protection Research Institute (PPRI) in 1962. The first Director was James E Vanderplank (refer to section 28.4). In 1962 the Mycological Unit (MU) appointed Walter FO Marasas (refer to section 28.7) and Konrad van Warmelo for a project entitled "The mycobiota of stock-feeds". Numerous mycotoxin-related investigations followed (refer to section 25.0). Van Warmelo joined the Rand Afrikaans University (later the University of Johannesburg) in 1970 and Marasas joined the Medical Research Council (MRC) in 1975. Between 1970 and 1992, numerous mycologists were appointed to the MU, notably Mike Holtzhauzen (1975) and Alice Baxter (1977), both later joining the National Department of Agriculture.

1992-2020

The Department of Agriculture underwent a number of name changes. In 1994 the National Department of Agriculture became the Department of Agriculture, Forestry and Fisheries (DAFF), and in 2020 the Department of Agriculture, Land Reform and Rural Development (DALRRD). There are two directorates linked to plant health: Inspection Services and Plant Health. The two directorates, together with the Directorate Food Imports and Exports form the National Plant Protection Organisation of South Africa (NPPOZA).

David Keetch was the director of Plant and Quality Control in the Department of Agriculture from 1992 to 1995. He was replaced by Eben Rademeyer, who held this position from 1996 to 2003. Marinda Visser joined the Department as director from 2004 to 2008. The Directorate Plant and Quality Control was then divided into Plant Health, Inspection Services, Plant and Quality and Genetic Resources. Marinda was replaced by Alice Baxter who retired in 2019. At the time of completing this book, the position of director responsible for Plant Health was vacant. The Director of Inspection Services is KE Phoku and the Director: Food Imports and Exports is Salamina Maelane.

The aim of the Directorate of Plant Health is to manage risks associated with plant health. Their functions are three-fold:

- To develop policy, legislation, norms and standards and guidelines to manage plant health risks
- Ensure compliance with national and international health obligations (the NPPOZA)
- Render management support services

NPPOZA issues regulations and control programmes in order to ensure that agricultural plant pests and pathogens are not imported, become established or allowed to spread in the country. In co-operation with governmental departments and directorates, the NPPO administers laws and regulations pertaining to plant health and plant quarantine, as well as eradication and control measures.

In order to prevent the introduction of exotic pests of quarantine importance into South Africa, the Directorate of Plant Health has a division Plant Health Diagnostic Services, that provides a service to detect harmful plant pathogens and pests on imported plant propagation material and plant products. These functions are terms of the Agricultural Pest Act, 1983

(Act No. 36 of 1983). They also provide a diagnostic service for plant material and products being exported.

Management and control of plant viruses is performed in the Directorate: Inspection Services, by ensuring phytosanitary regulations and diagnostics. Melanie Arendse has been the responsible manager for the Division Plant Health Diagnostic Services since 2009, with the current Virology team consisting of Lolita Frazenburg, Ramsey Maharaj and Molatela Mamabolo. This directorate also manages the control of plant-infecting fungi and bacteria by ensuring phytosanitary regulations and diagnostics. The current Mycology team includes Gordon Thomas, Wilhelm Laubscher, Veronica Serage and Chanté Engelbrecht. The current bacteriology team includes Zorina Dawood, Mmatlala Mamabolo, Lucky Madzivhandila, Ramola Chauhan and Serialong Sityo.

4.0 Current Status of the Agricultural and Forestry Sectors

Only 12% of South Africa's land (a total of 7.6 million hectares) can be used for crop production, of which 22% is high-potential arable land. The greatest limitation is the availability of water, with uneven and unreliable rainfall patterns. Approximately 1.3 million hectares are under irrigation, and around 50% of South Africa's water is used for agriculture. Despite this, South Africa has a flourishing agricultural industry, with an annual estimated income of R65 billion in 2017. Major crops under production include citrus, pome and stone fruit, grapes (table grape and wine), bananas, macadamia nuts, avocadoes, pineapples, maize, soybeans, sunflowers, wheat, sugarcane, potatoes, onions, tomatoes and cabbages. Several other minor crops, such as herbs, spices, berries, guavas, mangoes, litchis, leafy and other vegetables, barley, oats, sorghum, and date palm amongst others are also grown. Furthermore, 1.2 million hectares of land has been established as forestry plantations with an annual estimated income of R26 billion. Floriculture and the cultivation of ornamental and landscape plants, although a smaller industry, also makes a significant contribution.

Plant diseases are thought to account for 30-40% and even up to 60% loss in agricultural productivity. This is mainly due to fungal infections, but bacterial and viral diseases and infestations of plant parasitic nematodes contribute to these losses. Water scarcity and extreme weather events also contribute significantly to plant damage in South Africa.

Historically and even to this day, globally, the exact figures on the loss farmers experience to plant diseases are not known. In South Africa very few disease monitoring programmes that seek to gather data on crop losses and their exact causes are in place. Such information is needed for better management of food security. Currently, one-third to one-half of all food produced is lost from 'field to fork'. This is due to pre- and postharvest losses, as well as waste in the retail sector and at the consumer's table.

Source: http://awsassets.wwf.org.za/downloads/facts_brochure_mockup_04_b.pdf (as on 3 September 2020)

5.0 Plant Pathology in the Agricultural Research Council (ARC)

In 1992, Plant Health and Protection (then known as PPRI) together with a number of other institutes in government departments was transferred to the corporate ARC. The ARC is a statutory parastatal body, accountable to the board and Minister of the Department of Agriculture, Land Reform and Rural Development (DALRRD). Its core mandate is to serve as the principal agricultural research institution in South Africa, driving research and technology development and knowledge dissemination for agriculture and related industries.

CONTRIBUTIONS TO POLICY

After South Africa's admission to the Southern African Development Community (SADC), the ARC became the national representative on the board of the Southern African Centre for Cooperation in Agricultural and Natural Resources Research and

Training. This was followed by a number of key contributions by the ARC to national legislations and implementation of international treaties. These included the development of a National Policy on the Conservation and Sustainable Use of the Biodiversity of South Africa (1998), a policy for the Management and Curation of Agricultural Germplasm (1998), and in 2008 the National Agricultural Research and Development Strategy.

TRAINING

Training has been an essential component of the ARC's portfolio since its establishment. As the ARC has been involved in a large number of outreach and training projects over the past 27 years, the focus had been on both community-based training and formal training events. The most prominent of these with respect to plant pathology, is the annual Symposium of the Soilborne Plant Diseases Interest Group of South Africa, held at the Vredenburg Farm Research Centre of the ARC-Plant Health and Protection Division (PHP), based in Stellenbosch and organised by Sandra Lamprecht and her team. This event provides an opportunity for researchers and practitioners to interact on an annual basis and is discussed in more detail in section 13.1.

During 1997-1998 the ARC provided training to 38 SADC delegates in a series of workshops sanctioned by SAFRINET (Southern African Network of BIONET International), the Southern African Development Community and its Directorate for Food, Agriculture and Natural Resources (FANR). This was to expand taxonomic expertise in the region and to facilitate accurate diagnoses of plant diseases. These workshops were hosted by Isabel Rong, Elna van der Linde and Oloff O'Brien. Later, in 2014, the ARC-PHP facilitated the country's first Plant Health Clinic in the Limpopo province. The clinic provided expert advice and skills development in pest and disease management to small-scale farmers. These clinics were first established in Bolivia in 2003, as part of the CABI (Centre for Agriculture and Bioscience International) Plantwise Programme to support subsistence farmers, and have since spread to 30 developing countries. These clinics link farmers with experienced practitioners and up-to-date current information on pests and diseases that affect their crops.

The clinics and other training workshops hosted on various ARC campuses serve as a network between the ARC and rural farmers. These help to identify emerging threats to rural agriculture, and contribute to early disease identification as well as more rapid and effective disease prevention and management. The ARC division on Vegetable and Ornamental Plants (VOPI) has also provided training in home-based vegetable farming for 1252 beneficiaries of a national rural development programme supported by the Comprehensive Rural Development Programme (CRDP). This programme operates in all nine provinces, providing support through skills development initiatives, mentorship and agricultural monitoring. It not only serves as a method for agricultural researchers to identify new focus areas, but also as an early warning system for emerging diseases.

DIVISIONS

In 1992 eight divisions were established in the ARC and they all employed plant pathologists. These divisions were as follows: Tropical and Subtropical Crops (Nelspruit), Deciduous Fruit, Vine and Wine (Stellenbosch), Grain Crops (Potchefstroom), Industrial Crops (Rustenburg), Small Grain (Bethlehem), Vegetable and Ornamental Plants (Pretoria), Plant Health and Protection (Pretoria) and Biosystematics (Pretoria). They are treated individually below.

Tropical and Subtropical Crops (TSC)

The focus of this division is on providing technologies for production and postharvest handling of citrus and subtropical crops. One of their research programmes focuses on disease management, specifically diagnostics. The current pathologist is Maritha Schoeman. She has recently conducted research on pink disease of guava (caused by a *Ramularia* sp.), husk rot disease, and root and trunk rot disease of macadamia caused by *Phytophthora cinnamomi*. Her team is also investigating a number of disease problems on mango (malformation), litchi (dieback) and granadillas (Septoria leaf and fruit spot). Previous researchers included Nigel Grech, who worked on guava wilt disease and Barry Manicom, whose research dealt with the molecular identification of citrus viruses and viroids. John Moll, a virologist, was one of the first plant pathologists in the division and he conducted research on citrus diseases.

Deciduous Fruit, Vine and Wine (DFVW) (previously known as Infruitec-Nietvoorbij)

Researchers at this Division conduct research as well as technology transfer on the breeding, cultivation, protection and postharvest technology of deciduous fruit, grapevines, alternative crops and indigenous herbal teas. The major portion of their research and development is focused on improved crop production and mitigation of agricultural risks. They are the custodian of grapevine, deciduous fruit and wine yeast genebanks that preserve genetic resources for breeding purposes, training and comparative descriptions. Current researchers include Francois Haleen, Abraham Vermeulen, Yolanda Petersen and Louise Smit. Francois Haleen's grapevine research interests include the fungal pathogens responsible for wood rot, *Phialophora*, anthracnose and the Oomycete pathogen *Phytophthora*. He also has an interest in fungicide resistance. Abraham Vermeulen conducts research on Botrytis, powdery and downy mildews of grapevine and root rot of fruit trees. Yolanda Petersen's research is focused on both bacterial and viral diseases of grapevine and stone fruit tree crops. Louise Smit is a postharvest pathologist. Previous researchers include Isabel Roos, Lucienne Mansvelt, Hennie du Plessis, Adrian Smit, Wouter Schwabe, Johan Ferreira and Johan Combrink.

Grain Crops (GC)

The Grain Crops Division was established in 1981 in Potchefstroom in the North West Province. Their research focus is on cultivar evaluation, plant breeding, improvement of crop quality, weed control, tillage, plant nutrition, water utilisation, plant pathology, entomology and nematology. They focus on the summer grains, maize and sorghum, and oil and seed crops such as sunflower, soybeans, groundnuts, dry beans and cowpeas. There is a research focus on mycotoxins and researchers involved are Bradley Flett, Belinda Janse van Rensburg, Aneen Schoeman and Edson Ncube. This group is also involved in the development of integrated disease control systems for various crops including maize, soybeans, groundnuts and sunflowers. Deidre Fourie is responsible for the entire dry bean breeding programme that collaborates with researchers in the United States Department of Agriculture (USDA) and the Southern African Bean Research Network (SABRN) in the genetic improvement of dry beans using conventional and molecular approaches. Past researchers include Altus Viljoen, Neal McLaren, BL Jones, S Visser, Andre Cilliers and Kevin Chambers.

Industrial Crops (IC)

This group provides research and consultancy services regarding diseases of industrial crops (tobacco and cassava) and fibre (cotton, hemp, flax, sisal, kenaf and indigenous fibre crops). Research in plant pathology is directed towards the effects of viruses, bacteria and fungi on crop production. Plant breeders are also assisted by developing and applying techniques to screen breeding lines for disease resistance. Pathologists previously employed by this division of the ARC were John Thatcher (a virologist) and Jody Terblanche (a bacteriologist).

Small Grains (SG)

The Crop Protection group within this division focuses on insects, diseases and weeds of wheat, oats, barley etc. They assist producers in protecting their crops in the most cost-effective and environmentally-responsible way, thus insuring a good yield of a high quality. There are two pathologists currently employed in this division, namely, Nyiko Baloyi who focuses her research on Fusarium head blight and Karnal bunt, and Tarekegn Terefe who works on cereal rusts. The National Rust Survey programme of the ARC-SG (in collaboration with the University of the Free State) has conducted annual surveys over the past three decades and more than 25 different races of leaf and stem rust and four races of stripe rust have been identified. During the 2017/2018 season, three stem rust isolates (collected in the Free State province near Bethlehem) were identified as a new race and coded as race PTKSK. This race was previously reported as one of Ug99 variants from Ethiopia, Kenya and Yemen, bringing the number of Ug99 variants detected in South Africa to five. Five stem rust biotypes in the nurseries of the wheat breeding programme were also identified. These biotypes were able to overcome specific stem rust resistance in the host plants and will enable geneticists to proactively screen, select and release cultivars resistant to the ever-changing disease spectrum. Previous pathologists attached to this division include De Buys Scott, Kobus le Roux and Zakkie Pretorius.

Vegetable and Ornamental Plants (VOPI)

The Crop Protection group in this Division conducts research on indigenous vegetable food crops, medicinal plants, commercial vegetables and ornamental plants. They also offer expertise in research, development and technology transfer of related products and services to resource-poor and commercial farmers, as well as other agricultural organizations. The major objectives of the Division include:

- Identification and characterisation of pests and diseases to increase yield and quality of crops
- Generation, development and application of new knowledge, science and technology on pests and disease management, to ensure the sustainable use of land and natural resources under agricultural production
- Technology transfer and commercialization of research results to enhance the ability of the agricultural sector to manage and mitigate agricultural risks

The current manager of the Crop Protection Division is Dean Oelofse. Researchers include Michele Cloete, Mariette Truter, René Sutherland, Julia Mulabisana, Elsie Cruywagen and Kenneth Mabasa. Michele Cloete's research focuses on the molecular identification and characterization of viral bacterial and fungal pathogens of root and tuber crops. Mariette Truter focuses on the characterisation and identification of fungal phytopathogens of vegetables, medicinal and ornamental plants. René Sutherland does her research on fungal and bacterial diseases of vegetables. Julia Mulabisana is a plant virologist and her research focuses on the identification and genetic characterisation of viruses on vegetables. Elsie Cruywagen characterises fungal pathogens of vegetables and ornamental crops. Kenneth Mabasa is a virologist working on viruses on vegetables and indigenous vegetable crops. Previous pathologists include Freddie Denner and Sonya Venter.

Plant Health and Protection (PHP)

There are four research programmes in PHP and these include Biosystematics, Plant Microbiology, Pathology, and Weed Science. In the division Biosystematics, research is conducted on economically and environmentally important groups of arthropods, nematodes and fungi. They are also the custodians of the South African National Collections of Arachnida, Fungi, Insects and Nematodes, which form an invaluable basis for taxonomic research and services, as well as an archive of the country's biological diversity. Their wide-ranging taxonomic expertise and extensive reference sources enable them to provide comprehensive biosystematic advisory services and products for the research community concerned with agricultural and natural resource management in southern Africa and further afield. The Division is currently managed by Isabel Rong, while the curator of the National Culture Collection of Fungi and researcher in fungal biosystematics is Riana Jacobs-Venter. Her research focus is on *Fusarium* species diversity in soil with limited anthropogenic disturbance. She has also been involved in the diagnoses of diseases caused by a number of *Fusarium* spp.

The National Collection of Fungi currently accommodates 63 000 dried fungal specimens and 28 000 living fungal strains, representing 115 years of surveys, diagnostics and taxonomic research. After Wally Marasas (refer to section 27.7) joined the Medical Research Council (MRC) he established a world-renowned reference collection with a focus on South African mycotoxicological research at the PROMEC (Programme on Mycotoxins and Experimental Carcinogenesis) Unit of the South African MRC. Research at the Unit centered on risk assessment of fumonisins and intervention methods, to reduce the intake of this important mycotoxin that occurs in the maize staple diet of rural populations. Fungal strains representing the above research, as well as many subsequent surveys conducted by the PROMEC Unit, have been consolidated into the PROMEC fungal collection. This collection of 9000 fungal isolates was relocated to the National Collection of Fungi in 2016. There have been numerous researchers employed previously by the Mycology Unit (MU), now Biosystematics**.** They included James Vanderplank (refer to section 27.4), Deon van der Westhuizen, Wally Marasas, Konrad van Warmelo, Alice Baxter, Cecilia Roux, Alistair Thompson, De Buys Scott, Elna van der Linde, Mariette Truter, Draginja Pavlic and Cobus Visagie. Jim (James) Deacon, while on sabbatical from the University of Edinburgh, worked on Fusarium wilt of bananas from 1983-1985. George Herd, who had been head of Plant Protection in Zimbabwe, joined the staff of the MU to work on seed treatments for the prevention of seed-borne fungi. From 1983-1955, Alan Phillips, from the United Kingdom, also joined the group to work on *Sclerotinia sclerotiorum* and its control.

The Division of Plant Microbiology and Pathology

This division provides research, routine diagnostic as well as advisory services on plant diseases. These include soilborne, seed-borne and foliar diseases. Traditional and molecular techniques are used to identify fungal, bacterial and viral pathogens, with an emphasis on those affecting crops to industries, nurseries, commercial and small-scale farmers. The focus areas of this division are on virology, mycology, bacteriology, soil health and soilborne plant diseases. The division is managed by Elna van der Linde and the current researchers include Darius Goszczynski, Teresa Goszczynska, Wilhelm Botha, Sandra Lamprecht, Chris Spies and Susan Koch. The research focus of Sandra Lamprecht is on the epidemiology and management of soilborne diseases of field crops, caused by *Fusarium*, *Phytophthora*, *Pythium* and *Rhizoctonia* spp. One of the plant hosts on which she has conducted extensive pathology research is Rooibos (*Aspalathus linearis*). Chris Spies studies *Phaeoacremonium* species and has increased the number of known species in South Africa from 19 to 35. Species in the genus have been reported from grapevines, fruit trees, fynbos twig litter and arthropods. Sharon von Broembsen, who worked at the Plant Protection Research Institute (PPRI) in Stellenbosch in the 1980s, made a significant contribution to *Phytophthora* research in South Africa, particularly on members of the *Proteaceae* in the Western Cape. Previous researchers include Michael (Mike) Wingfield, Rupert Anelich, JL (Stapies) Staphort, Kobus Serfontein and Surentha Serfontein.

The Weed Science Division

This division is responsible for research on the ecology and control of invasive alien plants in South Africa. Their research emphasis is on non-native problem plants in conservation and pasture situations, as well as non-native aquatic weeds. Crop weeds do not normally fall within their research field. The division is managed by Roger Price and current researchers include Alan Wood and Alana den Breeyen**.** Mike Morris previously led the team on the biocontrol of invasive weeds, but he left in 1999 to start his own biocontrol company. Their current focus is on *Hakea sericea* and *Hakea gibbosa* (Proteaceae), small trees or shrubs that originate from Australia. *H. sericea* has become highly invasive and problematic in South Africa while *H. gibbosa* is less widespread and abundant, but nevertheless problematic. Biological control against *H. sericea* started in 1970 with the release of two seed-attacking insects, a seed-feeding weevil, *Erytenna consputa* (Coleoptera: Curculionidae), and a seed-moth, *Carposina autologa* (Lepidoptera: Carposinidae). Both of these agents, together with an indigenous fungus, *Colletotrichum acutatum* f.sp. *hakeae* (*Incertae sedis*: Glomerellaceae), and manual clearing have reduced the abundance, and possibly the invasiveness of *H. sericea*, but large infestations still persist in the coastal mountains of the Cape Floral Region in the Western and Eastern Cape provinces of South Africa. A previous researcher attached to this group was Cheryl Lennox.

6.0 Plant Pathology at Universities

Faculties of Agriculture, which included the departments of plant pathology, were funded by the Department of Agriculture until 1973. Staff in these departments held joint civil servant and university posts. There are currently two departments of plant pathology at South African Universities: KwaZulu-Natal and Stellenbosch University. Academic staff working as plant pathologists also reside in Departments of Microbiology, Plant Sciences or agriculture-related departments.

6.1 UNIVERSITY OF PRETORIA

The Department of Plant Pathology was established at the University of Pretoria in 1917 when JM Hector was appointed professor and head of department. In 1944, Barend J Dippenaar became head of department. His field of interest was common scab of potatoes and he became internationally recognised for his work on the effect of pH on the survival of *Actinomyces scabies*. He later discovered the relationship between mites and the phenomenon known as concentric blotch of citrus. Between 1945-1959 Barend Dippenaar focused his research on wheat, mushroom and citrus diseases. The first MSc (Agric) degree was awarded to Fritz Coenraad Loest in 1935 on ‘vergommingsiekte’ (gumming disease) on citrus. In 1941 the first PhD degree was awarded and this was also to Fritz Loest.

In 1958, PM le Roux became head of department which then became the Department of Plant Pathology and Microbiology. Le Roux was a maize breeder and his research interest was on maize rust. Chris J Rabie and OG Smith were appointed as lecturers in plant pathology in 1957 and 1963, respectively. In 1967, WJ Cronje joined plant pathology as a lecturer. APD McClean was appointed as an honorary professor and JBA Heyns as an honorary lecturer in 1969. In 1968 Ballie Kotzé (refer to section 27.9) became head of the department and was best known for his research on citrus black spot. His major contributions included the development of a "research culture" in the subtropical fruit industries, which resulted in the establishment of the Tea, Litchi, Mango and Avocado Yearbooks. The production of these books formed a benchmark for other industries and the concept is now followed in many countries. In 1971, the Department split into two Divisions namely Plant Pathology and Microbiology, but the following year (1972) the Divisions were combined again and the name of the Department was changed to the Department of Microbiology and Plant Pathology. In 1974, De Buys Scott and LJ Marais were appointed as senior lecturer and lecturer, respectively. In 1978 Fritz Wehner joined the Department as senior lecturer, later becoming professor in mycology, and remained at the University of Pretoria until he retired in 2008. In 1994, TE (Eugene) Cloete became head of this Department until 2008, whereafter SN (Fanus) Venter became head.

In 2016, plant pathology was moved to the Department of Plant and Soil Sciences, headed by Nigel Barker. Today, the Department has three staff members, namely, Lise Korsten, Terry Aveling and Jacquie van der Waals. During his 37 years at the University of Pretoria, Nico Labuschagne focused on soilborne diseases of, amongst others, citrus, cereal and vegetable crops. During the last 12 years of his career, he established a research team focusing on plant-growth promoting rhizobacteria (PGPR) as biocontrol agents and biofertilisers, and successfully commercialised a number of biological products for the agricultural sector. Although he retired as a full-time academic in 2019, he was appointed on a post-retirement project investigating PGPR as biocontrol agents against root diseases of tomatoes. Lise Korsten has focused her research mainly on the complementary fields of postharvest technology and food safety as related to international trade in fresh produce. She has established research teams in food safety, postharvest pathology, biocontrol and mushroom pathology and fruit health. Terry Aveling is a seed scientist and conducts research on micro-organisms, especially fungi, associated with diseases of seeds and transmitted by seed. This involves the detection and identification of seed-borne and seed-transmitted diseases, the characterization of the causal agents, their transmission, effect on seed germination and vigour and their control. The main focus of Jacquie van der Waal's research programme is the epidemiology, diagnosis and control of soil- and seedborne diseases of potatoes. Diseases currently being investigated in her research programme include powdery scab (*Spongospora subterranea* f.sp. *subterranea*), black scurf and stem canker (*Rhizoctonia solani*), and blackleg and soft rot (*Pectobacterium* and *Dickeya* spp.). Quenton Kritzinger leads the MycoBio research group, where his current research activities primarily involve the mycoflora and mycotoxins associated with orphan crops (including cowpea, marama bean and bambara groundnut) and South African medicinal plants. He also investigates the phytotoxic effects of mycotoxins on cowpea at the physiological, biochemical and molecular levels. The other research focus area of his group is the antifungal potential of plant extracts and their compounds from indigenous South African plant species against plant pathogens, and in particular mycotoxigenic fungi.

In 1998, the Forestry and Agricultural Biotechnology Institute (FABI) was established at the University of Pretoria. FABI was initially established by a group of mainly plant pathologists and biotechnologists that made up the Tree Protection Co-operative Programme (TPCP). The TPCP was established in 1990 at the University of the Orange Free State (now the Free State) and this entire team moved to the University of Pretoria in 1998, forming the nucleus for the stand-alone postgraduate research institute, FABI. The history of the TPCP is provided in section 8.1 and 8.3. Today this Programme has the largest single group in the world working on tree health problems. Currently, plant pathologists working in this programme include Mike Wingfield, Bernard Slippers, Brenda Wingfield, Emma Steenkamp, Martin Coetzee, Wilhelm de Beer, Irene Barnes, Almuth Hammerbacher, Cobus Visagie, Tuan Duong and Markus Wilken. Mike Wingfield is the founding member of the TPCP (and FABI) and his research interests are focused in the broad area of forest biotechnology. More specifically, his research group studies various aspects of insect pests and pathogens, particularly those that are important to the forestry industries of South Africa and other countries of the world.

Bernard Slippers, current director of the TPCP and

FABI, conducts research in the field of molecular ecology and evolution of fungal communities, fungal pathogens and insect pests of plants, especially trees, as well as their symbioses and their natural enemies. He is particularly interested in the anthropogenic impacts on the outcomes of the interactions between these organisms. These interests are explored within a context of both invasive tree pathogens and pests, and native pests or pathogens expanding their host ranges to attack introduced trees of forestry and agricultural importance. Brenda Wingfield's research focus is on speciation and evolution of fungi, predominantly non-model Ascomycetes. This includes research on genetic variation within as well as between species. Thus, a certain component of the work done in her group could also be considered to be molecular taxonomy. She also, however, has an interest in basic evolutionary biology based on ribosomal RNA-genes and mating type genes. Emma Steenkamp's research focuses on the evolutionary processes involved in microbial speciation. These include horizontal gene transfer between unrelated taxa, hybridization, as well as vegetative compatibility and sexual reproduction. This typically involves conventional genetic and microbiological procedures, as well as contemporary genomics approaches. The research focus of Martin Coetzee is on mechanisms involved in the evolution of organisms, the dynamics of speciation and the phylobiogeography of taxa. Wilhelm de Beer is a mycologist/fungal biologist and his research focuses on fungal plant and human pathogens belonging to the Ophiostomatales and Microascales (Ascomycetes), and the smut-like Microstromatales (Basidiomycetes). Irene Barnes focuses on two research fields, viz. taxonomy, phylogeny and population biology of the red-band needle blight pathogens and the taxonomy, phylogeny and population biology of *Ceratocystis* species. Almuth Hammerbacher's research focuses on chemical interactions of forest trees with insects and micro-organisms. She combines methodologies from diverse fields of specialization in her research, including ecology, natural product biosynthesis and analysis, enzymology, genetics, plant physiology, genetic engineering and microbiology. Cobus Visagie is a mycologist specialising on the taxonomy of *Aspergillus, Penicillium*, *Talaromyces* and other moulds from the natural and built environment. His research focus includes the biodiversity, ecology, phylogenetics, nomenclature and identification of these genera, with a particular interest in taxonomically robust ecological and biodiversity studies. Tuan Duong's research focuses on different aspects of plant pathogenic fungi including taxonomy, population biology, genetics and genomics. Markus Wilken conducts research on the molecular biology of plant pathogenic fungi. His research focus is on using genomics and molecular tools to study the basic biology of these species, particularly those of economic importance in the commercial forest and agricultural sectors.

A number of plant pathologists, other than those linked to the TPCP, reside in FABI. These include Teresa Coutinho, Dave Berger, Lucy Moleleki. Sanushka Naidoo, Noëlani van den Berg, Gerda Fourie and Thabiso Motaung. Teresa Coutinho's research programme focuses on plant pathogenic bacteria. Her areas of interest include the identification and characterisation of new and emerging bacterial diseases, understanding how bacteria, not generally considered to be primary plant pathogens, cause symptoms in their hosts, determining the role played by abiotic and biotic factors in disease outbreaks caused by opportunistic bacterial plant pathogens and investigating how bacterial pathogens, that typically infect herbaceous plants, adapt and infect woody hosts. Dave Berger's research aims to gain a better understanding of the molecular dialogue between plants and pathogens with the long-term goal of developing sustainable strategies to control crop diseases of relevance in Africa. His research group is currently focused on understanding the host-pathogen interaction in grey leaf spot disease of maize, implementing a range of approaches from whole plant phenotyping to genomics to investigate this pathosystem. Lucy Moleleki's research has two major components. One of her areas of research is on understanding virulence mechanisms of soft rot pathogens (specifically *Pectobacterium brasiliense*) and how these bacteria interact within their major host, potato. She is also interested in studying host defences in potato plants elicited by the soft rot pathogens. Her other focus area is on root knot nematodes of potatoes. The research programme of Sanushka Naidoo investigates the genomics and molecular biology of defence responses of forest trees to various pathogens. *Arabidopsis thaliana* is used to model plant-pathogen interactions in *Eucalyptus* or *Pinus,* in order to understand and identify resistance mechanisms that can be manipulated in trees in the future. Her group uses a genomics approach to perform gene discovery in *Arabidopsis*, *Eucalyptus* and *Pinus.* Noëlani van den Berg and her team conduct research on mechanisms and gene expression pathways whereby tolerant avocado rootstocks are protected against *Phytophthora cinnamomi*. She is the incumbent of the Hans Merensky Chair in Avocado Pathology. Gerda Fourie's research programme focuses on reducing the impact of pests and pathogens of macadamia. Thabiso Motaung's primary research interest is on understanding the molecular basis of microbial pathogen interaction with forest trees. He also has a research interest in fungi infecting summer grain crops.

6.2 STELLENBOSCH UNIVERSITY

Training in plant pathology commenced in 1887 when Fridolin Blersch (1861-1897), the principal of the newly established government School of Agriculture and Viticulture in Stellenbosch, presented a module in agriculture entitled "Principles of Plant Diseases". This school functioned under the auspices of Victoria College until 1898, eventually becoming Stellenbosch University. The Faculty of Agriculture was established in January 1918. The Department of Agricultural Botany was divided into two groups: Plant Breeding and Plant Pathology. In 1921 Paul van der Bijl (refer to section 27.1) was appointed the first professor of Plant Pathology. He was also the first professor of plant pathology in the British Commonwealth. Van der Bijl published the first South African book on plant diseases called *Plantsiektes: hul oorsaak en bestryding* (Plant diseases: their cause and control).

The name of the Department underwent several changes over the years. In 1947, the name was changed to Phytopathology, and in 1951 to Studies in Plant Disease and Microbiology. In 1961, the Department of Studies in Plant Disease and Microbiology was divided into two separate departments, but the name "Studies in Plant Disease" was retained. In 1978, the original name was re-introduced, and has since functioned as the Department of Plant Pathology.

From the start, the Department of Plant Pathology at Stellenbosch University had a strong focus on mycology. Van der Bijl and his student, Len Verwoerd, collected and described numerous plant pathogenic fungi, and maintained their own herbaria. These herbaria were eventually moved to the National Collection of Fungi in Pretoria.

In 1928, Paul van der Bijl was succeeded by Len Verwoerd. Verwoerd was a pioneer in applied plant pathology and emphasised disease control, including the use of chemical measures. He initiated the cereal pathology programme in the department and published extensively on topics such as rust and smut diseases of small grain crops. During World War II, when Verwoerd was involved in military service, Barend J Dippenaar acted as head of the Department. Dippenaar initiated research on fruit and vegetable diseases. He subsequently laid the foundation for chemical control of diseases of deciduous fruit and vegetables in the winter rainfall region.

In 1947, Verwoerd was succeeded by Stefanus J du Plessis, known as the father of postharvest pathology in South Africa. Much emphasis was placed on chemical control measures. Du Plessis also established South Africa's first quarantine service. In 1954 du Plessis was succeeded by Adriaan J Louw, a fruit pathologist. In 1970, Peter S Knox-Davies (refer to section 27.6) excelled in histopathology, cytology and seed pathology. He trained a number of significant pathologists and is remembered for his spirited enthusiasm. He became head of the Department in 1970 until he retired in 1992. He was succeeded by Gustav Holz, an applied pathologist who focused his research on postharvest diseases. In 2000, Pedro Crous, a mycologist, became the chairperson serving until 2002, when he resigned to take up a position as the Director of the Centraalbureau voor Schimmelcultures (CBS), now the Westerdijk Fungal Biodiversity Institute in the Netherlands. Holz again stepped in as chairperson until his retirement at the end of 2006 and was replaced in 2007 by Altus Viljoen. In 2020, Lizel Mostert took over the position of chairperson of the Department. Altus Viljoen's research programme focuses on *Fusarium* diseases of important agricultural crops, including Fusarium wilt of banana. Lizel Mostert's research focuses on the aetiology, epidemiology and management of trunk disease pathogens of grapevines and fruit trees. Characterising fungi associated with trunk diseases has provided the opportunity to focus on various fungal groups including the Togniniaceae, Botryosphaeriaceae, Diatrypaceae, Basidiomycetes, Diaporthaceae and Nectriaceae species. In pursuing the management of these diseases, she has conducted research on biocontrol, specifically on *Trichoderma* spp., as a sustainable option for the management of these diseases.

The Department of Plant Pathology at Stellenbosch University has had an extremely low turnover of lecturers since its inception in 1921, with only 19 lecturers teaching in the Department in total. Today, the Department has five full time staff members: Altus Viljoen, Lizel Mostert, Adele McLeod, Cheryl Lennox and Lindy Rose. Adele

McLeod's research programme focuses on soilborne pathogens, particularly Oomycetes. Cheryl Lennox's research programme focuses on postharvest decay of pome, stone, citrus and pomegranate fruit. Her team investigates the causes of decay and identifies effective management strategies by understanding the epidemiology of key postharvest pathogens. She also conducts research on the use of fungicides, including monitoring the sensitivity of key pathogens to postharvest fungicides, and investigating alternatives to fungicides for postharvest disease management. Lindy Rose conducts research on *Fusarium* spp. of cereals.

6.3 UNIVERSITY OF THE FREE STATE

Plant Pathology at the University of the Orange Free State (UOFS), renamed as University of the Free State (UFS) in 2001, was established in the Department of Plant Protection two years after the founding of the Faculty of Agriculture in 1958. EK Hartwig, an entomologist, was head of department and Sam H Smith the first plant pathology lecturer, followed by Gert DC Pauer, who was appointed as senior lecturer in 1960. When Smith resigned to take up a position in the citrus industry, Schalk W Baard was appointed as lecturer in 1962. According to available information, the Department of Plant Protection split into Entomology and Plant Pathology ("Plantsiektekunde") in 1967, with JCC (Jan) Nel and Gert Pauer as respective heads of department. Schalk Baard was promoted to senior lecturer and Gillaume W de Swardt joined the group as a third plant pathology lecturer shortly thereafter.

Gert Pauer obtained a DSc from UFS in 1966 with a thesis entitled "Die taksonomie van plantpatogeniese bakterieë" (The taxonomy of plant pathogenic bacteria), but eventually specialised in peanut diseases. Gert Pauer held the position of head of department until his retirement in 1987. He then settled in Empangeni where he joined the University of Zululand as head of the Department of Agriculture. Gert Pauer passed away on 7 July 2009.

Prior to his appointment at UFS, Schalk Baard had obtained the BSc Agric and MSc Agric degrees from Stellenbosch University and worked as a pathologist at the Agricultural Research Station in Potchefstroom. At UFS, his research focused on crown rot of wheat, cotton wilt and leaf spot of peanut. In 1979, he graduated from UFS with a PhD thesis entitled "Studies on the survival of *Verticillium dahliae* in soil". During that time his research emphasis shifted to black hull of peanut. His expertise in the complex field of soilborne diseases was instrumental in enthusing many students to understand and manage root rots. Following his appointment as head of department in 1988, Schalk Baard was promoted to professor in 1989, retired from UFS in 1995, and moved to Stilbaai. He passed away on 2 March 2008.

Gillaume de Swardt resigned and was succeeded in 1980 by Alwyn B van Jaarsveld, a pathologist from the Department of Agriculture in the Western Cape, who specialised in powdery mildews. Alwyn van Jaarsveld left the university for a cereal pathologist position at Monsanto and was replaced by Schalk P van Wyk, who worked primarily on *Fusarium* during his tenure at UFS. Following Gert Pauer's retirement, Wijnand J Swart, an Agricultural Researcher from the Plant Protection Research Institute at Stellenbosch and specialising in tree diseases, was appointed as lecturer in July 1988, and Zakkie A Pretorius, a wheat pathologist from the Small Grain Centre at Bethlehem and PhD graduate from the University of Natal (now UKZN), replaced Schalk van Wyk in 1989. Based on their respective backgrounds, the appointments of Wijnand Swart and Zakkie Pretorius changed the research directions of the department.

Wijnand Swart continued his research on tree diseases and Zakkie Pretorius, with his prior experience of cereal diseases, established a rust laboratory. At that time Wijnand Swart's research was closely associated with the Tree Pathology Co-operative Programme (TPCP) led by Mike Wingfield, who moved to Bloemfontein in July 1988, but to the Department of Microbiology and Biochemistry. This connection served as an important link between Microbiology and Plant Pathology, two departments that essentially functioned independently up to that time. Having completed a PhD in forest pathology at UFS under the supervision of Mike Wingfield, Wijnand Swart over time established his own areas of expertise in diseases of new/under-utilised crops as well as soil health management. He has served as the Division Head for Plant Pathology in the Department of Plant Sciences from June 2016 to the present time. Wijnand Swart, in 1998, co-founded the Southern African New Crop Research Association (SANCRA) and served as its first president from 1998-2001. He served as chairperson for the "Centre for Plant Health Management" (CePHMa) in the Faculty of Natural and Agricultural Sciences at the UFS from 2005-2010. Wijnand Swart also served as Director of the University of the Free State's Strategic Research Cluster entitled: "Technologies for Sustainable Crop Industries in Semi-arid Regions" from 2009-2014. Ensuing from this appointment, he served as Principal Investigator in the Collaborative Centre for Broadening the Food Base, established between the ARC, UFS and Durban University of Technology (DUT) from 2014-2018.

Zakkie Pretorius founded a cereal rust group with initial support from the Foundation for Research Development (now National Research Foundation) and appointed Rikus J Kloppers in 1991 to work on wheat leaf rust. Essential greenhouse and seed facilities were established with funding from the former Wheat Board. Rikus Kloppers was subsequently appointed as lecturer in the department, but left the university in 1998 for a position at Pannar, Greytown. His move to KwaZulu-Natal proved to be highly constructive for the UFS rust programme as it paved the way for setting up annual collaborative, and world-class, field rust nurseries. Highlights from Zakkie Pretorius's almost 30 years as a pathologist at UFS include the first descriptions of wheat stripe rust and soybean rust in South Africa, the deadly East African "Ug99" wheat stem rust strain, as well as rust projects in maize, sunflower, rye, dry bean, barley, oat and lentils. Based on his experience with the *Puccinia graminis* f. sp. *tritici* "Ug99" race group, he participated in the Durable Rust Resistance in Wheat project, managed by Cornell University, for several years. In addition, collaboration with molecular geneticists, breeders and colleagues formed the basis for an internationally-recognised rust laboratory centred at UFS. Zakkie Pretorius, who was promoted to professor in 1991, served as head of Plant Pathology from 1996-2001. In 2017 Willem HP Boshoff, who holds a PhD in rust pathology from UFS and has extensive industry experience as a wheat breeder, was appointed to continue the rust programme started by Zakkie Pretorius. As a research fellow, Zakkie Pretorius has continued rust research since his official retirement in 2017.

Wilmarie M Kriel (née Botes) was appointed as lecturer in Plant Pathology in 2001. She had a wide range of lecturing responsibilities, including mycology, introductory plant pathology and soil microbiology. She at first worked on tree diseases, but later on she investigated Fusarium head blight of wheat and developed an affinity for plant disease diagnostics.

In April 2000, the faculties of agriculture and natural science disciplines merged to form the Faculty of Agriculture and Natural Sciences at UFS. Botany and Genetics, originally single departments, and Plant Breeding and Plant Pathology, were combined to form a new Department of Plant Sciences, with Zakkie Pretorius as chairperson from 2002 until 2009. Although there was a central management structure and teaching programmes were streamlined, the respective divisions continued to maintain their own identities. Due to the multi-faceted nature of genetics, they became an independent department shortly after the merger. Although the advantages and disadvantages of the merger could be debated, it led to upgraded facilities for Plant Pathology, improved collaboration among colleagues, and a sense of security in belonging to a larger group.

One strategy to strengthen the division was to up-scale field and applied plant pathology. In 2005, Neal W McLaren was appointed as professor to fulfil this requirement. McLaren had a long career at the ARC-Grain Crops Institute and was highly experienced in diseases of crops such as sorghum and soybeans. He brought his extensive knowledge of quantitative epidemiology and statistical analysis to UFS, which positioned the division at the forefront of these specialised fields in South Africa. During his tenure at the ARC, Neal McLaren played a major role in the Southern African International Sorghum and Millet Collaborative Research Support Program (INTSORMIL-CRP), especially during the global sorghum ergot epidemic, and collaborated with the Sorghum Trust. INTSORMIL included a network with Kansas State University, University of Nebraska, Ohio State University, Purdue University, Texas A&M University, West Texas A&M University and the ARS/USDA in collaborations with national research programs in east Africa, west Africa, southern Africa and central America. These collaborations transferred with him to UFS, forming a platform for post-graduate studies in applied field pathology and epidemiology, as well as fostering international collaborations between these partners and UFS. Following the accidental introduction of soybean rust, Neal McLaren joined the Protein Research Foundation/Oil and Protein Seeds Development Trust (PRF/OPDT) task team which, together with chemical and seed companies, addressed the epidemiology of the outbreak. When the INTSORMIL-CRP was finalized in 2013, international collaboration on sorghum pathology continued with the Howard G Buffett Foundation through the Norman E Borlaug Institute for International Agriculture of Texas A&M AgriLife Research. Subsequently, the spread of Sclerotinia stem and head rot of soybean and sunflower respectively, led to further collaborations, including the current collaboration between UFS and Grain SA. This resulted in the formation of the South African Sclerotinia Network initiated by Lisa Rothmann, a PhD student mentored by Neal McLaren. Neal McLaren retired at the end of 2018 but remains involved as a research fellow in post-graduate student supervision. He has a MOU with the Western Cape Department of Agriculture to develop a risk model for *Sclerotinia* on canola.

In 2010, Marieka Gryzenhout was appointed as senior lecturer to build a molecular plant pathology programme and train students in this rapidly expanding field. Gryzenhout was transferred to the Department of Genetics in 2016 and Liezel Herselman, from the Division of Plant Breeding, took over the teaching duties for molecular pathology. Wilmarie Kriel resigned to take up a position at Starke-Ayres and in 2010 Gert Marais was appointed to lecture mycology. Marais has subsequently developed his research primarily on diseases of pecan nut trees.

Many colleagues, in a permanent or temporary support role, contributed to the activities of plant pathology over the years. Oene Los was seconded by Glen Agricultural College to the university from 1984–1994 and significantly contributed to the capacity of the group. In addition to lecturing duties at Glen, his main research focus was Fusarium crown rot and take-all of wheat. Cornel Bender has played a central role as professional officer, taking part in research projects and running student practicals, since the early 1990s. Earlier, Christa Laubscher assisted in this capacity and Gerald Moshodi acted as laboratory assistant. Zelda van der Linde, who first supported the research of Oene Los, provided invaluable assistance to the rust programme and later as administrative assistant to Plant Sciences.

6.4 UNIVERSITY OF KWAZULU-NATAL

In 1949, Susarah Truter (refer to section 27.5) joined the University of Natal's newly established Faculty of Agriculture as a senior lecturer in Plant Pathology. She initiated a focus on departmental excellence that has continued for seven decades.

As a woman, Susarah Truter was an anomaly in the male-dominated faculty, but she had the temperament to overcome the inevitable challenges. During World War 2 she had survived internment by Germans while studying for a PhD at Baarn in the Netherlands. Thus, having to build a department from scratch in Pietermaritzburg was a minor obstacle for her. Arriving to find that her 'facilities' consisted of a few microscopes and space at Oribi camp, a former war-time hospital, she set about establishing a sterile students' practical laboratory while teaching her students. In this task she was ably assisted by her sole member of staff, the laboratory assistant, Saul Mbeje.

Susarah Truter continued to build the department with steely determination. A story is told of her travelling to Pretoria, necessary because the faculty answered to the Department of Agricultural Technical Services and settling herself in front of the Secretary of Agriculture's offices for a few days. This was after telling officials that she was not moving unless they gave her additional staff. They relented and she returned to Pietermaritzburg.

The fledgling enterprise established by Susarah Truter became the Department of Plant Pathology and Microbiology. With her well-known forcefulness she managed to increase the academic staff complement to five, as well as acquire several additional technical staff members. In 1952, Peter Knox-Davies (refer to section 28.6), a student of Susarah Truter's, joined the department as a staff member and in 1956, Mike Martin was appointed as a virologist. He would succeed her as head of the department.

During these early years, Susarah Truter became a professor and official head of department. One of her students, Frits Rijkenberg, who became head of department after Mike Martin, replacing Mick Lloyd, described her as "indomitable", fighting Pretoria tooth and nail for her students and for her department.

"In the department her male students had to wear ties, her female students were sent home if their necklines were too plunging, no slops (rubber sandals) were allowed, and no one was allowed to whistle in the passages of the building," said Frits Rijkenberg, who enrolled as a student in the faculty in 1961 and was appointed a lecturer in Plant Pathology in 1967. Born in the Netherlands, Frits Rijkenberg had emigrated to South Africa with his parents as a boy. He described Susarah Truter as an "administrative" person. "Most of her knowledge came from books. I remember painfully learning taxonomic classifications from a book by B Gwynne-Vaughan and HCI Barnes: *The structure and development of the fungi*, and even the punctuation had to be correct! Yet we were fond of her and in awe of her meticulous approach to all she touched, but the Departmental approach has changed markedly since those days in becoming more applied".

In 1961, Susarah Truter was elected Dean of the Faculty of Agriculture, making her the first woman in the world to occupy such a position, and securing her a place in the *Guinness Book of Records*. She retired in June 1976, having trained, it has been said, more plant pathologists than all the other Plant Pathology departments in the country combined.

Under Truter, the benchmark for excellence was high and staff and student numbers had increased. This was influenced by the 1971 decision to admit not only students from the Faculty of Agriculture, but also those from the then Faculty of Science. A consequence of the latter move was that the department was left to do its work with minimal interference. In the same year, Mike Martin was appointed head of the department, which had been renamed the Department of Microbiology and Plant Pathology, because for some time the student numbers of the former had been greater than the latter department.

Mike Martin was a wise, reserved and a very conscientious person who, besides being an excellent virologist, was an epidemiologist. He had completed his PhD research at Wageningen in the Netherlands. He focused on the purification and electron microscopy of tomato spotted wilt virus and hypersensitive virus resistance in plants. Under his able leadership the Department's size and reputation continued to grow.

Frits Rijkenberg was appointed associate professor in 1978 and John da Graça joined a year later as a lecturer. John da Graça was a virologist who became an associate professor in 1991, before moving to the USA, where he went to work as a deputy head of station on the Mexican border under the auspices of Texas A&M University and the US Department of Agriculture. John da Graça currently holds the position of head of station while retaining strong links with his homeland, and he has attended several conferences of the SASPP.

From early in his career, Frits Rijkenberg had a passion for microscopy and "small things", pursuing his interest in fungi, which he found fascinating because they were "so varied and so clever". He was particularly interested in how fungi infect plants and penetrate the host epidermis, and he focused his research on parasitic rust fungi. His work required an electron microscope and in the early days of his research (in the late 1960s) he had to travel to Durban to use one. The Pietermaritzburg campus was eventually able to raise funds to establish what Rijkenberg described as "the finest electron microscope unit in South Africa", with electron microscopes costing millions of Rands. This facility was housed in the John Bews building and used by the departments of Plant Pathology and Microbiology, Botany, Zoology and Biochemistry. Frits Rijkenberg was director of the electron microscope unit before handing over the position to Tony Bruton.

A substantial change occurred for the entire Faculty in the mid-1970s when it parted ways with the Department of Agricultural Technical Services. "When the Faculty of Agriculture was established, we were part of the university reporting to the Dean, but salaried by the Department of Agricultural Technical Services under its Director, who was, with his staff, also housed in the Rabie Saunders building," explained Frits Rijkenberg. "We were in a very unusual position and it was a big change for all of us to become fully integrated in the university."

In 1987, Mike Martin's impending retirement prompted a review of the combined departments, that delivered a glowing assessment of the plant pathology section. Bill Guest, in his book, *A Fine Band of Farmers Are We*, writes: "It was recommended that Martin's post be filled by another plant pathologist so as not to 'debilitate' this successful department with its more than 20 research students, its active co-operation with the Department of Agriculture, research stations, the Wheat Board and other grower organisations and with the farming community in general."

Along with a long list of other achievements, the report noted that the Foundation for Research Development (FRD) (now the National Research Foundation (NRF)) had awarded a partial grant to John da Graça and comprehensive support to Frits Rijkenberg. This financial support was a game changer for Rijkenberg and the department. Four "B" rating awards, which he received between 1985 and 2003 for his electron microscopy of the rust fungi, meant that he suddenly had ample funds for research, his students and apparatus. "For the first time, there was money in the department for me to take my students to conferences. I did more publishing and went to overseas conferences. It made an enormous difference," he recalls. With some of the money Frits Rijkenberg established a new laboratory for phytopathological research that he named after his mentor, Susarah Truter. He also developed a large group of talented postgraduate students, the effect of which, he said, "became visible all over the country, and, with the work of Mark Laing, all over Africa."

In 1985, Rijkenberg received a five-year grant from the De Beers Chairman's Fund to support the creation of the post of Farmer Liaison Officer. He appointed Thelma Trench to this post, which eventually led to the formation of the Farmer Support Group (FSG) at the university, a programme that continues to provide valuable support to small-scale farmers. A notable achievement of the FSG was the publication in 1992 of the *South African Plant Disease Control Handbook*, which contained superb sections on plant disease-causing organisms, epidemiology, plant resistance, self-diagnosis, quarantine, pesticides and their application, and the important diseases of approximately 30 important crops.

The start of the new millennium in 2000 saw the separation of Microbiology and Plant Pathology into two departments. In the same year, Mark Laing took over the Chair of Plant Pathology from Frits Rijkenberg. Mark Laing, who had an interest in diseases affecting cabbages, biocontrol and plant breeding, had been a student in the department before starting as a lecturer under Mike Martin in 1984. When Mike Martin retired in 1987, Mark Laing took over his post and he was appointed a full-time lecturer in 1988 and senior lecturer in 1996. In 1997, Mark Laing obtained his doctorate and was made an associate professor in 1999.

There were two other new appointments at the start of the new century. Gus Gubba filled John da Graça's teaching post as a lecturer. He is currently an associate professor and the resident virologist, focusing on genetic engineering of virus resistance in plants. Pat Caldwell was appointed to fill Rijkenberg's lecturing post in 1998 when he moved to the dean's office. When she retired, Kwasi Yobo filled her position and his research focus is on biological control of fungal and bacterial diseases. Part of his research also focuses on integrated control of mycotoxins and mycotoxin-producing fungi in groundnuts, maize and wheat.

Mark Laing's tenure as chair of the Department ushered in several changes, one of which was to intensify a more applied approach to the discipline, which had happened gradually over the years. Frits Rijkenberg said that when he joined the department, 'book knowledge' ruled, partly because of personal preferences and partly because of a lack of facilities. "When I joined the staff there were no facilities except for microscopes. In 1967 I was a plant pathologist working in the department for the Natal region. All the plant pathology questions from farmers came to me, so I had my stint of applied work as well. However, Mark Laing became much more applied than either I or Mike Martin ever were, and the department has grown enormously under his exceptional leadership and ability".

Mark Laing ascribes his focus on the applied side of plant pathology to a keen awareness of the huge problems facing small-scale farmers and a belief that the department had a responsibility to deliver practical solutions. As a result, the department moved towards finding solutions for farmers. In tandem with this approach, significant changes were made to the curriculum, so that it reflected an African environment. Crops that were studied were African and had African diseases, and teaching changed to support this approach.

Laing's focus on Africa was enforced by his association with the African Centre for Crop Improvement, which he initiated in 2002 with a R50 million grant from the Rockefeller Foundation. Its brief was to train plant breeders from all over Africa and in this it has been highly successful with more than 120 PhD graduates to date, from 19 countries, working on 20 crops. Laing has been director of the centre since it started. "Interestingly, 70% of the student's plant breeding projects have involved breeding crops for resistance to pathogens, pests, parasitic weeds or drought stress, overlapping with the plant pathology perspective".

Another big change was the introduction of a research focus on biological control in 1989. "At the time this was seen as radical because agrochemicals were so dominant. Now, 30 years later, we've run many successful projects and produced so many postgraduate students with a good background of this field; this is where the global crop protection is going in terms of pest and disease management. Even the big agrochemical companies have joined the field, and they all have a biocontrol portfolio now," said Mark Laing. Gus Gubba's arrival also meant that they have had a 'front row view' of the genetic engineering revolution and its successes. Whilst technically successful, the costs of licensing patents on each of the genetic engineering steps, and cumbersome biosafety regulations have created massive barriers for all but the largest companies. Perhaps the CRISPR-CAS9 revolution will be more fruitful, and Gubba's transformed plants can reach the farmers.

During Mark Laing's time as head of the department, he built seven growth tunnels and two greenhouses, as well as developing more than 10 hectares of irrigated land at Ukulinga Farm where field research could be done. That meant that most of the department's students now conducted "hands-on" research on living plants, which changed the kind of research that could be undertaken for the department. This expansion was made possible by substantial funding that Mark Laing had secured. The department and partners received grants of R7.5 million in 1999 and R6.9 million in 2002 for biocontrol projects from the Department of Arts, Culture, Science and Technology Innovation Fund. Strong industry links have led to reliable industry-funded research with the avocado, citrus, dairy, maize, seedling, seed, timber, wheat and biocontrol industries.

The department founded by Susarah Truter continues to flourish. Its most recent staff appointment was Nokwazi Mbili in a new post, the first in 40 years. This development was a response to growing student numbers. Her research focus is on management of postharvest diseases of fruits and vegetables and improving shelf-life of horticultural commodities by application of eco-friendly methods.

6.5 UNIVERSITIES OF CAPE TOWN AND THE WITWATERSRAND

Plant Virology was and remains the focus of research at both the Universities of Cape Town and the Witwatersrand. Details pertaining to this history are presented in the section on plant virology (9.0).

6.6 UNIVERSITY OF JOHANNESBURG

Konrad van Warmelo was appointed as a mycologist at the National Fungus Herbarium, Plant Protection Research Institute (PPRI), Pretoria in 1964. He was seconded from that position to the Department of Toxicology, Veterinary Research Institute, Onderstepoort, becoming involved in investigations of fungal toxicoses, following the discovery of Aflatoxin in 1963. During this period, he also studied seed-borne diseases of peas. In 1970 he made a career shift to the Department of Botany, Rand Afrikaans University (now the University of Johannesburg), becoming Professor and teaching courses in mycology, genetics and microbiology to both undergraduate and postgraduate students.

In the final years of his career, Konrad van Warmelo became deputy to the dean in the Faculty of Science at the same university. His primary research interests were karyology, ontogeny and morphology in Ascomycetes and conidial fungi. Six years of his career were dedicated to the study of mycotoxins and mycotoxicoses, and in that period he proved that Lupinosis in sheep was caused by *Phomopsis leptostromiformis*, a hitherto unexplained cause of morbidity in sheep that has been known since 1887. Research culminating in publications followed a diverse number of subjects. These include identification of the fungus that causes pea blight, fungi in stock feeds, aflatoxin in naturally infected high-quality maize and studies on Coelomycetes fungi. Important to science, he drafted a proposal for the modifications of the Code of Botanical Nomenclature for the second International Mycological Congress (IMC2). His publications include collaborators and students well-known to South African plant pathology, namely Cecilia Roux, GA (Gideon) van der Westhuizen, FO (Wally) Marasas and TS Kellerman.

Ian Dubery joined the Department of Biochemistry in 1982. The primary objective of his research is to investigate the biochemical basis of inducible defence responses in crop plants to pathogenic organisms. This work seeks to manipulate the infection process to enhance natural disease resistance and to induce crop protection through measures that are benign to the environment. The focus of the research is on plant and microbial biochemistry, especially with regard to the complex plant-microbe interactions that might lead to either disease or resistance, depending on the perception capacity of the plant. The induction of defence-related genes and the immunization of plants against diseases that result in induced or acquired resistance are investigated. The aim is to develop novel strategies for crop protection, to complement traditional plant breeding efforts and to reduce the expense and environmental costs of reliance on conventional pesticide treatments.

For a brief period in the 2000s, plant virology research was conducted by the University of Johannesburg, when Henriette van Heerden and Lindy Esterhuizen were employed there (refer to section 11.0).

6.7 RHODES UNIVERSITY

The Mycorrhizal Research Laboratory, led by Joanna Dames at Rhodes University, is the only established laboratory in the country dedicated to this field of research. Research includes aspects of their biology, ecology, characterization, biodiversity, commercial development and application, their interaction with other soil microorganisms and benefits to both the soil environment and plant/crop production. There are several mycorrhizal associations, the ectomycorrhizas, arbuscular mycorrhizas, ericoid mycorrhizas and orchid mycorrhizas of interest to the group because of their importance in the forestry, agricultural, horticultural and environmental rehabilitation sectors. Assessment of mycorrhizal status of soils and colonisation of roots is conducted in consultation with Joanna Dames. The role and importance of mycorrhizal fungi in plant and soil health is emphasised through various public interaction forums.

6.8 UNIVERSITY OF LIMPOPO

The plant pathology section at the University of Limpopo was established in 2015. The section forms part of the Plant Protection Unit in the Department of Plant Production, Soil Science and Agricultural Engineering, School of Agriculture and Environmental Sciences. Other sections of the unit include entomology and nematology. The section is mandated to teach plant pathology-related modules at undergraduate and postgraduate levels, especially in the newly established MSc Plant Protection qualification. Since its establishment, Mapotso Kena has been involved in a number of research projects and has established research collaborations with universities and research institutions in South Africa and Africa. His main research activities include studying the impact of climate factors such as water stress and increased temperatures on diseases of vegetables and fruit trees (avocado), farming practices such as tillage, intercropping, use of cover crops and plant extracts for integrated management of soilborne diseases. The plant pathology section also works with the Risk and Vulnerability Centre at the University of Limpopo on a number of projects, including the use of remote sensing to map disease spread in Limpopo province. Since its establishment in 2015, five MSc candidates have graduated from the section. Current staff include Mapotso Kena who conducts research on fungal pathogens, diseases and their management and ND Mamphiswana.

6.9 NORTH-WEST UNIVERSITY

Plant pathology research and teaching at North-West University has been conducted since the establishment of the Department of Crop Production in 1988. The Department's name was later changed to Crop Science and more recently to the Department of Agronomy and Horticulture. Currently, plant pathology is taught in the module Plant Pathology and Nematology alongside other crop protection modules such as Agricultural Entomology and Weed Science. Plant pathology teaching and research is led by Khosi Ramachela, with support from a part-time lecturer. His research focus is on soilborne diseases, particularly on the use of vesicular-arbuscular mycorrhiza (VAM) and various biocontrol agents for the management and control of a wide range of soilborne fungal pathogens.

In addition to the research on plant pathology, the research team has a strong research program on mushroom production. There is currently an ongoing research project on the impact of low-cost technology on the production of oyster mushrooms under semi-arid conditions. In addition, research is also being conducted on *Termitomyces* mushroom production.

6.10 TSHWANE UNIVERSITY OF TECHNOLOGY

The Faculty of Sciences at the Tshwane University of Technology (TUT) is a core component of the University. Three of its departments, namely, the Department of Biotechnology and Food Technology, the Department of Chemistry and the Department of Crop Sciences have been involved in different aspects of the food chain with some focusing on plant health research. Since 2010, the Department of Biotechnology and Food Technology has hosted a very successful niche area in the field of biotechnology, plant health and food innovation including quality and safety. This niche area focuses on diverse biotechnology and food technological, chemical, physical and microbiological factors relating to the quality and safety of crops and food products produced in South Africa. The main goal of the Department is to maintain close collaboration with stakeholders at all levels, thus ensuring research and technology transfer. The Department has a long history of applied microbiology research. The molecular aspect of this programme has been emphasized to accelerate advances in identification of organisms, as well as phylogenetic analysis of isolates, with the emphasis on skills transfer to the students enrolled for their degrees.

Thierry Regnier and his collaborators are involved in the bioprospection of microorganisms from new and less-investigated ecological niches to discover new bioactive compounds, and potential biocontrol agents. He is involved in the use of aromatic plant extracts for the control of pre- and postharvest diseases caused by *Fusarium*, *Penicillium*, and *Colletotrichum*, in mango, avocado and citrus. His research in controlling the bubble disease in button mushroom using essential oil has been validated by the research team directed by David Beyer of

Penn State University. He collaborates closely with Mandira Manganyi from North-West University on the screening of endophytes for the control of postharvest pathogens.

Chemistry is extremely important for crop protection. Thus, the Department of Chemistry has also been involved in research related to this topic. The goals of this research are to investigate the mode of action of the biocontrol agents, and also to get a better understanding of the biochemical reactions and chemical compounds involved in host-pathogen interactions. Wilma Augustyn is involved in chemical ecological studies. Her group is mainly focused on determining interactions between and amongst organisms and their environment, that involve semiochemicals functioning as signals to initiate, modulate or terminate a variety of biological processes. The group has determined the chemical differences between cultivars resistant and susceptible to agricultural pests such as mango gall fly, blossom malformation caused by *Fusarium* infestation in mango, green mould, sour rot and Citrus black spot as well as the migration of stinkbugs from one crop to the next. Multivariate analyses were employed to determine biomarkers responsible for specific traits in fruit crops. Mango blossom malformation caused by *Fusarium* infections reduce fruit yield. Very few cultivars are resistant or tolerant to this fungal infection and by determining secondary metabolites responsible for resistance, farmers can make informed decisions on which cultivars to plant. Citrus Black Spot (CBS) is a fungal disease caused by *Guignardia citricarpa.* The essential oil composition as well as non-volatile metabolites of several cultivars with varying degrees of susceptibility are being determined at differing stages of fruit development for two full seasons. Ben Botha has actively participated in understanding the volatiles involved in the attack of stinkbugs on macadamia. This insect infests various fruit crops, but has a devastating effect on macadamia nuts and loss of fruit yield is severe. Identification of volatile pheromones will allow their application in insect traps.

Reinette Gouws-Meyer from the Department of Crop Sciences is involved with research projects that focus on bacterial and fungal pathogens, molecular identification, phytosanitation and postharvest quality of vegetable crops. Since 2016, her group has focused on the following projects: the characterization, pathogenicity and cultivar screening of *Fusarium* wilt of sweet potato in South Africa, disease characterisation, epidemiology and genetic diversity of *Pseudomonas syringae* pv. *lachrymans* (angular leaf spot) of cucurbits, the biological control of Fusarium wilt of sweet potato using non-pathogenic *Fusarium oxysporum* rhizospheric endophytes and *Trichoderma* spp., and the effect of smut (*Sporisorium scitaminium*) on the yield and quality of sugarcane varieties.

7.0 Fungal Plant Pathology

Most diseases of plants are caused by fungi and the greater part of the history of plant pathology in South Africa has concentrated on fungal diseases. This is evident from the majority of sections of this book, and in order to avoid undue repetition it was decided not to present a separate section covering the history of fungal plant pathology.

8.0 Phytobacteriology

1900-1970

Since the early 1900s, South African plant pathologists recognised and recorded the existence of bacterial pathogens of plants. The earliest recorded diseases were angular leaf spot of cotton (causal agent: *Xanthomonas citri* subsp. *malvacearum*) in 1907, crown gall (causal agent: *Agrobacterium tumefaciens*) of many host species, and bacterial knot on oleander (causal agent: *Pseudomonas savastanoi* pv. *savastanoi*) in 1908. The eradication of citrus canker (see section 26.1) in 1928 was a noteworthy event in the history of plant pathology in South Africa.

Between 1900 and 1970, the most significant publications to appear where those listing the symptoms of bacterial diseases, their causal agents and location of outbreaks in South Africa. In the first list published in 1924, 18 bacterial pathogens infecting 31 hosts were mentioned. In 1953, almost 30 years later, this number increased to 24 pathogens infecting 52 hosts. A number of bacterial pathogens were, however, not identified although the symptoms they caused were well described. During this period a number of scientists played a significant role in the development of phytobacteriology. These included Ethel M Doidge (refer to section 28.3), a pioneer of South African mycology. In 1914, she obtained a DSc, the first woman in South Africa to acquire this qualification, from the University of the Cape of Good Hope, with a thesis titled: "A bacterial disease of mango, *Bacillus mangiferae*, n.sp." She published various articles on bacterial diseases between 1915 to 1919 before turning her attention to fungi. Other scientists who actively conducted research, particularly on bacterial diseases of vegetable crops, were Vincent Wager and BH Boelema. Prior to joining Stellenbosch University, SD du Plessis undertook studies on pear blossom blight and he was the first scientist to describe bacterial blight of grapevines (vlamsiekte) in South Africa. Between 1947 to 1952, Robert A Dyer (1900-1987), a botanical taxonomist, published yearly reports in *Farming in South Africa* on "Botanical surveys and control of plant diseases". In these reports he recorded the occurrence of many bacterial diseases. Gert Pauer obtained a DSc from UFS in 1966 with a thesis entitled "Die taksonomie van plantpatogeniese bakterieë" (The taxonomy of plant pathogenic bacteria). He eventually became the head of plant pathology at UFS and moved his research focus from phytobacteriology to peanut diseases. JJ (Johan) Joubert joined UKZN in the mid-1960s, after completing his PhD at the University of Ghent in Belgium and conducted research on bacterial diseases of orchids and other crops. He left in 1973 to pursue a career in the medical field.

1970-2019

Significant publications during this period (1977, 1981, 1982) included the updating of the lists of plant pathogens present in South Africa. Research on plant pathogenic bacteria took place at a number of research institutes established by the Agricultural Research Council (ARC). Much of this research involved the identification and development of rapid diagnostic methods, developing management strategies including breeding of resistant plant material and the production of clean propagation material. Researchers that are currently actively involved in research on bacterial diseases include Teresa Goszczynska, Yolanda Petersen and Deidré Fourie. Teresa Goszczynka is the curator of the National Collection of Plant Pathogenic and Plant Associated Bacteria Culture Collection. Her research focuses on bacterial pathogens of onions and related hosts. Yolanda Petersen has been employed by the ARC-Infruitec since 2004. Her primary research focus has been on characterising the molecular basis for pathogenesis of *Xylophilus ampelinus*, the causal agent of bacterial blight of grapevine. In addition, she has conducted research on bacterial diseases of stone and pome fruit, and detection of *Agrobacterium* and phytoplasma species in vineyards. Deidré Fourie has been employed by the ARC-Grains Crops division since 1991. Her initial research focus was on the development of common bean cultivars with enhanced levels of disease resistance specifically to bacterial pathogens. She is currently responsible for the entire dry bean breeding programme at ARC and collaborates with researchers from the United States Department of Agriculture (USDA) and the Southern African Bean Research Network (SABRN) on the genetic improvement of dry beans using conventional and molecular approaches. Previously, Kobus and Surentha Serfontein (Plant Health and Protection), Barry Manicom (Tropical and Subtropical Crops) and Jody Terblanche (Industrial Crops) worked on a number of bacterial diseases, notably *Xanthomonas citri* pv. *mangiferaeindicae, Agrobacterium tumefaciens* and *Ralstonia solanacearum*. One of the noteworthy contributions of the ARC during this period was the pioneering research undertaken on the biocontrol of *A. tumefaciens* by Ferdi van Zyl, Ben Strydom and J (Stappie) Staphorst in the 1980s. The biocontrol agent F2/5, which they developed, is still available commercially in South Africa.

Three bacterial diseases significantly affect sugarcane production in South Africa, leading the South African Sugar Research Institute (SASRI) to actively pursue research, notably on leaf scald caused by *Xanthomonas albilineans* and ratoon stunt caused by *Leifsonia xyli* subsp. *xyli*. The focus of their research is on ensuring that sugarcane varieties released into the industry and/or imported through quarantine channels are disease-free. Researchers that have impacted on the development of phytobacteriology at SASRI have been Roger Baily and, more recently, Stuart Rutherford and Sharon McFarlane (refer to section 19.0).

A number of researchers at either Departments of Plant Pathology or Microbiology at South African universities have conducted research on bacterial plant diseases. Martin Hattingh was appointed as lecturer at Stellenbosch University in 1969, where he developed the first comprehensive undergraduate course on phytobacteriology at a South African university. He gained international recognition for his research on bacterial diseases of deciduous fruit and other important agricultural crops. He had a close collaboration with the ARC-Infruitec division. In 1984-1985, Martin Hattingh was on sabbatical leave as visiting professor for one year at Cornell University (New York) where he did research with Steve Beer on fire blight of stone fruit caused by *Erwinia amylovora*. During the course of his career in phytobacteriology, he supervised five doctoral and eleven master's students in agriculture. They included Isabel Roos and Lucienne Mansvelt, who both conducted pioneering research on bacterial canker of stone fruit trees. He produced more than 70 publications and participated in many national and international conferences. He became dean of the Agricultural Faculty at Stellenbosch University in 1991 and retired in 1999.

Mike Wallis undertook both his MSc and PhD research on the histopathology of three important bacterial diseases (black rot of cabbage, bacterial canker and wilt of tomato caused by *Xanthomonas campestris* pv. *campestris, Clavibacter michiganense* subsp. *michiganense* and *Ralstonia solanacearum*, respectively). He was involved in the training of postgraduate students in this field, although in later years he changed direction to industrial microbiology. In the 1980s to 1990s, the group led by Bala Pillay and Gansen Pillay, focused their research on leaf scald disease of sugarcane caused by *Xanthomonas albilineans*. They trained a number of postgraduate students and published extensively on this pathogen. They had close collaborations with Paul Birch and Ian Toth from the Hutton Research Institute in Scotland.

During the 1980s and 1990s, John Mildenhall from the University of Fort Hare conducted research on the bacterial pathogen of maize, *Dickeya zeae* (= *Erwinia chrysanthemi*). He worked closely with Bernard Prior (University of the Free State and Stellenbosch University). Molapo Qhobela, upon his return to South Africa after completing a PhD in the USA, joined the University of Cape Town and continued his research on bacterial streak disease of maize (*Xanthomonas zeae* = *Xanthomonas vasicola* pv. *vasculorum*). He subsequently left academia and served as the CEO of the National Research Foundation until December 2020. In recent years, Jacquie van der Waals, Piet Hammes and Lucy Moleleki, all from the University of Pretoria, have or had research programmes focusing on bacterial diseases of potato, notably the soft rot Enterobacteriaceae and bacterial wilt caused by *R. solanacearum*. Teresa Coutinho, also at the University of Pretoria, focuses her research on bacterial diseases of tree and vegetable crops. In 2010, she edited a book entitled *Bacterial diseases of plants in South Africa* together with Teresa Goszczynska, Cheryl Lennox and Fanus Venter.

An important bacterial disease causing significant economic losses in South Africa is citrus greening caused by *Candidatus* Liberibacter africanus (Laf) (refer to section 26.4). It was first reported in the country in 1928. A number of plant pathologists have undertaken research on this disease over the years, including developing detection methods and management strategies. The researchers involved included Ballie Kotzé and Lise Korsten (UP), Fanie van Vuuren, Hennie le Roux and MC Pretorius (CRI) and more recently Gerhard Pietersen (SU). Gerhard Pietersen's group confirmed that Laf has an African origin and is well adapted to commercial citrus.

9.0 Virology

South African plant virologists have always been few in numbers and far between, and their discipline has been chronically underfunded, given the importance, size and diversity of the South African horticultural and agricultural crop industry. Most early plant virology (until the 1960s) was performed within the Department of Agriculture, and then by the University of KwaZulu-Natal (formerly University of Natal) in Pietermaritzburg (UKZN), Stellenbosch University (SU) and the University of Pretoria (UP). From the early 1970s research on plant viruses was also conducted at the University of Cape Town (UCT), and from the early 1980s at the University of the Witwatersrand (Wits).

Currently, formal plant virology training in South Africa is conducted only at a small number of institutions. These are:

- UCT under the leadership of Darren Martin in the Department of Integrative Biomedical Sciences, Institute of Infectious Diseases and Molecular Medicine, with Ed Rybicki in the Department of Molecular and Cell Biology now only peripherally involved;
- UKZN Department of Plant Pathology with Gus Gubba;
- UP Department of Biochemistry, Genetics and Microbiology and the Forestry and Agricultural Biotechnology Institute (FABI), with Gerhard Pietersen (now at SU);
- SU in the Department of Genetics or Plant Pathology with Johan Burger, Hano Maree and Gerhard Pietersen; (Dirk Bellstedt from the Department of Biochemistry at Stellenbosch University retired at the end of 2019) and
- Wits under the leadership of Chrissie Rey.

Plant virology research positions at non-academic institutions are available only at the Agricultural Research Council (ARC) - Plant Protection Research Institute (PPRI) where Ronel Roberts and Dariusz Goszczynski are based; the ARC - Vegetable and Ornamental Crops (VOPI) with Michelle Cloete, Inge Gazendam and Julia Mulabisana; the ARC-Tropical and Subtropical Crops (ITSC) (Zamangwane Dlamini and Elize Jooste); Citrus Research International (CRI) (Glynnis Cook, Chanel Steyn and Hano Maree); and the South African Sugar Research Institute (SASRI) where Sharon McFarlane, Stuart Rutherford and Tania van Antwerpen are employed.

The nature of plant virology conducted in South Africa closely follows the development of detection and manipulation techniques employed internationally in the discipline. Initially, virus diseases were recognized by their ability to pass through bacterial filters and still be transmitted between hosts - and tobacco mosaic virus (TMV) was the first virus so described. Up until the 1960s most plant virology studies in South Africa, and elsewhere, involved transmission, symptomatology and host range studies. During this time, a large number of plant viruses were reported in South Africa with little or no information regarding the properties utilised to identify the viruses. No fewer than 20 viruses on 48 different host species were listed in a publication by Doidge *et al*. in 1953, with a further 32 viruses on 32 different hosts appearing in Gorter's 1977 list of plant pathogens in South Africa, without any reference as to the first report. Unfortunately, little or no stored reference materials from this era are available. This precludes confirmation of the first reports by current virologists utilising modern techniques.

In this section we look at the training, nature of research and the main research findings of individual plant virologists in South Africa, and we attempt to do this chronologically. In instances where postgraduate students contributed significantly to plant virology in South Africa through publications, but did not continue into plant virology posts, they are mentioned within the section devoted to their supervisor.

1925-1970

It is most likely that the first person working on a plant virus disease in South Africa was Harold Haydon Storey. He was briefly employed by the Natal Herbarium in Durban, under the Division of Botany of the Department of Agriculture of the Union of South Africa. In 1925 he reported on maize streak disease, later found to be associated with maize streak virus. He also conducted pioneering studies on rosette disease of peanuts (*Arachis hypogaea*) before leaving for East Africa in 1928. However, the most prominent virologists in South Africa from this era were APD McClean (1940-1963) and Pat Klesser (in the 1960s).

APD McClean completed a DSc at the University of South Africa (UNISA) in 1935 with a thesis titled "Some fundamental aspects of plant virus diseases". He started his career at the Natal Herbarium, but later moved to Pretoria to the Department of Agriculture, PPRI. He initially worked on viruses of horticultural crops, providing first reports between 1935 and 1940 of tomato bunchy top virus, tobacco leaf curl virus "petunia strain", and cabbage black ringspot virus in South Africa on Cape gooseberry, hollyhock and petunia, and the Cape forget-me-not, respectively. He later shifted his attention to maize streak virus and then to citrus, where he is also credited for the first reports in South Africa of citrus vein enation virus, citrus xyloporosis virus, citrus exocortis "virus" (now known to be a viroid) and citrus tristeza virus (CTV) on various citrus species. He conducted a large number of the initial studies in South Africa on CTV being amongst the first to demonstrate transmission of this virus by the citrus aphid *Toxoptera citricida*, and to identify CTV sources potentially useful for cross protection studies. He also studied citrus greening "virus", where in collaboration with PCJ Oberholzer they showed transmission, for the first time, of what was later shown to be a bacterium transmitted by the African citrus psyllid, *Trioza erytreae*.

Pat Klesser obtained her PhD at Cambridge University, UK, where she trained with Kenneth Smith, one of the fathers of plant virology. She spent her entire career in the Department of Agriculture, mainly at the Horticulture Institute at Roodeplaat (now ARC - Vegetable and Ornamental Plants). She was the head of the Virology Section until she resigned in 1978, after which she worked part-time until she retired in the early 1990s. Trained to recognize viruses based on the symptoms they produce, she had an uncanny ability to correctly identify viruses infecting many vegetable and ornamental plants. Pat Klesser's passion for assisting farmers to grow virus-free crops led her to initiate virus-free plant propagation schemes for sweet potatoes, strawberries and roses, some of which still exist today. To achieve this, she initiated virus elimination programmes using tissue culture carried out by DD Nel, a pioneer of plant tissue culture in South Africa. Pat Klesser reported 23 viruses for the first time in South Africa on 12 major commercial legume species during the 1960s, mostly through virus transmission on to indicator host ranges and symptomatology. A number of these were subsequently confirmed present in the country using more modern plant virology techniques.

Other persons from this period that published studies on plant viruses include Amy Hean, who reported a number of hosts of tomato spotted wilt virus in 1940; AJ Louw, a mycologist then of the Western Province Fruit Research Station, Stellenbosch (later ARC-Infruitec), who in 1949 provided the first report on the apple mosaic strain of Prunus necrotic ringspot virus on plums in South Africa; WK Buchanan, who reported on "sugarcane ratoon stunting virus" (a disease now known to be associated with bacteria) in 1953; FC Loest and FJ Stofberg, who in 1954 reported the presence of avocado sunblotch "virus", now known to be a viroid; the famous South African plant pathogen epidemiologist James Vanderplank, who in 1955 reported the presence of tomato spotted wilt virus on *Canna* spp.; and A van Oostroom, who reported in 1958 on citrus exocortis virus (now known to be a viroid) on lemons.

Between the mid-1960s and 1980s, purification of viruses, biochemical and biophysical characterisation, electron microscopy and serology for virology studies became common. Prominent South African plant virologists during this period were Alfred Polson, Dawid Engelbrecht, Marc von Regenmortel and Barbara von Wechmar.

Alfie Polson was employed in the Virus Research Unit at the then Medical School of UCT after he obtained his PhD in 1958 at the same institution with a thesis titled "Biophysical and biochemical research studies, 1936-1957". While a number of these studies dealt with animal and insect viruses, Alfie Polson moved to using plant viruses as models to develop various viral purification techniques and methods to measure biophysical and biochemical properties of viral particles. He supervised the PhD of Marc von Regenmortel, who at the time worked at the Paul van der Bijl Laboratory. Marc von Regenmortel would go on to be a plant virologist of immense international standing. During his retirement, Alfie Polson published the first successful purification protocol for potato leafroll virus, a serious viral disease of potatoes. He was also the first person, in collaboration with Barbara von Wechmar, to make use of IgY derived from immunized chickens in serological tests on plant viruses. While he was not a plant virologist *per se,* Alfie Polson had a profound influence on the plant virologists of the time due to his innovative approach to viral characterisation problems. For example, he was the first person to show the successful transmission of a previously non-mechanically transmissible virus (MSV) using the highly novel technique of electroendosmosis.

After living in Brussels for the first two decades of his life, Marc von Regenmortel moved to South Africa, where he earned his PhD with Alfie Polson at UCT in 1961 with a thesis entitled "The purification, biophysical and biological properties of some plant viruses”. Marc von Regenmortel was appointed at Stellenbosch University to work in the Paul van der Bijl Laboratory, but shortly thereafter moved to UCT where he was appointed as professor and Head of Microbiology. He left South Africa in 1978 and became Director of Research at the Centre National de la Recherche Scientifique Immunochemistry Laboratory at the University of Strasbourg. His international career has had an impact on plant virology in South Africa through his presidency of the International Committee on Taxonomy of Viruses from 1996 to 2002, and being the Editor-in-Chief of *Archives of Virology* for 20 years prior to retiring in 2018, during which time he championed plant virology. During his period in South Africa Marc von Regenmortel had significant collaboration with Alfie Polson concerning the biochemical and biophysical properties of plant viruses, and then worked with Barbara von Wechmar at UCT on the biophysics and serology of plant viruses, using mainly strains of TMV. He was also responsible for the first South African reports of watermelon mosaic virus and cucumber mosaic virus on pumpkin in 1960, of Prunus necrotic ringspot virus and apple latent virus on peach and apples respectively in 1960 with DJ Engelbrecht, of brome mosaic virus in the country along with his PhD student Barbara von Wechmar in 1966, and also of tobacco necrosis virus D on grapevines in 1969. Marc von Regenmortel was also one of the first people to pioneer internal calibration of electron micrographs by making use of a plant virus (Odontoglossum ringspot virus). Marc von Regenmortel inspired a young Ed Rybicki to continue with plant virology during his Honours course in 1977. Notable doctoral graduates of Marc von Regenmortel include D Hendry, who later worked at Rhodes University on insect viruses, and DH du Plessis who worked on cauliflower mosaic virus for his PhD, presented some virology classes at Stellenbosch University and then moved to Fort Hare and finally the ARC-OVI.

Barbara von Wechmar, working for the then Department of Agricultural Technical Services, but based at the Paul van der Bijl Laboratory at SU, completed a DPhil Agric at Stellenbosch University in 1967 with a thesis titled “Viruses affecting Graminae in South Africa” under the supervision of Marc von Regenmortel. This study recorded the first report in South Africa of barley yellow dwarf virus and barley stripe mosaic virus on barley, and brome mosaic virus on wheat. She also co-reported in 1968, with VD Wasserman, the first occurrence in South Africa of barley yellow dwarf virus on oats. In 1972, a few years after the attainment of her PhD, she joined Marc von Regenmortel at UCT, where she continued research on MSV. She had purified and produced antisera to MSV in the early 60s; however, the characteristic geminate virus particles were only first observed in South Africa in 1978, during a sabbatical visit by Bob Milne, an internationally-renowned electron microscopist who performed immunoelectron microscopy using the 1960s antisera. Barbara von Wechmar also collaborated with Alfie Polson during his retirement in pioneering the use of IgY from immunised chickens for the serological detection of plant viruses. Barbara von Wechmar trained various postgraduate students, many of who made significant advances in plant virology. Amongst her students were Ed Rybicki and Dion du Plessis, Reon Brand, Johan Burger, Michael-John Freeborough, Ramola Chauhan and Kobus Laubscher. By the time she retired in 1996, Barbara von Wechmar’s group had worked on viruses of a number of crops and ornamentals, including *Lachenalia* and *Ornithogalum* spp., granadillas, papaya and avocado, along with other viruses of maize and cereals, including maize dwarf and sugarcane mosaic viruses, cucumber mosaic and tobacco necrosis viruses.

Dawid Engelbrecht, initially of the Fruit and Food Technology Institute (FFTI) of the Department of Agricultural Technical Services in Stellenbosch, collaborated with Marc von Regenmortel from the Paul van der Bijl Laboratory at Stellenbosch University to report, in 1960, the first occurrence of Prunus necrotic ringspot virus on peach in South Africa. By 1961 he was already working on viruses of grapevines, a focus which would dominate the later stages of his career. He provided the first report of grapevine fanleaf virus in South Africa in 1961. He completed his MSc at Stellenbosch University in 1964 under the supervision of AJ Louw on virus diseases of strawberries in the Western Cape, reporting for the first time in South Africa occurrences of strawberry crinkle virus, strawberry mild yellow edge virus and strawberry mottle virus. He also made the first report in South Africa on pear stony-pit virus and pear ring pattern mosaic virus in 1965 and in 1968 respectively, and in collaboration with Marc von Regenmortel, the first reports internationally of apple latent virus and sowbane mosaic virus in *Chenopodium quinoa*. He moved to the Plant Protection Research Institute (PPRI), founding the Virology Unit of that institute in Stellenbosch in the 1970s, where he continued studies on viruses of stone and pome fruit and grapevines. His achievements in the latter field are recorded later in this book (refer to section 26.11). While never employed at an academic institution, Dawid Engelbrecht co-supervised a number of MSc studies, including those of WJK van der Walt in 1974 on apple chlorotic ringspot virus and apple stem grooving virus, and of Gerhard Pietersen in 1984 on alfalfa mosaic virus.

Mike Martin completed his BSc (Agric) at the then University of Natal (now University of KwaZulu-Natal, UKZN), and because there were no local virologists, he undertook his Master's degree through the Department of Virology at the University of Wageningen in the Netherlands. This was upgraded to a PhD after his return, and he was subsequently appointed as the local departmental Virologist at UKZN. His PhD, awarded in 1976, was on the "Purification and electron microscopy of the tomato spotted wilt virus". Mike Martin was particularly interested in the field of plant defences, specifically on how systemically acquired resistance was initiated and transmitted in plants in response to viral infection. The studies that he conducted with the assistance of Lynne Goudswaard were 30 years ahead of the field, but were unfortunately seldom published. Mike Martin was exceptionally successful in the training of students who would go on to become practicing plant virologists, including John de Graça, Graham Thompson and John Thatcher.

Other virologists between 1925 and 1970 included LD Wolfswinkel, who was the first person to head the quarantine station in Stellenbosch. He had reported the first occurrence of hibiscus line pattern virus on hibiscus in South Africa in 1966, but tragically passed away at a young age in a car accident. WJK van der Walt worked with Dawid Engelbrecht to detect apple chlorotic leafspot virus and apple stem grooving virus on apple for the first time in South Africa in 1974. RE Schwarz, who worked at the Department of Agriculture in Nelspruit, did a considerable amount of work on citrus blight, citrus tristeza virus and citrus greening, initially considered to be caused by a virus, but later shown to be associated with a bacterium.

1971-2020

John da Graça completed his BSc (Agric) at the University of Natal in 1971 and conducted an undergraduate research project on nasturtium mosaic virus with Mike Martin, which they published in 1977. He embarked on his MSc (Agric) degree under Mike Martin's guidance on the host-virus interactions of tobacco mosaic virus, graduating in 1975. From 1974 to 1979, he was employed at the Citrus and Subtropical Fruit Research Institute (CSFRI, now ITSC), Nelspruit, where, with John Moll and Fanie van Vuuren, he conducted studies on the woodiness disease of passionfruit, control of citrus greening, citrus impietratura, citrus young tree decline (aka citrus blight) and avocado sunblotch disease, and was responsible for indexing selected citrus trees for viruses as part of the Citrus Improvement Scheme. In 1981, da Graça completed his PhD at UKZN with a study on avocado sunblotch disease under the supervision of Mike Martin, demonstrating the involvement of a viroid. He returned to the Department of Microbiology and Plant Pathology, UKZN in 1979, first as a lecturer, but was later promoted to professor in 1998. In this period, he supervised 20 postgraduate students and expanded his interest beyond citrus to include tomato spotted wilt virus, nasturtium mosaic potyvirus, sugarcane mosaic and viruses of pepper and cucurbits. Amongst his students were Fanie van Vuuren, who completed both his MSc (Agric) on citrus tristeza virus and PhD on citrus viroids, and continued to work on citrus at Citrus Research International (CRI) in Nelspruit until he retired; Sanjay Maharaj whose MSc work on citrus vein enation gave important clues to the virus identity; Kris Budnik (MSc) who worked on pepper viruses; Erna Kruger (MSc) who worked on citrus tatterleaf virus, and Ken Cradock (MSc). In 1999 he relocated to the Texas A & M University-Kingsville Citrus Center in Weslaco TX as Center Director. He served as Secretary of the SASPP (1984-87) and Chairman of the International Organization of Citrus Virologists (2004-07). He maintains contact with South African virologists, attended the 50th SASPP conference in 2017, and is collaborating with Glynnis Cook (CRI, Nelspruit) and Gus Gubba (UKZN) on projects on citrus and nasturtium viruses, respectively. He retired in August 2020. Amongst John da Graça's most notable contributions to the field of plant virology are the identified mild CTV strains which were amongst the first to be used for cross-protection, the first evidence that citrus vein enation virus was a member of the *Luteoviridae,* his involvement in the characterization of citrus psorosis virus and his help in establishing the citrus virus indexing program for the interim Citrus Improvement Program for certified budwood.

Following his BSc at SU, Don Hendry was employed at the then Department of Agricultural Technical Services from 1966 until 1969, during which period he completed an MSc at Stellenbosch University entitled

"Biophysical studies of two viruses", primarily on the composition and molecular size of cucumber mosaic virus (CMV), but also of an insect virus, *Nudaurelia* beta virus (NβV). This study, involving analytical ultracentrifugation, diffusion and electrophoresis, was done under the supervision of Marc von Regenmortel at the Paul van der Bijl laboratory, SU. In 1969, Don Hendry took up employment at the Department of Biochemistry, Microbiology and Biotechnology at Rhodes University in Grahamstown, where he worked on plant and insect viruses until his retirement in 2003. In 1977, Don Hendry completed a PhD under the supervision of Marc van Regenmortel, then at UCT, and in collaboration with a postdoctoral researcher from Cambridge, ACH Durham, on the role of divalent cations (mainly calcium) on the stability and intracellular disassembly on a number of plant viruses. The thesis employed equilibrium dialysis, sensitive acid-base titration and ultracentrifugation and was entitled "On the binding of divalent cations to tobacco mosaic virus and to some isometric plant viruses".

Victor Whitlock, an insect virologist by training, was responsible for establishing a Plant Virology Unit at PPRI in Pretoria in the mid-1970s. He spent several months in the laboratories of Hollings and Stone in the UK, purifying and producing antisera to a number of plant viruses, which served as the basis whereby diagnostic services for plant viruses could be established at PPRI. He was appointed as a professor at the University of the Witwatersrand in 1983, where he conducted research mainly on insect viruses, but also reported on the first occurrence of tulip breaking virus and tobacco rattle virus isolated from tulips in South Africa, and on a strain of bean common mosaic virus. He left the field of virology in the early 1990s.

After completing his MSc on mycorrhizal effects on pine trees, Lawrence Marais was appointed from 1975 to 1981 in the Department of Plant Pathology at the University of Pretoria, during which time he completed his DSc at the University of Pretoria under the supervision of Ballie Kotzé, with external promotors Mike Martin of University of Natal and Harry Brodrick. This was on aspects of the Tristeza Virus Complex in South Africa. Thereafter he joined the Outspan Citrus Centre, Nelspruit (now CRI). He then relocated to the Department of Plant Pathology, University of California, Riverside, USA in 1999, where he became a Co-operative Extension Specialist (Plant Pathology). While in South Africa, Lawrence Marais undertook studies on CTV, citrus blight (a disease of unknown aetiology), citrus psorosis virus and "citrange stunt virus". Lawrence Marais was instrumental in establishing a cross-protection programme for grapefruit in South Africa, based on single aphid transmitted CTV mild protective isolates developed from the "Nartia" mild strain at the quarantine facility in Beltsville, Maryland, USA. He also developed a rapid diagnostic test for citrus blight, and associated a viroid with gum pocket disease of trifoliate orange.

John Thatcher completed a BSc majoring in Plant Virology in 1966 at UKZN, whereafter he was appointed to the Agricultural Technical Services at the Tobacco Research Institute in Rustenburg, where he conducted research on the viruses of tobacco. He completed an MSc (Agric) under the supervision of Mike Martin at UKZN in 1976 with a dissertation on the whitefly transmission and aetiology of tobacco leaf curl disease. In this time, he also discovered a new strain of PVY on tobacco. John Thatcher then moved to Stellenbosch in 1978, where he joined the team of Dawid Engelbrecht. He worked on the viruses of stone and pome fruit until the unit at the Quarantine Station was split between PPRI of the ARC and the Department of Agriculture. Whilst in the Department of Agriculture, John Thatcher became more involved in the control of exotic viruses, leading to work on viruses of olives, berries and hops. He retired in 1997. Also in the team of Dawid Engelbrecht, was Van Zyl Siebert, who was initially very involved in the biological indexing for pome and stone fruit viruses. With the split between the ARC and Department of Agriculture, Forestry and Fisheries (DAFF) he became increasingly involved in the management side, and later went on to become the Director of the Quarantine Station in Stellenbosch, where he made significant inputs into control of viruses in certification schemes.

Fanie van Vuuren started his career in citrus virology directly after school in 1960 as a learner technician at the Department of Agriculture, stationed at the Citrus and Subtropical Fruit Research Institute, now ARC-ITSC in Nelspruit. He obtained his National Diploma for Agricultural Technicians in 1966 and was the technician for RE Schwarz. Fanie van Vuuren completed an MSc in 1992 under the supervision of John da Graça at UKZN. The title of his MSc was "Evaluation of *Citrus Tristeza* virus isolates as cross protecting agents for citrus in southern Africa". In 1998 he obtained a PhD (Agric) at the same University and under the same supervisor, with the title "Application of transmissible agents to control citrus tree size".

Fanie van Vuuren left the employ of the ARC in 2003 to join Citrus Research International (CRI). As a CRI employee, Fanie van Vuuren served the citrus industry in virology research, and specifically supporting the Citrus Improvement Scheme (CIS) as member of the CIS Advisory Committee, chairperson of the CIS Virology Committee and co-ordinator for the virology diagnostic services. Fanie van Vuuren retired on 31 March 2017.

Fanie van Vuuren's 57 years in citrus pathology was mostly dedicated to the protection of the industry against graft-transmissible diseases. Having learnt from Hannes de Lange and Chet Roistacher, USA, Fanie van Vuuren continued with virus elimination using shoot-tip-grafting (STG), protecting trees from citrus tristeza virus (CTV) using mild-strain cross-protection and citrus virology research. Fanie van Vuuren's inputs contributed directly to South Africa's world-class Citrus Improvement Scheme and one of the healthiest citrus industries in the world. This resulted in uniform plantings, high production of 100 tons or more per hectare and in some instances an export pack-out of 98%. The productive lifespan of grapefruit was extended from less than 10 years, to more than 30 years, which actually saved the grapefruit industry in South Africa. While not formally involved in degree-related training, a number of colleagues were trained by Fanie van Vuuren. These included the following: JB Meyer, trained to do shoot-tip grafting, indexing for transmissible pathogens and mild strain cross-protection, who is currently employed by CRI and is the Manager of the Citrus Foundation Block at Uitenhage; Z Dlamini at the ARC-ITSC, also trained to do shoot-tip grafting and indexing and is still employed by the ARC-ITSC in Nelspruit, where she is responsible for quarantine of imported citrus; JHJ Breytenbach, trained to do shoot-tip grafting, indexing for transmissible pathogens and mild strain cross-protection, who is an employee of CRI and also responsible for maintaining the citrus Nucleus Block at Nelspruit, where more than a 1000 virus-free cultivars and selections are kept under insect-free conditions and finally, Glynnis Cook, who filled Fanie van Vuuren's position at CRI after his retirement.

While appointed at the then Department of Viticulture (SU), EF Beukman completed a PhD in 1969 on the anatomical effects of Corky Bark, a disease suspected of being viral-like at that stage. Beukman became the head of the plant improvement division within KWV, the large wine co-operative central to South Africa's wine exports in the 1960s to the early 1990s. While at KWV he co-supervised (with CJ Orffer) the MSc dissertations of two of the persons destined to subsequently lead this division. These were Gawie le Roux Kriel, who completed his MSc in 1973 on another grapevine disease suspected of being viral-like, in this instance stemgrooving (legno riccio), and then Nico Spreeth, who completed his MSc at Stellenbosch University on fleck disease of the *Vitis berlanderi* x *Vitis rupestris* hybrid rootstock Richter99 in 1986. Gawie Kriel took over the leadership of the division from EF Beukman from 1979 to 2001, being succeeded by Nico Spreeth, under whose leadership it separated from KWV, becoming the Plant Improvement Organisation, Vititec. Under Nico Spreeth's watch Vititec implemented increased ELISA testing for grapevine leafroll associated virus 1, 2 and 3. These ELISA tests were first done by Riaan Burger, who had completed an MSc. at Stellenbosch University on assessing a novel means of viral elimination, and then later by Tobie Oosthuizen a tissue culture specialist. Nico Spreeth was also instrumental in moving Vititec's foundation blocks out of commercial grape production areas, and implemented the integrated control of leafroll developed by Gerhard Pietersen. This strategy was implemented as a case study through the collaboration of Vititec, the University of Pretoria and Vergelegen wine estate, and is based on roguing infected vines, fallow periods between vineyards, managing mealybug spread through implements and works, and mealybug control for leafroll. Tobie Oosthuizen's laboratory probably conducts the largest number of plant virus tests annually in South Africa, with 700 000 vines tested for GLRaV-3 by ELISA in 2008 (the highest number).

The transition from serology to the molecular era of plant virology was not clearly defined. However, the molecular era was introduced primarily by Dion du Plessis, Ed Rybicki, Chrissie Rey, Johan Burger, Riaan Brand and others, from the1980s onward.

Dion du Plessis did his MSc on "Immunoassays with chemically modified bacteriophages" and initial phases of his PhD with a thesis title of "A serological study of some cauliflower mosaic isolates" under the supervision of Marc von Regenmortel at UCT, but completed the latter phase with Barbara von Wechmar. He was appointed a senior lecturer in the Department of Microbiology at Stellenbosch University, Paul van der Bijl Laboratory, and did a research fellowship in 1987 in the laboratory of Alan Dodd, in the Department of Plant Pathology at the

University of California Riverside. In 1989, Dion du Plessis relocated to the Onderstepoort Veterinary Institute (OVI) in Pretoria and effectively ceased plant virus research. He contributed to understanding the behaviour of cauliflower mosaic virus (CaMV) isolates in immunoassays and electrophoresis, and found evidence that the native CaMV CP may be glycosylated. The ELISA test he developed for CaMV is potentially the first ELISA test developed for a plant virus in South Africa, and this constituted Ed Rybicki's training in the technique. While at OVI, Dion du Plessis contributed to the application or modification of methods and approaches of plant virology, such as using IgY, Fab' and other ELISAs, phage display methods and novel immunisation protocols. He also collaborated with PPRI researchers using cucumber mosaic virus as a model virus to evaluate his group's recombinant chicken-derived phage display antibody library.

Ed Rybicki, who is now the Director of the Biopharming Research Unit in the Molecular and Cell Biology Department at UCT, completed a BSc at UCT in 1976 in Microbiology and Chemistry, and then started specialising in Virology in his BSc (Hons) in 1977, by doing a plant virus serology project on brome mosaic virus (BMV). He completed his MSc at UCT in 1979, during which time he studied advanced physical analytics of the bromoviruses, including by means of analytical ultracentrifugation and electrophoresis and also the then very novel ELISA techniques. In Ed Rybicki's PhD, which he completed in 1984 under the supervision of Barbara von Wechmar, he explored the purification and characterisation of barley yellow dwarf and brome mosaic and other viruses from wheat and barley plants, and the use of western blotting as an analytical tool. In 1981, prior to completing his PhD, Ed Rybicki was appointed to a lectureship in Virology at UCT, where he has stayed for the remainder of his career. Ed Rybicki's PhD was soon followed by a short study leave with a biotech company, Plant Genetic Systems, in Ghent, Belgium where he mastered the intricacies of DNA cloning. On his return to South Africa, he applied western blot techniques to the affinity purification of monospecific antibodies, and also discovered pathogenesis-related PR-1-type proteins in maize. In 1988 he initiated research on what would become a major focus of his group's work, namely maize streak virus (MSV): this is a small single-stranded DNA plant virus that was discovered and largely described from Africa over some 70 years prior (see HH Storey). Within one year, Ed Rybicki's group, in collaboration with UCT colleague Ralph Kirby, characterized three novel strains of the virus, and applied restriction map-based phylogenetic analysis techniques to determine their evolutionary relationships with other MSVs. Ed Rybicki also collaborated in this time with von Wechmar and PhD students Johan Burger and Riaan Brand on the molecular characterisation of two potyviruses. The Rybicki group's geminivirus work evolved as the molecular expertise of his group grew, with characterisations of both new potyviruses and geminiviruses by cloning and sequencing. This was followed by applications of the then new PCR DNA amplification technique to detect and characterize diverse potyviruses and cereal-infecting geminiviruses, leading to studies in virus evolution and culminating in the publication of major phylogenetic analyses on both potyviruses and geminiviruses.

From about 1997, Ed Rybicki also studied transgenic resistance to viruses in plants, initially collaborating with Jennifer Thomson and PhD student Andy Hackland. Along with PhD student Kenneth Palmer he pioneered using MSV in "molecular farming" for the production of high-value biologics in plants. In particular, Palmer showed stable, long-term (three years) high-level expression of foreign genes in plant cells from plasmid-like circular dsDNA replicating forms of engineered MSV genomes. Their work on MSV as an expression vector in cultured maize cells laid important groundwork for later molecular farming developments. This was with another bean-infecting geminivirus obtained from Gerhard Pietersen, initially known as bean yellow dwarf virus (BeYDV). During this time, Eric van der Walt in Rybicki's group also produced recombinant proteins in insect cells via engineered baculoviruses to provide "gold standard" geminivirus non-structural proteins for studying MSV molecular biology. Other foundational work on the diversity and evolution of grass-infecting geminiviruses and on the determinants of pathogenicity of mastreviruses was done by PhD students Wendelin Schnippenkoetter, Janet Willment and Darren Martin. Ed Rybicki also co-supervised PhD student Leigh Berrie at the University of the Witwatersrand with Chrissie Rey, on characterisation and sequencing of a novel South African cassava-infecting geminivirus (SA cassava mosaic virus). In a long-term project funded by Pannar Ltd., first Tichaona Mangwende and then Dionne Shepherd (née Miles), as PhD students, developed technology for investigating engineering transgenic resistance to MSV into maize breeding lines and this was continued by Dionne Shepherd as a postdoc, with significant success.

From about 2000, Ed Rybicki's team made a major detour into the animal and human vaccinology field. This was by first using transgenic plants and then transient expression to produce valuable biologics, and his attention on plant viruses has consequently been reduced. However, Ed Rybicki's plant virology expertise allowed him to make use of the mild strain of BeYDV, which they had characterised as an *Agrobacterium*-delivered replicating expression vector for tobacco. This proved to be a versatile and high-yielding vector system, and they continue to explore its use. Ed Rybicki has served as supervisor to a number of PhD students conducting research on a variety of plant viruses, many of whom have published numerous articles in the field of South African plant virology and in particular on mastreviruses. These included Andy Hackland, Janet Willment, Darren Martin, Arvind Varsani as a postdoc, Kenneth Palmer, Dionne Shepherd, Eric van der Walt, and most recently (and spectacularly) Aderito Monjane. Darren Martin and Arvind Varsani have gone on to be highly successful in their own rights in virus metagenome exploration and diversity analysis, mainly of plant viruses. Ed Rybicki believes his most notable contributions to South African plant virology have been the applications of ELISA, western blotting and PCR to virus discovery and characterisation; the exploration of potyvirus and geminivirus diversity and relationships by partial and complete genome sequencing and phylogenetic analysis; initiating studies leading to the characterisation of the genetic diversity of maize- and grass-infecting geminiviruses and of their evolution; and initiating genetically engineering maize for MSV resistance. He is also proud of recently finding a novel potyvirus in a Namib Desert ephemeral *Albuca* sp., with a former student of Gerhard Pietersen, Olivier Zablocki.

Chrissie Rey started an MSc at the University of the Witwatersrand in 1979, which was converted to a PhD and completed in 1982 under the supervision of Helen Garnett. The title of her PhD was "Epidemiological, morphological, and physiological studies of selected plant diseases at Nylsvley". Chrissie Rey was appointed at the University of the Witwatersrand in the then Microbiology department and has continued her career in that institution. While both her PhD and subsequent postdoctoral fellowship at the University of Cambridge were on fungal pathogens, her first foray into virology began upon her return from the UK in 1985, when she started researching viral diseases with Brian Beck and the small-scale growers in the KaNgwane homeland (now a part of Mpumalanga). There she discovered two new viruses, guar green-sterile virus (ssRNA potyvirus) and South African cassava mosaic virus (ssDNA begomovirus). The latter work was done by PhD student Leigh Berrie, in collaboration with Ed Rybicki. She went on to work on avocado sunblotch viroid funded by the South African Avocado Growers Association. In the next 15 years or so she worked on ryegrass mosaic virus (ssRNA rymovirus) (PhD Sarah Salm), tobacco leaf curl Zimbabwe virus in Zimbabwe (PhD Maria Paximadis), and discovered the first phytoreovirus (tobacco enation leaf curl virus) on the African continent. Chrissie Rey also worked on an RNA satellite virus of tobacco with Gael Kurath and Alan Dodds while on sabbatical at the University of California, Riverside USA. Notable amongst a large number of projects and postgraduate students, Chrissie Rey has worked on projects in India (tobacco leaf curl with Dr Muniyappa), Mozambique, Uganda, Tanzania, Zimbabwe, Ghana, Nigeria, Togo and Benin (yam viruses; PhD Angela Eni), Cameroon (East African cassava mosaic virus and African cassava mosaic Cameroon virus; PhD Vincent Fondong) amongst others, and has graduated too many MSc and PhD students to list. She was awarded the National Science and Technology Forum (NSTF) Award for Capacity Development in 2010.

To highlight a few later virus research projects, Chrissie Rey has researched cassava mosaic and streak diseases of cassava in Mozambique (Nurbibi Cossa and Jamisse Amisse), Tanzania (Gration Rwegasira), Uganda (Emmy Ogwok), and South Africa. She also worked on geminiviruses in tomatoes in South Africa and Mozambique (MSc students Valter Nuaila and Nurbibi Cossa; PhD student Lindy Esterhuizen). More recently she has worked on viruses in sweet potatoes in South Africa (PhD students Julia Mulabisana and Thuli Nhlapo). Chrissie Rey also pursued studies on the phylogeny of whitefly vectors of begomoviruses in tomato and cassava, along with her research collaborator Judy Brown from University of Arizona and postgraduate students (S Berry, P Sseruwagi, H Mugerwa and L Esterhuizen). In addition, Chrissie Rey extended her basic research on viruses and their vectors to biotechnology, and began research in the early 2000s on genetic engineering for resistance to cassava mosaic disease (principal postgraduate students: Murunwa Makwarela, Sarah Taylor, Maabo Moralo, Don Mvududu and Helen Walsh) and host-geminivirus interactions (collaborator H Vanderschuren) which are her current areas of focus.

Graham Thompson started employment at the then Department of Agricultural Technical Services in the Horticultural Research Institute in 1975 with Pat Klesser, after completing his BSc at UKZN. Graham Thompson then completed his MSc Agric (Plant Virology) at UKZN in 1980 under the guidance of Mike Martin on “The characterisation of a mosaic disease of *Capsicum* and the relationship between tomato spotted wilt virus infection and the cytokinin content of tomato.” In 1979, after the retirement of Pat Klesser, Graham Thompson became the head of the Virology Unit. In 1990, Graham Thompson completed his PhD under the supervision of Helen Garnett and MM Sibara at the University of the Witwatersrand with a thesis entitled “Characterization of strains of potato virus Y found in South Africa.” During his period of active research until 1994, when he took over managerial responsibilities, Graham Thompson published on viruses of potatoes, tomatoes, and cassava. He was a practical plant virologist with a keen interest in viral epidemiology as a means of controlling virus diseases and helping farmers. He was responsible for introducing ELISA as a means for testing for potato viruses in seed potato certification, along with his technician ‘Oom Piet’ Prins. While not at an academic institution, Graham Thompson co-promoted five postgraduate studies in plant virology. These were an MSc of Charles Jericho (1997-1999) at University of Fort Hare, MSc of MJ Mulabisana (née Domola) (2001-2003), a PhD of J Ndunguru (2002-2005) and an MSc of N Rabambi (2003-2003), the latter four all at UP.

Directly after completing an undergraduate degree at the University of the Witwatersrand, Gerhard Pietersen was appointed in 1980 at the Virology Unit of PPRI, then under the leadership of Victor Whitlock, where he stayed until 2004. He completed an MSc degree on characterisation of local isolates of alfalfa mosaic virus at the University of Pretoria under the initial supervision of Lawrence Marais, but when Marais moved to Outspan, supervision was continued by Ballie Kotzé with co-supervision by Dawid Engelbrecht. He completed his PhD on seed-transmitted viruses of soybeans in 1988 at the University of the Witwatersrand under the supervision of Helen Garnett, a medical virologist. In collaboration with various colleagues at PPRI between 1980 and 2004 (CW Vroon, M Koch, T van Tonder, G Cook, AEC Jooste, DE Goszczynski, H Olivier, MS Staples and GGF Kasdorf) Pietersen worked on improved phytosanitary control of viruses of various commercial legume crops by conducting surveys and preparing ELISA to local and seed-transmitted exotic viruses of legumes.

From 1990, with the retirement of Dawid Engelbrecht, Gerhard Pietersen’s group started research on viruses of grapevines. In 2004, Gerhard Pietersen changed employment to CRI, where he was seconded to UP. As part of training postgraduate students (K Scott, MNB Phlahladira, DA Read, O Zablocki, R Viljoen (née Roberts) and J Lubbe) he conducted research on citrus tristeza virus and citrus greening. In 2009, Pietersen returned to PPRI, but remained physically at the University of Pretoria where he continued with research on CTV, citrus greening, grapevine leafroll disease and viruses of maize. Amongst his students at this stage were RL Lambrechts, HA Walsh, M Harris, J Wayland, S Schulze, S Facey and E Strydom. In 2017 Gerhard Pietersen joined the research group of Johan Burger and Hano Maree at SU, where he continues with research on wine and table grapes and maize with student MC Gagiano.

Pietersen and co-workers confirmed the presence of numerous viruses primarily of legumes in South Africa, provided first reports of a number of others, and also detected five viruses previously unknown to science (soybean blotchy mosaic virus, tomato curly stunt virus, groundnut ringspot virus, bean yellow dwarf geminivirus, and peanut chlorotic blotch potyvirus). Gerhard Pietersen studied the spatio-temporal spread of grapevine leafroll disease, devised and tested a number of interventions to control the spread and has implemented this both locally and internationally to control this serious grapevine disease. Gerhard Pietersen’s PhD student, Ronel Roberts (née Viljoen), having completed her MSc (2013) and PhD (2019), has gone on to lead the Plant Virology Unit at PPRI, where she was instrumental in the first report of beet necrotic yellow vein virus (BNYVV) on red table beet in South Africa in 2006. She also collaborated with Schulze and Pietersen on the first report of bean yellow mosaic virus (BYMV) on *Tropaeolum majus; Hippeastrum* spp., and *Liatris* spp. in South Africa. Another student of Gerhard Pietersen, David Read, completed both his MSc (2011) and PhD (2015) at the University of Pretoria on citrus tristeza virus. David Read developed a method to determine the composition of populations of mixed infections of CTV genotypes and has written a book chapter on this topic. Read undertook a postdoctoral study with the Centre for Microbial Ecology & Genomics (CMEG) at the University of Pretoria, as well as one at the Biotechnology Platform of the ARC. He has published extensively on citrus tristeza viruses and on viruses of maize.

After completing his BSc (Agric) at Stellenbosch University in 1982, Johan Burger was appointed at VOPI, Agricultural Research Council, and did his two-year compulsory military service. He commenced full-time postgraduate studies at UCT in 1986 where he started an MSc, which was upgraded to a PhD and completed in 1991, with a thesis entitled "The characterisation of ornithogalum mosaic virus". This was under the supervision of Barbara von Wechmar and Ed Rybicki. Johan Burger then relocated to VOPI in Pretoria where he conducted research on coat protein-mediated resistance against potato leafroll virus and potato virus Y of potatoes, and the application of molecular markers (Isozymes, RFLPs and RAPDs) for seed-lot purity testing and cultivar identification on a semi-commercial scale; the identification of polygalacturonase inhibiting protein (PGIP) gene(s) in indigenous South African plants and the subsequent transfer to agronomically important crops. In 1995, he changed employment and joined the Biotechnology Division at Foodtek, Council for Scientific and Industrial Research (CSIR), also in Pretoria. Here he conducted plant biotechnology research on maize, sorghum, barley, millet, sunflower, soybean, chicory and horseradish. Burger returned to his home town of Stellenbosch in 1997 where he was employed in the Department of Genetics at Stellenbosch University, and he has remained there until the present. In this period, he has focused on grapevine virus and grape genomics research.

Johan Burger's group developed PCR-based detection assays for locally-important grapevine viruses, and used these to study the aetiology of important grapevine virus diseases. The group also conducted molecular characterisation of these viruses and their genetic variants, as well as the influence of these pathogens on their grapevine host at the molecular level. In 2006, the group was the first to report the presence of grapevine yellows disease, and characterised the phytoplasma causal agent of this devastating disease. Other key breakthroughs were the determination of the first "virome of a vineyard" in 2010, and the sequencing of the genome of the uniquely South African red wine cultivar, Pinotage. Currently, the group has embarked on the establishment of CRISPR/CAS9 genome editing technology in grapevine, with the ultimate aim to introduce drought tolerance and virus resistance in wine cultivars. A number of PhD studies on the aspects described above were completed under his supervision or co-supervision, including those of M-J Freeborough, J du Preez, HJ Maree, AEC Jooste, R Lamprecht, M Visser, R Bester, B Coetzee, M Snyman and G Cook.

Reon Brand was appointed at the ARC-CSFRI in Nelspruit following his undergraduate studies at Stellenbosch University in 1982. In 1985 he was seconded to US Department of Microbiology where he completed his BSc Hons (*cum laude*) under the supervision of Brenda Wingfield. During his BSc Honours year, he worked on dsRNA mycoviruses responsible for the "Killer Yeast" phenotype in *Saccharomyces cerevisiae.* Thereafter he was seconded to the Microbiology Department of UCT where he did an MSc on woodiness disease of passionfruit, which was upgraded to a PhD, under the supervision of Barbara von Wechmar and Ed Rybicki. In 1992, Reon Brand completed his PhD having discovered a new potyvirus designated South African passiflora virus (SAPV) (later cowpea aphid-borne mosaic virus, CaBMV) and cucumber mosaic virus in woodiness-affected passionfruit plants. He transferred to the ARC-Infruitec where he continued with work on viruses until he left the discipline in 1997. Reon Brand was probably the first person to produce a virus coat protein-expressing *N. benthamiana* plant, which, in collaboration with PPRI, was shown to mitigate the effect of its homologous virus (CaBMV); sadly, this work was never published.

Darren Martin completed a PhD with Ed Rybicki at UCT entitled "Maize streak virus: diversity and virulence". He subsequently did a postdoc with Carolyn Williamson at the UCT Faculty of Medicine and Health Sciences, where he was appointed in 2005 as a Senior Research Officer and in 2014 as an Associate Professor. Darren Martin is internationally recognized for his computational work on the detection of recombination, which started when he wrote the first version of the widely utilised RDP software program to determine how geminiviruses are recombining. He has conducted a large body of experimental and computational work using maize streak virus (MSV) as a plant virus model to assess constraints on the evolutionary value of genetic recombination, to predict and verify the biological functionality of genomic secondary structures and to determine the rates at which MSV is evolving. This was when it emerged how the virus has moved around Africa, and how its symptoms have evolved over the past 100 years. He co-supervised Aderito Monjane's PhD project with Ed Rybicki, which, with side work with several others, resulted in 22 papers on MSV and other mastreviruses. Darren Martin has collaborated widely internationally as well as with UCT colleagues EP Rybicki, D Shepherd, E van der Walt and J Willment, and has published widely on his research. Darren Martin's postdoctoral students Pierre Lefeuvre (2009-2011) and Benjamin Murrell (2014) have continued careers in plant virology; the former is now a senior researcher at CIRAD in La Réunion, and the latter an associate professor at the Karolinska Institute in Sweden. Darren Martin also conducts research on viruses of medical and veterinary importance.

Directly after Glynnis Cook completed her MSc under the supervision of Louis Nel (an animal virologist) at the University of Pretoria, she took up employment at the ARC-VOPI in 1992 under the leadership of Graham Thompson. She developed a number of detection systems, mostly ELISA-based, for viruses of vegetable and ornamental crops, and performed routine plant virology diagnostics. In 1994, she moved to the ARC-PPRI Virology unit under the leadership of Gerhard Pietersen, where she surveyed commercial peanuts for viruses, resulting in a number of identifications confirming previous first reports based on symptomatology and transmission alone. In collaboration with Gerhard Pietersen, Glynnis Cook identified and characterised a number of properties of peanut chlorotic blotch potyvirus, a previously undescribed virus. Glynnis Cook also collaborated on the establishment and evaluation of diagnostic techniques for banana viruses for screening local propagation material and as part of an international virus indexing centre for INIBAP, situated at PPRI. In 2006 Glynnis Cook was appointed as a plant pathologist at the tomato breeding facility of Sakata Vegenetics, where she optimised resistance screening methods for tomato spotted wilt virus and tomato mosaic virus, and conducted seed testing for seed transmitted viruses using ELISA and bioassays. In 2009, Glynnis Cook relocated to Nelspruit and was employed at CRI, where her research has focused on the requirements of the Citrus Improvement Scheme (CIS). In this regard, her research has focused on the CTV cross-protection programme implemented to mitigate the effects of this virus, for which she had conducted CTV strain genome characterization and biological expression. She is also investigating the effects of viroids on tree health and production. In 2019, Glynnis Cook completed her PhD at Stellenbosch University under the supervision of Hano Maree and Johan Burger, with a thesis entitled "Characterisation of citrus tristeza virus variants and their influence on symptoms expression in grapefruit".

After completing a BSc at the then University of the Orange Free State (UOFS), Elize Jooste joined the Virology Unit of the ARC-PPRI in Pretoria, then under the leadership of Gerhard Pietersen. She conducted research on the viruses of peas at PPRI, culminating in 2000 in an MSc entitled "Isolation, identification and characterisation of three viruses of *Pisum sativum* in South Africa" under the supervision of Ed Rybicki and Gerhard Pietersen. In that study she detected pea enation mosaic virus, broad bean wilt virus and the pea mosaic strain of bean yellow mosaic virus for the first time in South Africa. Elize Jooste also collaborated with Dariusz Gozczynski on studies of viruses of grapevine. She completed her PhD on "Molecular and biological characterisation of two divergent molecular variants of GLRaV-3" in 2011 under the supervision of Johan Burger and Dariusz Goszczynski. In 2017, Jooste relocated to the ARC-Tropical and Subtropical Crops (TSC) in Nelspruit where she works on banana bunchy top virus and citrus and avocado sunblotch virus. She was the first to identify banana bunchy top virus (BBTV), a devastating disease of bananas and new to South Africa, in samples submitted to her in 2016.

After attaining his PhD in Poland, Dariusz Goszczynski joined the research group of Gerhard Pietersen at PPRI in 1993, where he has remained. In this period, Dariusz Goszczynski has conducted research on various viruses of wine grapes. Initial studies were on grapevine leafroll associated viruses -1, -2, and -3, where he was instrumental in collaboration with Gerhard Pietersen and GG Kasdorf in developing ELISA methods for detection of these viruses that have been employed for over 20 years in the grapevine certification scheme. Dariusz Goszczynski was amongst the first to show the presence of biological strains of GLRaV-2; he revealed the serological relation between the Vitiviruses GVA and GVB; demonstrated the genetic variability of GVA and GVB; reported the association of genetic variants of GVA of group II with Shiraz disease. Later, Dariusz Goszczynski focused on studies on the grapevine vitiviruses grapevine virus A (GVA), and identified and deposited in GenBank full genomes of seven genetic variants of GVA and three genetic variants of GVB grapevine virus B.

Dirk Bellstedt, a biochemist by training, did his PhD at Stellenbosch University by developing a method for the production of antibodies. The expertise he gained in serology was subsequently applied in plant pathology for the detection of viral and bacterial pathogens of potatoes, vines and fruit trees. After his postgraduate studies, Dirk Bellstedt continued at Stellenbosch University until his retirement at the end of 2019, and has been appointed as an emeritus professor. Along with student Mark Matzopolous (MSc 2005) he developed ELISA kits for the detection of potato virus Y (PVY) and potato leafroll virus (PLRV) for use in the potato certification scheme. Dirk Bellstedt and MSc student (2007) Adrie Rothmann assessed the mutation patterns in South African strains of potato leafroll virus and the expression of recombinant viral coat protein genes in *E. coli.* Under Bellstedt's supervision, MSc (2008) and PhD (2012) student Chris Visser studied genomic variation, evolution, recombination and detection of PVY, and the development of techniques for strain detection. With Wiets Roos (MSc 2012; PhD 2018), Dirk Bellstedt determined the prevalence, detection and race identification of South African potato viruses and assessed the diversity and pathogenicity of PLRV. Bellstedt also supervised two MSc students working on pome fruit viruses, with Sophie Malan (MSc 2014) working on apple chlorotic leafspot virus (ACLSV) and apple mosaic virus (ApMV) and Emcee Gagiano (MSc 2015) working on apple stem grooving virus (ASGV) and apple stem pitting virus (ASPV). During the course of their studies both the latter students were employed at SAPO Trust, Stellenbosch, where they were engaged in plant virus control in the certification schemes of grapes, stone and pome fruit. Malan's and Gagiano's studies were the first comparison of South African isolates of ApMV, ACLSV, ASGV and ASPV to worldwide isolates.

Augustine (Gus) Gubba, did his undergraduate studies at the University of Zimbabwe (1982-1984), and received a BSc Crop Science Honours degree. He then joined the Zimbabwean Ministry of Agriculture as an extension officer responsible for curriculum development (1985-1986). He transferred to the Department of Research and Specialist Services in the same ministry and worked in the Plant Protection Research Institute (1986-1994). While in this position, he was awarded a British Council scholarship to study for an MSc Applied Plant Science at Wye College, University of London, UK (1987-1988). The title of the research dissertation was: "The effects of Zimbabwean isolates of cowpea mosaic and cucumber mosaic viruses on the early stages of growth of three cowpea varieties". In 1994, he was awarded a Rockefeller Foundation Fellowship to study for a PhD in the Department of Plant Pathology, Cornell University, USA, completing this in 2000 with a thesis entitled "Transgenic and natural resistance: towards developing tomato (*Lycorpersicon esculentum* Mill.) and pepper (*Capsicum annuum* L.) plants with broad resistance to virus infection". After graduation, he worked as a postdoctoral fellow for six months in the laboratory of his PhD supervisor, Dennis Gonsalves, at the Geneva Experimental Station in Geneva, New York. In December 2000, he joined the Department of Plant Pathology at the University of KwaZulu-Natal, where he is currently an associate professor.

Gus Gubba's research has focussed on the identification and characterization of viruses infecting fruit and vegetable crops and further to use the generated information to develop sustainable strategies to control diseases caused by these viruses, including the use of transgenic crops with virus resistance. Gus Gubba has supervised of a number of MSc and PhD students conducting studies mostly on South African plant viruses. The PhD students include Bernice Sivparsad (2009) who developed a transgenic sweet potato with a broad virus resistance; JD Ibaba (2016) who identified and characterized a number of viruses infecting cucurbits in KwaZulu-Natal; and V Moodley (2019) who studied whitefly-transmitted viruses of tomato and the impact of climate change on their epidemiology. Current PhD research projects focus on banana bunchy top virus and avocado sunblotch viroid. The major findings from the Gus Gubba research group include showing the efficacy of combining transgenic and natural resistance to combat the effects of tomato spotted wilt virus in tomato. Research findings have also led to the publication of several first reports of different virus species, infecting a number of plant species in South Africa and Zimbabwe. Two new virus species (zucchini shoestring virus and pepo-aphid borne yellows virus), which have since been officially recognized by the International Committee on Taxonomy of Viruses, are included in their research highlights. The emergence of a number of whitefly-transmitted viruses on tomatoes has recently been demonstrated by members of Gus Gubba's research group.

Lindi Esterhuizen completed her PhD in 2012 under the supervision of Henriette van Heerden at the University of Johannesburg (UJ), where she was co-supervised by Chrissie Rey of the University of the Witwatersrand and Schalk van Heerden of Sakata. Her study focussed on the epidemiology, molecular diversity and resistance to tomato curly stunt virus, a begomovirus recorded for the first time in 1998 by Gerhard Pietersen and unique to South Africa. Lindi Esterhuizen was appointed as a senior lecturer at the University of Johannesburg, where she continued research on sweet-potato-infecting viruses with collaborators Chrissie Rey (Wits), Schalk van Heerden (Sakata), Julia Mulabisana, Michelle Cloete, KG Mabasa, SM Laurie and Deon Oelofse (ARC-VOPI). She also conducted studies on turnip yellows virus associated with the *Brassica* stunting disorder in South Africa. This was done by her PhD student S-A New, in collaboration with Schalk van Heerden and Gerhard Pietersen. Lindi Esterhuizen left academia in 2018.

Michelle Cloete started her career at the ARC-Onderstepoort Veterinary Institute, but later moved to the ARC-VOPI, where she is based at present. Michelle Cloete worked on viruses of potato, sweet potato and various ornamental crops. Also, with Michelle Cloete at ARC-VOPI is Julia Mulabisana (née Domola), who has specialised in viruses of sweet potato, having completed her MSc in 2003 at the University of Pretoria under the supervision of Terry Aveling and Graham Thompson with a dissertation entitled "Survey and characterisation of sweet potato viruses in South Africa". She then did a PhD at the University of the Witwatersrand with Chrissie Rey in which Julia Mulabisana showed that sweet potato feathery mottle virus and sweet potato virus G were the most common viruses of sweet potato in South Africa. In collaboration with Johan Burger and Hano Maree at SU, Michelle Cloete and Julia Mulabisana helped determine the complete genome sequence of a novel polerovirus in *Ornithogalum thyrsoides* in 2019.

Hano Maree, a former PhD student of Johan Burger at SU, started his plant virology career by identifying and characterising grapevine leafroll-associated virus 3 genomic and subgenomic RNAs as part of his PhD, which he completed in 2010. While staying at Stellenbosch University with Johan Burger, Hano Maree undertook a postdoctoral study at the ARC-Biotech Platform until 2013, where he conducted research on using a metagenomic sequencing approach to study a range of plant virus diseases mainly in perennial crops. Following this he served as a senior researcher at ARC-Infruitec-Nietvoorbij until 2018, working mainly on grapevine and citrus disease. He was awarded an extraordinary associate professor appointment in 2017 at Stellenbosch University. In 2018, he was appointed as a biotechnology researcher at Citrus Research International.

Hano Maree sequenced the first complete genome of GLRaV-3, the main cause of the worldwide and important leafroll disease of grapevine. At Stellenbosch University several postdoctoral fellows and postgraduate students have been hosted and trained that contributed to Maree's research outputs. In the Maree group, they have specialised in the application of high throughput sequencing (HTS), first for virus discovery, but later to also study plant pathogen interactions and further development of the technology for implementation in routine diagnostics.

In the application of HTS for discovery, several novel viruses and new genotypes of viruses were discovered and characterised biologically and molecularly (postdoctoral fellows: R Bester and B Coetzee; PhD students: G Cook; MSc students: R Bester, N Molenaar, Y Espach, and I Mostert). Plant pathogen interactions were studied using combinations of small RNA and transcriptome HTS approaches with molecular validation (PhDs: M Visser and R Bester; MSc: DJ Aldrich). In the development of plant virus diagnostic assays using conventional molecular techniques and HTS, several assays and tools have been developed (postdoctoral fellows: M Visser, R Bester, PhD: G Cook and R Bester; MSc: TL Jooste). Rachel Bester undertook a PhD entitled "Small RNA (sRNA) profiling of grapevine leafroll associated virus-3 infected grapevine plants" and was appointed to successive postdoctoral positions from 2017 with Hano Maree at Stellenbosch University and at ARC-Infruitec-Nietvoorbij. She continues to conduct research on the development of GLRaV-3 detection assays, characterisation of plant-virus interactions in the GLRaV-3 pathosystem by applying high throughput sequencing, and using high-throughput sequencing for the detection of known and novel viruses and viroids.

10.0 Molecular Plant Pathology

Molecular plant pathology was largely led by the plant virologists (refer to section 9.0). In the case of plant bacteriology, DNA-based techniques were being deployed by numerous researchers in the 1990s to identify bacteria (refer to section 8.0). Brenda Wingfield was among the first in the country to use this technology to study fungi.

If one examines the abstracts of presentations at the SASPP meetings in the early 1980s, there was a focus by the virologists on immune assays, ELISA and antibody tests, particularly for viral disease. By the late 1980s, some of the presentations described using techniques such as GC/MS and HPLC. The first presentations using nucleic acid technologies were in 1986 and were by staff and students at the University of the Witwatersrand. Helen Garnett's group used DNA/DNA hybridisation for bacterial identification, Lise Korsten (University of Pretoria) presented work using Dot-Blots to study the sunblotch viroid and Barry Manicom (Citrus and Subtropical Fruit Research Institute) presented research using random DNA probes and Restriction Fragment Length. At the same time there was also work presented using Polyacrylamide Gel Electrophoresis (PAGE) to separate viral coat proteins and genomes.

In 1988, Ed Rybicki presented a nucleic acid workshop with Renate Koenig, assisted by Johan Burger and Reon Brand in Cape Town. This was a laboratory techniques course using cloned nucleic acid probes, dot blotting, southern and northern blotting technologies. The focus of the workshop was on viruses, fungi and bacteria for which probes were available. In many ways, that workshop served to launch many other studies on plant pathogens using nucleic acid-based techniques.

Brenda Wingfield's research on the identification of fungi was based on ribosomal RNA sequences. While she had learnt how to do Sanger sequencing during her MSc degree in Minnesota, there was no other way at the time, to easily use nucleic acid sequences for identification of fungi. She spent two months in the USA with Cletus Kurtman to learn how to isolate and sequence rRNA, similar but different to DNA. This technique was rapidly replaced when the polymerase chain reaction became available, and made it possible to target DNA sequences. In the early days, sequence data were not available for many genes and researchers were reliant on a limited number of primers, often degenerate primers.

While Brenda Wingfield and her students were developing a strong base in phylogenetics using PCR, the virologists were using this technology to sequence an increasing number of viruses and developing their own phylogenies. The bacteriologists started with bacterial plasmids and this was profiled by a presentation from the Bala and Gansen Pillay collaboration in 1991. At the same time, genetic modification of plants was also becoming more accessible and Jennifer Thompson was invited to speak at two SASPP meetings in the early 1990s. Much of the early GMO work was done using *Agrobacterium tumefaciens*, a well-known plant pathogen, as a vector.

In 1992, Brenda Wingfield was invited to give a keynote address at the SASPP meeting held in Cintsa, Eastern Cape, where she presented the first DNA sequence-based phylogenetic work to have been undertaken in South Africa. This meeting was more memorable for the fact that it was held in a tent, than necessarily only for the science. The focus of the meeting was very much on molecular technologies and Ed Rybicki also presented a keynote address on molecular taxonomy of the potyviridae.

The early 1990s saw many presentations using Restriction Fragment Length Polymorphisms (RFLPs) and Random Amplified Polymorphic DNA sequences (RAPDs) for diagnostics of plant pathogens. In 1994, there was a whole session on systematics at the SASPP meeting and this included presentations using RAPDs and RFLPs and AFLPs (Amplified Fragment Length Polymorphisms). These technologies are hardly seen in the literature today. RAPDs, while useful at the time, provided unduly variable results between laboratories while RFLPs have largely been replaced by DNA fragment sequencing. AFLPs, while very useful and popular for population analyses, have largely been replaced by microsatellite analyses.

In the mid-1990s Brenda Wingfield worked on dsRNA viruses in a variety of plant pathogens. This is reflected by a number of presentations by students in her research programme at the SASPP meetings. In the mid-1990s, there was an increase in studies using bacterial transformation systems predominantly from researchers at the University of Cape Town. In addition, there were a number of presentations on genetic engineering of plants from researchers at the CSIR.

The names of researchers reflected in the SASPP abstracts during the 1990s strongly reflect some of the research leaders in the field today. Ed Rybicki features strongly in his work on viruses, as does Caroline Williamson, who completed a PhD under Rybicki's supervision. Chrissie Rey and her research group also feature very prominently. The University of Pretoria was strongly represented by the work of Lise Korsten and Ballie Kotzé. Free State University was very obvious with many presentations by Brenda and Mike Wingfield's students. Interestingly, Molapo Qhobela (previous CEO of the NRF) participated actively, often in association with Mark Laing at the University of Natal in Pietermaritzburg. Mark's contribution to the field is also clear during this time, as are the many presentations from Durban-Westville, many of which involved Bala and Gansen Pillay.

By 1999, many of the molecular techniques mentioned above were in common use, as is evident from the presentations at the 1999 meeting. In the early 2000s, the application of DNA sequencing increased dramatically. There was also an increase in phylogenetic studies being presented at the meetings. Initially, most of the presentations came from FABI at the University of Pretoria, but by the end of the 2000s, use of this technology by many laboratories in the country was obvious. In addition, during the 2000s there was an increase in the number of studies where microsatellite markers were being developed and used in population studies on fungal pathogens.

While there were already a number of bacterial plant pathogen genomes available in the early 2000s, the availability of fungal genomes lagged behind significantly. The first plant pathogen to have its genome sequenced in Africa was *Pantoea ananatis*, the cause of bacterial blight and die-back of *Eucalyptus*. This was done by Teresa Coutinho and her group in the mid-2000s. The reason why bacterial genomes were commonly sequenced was due to the cost of DNA sequencing at that time. Bacterial genomes are significantly smaller than their fungal counterparts and the fungi were consequently much more expensive to sequence. The first quote received to sequence the *Fusarium circinatum* genome was R3 million. Brenda Wingfield and her group finally sequenced the genome of that fungus in 2009 at a cost of just over R300 000. This seems hugely expensive by today's standards where one can get a low-level genome sequence of a fungus for a few thousand rand - and these prices continue to decline.

The genome of a fungus, the brewer's yeast *Saccharomyces cerevisiae*, was published in 2000. The fact that just a decade later, it was possible to sequence a non-model fungal genome relatively inexpensively speaks volumes to the rapid developments in DNA sequencing technology globally. Ten years on from sequencing the first fungal genome in South Africa, various plant pathologists are now conducting population genomics studies based on large numbers of fungal genomes. This work is also enabling teams such as those at FABI to conduct genome-wide association studies on important plant pathogenic fungi. These studies, linked to phenotypic traits, have the potential to allow for a better understanding of how fungal and bacterial pathogens cause disease and how they evolve resistance to fungicides and crop-plant cultivars. This information will be essential in developing management strategies for plant pathogens in the future.

Alongside the development of DNA sequencing technologies and their application by plant pathologists in South Africa, there has been an increase in genetic modification of plant pathogens. A multiplicity of transformation technologies have been presented at SASPP meetings during the course of the last 10 years. The most common studies have used *Agrobacterium tumefaciens* as a transformation vector. This has, however, rapidly been followed by random and specific integration of DNA sequences using protoplasts and most recently the use of the new CRISPR technology. Molecular Biology and the associated technologies have led to a revolution in plant pathology research, and South African plant pathologist have not lagged behind their colleagues globally in embracing these opportunities.

11.0 Symposia, Workshops and Courses

In this section we include symposia, workshops and courses organised in South Africa, but not linked to the Southern African Society for Plant Pathology (SASPP) congresses. The list is not comprehensive and availability of information has determined those that have been included. This information either came from SASPP newsletters or from the plant pathologists who organised these events.

11.1 SYMPOSIA

International Symposium on Mycotoxins and Phycotoxins

The 6th IUPAC symposium was held from 22-25 July 1995 in Pretoria under the auspices of the International Union of Pure and Applied Chemistry. More than 250 delegates from South Africa and 23 overseas countries participated in the 14 sessions of oral presentations, including 60 invited papers and 13 plenary lectures. During the poster session, 79 posters were displayed for perusal and discussion.

The president of the CSIR, CF Geber delivered the opening address of the 6th IUPAC, after a welcome from the chairman of the organising committee, PS Steyn. Thereafter, CW Hesseltine, a mycologist from the Northern Regional Research Centre, Peoria, Illinois, delivered the keynote address on "Global significance of mycotoxins". This set the stage for the remainder of the congress, which included lectures on structures of mycotoxins and phycotoxins, synthesis and biosynthesis of toxins and metabolites, detection and determination of mycotoxins, pathology of myco- and phycotoxins and the biology of toxigenic fungi. These fields were also covered in the posters.

The lectures were without exception interesting, informative, stimulating and well prepared. The quality of papers given by South Africans demonstrated clearly why they were at the forefront of mycotoxicology research. Wally Marasas presented a paper on "*Fusarium moniliforme*: a mycotoxicology miasma" and Chris Rabie on the "Important lesser-known toxigenic fungi". Marasas showed that although *F. moniliforme* is a common and widespread fungus that poses a real threat to human and animal health, it is surrounded by confusion and ignorance with respect to its taxonomy and toxicology. Rabie reported on toxins produced by species of *Rhizopus* which are common contaminants of sorghum malt and low grades of oats, and the neuromuscular disease of ruminants, diplodiosis, caused by *Diplodia maydis*, an important pathogen of maize.

Source: SA Plant Pathologist Plantpatoloog Vol. 5 (1), 1985

Annual Soilborne Plant Disease Symposia

Soilborne diseases represent some of the most important yield-limiting factors in crop production. The complexity of interacting factors underlying soilborne diseases often requires multidisciplinary research to develop management strategies for these diseases. To improve interdisciplinary communication and networking and to foster multidisciplinary collaboration on soilborne diseases, the Soilborne Plant Diseases Interest Group of South Africa (SBPDIG-SA) was established in 1990 by Sandra Lamprecht of the Soilborne Plant Diseases unit of the Agricultural Research Council's Institute for Plant Health and Protection. The organising committee of the group included members from different institutions and, since 1990, symposia have been held annually (excluding 2003), to introduce and discuss topics relating to soilborne diseases of importance to agriculture. The topics addressed to date are:

- **1990** Common interests between soil science and research on soilborne plant diseases
- **1991** Minimum tillage and soilborne plant diseases
- **1992** Water and soilborne plant diseases
- **1993** Propagation material and soilborne plant diseases
- **1994** Soil rehabilitation and soilborne plant diseases
- **1995** Resistance and soilborne plant diseases
- **1996** Integrated pest management and soilborne plant diseases
- **1997** Plant stress and soilborne plant diseases
- **1998** Sustainable agriculture and soilborne plant diseases
- **1999** Methyl bromide and soilborne plant diseases
- **2000** Beneficial organisms and soilborne plant diseases
- **2001** Organic farming and soilborne plant diseases
- **2002** Soil and soilborne plant diseases
- **2004** Crop rotation and soilborne plant diseases
- **2005** Ecology and soilborne plant diseases

- **2006** Micronutrients and soilborne plant diseases
- **2007** Integrated management and soilborne plant diseases
- **2008** Soil health and soilborne plant diseases
- **2009** Soil biology and soilborne plant diseases
- **2010** Compost and soilborne plant diseases
- **2011** Advances in technology and soilborne plant diseases
- **2012** Interactions and soilborne plant diseases
- **2013** Resistance and soilborne plant diseases
- **2014** Integrated management and soilborne plant diseases
- **2015** Multitrophic interactions and soilborne plant diseases
- **2016** Soil rehabilitation and soilborne plant diseases
- **2017** Climate and soilborne plant diseases
- **2018** Diversity and soilborne plant diseases
- **2019** Propagation material and soilborne plant diseases

Many prominent international researchers were invited and sponsored by private companies to be keynote speakers at the symposia (refer to Table 1).

Participants at the annual soilborne disease symposia represent a wide range of disciplines, including agronomy, botany, economy, ecology, entomology, genetics, horticulture, meteorology, microbiology, soil microbiology, nematology, plant pathology, plant physiology, soil science and zoology. It is this multi-disciplinary nature that distinguishes the annual Soilborne Plant Diseases Symposium from other conferences/symposia focused on plant diseases. Following presentations, ample time is given to discussion, which is usually held in a semi-formal manner. Given that the delegates represent a diverse range of disciplines, post-presentation discussions often yield diverse and novel views to approach soilborne diseases.

Discussions on current research and a wide-range of aspects regarding soilborne diseases are held the afternoon prior to the symposium. In the past, separate discussion groups have been held on some of the main fungal genera involved in soilborne diseases such as *Fusarium*, *Rhizoctonia*, *Pythium/Phytophthora* and others, as well as bacteria and nematode discussion groups. Since many soilborne diseases are caused by a complex of pathogens, the need arose to integrate these discussion groups. Consequently, there is now only one discussion group that includes all the major soilborne fungal pathogens as well as nematodes. Topics that are discussed, amongst others, include research methodology, taxonomy, reporting of new diseases as well as management strategies. This also allows for one of the few occasions where researchers working in similar fields can meet and discuss topics of interest annually.

The topic for the 2020 symposium is “Plant health and soilborne plant diseases”. This topic was decided on at the annual general meeting of the 2019 symposium, since 2020 is the UN’s International Year of Plant Health. This also coincides with the 30th Annual Symposium of the SBPDIG-SA. Permission has been obtained by the FAO to list the 2020 Symposium on their website as part of the list of global events of the International Year of Plant Health.

The symposia are held shortly before the South African September school holidays. Following the discussion group meeting on the Tuesday, the symposium begins on the Wednesday morning and ends with lunch on Thursday. Catering for the Wednesday evening dinner has, for the past 14 years, been provided by Muisbosskerm, who prepare all the seafood dishes that are served at Muisbosskerm restaurant near Lambert’s Bay for the delegates. Entertainment for the evening has been provided over the years by the Kaapse Klopse, a drumming circle, and enactments of stories by author Herman Charles Bosman, amongst others. It is these stories of Bosman that resulted in a new tradition, namely the “bloubaadjies” (blue coats). In his autobiographical essay, Cold Stone Jug, Bosman described how habitual criminals were eventually classified by the criminal justice system as repeat offenders, after which they received blue overall coats with their prison number and number of years served embroidered onto the front of the jacket. They were not sentenced for a specific term, but served their sentences at the grace of His Majesty, whose Administration decided their fate in terms of time served, previous parole etc. In keeping with this practice, it was decided that delegates who had attended at least 20 symposia would receive a blue coat, onto which is embroidered their surname and initials, as well as the year they first attended a symposium. This would be followed by a hyphen (-) and a blank space, symbolising that they would thereafter be classified as repeat symposium attendees who are sentenced to a lifetime of symposium attendance, with no chance of parole. To date, Sandra Lamprecht, Alta Schoeman, Ferdi Van Zyl, Annette Swanepoel, Sheila Storey, Neal McLaren and Johan Janse van Rensburg are recipients of the prestigious blue jacket.

TABLE 1 LIST OF KEYNOTE SPEAKERS WHO PRESENTED AT THE ANNUAL SOILBORNE SYMPOSIA

Year	Keynote speaker	
1994	Yaacov Katan	Volcani Center, Israel
1999	Mark Mazzola	USDA-ARS, USA
	Mohamed Besri	Institute Agronomique et Veterinaire Hassan II, Morocco
2001	Bill R Quinn	New Zealand
2002	Christian Steinberg	INRA, Centre of Microbiology of the Soil and the Environment, France
	Mark Mazzola	USDA-ARS, USA
2005	Mark Mazzola	USDA-ARS, USA
	Patrice Cadet	Institute of Research for Development, France
2007	Richard Sikora	University of Bonn, Germany
2008	George Abawi	Cornell University, USA
2009	Janice Thies	Cornell University, USA
	Mark Mazzola	USDA-ARS, USA
2010	Aad Termorshuizen	BLGG Agro Xpertus, the Netherlands
2011	Pedro Crous	Centraalbureau voor Schimmelcultures, Utrecht, the Netherlands
	Philippe Lucas	INRA, Biology of Organisms and Populations for Plant Protection (BiO3P) Research Unit, France
	Harold van Es	Cornell University, USA
2012	Deborah Neher	University of Vermont, USA
2013	Jay Scott	University of Florida, USA
2014	Frank Louws	North Carolina State University, USA
2015	Beth Gugino	Pennsylvania State University, USA
2016	Abraham Gamliel	Volcani Center, Israel
	Mark Mazzola	USDA-ARS, USA
2017	Leandro Marcuzzo	Instituto Federal Catarinense – IFC, Brazil
	William Underwood	ARS-USDA, Northern Crop Science Laboratory, USA
2018	Patrick Lavelle	The University of Pierre et Marie Curie, France
	Michael Raviv	Newe Ya'ar Research Center, Israel
2019	Lindsey du Toit	Washington State University, USA

The annual symposia of the Soilborne Plant Diseases Interest Group of South Africa contribute significantly to create awareness not only of the importance of soilborne plant diseases, but also of the complexity of research on these diseases. Likewise, on the importance of multidisciplinary collaboration to develop management strategies for sustainable crop production.

Third International Bacterial Wilt Symposium

The third international symposium was held from 28 February 2002 in White River, Mpumalanga. The symposium was organised by Jody Terblanche (ARC-IC) and her team. This meeting was attended by a number of researchers from Asia, Africa, Europe and South

America, as well as from the USA and Australia. Topics included plant-pathogen interactions, plant defence responses, virulence mechanisms, signalling pathways and management strategies.

11.2 WORKSHOPS

Fusarium Workshops

1984

The first workshop on the taxonomy of *Fusarium* species was held from the 23-27 July 1984 in Stellenbosch. The workshop was led by LW Burgess (from Australia) and WFO Marasas. Attendees were researchers who, at the time, were actively engaged in *Fusarium* research. The workshop focused on the taxonomy of those *Fusarium* species that are plant pathogens or caused mycotoxicosis.

2003 AND 2015

Every year a hands-on international *Fusarium* laboratory workshop is held, either at Kansas State University (KSU) or in intervening years at different locations in the world. The scope of the workshop includes morphological and molecular characterisation of species in this important fungal genus. In 2003 and 2015, the Forestry and Agricultural Biotechnology Institute (FABI) at the University of Pretoria hosted the workshops. The instructors were internationally recognised experts in the field of *Fusarium* taxonomy. They included David Geiser (Department of Plant Pathology and Director of the *Fusarium* Research Center, Pennsylvania State University, USA), John Leslie (Department of Plant Pathology, Kansas State University, USA), Wally Marasas (South African Medical Research Council), Brett Summerell (Royal Botanic Gardens, Sydney, Australia) and Brenda Wingfield (FABI). Additional instructors were recruited for the workshop held in 2016, namely Emma Steenkamp, Mike Wingfield, Gerda Fourie and Lieschen de Vos from FABI, Pedro Crous and Lorenzo Lombard from the Westerdijk Fungal Biodiversity Institute, the Netherlands and Gordon Shephard (Institute of Biomedical and Microbial Biotechnology, Cape Peninsula University of Technology).

The *Fusarium* Laboratory Workshop held in South Africa followed a similar format to those held at KSU. They included lectures on a wide range of topics, such as laboratory strain identification, molecular identification, mycotoxins, VCG analysis, mating types as well as species concepts, phylogenetics, population genetics and genomics. The hands-on laboratory sessions taught participants how to culture, isolate and store strains and how to use PCR, DNA sequences and BLAST searches for molecular identification. The participants were also given the unique opportunity to observe and compare the various morphological characters of more than 80 *Fusarium* species in one week.

Forty-two delegates from seven African countries, Sweden, the Netherlands, Switzerland, Venezuela, Chile, Brazil, Argentina, USA, Canada and New Zealand attended the 2004 workshop. Thirty delegates from 11 countries, including South Africa, Zimbabwe, Nigeria, Philippines, New Zealand, Australia, the Netherlands and Norway attended the 2016 workshop. Whilst both workshops were more southern hemisphere focused in terms of delegates, it allowed researchers from the northern and southern hemisphere countries to interact and foster new collaborative efforts that would further research on this important fungal genus.

Mycorrhizae Workshop

A mycorrhizae workshop was held in Pretoria from 10 to 12 June 1997, organised by Beatrix Bouwman (ARC-PPRI). More than 50 participants attended, representing 26 organisations and 11 institutions. Although the majority of the participants were from South Africa, researchers from Zambia and Kenya also attended.

Joe Morton, the curator of the International Culture Collection of VA Mycorrhizal Fungi (INVAM) at the University of West Virginia, presented a lecture on arbuscular mycorrhizal (AM) fungi. He discussed the management of indigenous AM, current methods used to manipulate and restore inoculum, the types of infectious propagules, when introducing inoculum is feasible and the evaluation of inoculum production. He closed his presentation by discussing some proposed applications of mycorrhizal fungi, which included site rehabitation and inoculation of bare rooted plants and seedlings prior to transplant. This presentation was followed by an introduction to the ectomycorrhizae and their applications by Joanne Dames (Rhodes University) and Samina Khalil (University of Pretoria), and the ericoid mycorrhizae by Colin Straker (Wits).

During the two-day hands-on workshop presented by Joe Morton, the basic taxonomy, life cycles and ecology of the Glomeralean fungi were covered.

The production of inoculum, storage conditions and inoculum properties were also discussed.

11.3 COURSES

An annual seed technology course at the Margaretha Mes Institute for Seed Research, within the then Department of Botany at the University of Pretoria was presented by various lecturers from the department during the 1980s and 1990s. These included Albie van der Venter, Albert Eicker, Veldie van Greuning, Lou Coetzer, Hannes Robbertse and Terry Aveling. Terry Aveling completed the course in 1988 and took over lecturing the seed pathology section from Albert Eicker in subsequent years. The course typically commenced on a Monday with welcoming drinks on the first evening. It ran over a week and concluded on a Friday with a lunch, when certificates were handed out to the delegates. It is no wonder that it is fondly remembered by the older members of the seed industry fraternity. Unfortunately, the Seed Institute was closed when Albe van de Venter took early retirement and with it, the termination of the seed technology course.

At some stage the seed technology course was again offered to the seed industry by two of Albie van de Venter's graduated PhD students (Gwen Koning and Bridget Hamman) at the University of the Western Cape. Later the seed industry had to search for new presenters when Gwen and Bridget were employed by Syngenta in Switzerland. By this time Terry Aveling had established herself as a seed scientist and pathologist, training many postgraduate students in seed science, seed pathology and seed treatment in the Department of Microbiology and Plant Pathology and later in the Department of Plant and Soil Science, both at the University of Pretoria. The South African National Seed Organisation (SANSOR) subsequently approached her to present the course to the seed industry.

All seed analysts must successfully complete the Seed Technology course and have a pass mark above 70% in order to be registered as South African seed analysts. Since 2006, the course is run annually by Terry Aveling, and Quenton Kritzinger supports her in this task. Occasionally guest lecturers are invited, or students have a chance to present a small component and thus to gain experience and exposure to members of the seed industry. The course includes the latest rules and methods validated by the International Seed Testing Association (ISTA), including those of the various committees such as the ISTA Seed Health Committee. Presented work includes plant classification, plant reproduction, seed physiology and dormancy, genetics, seed vigour, seed storage, seed treatment and seed pathology.

12.0 *Phytophylactica* – a South African Plant Pathology Journal

The first volume of the journal *Phytophylactica* was published in 1969 by the Department of Agricultural Technical Services, later by the Department of Agriculture. The journal focused on plant protection sciences and microbiology and included articles on topics such as entomology, nematology, plant pathology and mycology. The editorial board consisted of a chairman and a number of scientists from both academia and the government, as well as an editor. The first chairman of the journal was DM Joubert (from 1969-1978) followed by BW Strydom (from 1979-1993). The editor from 1969-1973 was Q Momberg. PJJ Steyn was appointed editor in 1974 and remained in that position until 1993. Four issues were published each year, except in the first year when issues three and four were combined, and in the last year of the journal (1993), when only three issues were published.

The publication of the journal was discontinued at the end of 1993. There were a number of reasons for this decision. The scientific community felt that its impact was very low and the Department of Agriculture was no longer willing to cover the publication costs. There were discussions in SASPP as to whether or not they could cover the printing costs, but this would have resulted in significant increases in membership fees. The publication of the journal was therefore discontinued.

In 1995, *Phytophylactica* was replaced by the journal *African Plant Protection*, which was published under the auspices of the Agricultural Research Council with open access. This journal was published until 2016. It provided a unique forum for research in the plant protection sciences, and promoted African authorship and/or content. The journal was multidisciplinary and included original research and review articles, both basic and applied, in the pest management of crops and plants.

13.0 Organisations/Associations Producing Specific Agricultural or Forestry Produce

13.1 HORTGRO

Hortgro's roots date back to the spring of 1652 when the Dutch East India Company founded the Cape of Good Hope as a refreshment outpost for its passing ships. Deciduous fruit trees, as well as a number of other crops, were planted to supply ships with fresh produce. On 17 April 1662, the first two ripe apples (*Wittewijn appels*) were picked in the Cape. Stone fruit and pears followed. Gradually small farmers started experimenting with other fruit crops and sold their produce to passing ships.

The South African fruit export industry was "founded" by Percy Molteno in 1892 when he successfully exported a small consignment of 14 cases of peaches to the United Kingdom, which was sold at the Covent Garden market. The fruit left Table Bay harbour on 13 January 1892, destined for England on board the Drummond Castle. When the consignment arrived 19 days later, less than 5% of the fruit had suffered damage. Thereafter, the fruit export market blossomed, and by 1903 more than 22 000 fruit packages were being exported.

After years of exporting individually, the deciduous fruit producers realised they needed a governing body to offer support and the Deciduous Fruit Exchange was established in 1926. This name was later changed to the Deciduous Fruit Board (1939), Universal Fruit Trade Co-operative (1987), Unifruco (1989), Deciduous Fruit Producers' Trust (1997) and ultimately Hortgro in 2013.

Hortgro has two main members: Hortgro Stone (SASPA) and Hortgro Pome (SAAPPA). Hortgro Science funds research focused on generating new knowledge, technologies or practices that are required to mitigate, avoid or overcome threats and risks and to exploit opportunities. Their Crop Protection Programme is multidisciplinary and includes research on nematology, entomology and plant pathology. The programme includes a number of themes, including phytosanitary and market access, nematology, soil health, pre- and postharvest pathology, integrated pest management and precision agriculture. Sustainability of the fruit production process is regarded as a critical aspect in crop protection research and emphasis is placed on biological control of pests and diseases, orchard ecology, phytosanitary issues and precision agriculture.

Source: https://hortgro.co.za/ (as on 1 September 2020)

South African Stone Fruit Producers' Association (SASPA)

In August 1990, the Plum Producers' Association and the Nectarine and Peach Producers' Association dissolved and founded the South African Stone Fruit Producers' Association (SASPA). Following the changes initiated by the new Agricultural Marketing Act of 1996, SASPA converted to a Section 21 (non-profit) company in 1997. In 2018 SASPA changed its name to Hortgro Stone, in line with the continuous growth of the industry.

Today, South African stone fruit growers produce plums, peaches, apricots, nectarines and cherries. Approximately 350 000 tonnes of apricots, nectarines, peaches and plums are produced per year, from over 18 000 hectares of planted trees. Apricots contribute 16% to the total production, peaches and nectarines collectively account for 60%, and plums a further 23%. South Africa exports only 22% of its total stone fruit production, as the greatest proportion of apricots and cling peaches are processed. Half of all peaches and nectarines destined for the fresh market are sold on the local market. Plums are the exception, with 74% of production exported to mainly the European Union, the United Kingdom and the Middle East.

Major diseases of stone fruit include brown rot blossom blight and fruit rot caused by *Monilinia laxa, Botrytis cinerea* and *Rhizopus* spp. They are important, as they cause problems in storage and transit. Bacterial canker, Leucostoma canker and powdery mildew are preharvest diseases that can cause significant economic losses.

Source: https://postharvestinnovation.org.za/commodities/stone-fruit/ (as on 1 September 2020)

South African Apple and Pear Producers' Association (SAAPPA)

Hortgro Pome, previously known as the South African Apple and Pear Producers' Association (SAAPPA), was established in the early 1970s to promote and protect the interests of the apple growers, and later also those of the pear growers of South Africa. The association is a Section 21 (non-profit) company, which is administered by a board of directors representing the main pome fruit production regions in South Africa.

As mentioned above, the pome fruit industry has a long history in South Africa. By 1916, three million apple trees had been planted in the country and by 1966, five million cases of apples were being exported annually. Today, there are over 35 000 hectares of pome fruit trees planted in South Africa and over 1.2 million tons of fruit produced each year. Some 45% of the total pome fruit production is destined for the export market, with the main destinations being the Far East and Asia, Africa and the EU.

The major postharvest pathogens on apple and pear fruit grown in South African orchards are the latent fungal pathogens, *Botrytis cinerea* and *Neofabraea vagabunda*. The diseases caused by these two pathogens are grey mould and bull's eye rot, respectively. Often the symptoms of the primary disease-causing pathogens are masked due to secondary fungal pathogens such as *Penicillium expansum,* which causes blue mould. Pre-harvest diseases of pome fruit include apple scab, caused by *Venturia inaequalis*, and powdery mildew caused by *Podosphaera leucotricha*.

Source: https://postharvestinnovation.org.za/commodities/pome-fruit/ (as on 1 September 2020)

13.2 SOUTH AFRICAN PLANT IMPROVEMENT ORGANISATION (SAPO) TRUST

The idea of plant improvement started as early as 1945 when SJ du Plessis, then chief of quarantine, stated that better quality plant material was needed for the deciduous fruit industry to meet profitability and market demands. It was evident that for deciduous fruit growers to become more competitive, factors associated with the plant material that limited production performance had to be eliminated. Those limiting factors relate to the presence of harmful pathogens such as viruses, as well as poor genetic material. In 1974, the Deciduous, Canning and Dried Fruit Boards founded the South African Plant Improvement Organisation (SAPO) as a partnership agreement with equal representation and clear objectives of supplying improved plant material to the industry. The deciduous fruit industry expanded rapidly and two independent plant improvement organizations, TopFruit (in 1983) and Stargrow (in 1992), were registered. Meanwhile, in 1988, the Department of Agriculture decided that they could no longer take sole responsibility for the management of plant improvement. Following this, the Deciduous Fruit Plant Certification Scheme was announced in 1993 under the Plant Improvement Act (Act No. 53 of 1976). New facilities for virus elimination were established and SAPO began to sign contracts with breeders and developers around the world. They continue to act as the plant improvement and distribution agent for many of them.

In 1999, SAPO became a Trust and the name was changed to SAPO Trust with the five producer associations as beneficiaries (Hortgro Pome, Hortgro Stone, the Canning Fruit Producers Association, SA Table Grapes and Raisins SA). Their objective is to ensure that plant pathogens occurring within South African pome and stone fruit trees and table grapes planting material is minimized or eliminated, before being supplied to the industry. The plant material is initially established and multiplied using the nucleus plants at Fleurbaix just outside of Stellenbosch. SAPO Trust also established their own foundation blocks in all the different climatic areas where these plants are established and a stone fruit nursery and foundation facility at Tygerhoek, Riviersonderend.

SAPO has its own laboratory where ELISA and PCR tests are performed on pome and stone fruit and table grapes. Plant material is tested for several virus diseases as prescribed by the Certification Scheme and field inspections are performed to ensure that plants are disease and pest free and true to type. High quality planting material is supplied to the nurseries and producers.

Chris Goodman was employed as the plant pathologist for SAPO from 1984-1981. He was replaced by Ferdi van Zyl, who resigned from his position as manager of the section Plant Improvement, Disease Management and Testing in 2015. Currently, Roleen Carstens is the senior plant pathologist responsible for the laboratory where SAPO test for the viruses that are prescribed in the Deciduous Fruit and Grapevine Plant Improvement Scheme. Roleen Carstens is also involved with investigation of disease problems in commercial plantings. Lize van der Merwe is the Senior Laboratory Analyst responsible for ELISA and PCR testing of viruses and other pathogens, as well as improvement of pome fruit, stone fruit and grapevines using virus elimination procedures.

13.3 SUBTROPICAL GROWERS' ASSOCIATION (SUBTROP)

The main objectives of Subtrop are to promote and enable the farming, marketing and distribution of avocados, mangoes and litchis, and to provide services to its member associations as required. Their members include the South African Avocado, Litchi and Mango Growers' Associations.

Source: https://www.subtrop.co.za (as on 1 September 2020)

South African Avocado Growers' Association (SAAGA)

After the establishment of the first avocado orchard in the 1920s by Harry Ludman, the number of farmers who began to produce avocado crops grew rapidly. In the mid-1960s, these same farmers realised that they needed to co-operate if they wished to obtain the greatest possible benefits from their investments.

On 27 November 1967, the first meeting of avocado growers was held at Westfalia Estates near Tzaneen. The farmers discussed the possibility of better communication and the chances of increasing the potential they saw for the avocado on the overseas markets. Ballie Kotzé was the chairman at the meeting. He retired as the research co-ordinator in 1994. The meeting led to the formation of an Avocado Growers Export Co-ordinating Committee with AJ Cresswell of Koolkat (Pty) Ltd, an export agent, as convener. In January 1969, the name was changed to the Transvaal Avocado Growers' Association, and thus the organization continued until 9 August 1971, when it became known as the South African Avocado Growers' Association.

Today, the South African avocado industry consists of 17 500 hectares of commercial avocado orchards, the majority of which are situated in the north-eastern part of the country in the Limpopo and Mpumalanga provinces. Avocados are also grown commercially in certain areas of KwaZulu-Natal province and parts of the Eastern and Western Cape. Annual production is in the region of 125 000 tonnes, of which approximately 60 000 tonnes is exported to Europe and the United Kingdom. The remainder is consumed domestically, of which approximately 10% is processed (oil and purée).

The disease which is the major limiting factor in avocado production today is Phytophthora root rot caused by *Phytophthora cinnamomi*. Other diseases that cause considerable losses of avocado in South Africa are white root rot (*Rosellinia necatrix*), Avocado Sunblotch viroid disease and Cercospora spot (*Pseudocercospora purpurea*). Diseases of varying importance include Armillaria root rot, Botryosphaeriaceae die-back, Verticillium wilt and several leaf and fruit spots. Postharvest diseases cause fruit blemishes and fruit rots which are of importance in the fresh produce and export market. They are caused by species of *Colletotrichum* (*C. siamense*), *Lasiodiplodia* (*L. theobromae*), *Diaporthe* (*D. perseae*), *Sphaceloma* (*S. perseae*) and *Nectria* (*N. pseudotrichia*).

South African Litchi Growers' Association (SALGA)

South Africa is a fairly young litchi-producing country in comparison to China. Worldwide, litchis were obtained from China with records dating back to more than 2100 years BC, and trees were distributed around the world to tropical and subtropical areas. In the southern hemisphere litchis were first planted in Madagascar, Mauritius and the east coast of Central Africa. Litchis reached South Africa from Mauritius in 1875 and the first and oldest litchi orchards were established on the east coast of South Africa. Litchi plantings spread from Durban to the Mpumalanga province, as well as other suitable frost-free areas of the country.

Today, the South African litchi industry consists of 1 730 hectares of commercial litchi orchards, the majority of which are situated in the north eastern part of the country in the Limpopo and Mpumalanga provinces. Annual production is in the region of 6 000 tonnes per annum, with product sold as fresh fruit and to juice processors. Europe is presently the largest export market.

The predominant fungal genera associated with litchi in South Africa are *Phomopsis, Pestalotiopsis, Penicillium, Trichoderma, Alternaria, Botryosphaeria* and *Fusarium* spp. Many *Penicillium* spp. have been isolated post-harvest from litchi fruit, of which *P. expansum* is the major pathogenic species.

South African Mango Growers' Association (SAMGA)

Mangoes were introduced into South Africa in the 17th century. Today, the South African mango industry consists of 6 000 hectares of commercial mango orchards producing around 74 000 tonnes per annum. Approximately two thirds of the crop is processed for juice, dried mango and achar. Most of the remainder of the crop is consumed as fresh fruit in South Africa, and some fruit is exported to the Middle East, Africa and Europe. The main growing areas are in the Limpopo and Mpumalanga provinces.

Powdery mildew, blossom malformation, blossom blight and bacterial black spot are important preharvest diseases, with anthracnose and soft brown rot causing most of the postharvest problems. Among these, the main diseases are anthracnose (*Colletotrichium* spp.), powdery mildew (*Oidium mangiferae*), blossom malformation (*Fusarium mangiferae* and *F. sterilihyphosum*), bacterial leaf spot (*Xanthomonas axonopodis* pv. *mangiferaindicae*), fruit rot (*C. queenslandicum* and *Aspergillus niger*), dieback (*Lasiodiplodia theobromae*, *Neofusicoccum mangiferae,* and *N. parvum*), and gummosis (*L. theobromae*).

13.4 POTATOES SOUTH AFRICA (PSA)

Potatoes South Africa (PSA) is a non-profit company registered under the Companies Act, 2008 (Act 71 of 2008). PSA operates as an industry association and its structure represents a network of participating role players and individuals who are involved in various forums and committees. The vision of PSA is to build a viable potato industry in South Africa.

PSA has four divisions: marketing, transformation, research and industry information. The main objective of the research programme is the improvement and maintenance of sustainable potato production. This implies production technology that does not impact negatively on the environment and natural resources. The effect that climate change will have on potato production needs to be determined, as it will also put pressure on the effective utilisation of resources such as water.

Potatoes South Africa's research is currently focusing on the following:

- Cultivar evaluation to increase yield
- Soil health, soil improvement and natural resource conservation
- Quality
- Virus and aphid control
- Water use and quality
- Cultivation/agronomy, especially fertilisation and volunteer control
- Management of soilborne diseases: common scab; rootknot nematodes; powdery scab and soft rot
- Potato tuber moth management

Source: https://www.potatoes.co.za/ (as on 1 September 2020)

13.5 MACADAMIAS SOUTH AFRICA NPC (SAMAC)

Macadamias South Africa NPC (SAMAC – previously the South African Macadamia Association) was formed in the early 1970s by a group of growers seeking to pool their resources, in order to address their common problems and issues. It is funded by a statutory levy and voluntary membership contributions and directed by macadamia industry participants who have the orderly growth and development of the industry at heart. Global contacts and co-operation have been further developed through the participation in the eight International Macadamia Symposia that have taken place since its inception in 1999, three of which were hosted in South Africa (1999, 2009 and 2015). SAMAC is also a member of the International Nut and Dried Fruit Council (INC), where the industry has the opportunity to interact not only with international macadamia role players, but with various other key role players within the international nut trade.

Macadamias were first introduced into the country in the 1960s. Today, the South African macadamia industry has grown into a major world force, competing with Australia in terms of being the largest producer. It is arguably the fastest growing tree crop industry in South Africa, with production increasing more than twenty-fold in the past 20 years, from 1 211 tonnes of nut in shell (NIS) in 1991 to 59 050 tonnes in 2019. Compared to 2018 production, the industry's production grew with an additional 2 550 tonnes in 2019. The total value of annual production has increased from R32 million in 1996 to approximately R4.8 billion in 2019.

In 2019, the industry planted 5 887 new hectares to macadamias. KwaZulu-Natal remained, for a second year, the province that established the most hectares, followed by Mpumalanga and then Limpopo. The main growing areas are Levubu and Tzaneen in the Limpopo province, Hazyview and Barberton in Mpumalanga, coastal KwaZulu-Natal and the Eastern Cape.

The industry is export-based, with more than 97% of annual production shipped to international markets. The demand for South African macadamias remains strong. According to information given by SAMAC handlers, in 2019 approximately 41% was exported to North America, 47% to the European Union (including UK), 2% to Southeast Asia (China) and 7% to the Middle East.

SAMAC's plant pathology research is currently focused on the following topics:

- The Macadamia Protection Programme, currently focusing on identifying and characterising the causal agents of husk rot, flower blight and dieback; and determining the presence and pathogenicity of *Rosellinia necatrix* in macadamia orchards (Gerda Fourie, FABI, University of Pretoria)
- Soil nematodes, soil mycobiota and soil health (Wilhelm Botha, ARC-PHP)
- Detection of the causal agent associated with macadamia chlorosis disease (Ronel Roberts, ARC-PHP)
- Management of Phytophthora root rot and stem canker using phosphonates and root colonisation patterns, and *Phytophthora* and *Pythium* associated with macadamia trees (Adele McLeod, Department of Plant Pathology, Stellenbosch University)
- Timing and infection of macadamia by husk rot fungi (Maritha Schoeman, ARC-TSC)

Source: https://www.samac.org.za/ (as on 1 September 2020)

13.6 GRAIN SA

In 2016, David Theron and his co-authors wrote a book published by Grain SA called "*The grain and oilseeds industry – a journey through time*". The details are not repeated here, but if you are interested, the book is available on Grain SA's website (www.grainsa.co.za).

Diseases of importance to Grain SA are mentioned elsewhere in sections 22.0, 23.0, 25.0, and 26.12 of this book.

13.7 SEEDLING GROWERS' ASSOCIATION OF SOUTH AFRICA (SGASA)

The Seedling Growers Association of South Africa (SGASA) represents commercial seedling growers and their interests in South Africa. It is a non-profit organization and was first constituted in 1981, two years after Roode Lyon first introduced seedling trays to South Africa. It was soon realized that the system had tremendous advantages over seedbed production of seedlings and was adopted by innovative growers. The seedling industry grew from then to dominate all timber, vegetable and bedding plant seedling production within 10 years. Two of SGASA's objectives are relevant to plant pathology: to provide a rigorous and comprehensive certification scheme for members and to conduct research on pertinent topics as and when the need arises.

Certification and Research

SGASA has an in-house certification scheme aimed at adding value to individual nurseries. Nursery growers that are certified find it an extremely useful tool in improving their nursery. This certification is performed by a plant pathologist who has broad knowledge of the seedling industry. Results are benchmarked to enable individual nurseries to see how they score against other certified nurseries. These figures are kept strictly confidential.

SGASA maintains a dynamic research programme that is led and managed by a research committee. An annual survey is conducted among members to determine the type of research in which SGASA should invest. This ensures that the research is relevant. Research projects conducted in past years include, among others, projects on downy mildew, damping off, algae control, nutrition, the use of plant growth regulators, vegetable seed pathology, bacterial speck and spot, super absorbents, root diseases caused by *Phytophthora* and *Thielaviopsis*, *Alternaria* on tobacco, pine nutrition, medium quality, *Trichoderma* and virus control in peppers and seed vigour. Results are presented at an annual symposium.

Source: https://www.seedlinggrowers.co.za (as on 3 September 2020)

13.8 FORESTRY SOUTH AFRICA (FSA)

Forestry South Africa (FSA) represents 11 corporate forestry companies, approximately 1 100 commercial timber farmers and some 20 000 small-scale growers. Collectively, these growers own or control no less than 93% of the country's total plantation area of 1.2 million hectares. It supports the industry in common and precompetitive areas, such as research and protection against pests and disease, environmental issues, education and training and legislation.

Pests, diseases and fire lead to losses totalling around 27% of the sector's annual harvest - an approximately R938 million loss in roundwood production. An additional R4.8 billion is lost in downstream value addition, and as such, pose a substantial and increasing risk to forestry and the integrated value chain it creates in South Africa. Ongoing investment into research and protection initiatives by the sector over the past three decades has been relatively effective in reducing the impact of pests and diseases. This is illustrated by the decline in losses to pests and diseases despite the frequent introduction of new pest and disease threats. In the last few years, however, several new and potentially more devastating pests and diseases established themselves and a holistic strategic response and greater resources are required to manage this escalating threat.

In 2015, Forestry South Africa (FSA) pro-actively established a National Forestry Pests and Diseases Committee (NFPDC) to oversee shared industry objectives and lead working groups that function independently, driving the implementation of certain priority pest and disease objectives. The working group structure has proven to be very effective at executing focused industry interventions. It is also highly adaptive, enabling the consolidation and expansion of working groups in response to the level of threat posed, the expansion of the original *Leptocybe* working group into the *Eucalyptus* pest and disease working group being a great example of this.

FSA is committed to playing a central role in the collaborative efforts of industry, research partners and Government, as the sector continues to address the escalating threats posed by pests and diseases and reduce the impact that these threats have on the industry, sector and the South African economy in general.

Research on diseases is undertaken in-house by the corporate forestry companies, the Institute for Commercial Forestry Research (ICFR) and universities, notably Stellenbosch University and the Tree Protection Co-operative Programme (TPCP) at FABI, University of Pretoria. Information on pathogens affecting commercial forestry is available in sections 8.1, 8.2, 8.3, 21.0, 26.7, 26.8 and 26.9.

Source: https://www.forestrysouthafrica.co.za/ (as on 3 September 2020)

13.9 SOUTH AFRICAN BIOPRODUCTS ORGANISATION (SABO)

The South African Bioproducts Organisation (SABO) was established in 2013 as a partnership between the Department of Agriculture, Forestry and Fisheries (DAFF), various universities and research institutions, as well as the bioproduct industry. The objective is to improve the standards of bioproducts in the market in order to protect both the market and the end users. The purpose of SABO is to develop the bioproduct industry in South Africa and to regulate the activities of participants in accordance with high ethical and science-based standards.

Training in the effective application and responsible integrated pest, disease and weed control is included as an accredited qualification by the South African Qualifications Authority (SAQA). A component of this training is in biological control. Research on biological control of pests and pathogens is undertaken by a number of divisions in the ARC (section 7.0), Hortgro Science (section 15.1), SASRI (section 19.0), private companies, notably Absolute Neem Oil, Biological Crop Health and Koppert Biological Systems, and universities (UKZN, UP, Wits, UCT, RU, and SU). A number of companies provide biological control products to the agricultural and forestry sectors, of which 25 member companies are included in the organisation's website.

Source: https://agribook.co.za/inputs/biocontrol/ (as on 3 September 2020)

14.0 Seed Production, Diagnostic Services and Certification Schemes

14.1 SEED PRODUCTION

In order to prevent the introduction of pathogens into new areas, various industry bodies forming part of certification schemes or seed companies provide planting material free of pathogens. These include Bosman-Adama (Mariëtta Louw); CRI (Hano Maree, Glynnis Cook, Chanel Steyn, JB Meyer, Rochelle de Bruyn and Kobus Breytenbach); Plantovita (Marieta Botha); SAPO Trust (Roleen Carstens, Sophie Malan and Emcee Gagiano); Vititec (Nico Spreeth and WT Oosthuizen); SASRI (Stuart Rutherford, Sharon McFarlane and Tania van Antwerpen); Starke-Ayres (Wilmarie Kriel and Rosandya Govender); Sakata (Schalk van Heerden and Christie Snijders); Pannar Seed (Corteva) (Rikus Kloppers, Stephanie Tweer and Vicky Coetzee) and the Potato Certification Scheme. Dave Nowell was employed by Pioneer Seed before taking up a position at the United Nations Food and Agriculture Organization (FAO) in Rome.

14.2 DIAGNOSTIC SERVICES

Diagnostic services are provided by the ARC-Plant Health and Protection (for viruses: Ronel Roberts and Marika van der Merwe; for bacteria: Teresa Goszczynska; for fungi: Riana Jacobs-Venter and Wilhelm Botha); Stellenbosch University (Vironostix) with Johan Burger and Mandi Engelbrecht, and at the university's biochemistry department for potato viruses (Dirk Bellstedt, Chris Visser and Wiets Roos); and at a recently formed private company, Pathosolutions (Gert Pietersen and Inge Pietersen). Stellenbosch University and University of Pretoria both have diagnostic clinics. The clinic at Stellenbosch University, run by Sonja Coetzee, started its activities in October 2000 and they are in the process of privatising this centre. They diagnose all types of fungal and bacterial diseases on various crops, including trees, shrubs, vegetables, fruit and ornamentals. There are two clinics at UP. The first one resides in the Department of Plant and Soil Sciences and is run by Jacquie van der Waals. It operates in a similar manner to the one at SU. The diagnostic clinic in FABI, which has been in operation since 1998, is run by Trudy Paap, and focuses primarily on pests and pathogens of trees, including macadamia and avocado, oilseed crops and maize. This clinic is in the process of being integrated into the structures of Innovation Africa @UP.

14.3 POTATO CERTIFICATION SCHEME

The South African Seed Potato Certification Scheme was promulgated in terms of the Plant Improvement Act, 1976 (Act No. 53 of 1976). The purpose of certification is to certify seed potatoes where the phytosanitary status in terms of diseases and pests falls within predetermined norms and that are 'true to type'. To ensure the sustainability of potato production in South Africa, the Scheme is based on disease-free material as starting material.

Successful potato production largely depends on the quality of the planting material. Due to the susceptibility of the potato to several transmissible diseases, it is not possible to multiply the same seed source for an indefinite period of time. The South African potato industry maintains a sophisticated seed potato programme, which plays a vital role in the growth of the 'ware potato' and processing industries. Stringent requirements are set with respect to the production of seed potatoes and 'certification officials' of the Potato Certification Service (PCS) ensure that certified seed potatoes meet the requirements of the Scheme.

Field and tuber inspection findings are supported by laboratory test results with regard to certain bacterial diseases and viruses, before certification is awarded. The process of certification is managed by a sophisticated data management system. Approximately 11 000 hectares are registered annually for seed potato production. Only laboratories registered with the Department of Agriculture, Land Reform and Rural Development (DALRRD) and approved by the Independent Certification Council for Seed Potatoes (ICCSP), the authority in terms of the Scheme, are permitted to conduct laboratory tests for certification of seed potatoes. Once seed potatoes comply with all the requirements of the Scheme, certification is awarded. Certification is evidenced by an official certification label attached to the seed potato bag.

The Potato Quarantine Pest Committee (PQPC), under the chairmanship of the Directorate Inspection Services, DALRRD, is the regulator of the potato industry for quarantine pests. Bacterial wilt, caused by *Ralstonia* Species Complex (RSC), Potato Cyst

Nematode (PCN - *Globodera rostochiensis*) and wart disease, caused by *Synchytrium endobioticum*, are officially controlled in terms of the Scheme. Import regulations and biosecurity also falls under the jurisdiction of this committee.

15.0 Plant Pathology in the Commercial Sector

The history of plant pathology in the commercial sector has been poorly documented. Although some historical information on the topic was occasionally presented at conferences or in undergraduate modules, no comprehensive overview exists. Most aspects of how the industry came about, the sequence of events, the milestones, landmarks and challenges are unavailable.

Numerous plant pathologists have made significant contributions to the management of plant diseases in South Africa. While historical accounts of academic plant pathology departments at universities are available, it is not possible to document the contributions of these pathologists to the commercial industry in a similar manner. There are presently, and have in the past been, hundreds of professionals that have supported plant disease management directly or indirectly for the commercial sector.

The following groups of professionals have and continue to play a role in plant disease management:

- Industry plant pathologists
- Industry researchers working on topics related to plant pathology
- Commercial agricultural consultants
- Professionals in the agrochemical industry, including technical staff
- Professionals at companies that develop biological control products
- Plant pathology professionals supporting industry bodies
- Technical staff at farmer co-operatives who often conduct plant disease management trials
- Private agricultural research and development companies
- Diagnostic laboratories, many at institutes of higher learning, but also private and commercial laboratories
- Commercial molecular biology and biotechnology laboratories
- Seed production companies
- Plant improvement companies, particularly those that breed plant disease resistant plants
- Plant production companies
- Nurseries, including agricultural and ornamental nurseries
- Tissue culture laboratories
- Botanical gardens and arboreta
- Lawn and landscape firms
- Arborists

THE HISTORY OF CHEMICAL PLANT DISEASE CONTROL IN SOUTH AFRICA

The use of elemental sulphur in plant pathology dates from 1802 when William Forsyth, the gardener to King George IV, used this compound to treat mildew of fruit trees. Thereafter and until 1934, sulphur was either used alone or combined with lime to treat a number of plant diseases. The first record of where this compound was used in South Africa was in 1859 to treat grapevine mildew at Constantia. Today dithiocarbamates fungicides contain between 10-50% bound sulphur.

Copper sulphate was first used as a seed treatment against wheat bunt in 1761. But it was not until the late 1880s that copper-based fungicides replaced sulphur as the leading fungicide when Bordeaux mixture was developed in 1885 by Millardet. In South Africa, copper carbonate and Bordeaux mixture was used to treat trees infected with citrus canker in 1908.

A technical guidebook for farmers, published in 1910, documents crop rotation and the regeneration of soil organic matter. It also encouraged other sustainable agricultural practices such as the prevention of soil erosion for the management of crop health. Intensive chemical inputs were discouraged at the time, being detrimental to the health of the soil and the environment. This is the view to which the plant protection community in South Africa is strongly returning to in 2020, more than a century later.

From the early onset of plant disease management, the focus has been on delivering some form of chemical solution to the problem. In the early 1900s, Bordeaux mixture was one of the earliest products used widely for the control of plant diseases. Formaldehyde and lime-sulfur were commonly used products for plant disease management in 1914. Other aspects of disease control, such as making use of resistant crop plants and understanding the role that the environment plays in the proliferation of the disease was also known in the early 1900s.

In 1926, Paul van der Bijl (refer to section 28.1) provided an overview of the science of plant pathology and disease control in South Africa (reference cited in section 34.0). However, this was mostly an account of the international developments in plant disease management up to 1920. Little information on the measures used during that time in South Africa were documented. In the South African context, he explained the origins of the Bordeaux mixture, a copper-based product, in detail, and mentioned that it gave hope to South African nurserymen. This was particularly in the context of crown gall (caused by *Agrobacterium tumefaciens*) known to cause damage to fruit trees in the nursery industry. Grafted plants were dipped into the mixture before planting. He also mentioned that in the 1920s, South African wheat farmers used copper carbonate to disinfect wheat seeds from stinking smut. In this overview he mentions lime-sulfur (active ingredient sulfur) as a remedy against powdery mildew diseases in South Africa, particularly used on peaches, as it did not burn the foliage as Bordeaux mixture did. He also focused on the importance of understanding the biology of the disease and the impacts of environmental factors on the occurrence of plant diseases.

Taeuber & Corssen (Pty) Ltd were appointed as agents of Bayer AG in the 1920s. Bayer (Pty) Ltd only formally came into being in South Africa in 1993. With the exception of AECI Ltd, which was registered in the country in 1924, all of the other major producers of pesticides were established from 1979 onwards. Today over 3 000 pesticides are registered for use in South Africa and the country is one of the four largest importers of pesticides in sub-Saharan Africa. The vast majority of these chemicals are carbamates, organophosphates and pyrethroids. The South African National Pesticide Registration Authority was established in 1947 and is tasked with ensuring that good quality crop protection chemicals are supplied to users, and that these chemicals do not adversely affect the public interest.

Knapsack sprayers, barrel and power sprays were reported as methods superior to the use of brooms to apply products on plants prior to 1926. Although the value of breeding resistant varieties of field crops was known at the time, no breeding efforts were applied in South Africa during the 1920s. Borax is mentioned as a chemical for the control of postharvest decay of citrus fruit (*Penicillium* spp.) in Europe, although at the time it had yet to be used in South Africa for this purpose.

From the scientific perspective, and no different from the present, chemical products were thought to be abused without consideration of the greater repercussions or negative impacts they might have on the environment. Jones, in 1914, called for the education of the public to become better aware of the potential for loss they might experience from diseases and the gains that could be achieved using chemical control. Despite our knowledge of the importance of economic impact of diseases, there remains almost no realistic information on the true losses that would have been experienced without intervention. Neither have control interventions been economically justified.

As early as 1914, the importance of understanding the fundamentals of the biology and management of pathogens became clear. Jones made the point that "This is the permanent foundation on which plant disease management efforts should be grounded*"*. It has become widely acknowledged that chemical control measures are useful, but that they can also be transient. This is due to a limited lifespan of many active ingredients, pathogens gaining resistance to pesticides, regulations that increasingly restrict the use of pesticides and in some instances (mostly for developing nations) the fact that they are inordinately expensive.

The value of cultural practices, such as sanitation, exclusion and disease resistance were also known as useful tools in the management of diseases in the early 1900s. Jones argued that adoption of the use of chemical spray solutions for plant disease control in the USA was rapid, but that the "destruction of diseased plant tissues", crop rotation and other cultural control methods had not gained traction. Chemical intervention, at least for large commercial operations, remains the preferred method of intervention.

An account of the Australian plant pathologist Simmonds in 1991 provides a more detailed account of the life of a plant pathologist in the 1920s and 1930s. In the following quote he suggested that "plant pathology work was less complicated… than today." There were few textbooks and literature was scanty by present-day standards. Consequently, one was left more to one's own resources. Pathology workers were relatively few the world over and it was possible to keep in touch with others in the field. In the laboratory, modern techniques and equipment were unknown as was the impact of modern biochemistry. Virus disease investigation was in its infancy and the electron microscope not yet available. In the field, fungicides were limited to modifications of Bordeaux mixture, Lime sulphur and sulphur. Field experiments were not complicated by the requirement of a statistical layout and subsequent analysis. A little scientific intuition could be used to advantage. For the person working in the field, conditions were very different from those now taken for granted.

Between 1940 and 1990, developments in chemistry allowed the introduction of various new classes of fungicide. The period between 1940 and 1960 saw the introduction of dithiocarbonate and benzimidazoles. Both groups of active ingredients are still used widely in South Africa today. In general, the new products introduced between 1940 and 1960 were more effective and less phytotoxic than earlier predecessors. Between 1960 and 1970 fungicide markets grew rapidly and the protectant fungicides, Mancozeb and Chlorothalonil became available. Carboxin and Thiabendazole also became available in this decade. Advances in research methodology made significant contributions to the development of new products. In the 1970s, Triazoles were developed. They were, and are, of the largest classes of fungicides ever developed and they are widely used in agriculture in South Africa. Strobilurins were introduced in 1996 and became a common fungicide group, used on various crops in South Africa.

Accounts of the history of agrochemical companies focus mostly on how the larger multinational agrochemical companies came about, how their operations expanded, and where their research stations were located. There is little information on other smaller role-players in the industry over the years. As far as could be ascertained, there is almost no information on the history of the general agrochemical industry in South Africa.

Currently, a few multinational companies dominate the global agrochemical and plant protection market. This follows after large multinational companies merged in recent years. In 2017, Chem China, Syngenta and DuPont merged with Dow, to become Corteva Agriscience. In June 2018, Monsanto merged with Bayer. These two colossal agribusinesses currently control 70% of the global agrochemical industry and over 60% of the global seed market.

Earlier plant disease surveillance programs (information of which are available in the annual reports of the Agricultural Research Council) conducted via governmental institutions have also become scant, although they never had a high priority. Urgent commitment is needed towards the long-term surveillance and monitoring of plant diseases. There is also a need for platforms for the evaluation of interventions and from which recommendations for improvement of current commercial practises can be made. This lack of surveillance also results in a gap in knowledge in terms of the pathotypes against which breeders must select resistance, and a lack of knowledge as to which research projects should be prioritised. Early detection and rapid interventions are needed to protect South African plant resources from invading alien pathogens. Although some comprehensive programmes are in place for some major biosecurity threats to the major crops, such as maize and some of the export fruit crops, there is a lack of capacity to understand the distribution of pathogens or the risks of new pathogens that may harm the South African agricultural industries in the future. Regulatory frameworks and legislation also fall short, with the registration of products for plant protection still falling under the Fertilizers, Farm Feeds, Seeds and Remedies Act 36 of 1947. Although amendments have been made over the years, this act has not been fully revised.

There has been a natural progression of plant disease management in South Africa, with a strong trend for the adoption of synthetic chemicals in the industry. This has resulted in highly-intensive farming practices in the commercial environment and, in some cases, negative impacts on environmental, soil, human and animal health. Overuse of pesticides reduces soil fertility, pollutes water, poisons ecosystems, exposes humans to toxins and contributes to climate change, since many synthetic products originate from petroleum products. In the long term, productivity declines on these degraded farmlands, while input costs for intensive farming places pressure on famers, particularly with the dependence on external factors such as the oil price and the exchange rate.

A lack of knowledge on how to best manage diseases leads farmers, foresters and nursery growers to intensify fungicide spraying programmes as an ‘only resort’ for a better outcome when they are faced with plant disease management problems. This results in a ‘pesticide treadmill’, where the likelihood of the effective control might decline as, for example, the population of a pathogen builds up resistance to a particular pesticide. For many crops in South Africa there remains a significant gap in knowledge regarding the handling at harvest, postharvest handling and storage of fresh produce.

Many graduates trained in plant pathology are employed by the Agrochemical industry. Today, some of these graduates hold senior managerial positions and include, for example, Gina Swart (Syngenta), Dirk Uys (Bayer), Rikus Kloppers (Corteva Agriscience), Andre Cilliers (Plaaskem), Rupert Anelich (BASF), Johann Korkie (Miller Chemicals), Johan Janse van Rensburg (Oro Agri SA), Freddie Denner (Upl Ltd), Cheusi Mutamila (Monsanto SA), Henk van der Westhuizen (Philagro SA), Filicity Vries (Tessara (Pty) Ltd), Kerien van Dyk (Syngenta), Gloria Mandiriza (Dow AgroSciences (Pty) Ltd), Kobus Serfontein and Wouter Schreuder (ICA International Chemicals (Pty) Ltd) and Johann Korkie (Miller Chemicals).

16.0 Citrus Pathology

In this section, the focus is strongly on the history of the South African citrus industry. It is included as an example of an industry that has the longest association with plant pathology in the country. This includes the eradication of citrus canker and the more recent impact that citrus black spot has had on the export of fruit to Europe.

The first citrus plantings in South Africa can be traced back to the travels of some European explorers. During the 1500s, Portuguese explorer Vasco da Gama obtained oranges for the crew of his ships during stops at Mombasa and Malindi in Kenya during his historic voyage from Portugal to India. It is understood by historians that oranges were introduced to East Africa by early Arab traders from Persia and later India. Da Gama's discovery of the trading route between Portugal and India led to the establishment of a victualling station on the island of St Helena. Since citrus fruit were a remedy against scurvy, orchards with orange, lemon and citron trees were established on the island.

When Jan van Riebeeck arrived at the Cape of Good Hope in 1652, his directive was to establish a garden to provide fruit and vegetables to passing ships of the Dutch East India Company. Upon his request, orange trees were brought to the Cape from St. Helena Island in 1654 and planted in the Company's Garden. These trees bore fruit seven years later and by this time more than 1 000 trees had been established. However, it would be almost 200 years before the next significant development in the industry.

In 1850, the first budded Bahia trees (Washington navel oranges), unfortunately of poor quality, were imported from Brazil by an Eastern Cape grower. Four years later, another grower in the Eastern Cape budded Bahia trees and distributed them further into the then Cape province. However, despite these significant early developments, the citrus industry remained in the hands of small-scale farmers.

THE GROWING NEED FOR RESEARCH AND TECHNICAL SERVICES

The evolution of South Africa's citrus research and technical services was always in tandem with the development of the industry itself. This dates back to 1890, when news reached the pioneers of the first commercial citrus plantings in South Africa that American growers had succeeded in exporting citrus under refrigeration by ship to Europe. In 1895, Cecil John Rhodes (prime minister of the Cape Colony) hired horticulturists, mainly from California, and employed them in the Cape Province to further develop the fruit tree industry. The first exports to London occurred in 1902, with a positive technical report on the quality of the fruit contained in a letter by Rudyard Kipling to HEV Pickstone. In 1906, South African fruit was exhibited at the Royal Horticultural Society Show in London and the high quality created much interest in South African fruit.

In 1910, a group of Rustenburg farmers built a packhouse near the town's railway station and organised themselves into the Rustenburg Co-operative Citrus Union, which was the first co-operative growers' association in South Africa. More co-operatives were subsequently established in the country, and by 1921 it was clear that challenges associated with packing, shipping and marketing required a national and co-ordinated approach.

In 1922, the Fruit Growers' Co-operative Exchange (FGCE) was formed as a private company to help co-ordinate shipping of the rapidly developing deciduous and citrus fruit industries. By 1925, South African citrus exports had reached the one million box mark and it was clear that a shipping and forwarding agency was required to support the rapidly growing fruit export sector. This resulted in the formation of the Co-operative Shipping Service Ltd (FGCE). The FGCE was required to engage with the Minister of Agriculture, leading to the establishment of the Fruit Export Control Board (the forerunner of the Perishable Products Export Control Board [PPECB]).

With citrus export volumes growing steadily and therewith the need for technical infrastructure and expertise, citrus growers decided to break away from the FGCE in 1925 and formed their own South African Co-operative Citrus Exchange (SACCE), consisting of 24 local citrus co-operatives. The first board of directors meeting was held under the chairmanship of JA du Plessis of the Rustenburg Co-operative Citrus Union on 31 August 1926. At this meeting, a grading committee was formed to advise the Minister on citrus export regulations. These events led directly to the establishment of co-operative citrus packhouses, and by 1939 three quarters of the total crop was packed by just eight co-operatives. John Webb was appointed SACCE's first general manager in April 1927.

Later in 1927, SACCE appointed its first part-time technical adviser, H Clark Powell. One of the tasks assigned to him was to begin the selection of parent trees to serve as budwood sources for the propagation of true-to-type, disease-tolerant nursery trees. By 1928, more than three million citrus trees were planted in South Africa, and in 1930, 1.7 million boxes of citrus were exported. In March 1930, M van den Hoek, a trained horticulturist, was appointed as SACCE's first full-time technical adviser. The field department, which was developed under his control, was to maintain personal contact with all citrus growers and, in addition to providing technical advice, to operate as 'the eyes and ears' in respect of all developments in the industry. This heralded the birth of SACCE's technical department. At a SACCE executive meeting in 1935, the role and functions of the field department were endorsed and approved. These included advisory, observational and experimental work, as well as parent tree recording and inspection. WJ Allwright succeeded M van den Hoek as technical adviser in 1936. By 1939, the work undertaken by the field department had produced valuable results in all phases of its activities, including co-ordinating research into the control of citrus thrips and frost protection. During this period, the Citrus Board was established under the Marketing Act (No. 26/1937) to bring about complete control of the export and sale (locally and abroad) of citrus by producers who had more than 300 trees (representing 75% of total production).

In 1946, the field department conducted an extensive survey to determine the industry's potential for expanding. This was followed by a visit of government plant pathologist Vincent Wager to Australia to study citrus black spot disease, which, after making its first appearance in Pietermaritzburg, was causing serious damage to plantings in Barberton and Tzaneen.

In 1948, SACCE sent its technical adviser, PA Crous, to South America and the USA to study the latest technical developments. Following his extensive report, another citriculturist was appointed in 1949, and later that year a Citrus Research Committee was formed. It consisted of representatives from government institutes, the University of Pretoria, the Citrus Exchange, and private technical research companies. GF Anderson, Chief Horticulturist of the Union, was its first chairperson. The object of the Committee was to co-ordinate all the investigational work done in the citrus industry.

In 1950, the industry exported six million cartons and the SACCE technical staff consisted of a technical advisor, a professional assistant and seven field officers in the production areas. This was the start of a decade of considerable expansion in research activities to improve citrus production, packing and transport practices. OT van Niekerk was appointed technical advisor in 1950, a post he held until 1975.

In 1953, SACCE created three research officer posts to undertake work in identified problem areas that were not adequately investigated by government and other research institutions. In 1955, SACCE approved the doubling in the number of field officers to 14. In 1956, Malvern Georgala was appointed research entomologist and in 1957 Danie Esselen was appointed as technical advisor to the London office. In addition, SACCE created a bursary scheme whereby three students were sent for training in California and four at South African universities. This far-sighted strengthening of the training pipeline lay the foundation of an internally controlled research and technical resource that would serve the industry for decades to come.

From 1960-1970, SACCE's research team grew with the appointment of three California-trained doctorates, namely postharvest pathologist Toit Pelser, horticulturist Ian Gilfillan and preharvest pathologist Cameron McOnie. Cameron McOnie conducted ground-breaking work on citrus black spot and soon became manager of the Research and Technical department and subsequently general manager of SACCE in 1971.

SACCE's researchers were accommodated at the Citrus and Subtropical Fruit Research Institute (CSFRI) in Nelspruit (later known as the Agricultural Research Council - Tropical and Subtropical Crops; ARC-TSC), in facilities funded by the citrus industry. Other SACCE researchers who joined the industry between 1965 to 1975 included Chris Kellerman, Hendrik Hofmeyr, Carel Buitendag, Louis von Broembsen and Anton Hough, who had also studied in California.

INDUSTRY RESEARCH FACILITIES, STRUCTURES AND FUNDING

By the late 1960s, the expansion of the citrus industry's research efforts had already led to the establishment of Outspan Laboratories, which provided nutritional programmes based on soil and leaf analyses. A momentous decision was taken by SACCE to establish the Outspan Citrus Centre (OCC) in Nelspruit in 1974, as the citrus industry's own research and technical station. The buildings for this facility were constructed on a 3.1-hectare property that was donated (at the time) by the Solomon family of the Crocodile Valley Citrus Company. The SACCE research team moved from CSFRI to these facilities and the Outspan Citrus Centre became the headquarters for industry driven research and extension services. Interestingly, "Outspan" had been the trade name for all South African export citrus fruit since 1936; the name was originally the trademark of Amanzi Citrus Estate, owned by Sir Percy Fitzpatrick, the famous author of the novel Jock of the Bushveld. Prior to the onset of deregulation in 1996, the research and field services personnel complement of SACCE exceeded 100, of which six were plant pathology researchers.

The deregulation of the fruit and other industries in 1997 saw the transition from a single export channel to approximately 300 export entities within a very short space of time, thereby creating a chaotic situation. The deregulation era was a difficult time for citrus research, resulting in an unfortunate downsizing of the industry's research and technical support capacity. Grower parties, however, had two shared strategic objectives, namely research and market access. This contributed significantly to the formation of the Citrus Growers Association (CGA), which was a visionary move to reinstate structure and order in the industry. Initial research funding collected by the CGA (with Jan-Willem van Staden as chairman and Ian Moore as CEO) was on a voluntary basis. The CGA's primary focus from 1997 was to maintain research and market access and for the next four years, co-ordination of industry research was overseen by a Citrus Research Committee, initially under the chairmanship of Johan Pienaar.

Another milestone in the development of the citrus industry was reached in 2000, when the CGA (with Peter Nicholson as chairman and Justin Chadwick as CEO) was successful in raising sufficient grower support to instate a statutory levy under the Marketing of Agricultural Products Act, 1996 (Act No. 47 of 1996), primarily to fund research and market access. In 2001, the CGA formed Citrus Research International (CRI) as a home for the citrus industry's research and technical functions. Under the leadership of Jock Danckwerts as first chairman and Vaughan Hattingh as CEO, the Outspan Citrus Centre in Nelspruit and the Outspan Foundation block in Uitenhage (renamed as the Citrus Research Centre and the Citrus Foundation Block, respectively) were managed by CRI. In 2019, the CGA bought these facilities from Capespan, which was the owner at that time.

HISTORY OF THE CITRUS IMPROVEMENT SCHEME

In the early 1970s, the South African citrus industry was severely compromised as a result of citrus diseases, including African citrus greening, Exocortis, Tristeza, Psorosis and Cachexia, which were uncontrolled and transmissible by vector or budwood. In addition, Rough Lemon rootstock, then being used for more than 90% of the industry's plantings, had emerged as susceptible to soilborne pathogens and particularly Phytophthora root rot, which was reaching disastrous levels in new orchards at the time. Where orchards were replanted, many were severely affected by fungal pathogens, nematodes, poor soil aeration and salinity. It was also estimated that less than 25% of nursery trees that were being planted in commercial citrus orchards were propagated using specifically selected budwood source trees. This situation also meant that growers were unable to increase their yields and the industry average production remained at around 25 tons/hectare. The industry's total exports had been static at around 20 million cartons for several years and it had become clear that there was an urgent need for improved trifoliate and trifoliate hybrid rootstocks and disease-free, horticulturally true-to-type plant material.

It was about this time (late 1960s) that visionary industry leaders embraced the importance of the industry embarking on a Citrus Improvement Programme (CIP). These individuals were the regionally-elected board members of SACCE under the chairmanship of Gustav van Veijeren, and soon after the equally broadminded and congenial Lance Danckwerts. The initiative was led on the ground by the strategic Cameron McOnie, SACCE's general manager at the time, and Doug Stanton who was appointed to replace Cameron McOnie as head of Research and Technical. During this period, a virus-free budwood source was established at the CFSRI's Mussina experimental farm by using nucellar seedlings. However, this initiative failed due to subsequent tristeza infection, spread by aphids.

The Sixth Conference of the International Organisation of Citrus Virologists (IOCV), which was hosted in Swaziland in 1972, was a watershed moment in the history of the citrus industry in South Africa. Apart from the need to establish a CIP, the IOCV congress also highlighted the dangers posed by exotic diseases, such as Huanglongbing, or Asian Citrus Greening.

A joint CIP committee was established by SACCE (Doug Stanton and Louis von Broembsen) with representatives of the Department of Agriculture and CSFRI, namely Johan Grobler, Gawie Bredell, Cas Holtzhauzen and Hannes de Lange. The CIP was officially established in 1973, and the first consignment of trees certified under the interim-CIP were planted five years later. The interim CIP focused on field selection of horticulturally superior propagation material, collaboration with commercial nurseries to create formal participating structures and the publicity and administration of the citrus nursery and tree certification scheme.

In 1976, Louis von Broembsen conducted a study tour on the functioning of other CIPs in the USA, Spain, Israel and South America. He also visited Chet Roistacher's laboratory in Riverside, California, where he was engaged in perfecting the ground-breaking shoot tip grafting (STG) process of pathogen elimination from citrus plant material, and the related biological indexing for graft-transmissible pathogens. This gave impetus to the CSFRI's Hannes de Lange, who in close collaboration with Roistacher established these procedures in the CIP. In 1999, the University of Pretoria awarded an honorary doctorate to Roistacher for his contribution to the South African citrus industry.

A state-of-the-art STG and citrus virus indexing facility was established at the CSFRI in Nelspruit under the experienced and professional care of Hannes de Lange and John da Graça in 1977. This was to provide a virus-free source of budwood material for the industry. At the time, STG and subsequent indexing to demonstrate pathogen free plants became mandatory for all imported citrus cultivars. This post-entry quarantine service was conducted at CSFRI, initially managed by de Lange and da Graça, and in later years by Fanie van Vuuren, Barry Manicom, Desmond Ncango and currently by Elize Jooste.

In the mid-1970s, industry leaders recognised the need to establish an isolated budwood supply and certification facility from which pathogen-free and horticulturally-superior propagation material could be supplied to approved nurseries. A suitable location was found near Uitenhage and the Outspan Foundation Block was established in 1980, releasing the first virus-free certified budwood in 1984 and the first certified seed in 1986. The foundation block was managed by Thys du Toit from establishment in 1980 until 2017. Andrew Lee was CIP manager from 1988 until mid-1990s and notably developed the procedural guide for the CIP, established a nursery advisory service and standards for certified citrus nursery trees, and together with Hennie le Roux and Keith Roxburgh achieved the almost complete elimination of *Phytophthora* and citrus greening in certified nursery trees.

In 1985, John Moll arranged an international workshop on Citrus tristeza virus (CTV) in South Africa. Scientists from California (Chet Roistacher, Alan Dodd, and David Gumpf), Florida (Richard Lee, Ron Bransky, and Stephen Garnsey), Brazil (Gerd Müller) and Israel (Moshe Bar-Joseph) attended. Delegates were met at Durban airport and travelled by bus to grapefruit orchards in Natal, and through Swaziland to Nelspruit. All delegates presented at the workshop, hosted by CSFRI, and the proceedings were published in the South African plant pathology journal *Phytophylactica* in 1987. One of the major outcomes from this workshop was the initiation of research on CTV cross-protection in South Africa, specifically the evaluation of suitable CTV sources.

The CIP formed an advisory committee in 2002, which included participation by all stakeholders, CRI, CGA, the national Department of Agriculture, Agricultural Research Council (ARC, formerly CSFRI), citrus and retail nurseries, private cultivar managers, as well as the citrus horticulturists and pathologists involved in the technical services to the CIS. At its inaugural meeting in 2002, the advisory committee proposed that a citrus-free buffer zone with a radius of 5km around the Foundation Block should be considered to protect its phytosanitary status. This buffer zone was officially promulgated under Regulation 110 of the Agricultural Pest Act in 2011, notably with significant inputs made by Mike Holtzhausen from the Department of Agriculture, who served on CISAC from 2003 until 2011.

From 2002, STG and indexing services were also established at CRI in Nelspruit by Fanie van Vuuren, specifically for the training of Kobus Breytenbach as technician, and co-ordinating CIS diagnostic services. Re-indexing of Citrus Foundation Block mother trees to ensure virus-freedom was conducted at this facility, and local cultivar selections could also be submitted for STG pathogen-elimination prior to introduction into the CIP, called the Citrus Improvement Scheme (CIS) from 2008. In 2017, CRI recognised Fanie van Vuuren's lifelong dedicated service to the citrus industry of South Africa and the CIS in particular by naming the CIS facilities at the CRC in Nelspruit the "Dr Fanie van Vuuren - Citrus Improvement Scheme Laboratory and Nucleus Block".

In 2006, Fanie van Vuuren reported to the advisory committee that a viroid was found in a mother tree at CFB, and that PCR must be used for diagnosis as prior biological indexing led to false negative results. PCR diagnostics as a supplement to biological indexing was thereafter implemented by Manicom at ARC and at CRI, initially by Gerhard Pietersen and Jacolene Meyer, and later by Glynnis Cook. This led to detection of viroid infection in several cultivar lines by PCR, with biological indexing showing easily-missed transient and cryptic symptoms on the indicator plants. Some of these were protected high-demand cultivars, and the CIS decision to suspend budwood supply until the cultivar could be re-STGd to remove the viroid, was not popular with the owners or managers of the implicated cultivars. The CIS was heavily criticised at the time, and in 2009 the advisory committee supported a recommendation to subject the phytosanitary procedures within the CIS to independent external review.

In 2010, the CIS was extensively reviewed by an international panel of experts, consisting of John da Graça, Moshe Bar-Joseph (Israel) and Patricia Barkley (Australia). The reviewers made several constructive criticisms, but agreed that the CIS facilities and procedures "meet, and may even exceed, world standards". The CIS was again reviewed in 2016 by an international panel, including Georgios Vidalakis (USA-California), Jim Graham (USA-Florida) and Juliano Ayres (Brazil). This review highlighted the urgency of increased biosecurity measures in the CIS, as well as citrus participating nurseries (for example tree production inside insect-secure structures), in preparedness for imminent incursion of feared exotic pests and diseases.

The CIP/CIS proved to be very successful, with a high level of industry participation and constant improvements over the years implemented by dedicated people based on industry and stakeholder research outputs, most notably in the fields of soilborne and graft-transmissible diseases.

The CIP and Outspan Foundation Block are currently known as the South African Citrus Improvement Scheme (CIS) and Citrus Foundation Block. These are managed by Paul Fourie and Jacolene Meyer. The CIS is operated by CRI on behalf of the CGA, and it is the primary supplier of citrus propagation material in southern Africa, the veritable "birthplace of citrus in southern Africa". The CIS certifies nurseries and citrus trees to ensure that growers are supplied with horticulturally superior plants that are free from declared viruses, diseases and pests. The CIS is currently a voluntary scheme, but with excellent participation from nurseries and growers. The CIS certified 36 commercial citrus nurseries in 2020, and an estimated 95% of all citrus trees grown and sold in South Africa originate from CIS-certified sources. Over the past 10 years, certified budwood supply ranged between 3.1 and 7.3 million buds per season; these buds are grafted on rootstock seedlings grown from certified seed. As a result of the sustained planting of certified, disease-free trees, South African citrus orchards are remarkably free from graft transmissible diseases.

INDUSTRY RESEARCH FUNDING AND ADMINISTRATION

The CRI structured industry research into portfolios (disease management, integrated pest management, citriculture), formed research advisory committees and established wide-ranging co-operative research agreements with universities and public and private research institutions. In the period from 2001 to 2020, CRI directed the industry research agenda, reinstated an extension division and provided priceless support to industry and the Department of Agriculture to gain, retain and optimize market access for the citrus industry. This resulted in accessing several new markets and improving technical conditions of access to markets. The most dramatic increased growth in the history of the citrus industry ensued, with export volumes increasing from 58 million cartons in 2000 to over 120 million cartons in recent years.

Currently, the industry plant pathology research as administered by CRI is divided into three research programmes, namely graft-transmissible diseases, preharvest diseases (including soilborne and fruit and foliar diseases) and postharvest diseases, whilst diagnostic services are consolidated in the diagnostic centre at CRC in Nelspruit. The research programmes expanded as industry priorities changed over time. Research in various fields of citrus production and its supply chain, market access and biosecurity was largely applied and aimed at ensuring the sustained global competitiveness of the South African citrus growers.

The South African citrus industry has grown from its rather modest start in the Company's Garden in Cape Town to currently being the most important fruit industry in the country, with a world-class citrus research and technical services capacity and a gross domestic product value of R20 billion per annum. The industry spans 88 569 hectares across seven provinces. It is the 14th largest producer of citrus in the world, but the second largest exporter of fruit after Spain. Production is mostly oranges (50%), with significant recent expansion in lemon (19%), soft citrus (22%) and grapefruit (9%) plantings. The industry is focused on fresh fruit exports (almost 90%), with limited processing and local fresh fruit consumption. In terms of export markets for fresh citrus, South Africa is the world leader, with export programmes to most countries. Most of this fruit is exported to the European Union and United Kingdom (42%), Middle East, Asia and South East Asia (42%) and established markets in Russia (8%) and North America (7%).

DIAGNOSTIC CENTRE

Research in the late 1970s led to the improved management of oomycete pathogens and plant parasitic nematodes in citrus nurseries. The need arose for quick and effective tests to establish the presence of *Phytophthora* in the irrigation water and potting soils. During 1984, Anton Hough was tasked with the responsibility of establishing a diagnostic facility to which samples could be sent for testing. A commercial testing facility named the Diagnostic Centre (DC) was established at the OCC in Nelspruit in 1984, with Mark Rea as its first manager and Rita Bronkhorst the first diagnostician. Within a short space of time, samples were pouring in from all the different production regions and the DC became financially self-sustaining. Over the years, several people served as diagnosticians, including Laura Huisman (1985-2008), Cecile Holtzhauzen (1988-1993), Wilma van der Westhuizen (2008-2010), Lorika Beukes (2011-2012), Elbie Liebenberg (2012), Elaine Basson (2012 till present) and Charmaine Olivier (2017 till present). The guidance of researchers and managers at OCC was instrumental in the perpetual growth and expansion of DC services, notably Lawrence Marais, Hennie le Roux, MC Pretorius, Paul Fourie and currently Jan van Niekerk. Currently, the DC serves the broader citrus grower community, the CIS and participating citrus nurseries and agrochemical companies, and renders a technical support service to CRI researchers. Over time, the services were expanded and include mycological, nematological and entomological diagnostics using conventional and molecular diagnostics and technical services. The DC currently analyse more than 12 000 samples annually.

FUTURE PROSPECTS

The rich history of citrus pathology in South Africa clearly demonstrates the close link between industry, researchers and the academic fraternity. This link was mutually beneficial to all role players. The formation of long-standing alliance partnerships and sustained research funding led to researchers forming close relationships with industry, and therewith, an understanding of its research priorities and strategies. Many researchers built world-recognised research programmes, whilst industry benefited from the innovative and applied research outputs. Although not elaborated on in this part of the book, industry encouraged citrus pathology researchers to collaborate with international counterparts, and these engagements, collaborations and friendships have also been highly instrumental in the quality and relevance of the research output. Through this co-ordinated, sustained and strategic research effort, citrus pathology research has equipped the industry with the technologies to remain a world leader in fresh citrus fruit exports.

17.0 Citrus Postharvest Pathology

The postharvest process is the culmination of the value chain, with the cost of harvesting, packing and shipping being a major component. Postharvest losses are therefore not only extremely expensive, but also result in reputational damage in export markets. Citrus fruit can be unacceptable to a market for physiological or pathological reasons. However, the majority of the losses experienced are due to fungal attack, and in particular, green mould caused by *Penicillium digitatum* that causes approximately 90% of postharvest citrus decay losses in South Africa. Control of this pathogen has always been the primary goal of citrus postharvest pathology.

In 1930, Vincent A Putterill published a Union of South Africa government article on the prevention of mould wastage in oranges, citing work done by various South Africans in the early 1920s. Miss Thompson of the Division of Botany in Pretoria worked on the conditions conducive to *P. digitatum* infection, improving the understanding on how *P. digitatum* and *P. italicum* infect citrus. Putterill cited several experiments carried out by his team in 1925 testing chemical action against *Penicillium* spp. Boric acid and borax were found to control decay much more satisfactorily than hot water treatments alone. These compounds, together with sodium carbonate, formed the earliest known postharvest chemical control methods of *Penicillium* rots on citrus. In 1934, James Vanderplank wrote a book on *Observations on the infection of navel oranges by green mould* (*Penicillium digitatum*, Sacc.), and in 1936, Ethel Doidge and James Vanderplank wrote a book on *The fungi which cause rots of stored citrus fruits in South Africa*.

In 1968, RS Pienaar reported that green mould was the most prevalent decay type (61%) on fruit arriving in the United Kingdom, followed by lesser brown rots. In 1971, a follow-up survey was done by Chris Kellerman and green mould was still the most prevalent fungal decay type (66%), followed by sour rot (*Galactomyces citrii-aurantii*) and blue mould (*P. italicum*). The prevailing fungicide at the time was thiabendazole, but with the increased use of benomyl in orchards, resistance to the benzimidazole group was becoming prominent, resulting in an increase in decay in overseas markets.

In light of the benzimidazole resistance, integrated disease management was necessary and in 1970, Anton Hough proved that orchard sanitation helped control postharvest diseases in the packhouse, and not least among that group was green mould. Yet alternative chemical control methods were still required, and in 1978, P du Toit Pelser and Hans la Grange were the lead researchers behind the use of alternative fungicides such as Imazalil and sodium *o*-phenylphenate (SOPP). It was on their recommendation that Imazalil was registered for the citrus industry in 1980. This revolutionary introduction to South African postharvest citrus treatments resulted in a 47% reduction in the costs associated with export losses between the years 1979 and 1980. Today (2020), Imazalil is still the most widely-used and effective fungicide against green mould in South Africa.

The role played by Toit Pelser in the history of postharvest citrus pathology in South Africa deserves special mention. He was one of the SACCE bursary students who studied at the University of California during the late 1960s and returned to South Africa to lead the SACCE postharvest plant pathology research programme. He was initially stationed at the CSFRI in Nelspruit, together with other SACCE researchers, but in 1973 moved to the newly-built Outspan Citrus Centre (OCC) industry research facilities. Subsequent expansion of the OCC facilities included the building of a state-of-the-art complex of cold rooms and an attached fruit testing laboratory.

The cold room complex at OCC made it possible to simulate shipping and cold storage of citrus fruit on a semi-commercial scale and simultaneously to compare different cold chain handling regimes. These facilities were unique in being sufficiently large to accommodate multiple replications of large volumes of test fruit. The postharvest research at that time was focused on developing shipping and storage protocols that provided a balance between minimising postharvest losses from decay, preserving fruit quality and providing for adequate postharvest colour development of the fruit, considering that this was an era that pre-dated the development of ethylene de-greening rooms.

From 1992-2013, the citrus industry funded research projects on biological control of postharvest diseases at the University of Pretoria. Under the guidance of Lise Korsten, two PhD (Erika Auret and Joseph Obagwa) and three MSc students (Patrick Mphahlele, Sissay Mekbib and Vicky Knight) graduated from this programme. The studies clearly showed the potential of using natural antagonistic organisms, plant extracts and/or essential oils to control postharvest diseases (and some preharvest diseases) of citrus, and having the potential to also control foodborne pathogens, which at the time were not considered important in the fresh produce industry.

During this time (2003-2016), Lise Korsten's research group also studied various other aspects of citrus postharvest pathology, including occurrence of *Penicillium* spp. in the whole citrus supply chain (researched by Rene Jacobs), pathogenicity and host specificity of the various *Penicillium* spp. on citrus fruit (studied by Pieter Louw), and fungicide resistance in *P. digitatum* and *P. italicum* isolates from citrus packhouses (done by Rene Jacobs). In later years, research projects (by Gerda Britz and Noncy Gomba) investigated food safety aspects, which identified potential contamination points on the citrus supply chain (notably packhouse water baths). The results of above research projects indicated the effects of postharvest treatments on microbial communities on fruit surfaces, and demonstrated that *Salmonella* can attach to and colonise citrus peel, but that it did not survive simulated cold storage conditions.

Various research teams led by Paul Fourie (CRI employed and seconded to the University of Stellenbosch) have refined the use parameters of Imazalil for citrus packhouses in South Africa between the years 2008 and 2017. During this time, excellent work was done by Arno Erasmus, Ncumisa Njombolwana, Elbie Liebenberg, Mareli Kellerman, Catherine Savage, Charmaine Christie, Cheryl Lennox and Wilma du Plooy. This research was a collaboration between CRI and the department of Plant Pathology at Stellenbosch University, most being postgraduate studies under the leadership of Paul Fourie, Arno Erasmus, Cheryl Lennox, and Wilma du Plooy, who replaced Arno Erasmus as CRI's lead postharvest pathology researcher in 2016.

Keith Lesar became the lead postharvest researcher from 1999-2011 and was responsible for commissioning the mini packline at Outspan Citrus Centre, so that semi-commercial packhouse trials could be conducted in-house. This equipment, which was added to over the years, was used by his successors, Arno Erasmus (2011-2016) and Wilma du Plooy (2016 to present). Keith Lesar continued after his 2011 retirement as a postharvest extension officer and was joined by Catherine Savage in 2017. With the relative stability in green mould control, other notable research was possible on different citrus postharvest fungicides and diseases, in studies of Wouter Schreuder on postharvest control of citrus black spot, and Lindokuhle Mamba and Charles Stevens on sour rot.

Resistance development against the postharvest fungicides is limited through carefully devised application strategies, which reduce the use of at-risk compounds. Nonetheless, resistance of *Penicillium* against thiabendazole and Imazalil had to be monitored. This was pioneered by John Mildenhall, in his capacity as CRI board member and technical advisor to a co-operative packhouse in the Katriver Valley, Eastern Cape. This work was continued at University of Pretoria by Lise Korsten and her team, and in later years at Stellenbosch University by Paul Fourie and Cheryl Lennox in various student projects. Cheryl Lennox expanded this fungicide resistance monitoring to include sour rot, as well as baseline resistance screenings for new chemistry.

In a globally-competitive market, postharvest research on citrus now moves at a rapid pace. Although the work laid down by pioneers such as Pelser is still used today, collaboration with South African universities, funding initiatives such as the Postharvest Innovation and Research for Citrus Exports programmes, and chemical suppliers are important in expanding CRI's ability to stay abreast of market related changes and threats. Most notable is the increasing food safety and market pressures on chemical residues, and the potential loss of Imazalil and other synthetic chemicals. Research in recent times, led by Wilma du Plooy as CRI's programme coordinator for postharvest diseases, focused on alternative options for postharvest fungicides and sanitisers, as well as non-chemical approaches to protect citrus fruit *en route* to export markets.

18.0 Sugarcane Pathology

THE EARLY YEARS

Reports of sugarcane being grown in South Africa date back to the 1600s, but the crop was first planted commercially in South Africa in 1848. The first official record of a disease on sugarcane in the industry was of smut (*Sporisorum scitamineaum*) on the north coast of Natal in 1877. This was also the first report of sugarcane smut worldwide. As the area under sugarcane expanded, the search for new varieties from other sugarcane-growing countries began. Varieties were imported in large numbers, and with the process being unregulated, various diseases were introduced. The most notable was mosaic, caused by the Sugarcane mosaic virus (SCMV), a single-stranded positive sense RNA virus from the family Potyviridae. A government mycologist, HH Storey recognised mosaic to be an important disease of sugarcane in South Africa in 1922. His recommendations resulted in legislation being passed in 1927 requiring all varieties, apart from the mosaic-resistant Indian variety Uba, to be eradicated. Despite continuing to import varieties, the industry became heavily reliant on Uba, which served the industry well for many years. The variety was, however, highly susceptible to sugarcane streak, caused by the Sugarcane streak virus (SSV – Mastrevirus: Geminiviridae). This disease was first reported as a variant of mosaic on sugarcane in Natal in 1914, but was later recognised as a separate disease in 1924. Its widespread distribution indicated that it had been present in South Africa for many years. Uba eventually succumbed to SSV, leaving the industry in crisis. This ultimately led to the establishment of the industry-funded South African Sugar Experiment Station (now the South African Sugarcane Research Institute - SASRI) in 1925. The dangers of relying on a limited number of varieties was recognised and the focus of the Experiment Station at the time was to obtain disease-resistant replacement varieties for Uba. This resulted in the construction of a quarantine glasshouse at the Durban Botanic Gardens in June 1925. In the 1930s, the first new varieties imported by the Director HH Dodds were released from quarantine for planting. The glasshouse at the botanic gardens was eventually demolished and a new quarantine facility was opened at the experiment station in Mount Edgecombe in 1984. In 1933, A McMartin was appointed as a Botanist-*cum*-Mycologist at the experiment station and began a research programme on the impact and management of the main diseases in the industry.

VIRAL AND PHYTOPLASMAL DISEASES

Mosaic has remained one of the most important viral diseases in the industry. Spreading takes place by planting infected clonal propagating material (seedcane) and by a number of different aphid species, with *Rhopalosiphum maidis* and *Hysteroneura setariae* being the most efficient. Roger A Bailey and GR Bechet developed effective mosaic resistance screening trials in the late 1970s which have become a routine part of the pathology programme and have played a key role in reducing incidence in the industry. KM Harborne and Roger Bailey studied aphid population dynamics, the effect of planting date on disease incidence and yield loss in the 1980s. In 1986, KM Harborne and John da Graça (UKZN) introduced SCMV detection by enzyme-linked immunosorbent assay. A reverse transcription polymerase chain reaction (RT-PCR) test was established at SASRI using the method of Yang and Mirkov developed at Texas A&M in 1997. Goodman detected different strains of SCMV by sequencing the 5' end of the coat protein gene in 1998. In 2013, Tania van Antwerpen developed a real-time quantitative PCR test for the detection of SCMV at SASRI. In 2019, Sharon McFarlane and CJ Kistan showed that the yellow sugarcane aphid *Sipha flava*, which arrived in southern Africa in 2013, does not transmit SCMV.

Yellow leaf syndrome was first reported in South Africa in 1994 by Roger Bailey. The symptoms resembled those reported from Hawaii in the late 1980s and were similar to those of yellow wilt, which was observed in east and central Africa in 1968 and the early 1970s. Sugarcane yellow leaf virus (SCYLV – Polerovirus: Luteoviridae) was detected in plants with YLS symptoms in 1997 using a specific antiserum in a tissue blot enzyme linked immunoassay (TB-EIA) developed by BEL Lockhart in 1996 at the University of Minnesota. CPR Cronje, working with A Tymon and P Jones (IACR Rothamstead, UK), reported Sugarcane yellows phytoplasma (SCYP - *Candidatus* Phytoplasma species 16SrXVI-A) in symptomatic cane in South Africa. Sugarcane yellow leaf virus was detected for the first time in South Africa by CPR Cronje in the same year. Mixed infections of the two pathogens were reported in South Africa in

1999. While the presence of SCYP was confirmed in some countries, SCYLV was more widely distributed and research on the virus is more extensive. Several genotypes of SCYLV exist worldwide: these are BRA for Brazil, CUB for Cuba, PER for Peru, and REU for Réunion Island. Tania van Antwerpen showed that the most common viral genotype found in commercial fields in South Africa is BRA. In 2013, Prabashnie Ramouthar and Stuart Rutherford reported yield reductions of 35-43% in some sugarcane varieties, while one variety gave an increased yield when infected. This virus is now widespread throughout the industry. SCYLV is vectored by two aphid species, *Melanaphis sacchari* and *Rhopalosiphum maidis*, as well as by planting infected seedcane. The more recent variety releases appear to be more tolerant to infection, with natural exposure to the pathogens in the early stages of the plant breeding selection programme eliminating the most susceptible and intolerant genotypes. Precautions are being taken to prevent the introduction of new strains of SCYLV, primarily through molecular testing of imported material and tissue culture that have been included in the quarantine protocols by Tania van Antwerpen and Stuart Rutherford.

In 2007, symptoms similar to maize streak (MS) were first observed in the newly released N44 variety in the lower south coast region of KwaZulu-Natal. Maize streak in maize is caused by Maize streak virus (MSV – Mastrevirus: Geminiviridae). Phylogenetic analyses done in collaboration with Ed Rybicki's group determined that the virus closely resembled the South African maize-adapted MSV strain, MSV-A, subtype MSV-A4, the most virulent strain on maize. The virus reduced the yield of infected N44 plants by more than 30%. Leafhopper species that act as vectors of MSV (*Cicadulina mbila* and *C. anestae*) were found to be widespread. In 2009, a decision was taken to cease planting N44 due to its susceptibility to the MSV-A4 strain. Growers were required to eradicate the variety by June 2015. A new species of Mastrevirus, Saccharum streak virus (SaSV), was discovered in sugarcane by Diane Shepherd and others at UCT in 2009.

BACTERIAL DISEASES

Ratoon stunt (formerly ratoon stunting disease (RSD)) was first identified in the industry in 1952, although the effects of the disease were probably already being experienced in the 1940s when the yields of Co281 inexplicably crashed. Researchers at the time relied on the more obvious symptom of stunting to diagnose the disease, but later found that some varieties exhibited an orange-red discolouration in the nodal regions of infected cane stalks. These symptoms were reported to be widespread in the South African industry and NC King initiated research on yield loss and control measures. Research in Australia indicated that RSD was spread on cutting implements and in seedcane. Based on these reports, NC King found that hot water treatment of seedcane at 50ºC for two hours was effective in reducing the incidence and impact of the disease in newly planted fields, and heat treatment facilities were established throughout the industry. It was only in 1972 that a bacterium was associated with the disease, making routine diagnosis with phase contrast microscopy possible. The bacterium was isolated by MJ Davis and his team in the United States in 1980 and identified as *Clavibacter xyli* subsp. *xyli*. It was later re-classified in 2000 as *Leifsonia xyli* subsp. *xyli*. The presence of the bacterium in South Africa was confirmed by Roger Bailey in 1975 and a routine diagnostic service was introduced in 1977 using phase contrast microscopy. Sharon McFarlane adapted an evaporative binding-enzyme immunoassay (EB-EIA) that was developed in Australia for routine diagnosis in 1998. Over 570 000 samples have been processed using phase contrast microscopy and EB-EIA since the service was first introduced. Tania van Antwerpen and FC Botha developed a *L. xyli* subsp. *xyli*-specific PCR in 1999 for research and quarantine purposes. With a shift in focus to the development of an in-field test for RSD diagnosis, M Ghai and her team at UKZN, in collaboration with SASRI researchers, developed a *L. xyli* subsp. *xyli*-specific modified loop-mediated isothermal amplification (LAMP) in 2014. The group modified the assay to eliminate carry-over contamination and replace colorimetric detection with a lateral flow device in 2017. A lateral flow device for the in-field serological detection of *L. xyli* subsp. *xyli* is currently being developed in partnership with the Technology Innovations Agency. In addition to developments in methods of diagnosis, SA McFarlane adapted a tissue blot-enzyme immunoassay developed in the United States to routinely screen varieties for RSD resistance in 2001 while regular yield loss trials provide information on the effect of RSD on different varieties.

While RSD has always been considered the most important bacterial disease in the industry, others have occasionally caused yield loss. Gumming (*Xanthomonas vasicola* pv. *vasculorum*) was the first disease of sugarcane recognized to be caused by a bacterium and was observed for the first time in South Africa in 1956. Graham Thomson reported the disease in a field of NCo310 showing “growth failure and general lack of vigour”. Since then, the disease has occasionally been observed in some varieties without causing notable yield loss and is currently considered to be of minor importance. In 1968, Graham Thomson confirmed the presence of leaf scald (*Xanthomonas albilineans* [Ashby 1929] Dowson 1943) in the industry. Roger Bailey reported periodic severe damage in some susceptible varieties and the disease has prevented the release of otherwise promising new varieties from time to time.

FUNGAL DISEASES

Smut re-appeared in the industry in 1945, causing serious losses in the highly susceptible variety Co301 in areas north of Durban. Further outbreaks occurred in the 1960s and 70s when NCo310 was widely grown. Roger Bailey and GR Bechet made extensive changes to the smut screening programme in the 1980s and the release of varieties with better resistance played an important role in reducing smut incidence in the industry over time. Besides spore transmission, smut is spread in seedcane and Roger Bailey showed that the addition of triadimefon to the hot water treatment tank when establishing certified nurseries provided some protection against infection. After a recent smut outbreak in the northern irrigated region, research is currently focused on developing methods to screen varieties more efficiently and at an earlier stage in the selection programme, providing evidence of the efficacy of broad-spectrum fungicides in reducing smut incidence and improving yields for product registration, and developing more effective methods to reduce inoculum levels in the field.

Brown rust (*Puccinia melanocephala*) was first reported in South Africa (and Africa) on Co301 by A McMartin in 1941. There was a resurgence of brown rust on susceptible varieties in the mid-1970s and again in the late 1990s. Sharon McFarlane showed that a strobilurin-triazole fungicide was effective in limiting yield loss caused by brown rust, and a number of foliar fungicides have since been registered for use against the disease. PR Ramouthar, working with Pat Caldwell (UKZN) and Sharon McFarlane, investigated the influence of temperature, leaf wetness and relative humidity on the severity of brown rust infections. This information was included in a rust risk model, developed to inform growers on optimal timing of fungicide application.

In 2008, an unknown species of rust was observed on sugarcane in Swaziland (eSwatini) and South Africa. LA Martin and D Lloyd Evans, working with LA Castlebury (USDA-ARS) showed that the symptoms were caused by a unique and previously unidentified rust pathogen. The name *Macruropyxis fulva*, causal agent of tawny rust, was accepted for this newly discovered rust species. *Miscanthidium capense,* a close relative of sugarcane, is thought to represent the native original host of *M. fulva* after the pathogen was confirmed to be the causal agent of similar symptoms observed on this grass species in the Drakensberg.

Monitoring of aerial rust inoculum was initiated by Stuart Rutherford and Sharon McFarlane in 2010. The primary aim was to provide early warning of an orange rust (*Puccinia kuehnii*) incursion, a disease that has recently spread around the world causing considerable yield loss. Protocols to detect *P. kuehnii, P. melanocephala* and *M. fulva* on the spore traps were refined by LA Martin and later by AC Koch. Orange rust spores were detected on traps periodically from July 2016, but the disease has not been observed on sugarcane in South Africa to date.

In the early 1940s, red rot (*Glomerella tucumanensis*) caused considerable damage in the industry, but was eventually brought under control with the use of resistant varieties. Surveys conducted by KL Trenor in the late 1980s indicated that the disease was most prevalent in the higher altitude areas with long growing cycles, and where crops were damaged by the lepidopteran stalk borers *Eldana saccharina* and *Sesamia calamistis*. In 2009, Sharon McFarlane and Stuart Rutherford reported that the reddening associated with eldana damage throughout the industry was more commonly caused by a *Fusarium* sp.

Another stalk rot, affecting sugarcane in the midlands in 1998, was identified as sour rot (*Phaeocytostroma sacchari*) by JL Goodall and Sharon McFarlane, working with Cecilia Roux (PREM, Pretoria). Normally a saprophyte or minor pathogen of the rind, the fungus caused severe rotting of the internal tissue of mature cane stalks after a prolonged dry period. This had a serious effect on juice quality. The disease continues to be problematic in stressed sugarcane, primarily in areas with long growing cycles.

QUARANTINE

Although the South African Agricultural Food, Quarantine and Inspection Services (SAAFQIS) is ultimately responsible for all plant quarantine in South Africa, SASRI pathologists were granted authority over their quarantine glasshouse since it first opened in the 1920s. The standards followed in the facility are based on the FAO/IBPGR guidelines for the safe movement of sugarcane germplasm. SASRI is also required to comply with the relevant provisions of the Agricultural Pests Act, 1983 (Act No. 36 of 1983), Control Measures R.110 of 27 January 1984 as amended.

SASRI exchanges sugarcane genotypes with many different countries, including Australia, Barbados, Brazil, Colombia, United States of America and Zimbabwe, to increase the genetic diversity of parents for breeding new varieties. The movement of sugarcane between countries carries a risk of introducing potentially serious diseases and therefore requires stringent quarantine procedures. Fungicides and thermotherapy should be effective in eliminating most fungal and bacterial pathogens from imported planting material on arrival at the quarantine facility. Viral pathogens such as Sugarcane streak mosaic virus, Fiji disease virus, Peanut clump virus, and Maize chlorotic mottle virus (MCMV), all infecting sugarcane elsewhere, pose the main risk. Of these, MCMV is found on the African continent. Maize lethal necrosis is a disease caused by a synergistic interaction between MCMV and certain viruses from the family Potyviridae, including SCMV. This disease is having a serious impact on maize yields in several African countries and the virus combination was reported in sugarcane in China in 2013. In 2009, S Ramgareeb and SJ Snyman developed a small apical meristem tissue culture technique that is currently in use at SASRI under the registered trademark Novacane®. In the SASRI quarantine facility, this technique limits the introduction and spread of known pathogens, as well as unknown pathogens for which there are no molecular tests. This methodology is also used to bulk up clonal planting material, ensuring that it is free of SCMV and SCYLV when distributed to growers. Currently, SJ Snyman and S Naidoo (UKZN) are developing cryotherapy of sugarcane meristems as an improved means of virus elimination, as well as for long-term storage of sugarcane germplasm at SASRI. Tania van Antwerpen introduced a range of molecular diagnostic assays which are used, together with selected serological assays and regular visual inspections, to confirm freedom from known pathogens before material is released from the quarantine facility.

DISEASE MONITORING

With the industry encompassing a wide range of environmental conditions that favour the development of different pests and diseases, centralised pest and disease management is challenging. Local Pest and Disease Control Committees (LP&DCC), now known as the Local Pest, Disease and Variety Control Committees (LPD&VCCs) were introduced in 1982 under the guidance of Graham Thompson, Roger Bailey and PH Paxton. This was mainly in response to the rapid spread and increase of the eldana stalk borer in the 1970s. However, the South African Sugar Association requested the preparation of draft regulations to enforce measures for the control of all pests and diseases that had the potential of spreading from farm to farm. The need to control the planting of varieties with differing levels of pest and disease resistance on a regional basis was also later recognized. This was achieved through the Sugar Act (Act 9 of 1978) and the Sugar Industry Agreement (2000), which make provision for the establishment of the LPD&VCCs and provide a means of protecting sugarcane growers against the effects of pests and diseases through routine monitoring of intended seedcane sources and commercial fields. Management and reporting structures have changed from time to time, but the system continues to provide an invaluable service to the industry.

19.0 Potato Pathology

Before the establishment of the Agricultural Research Council (ARC), all agricultural research was funded by the Department of Agriculture. The various institutions involved in agricultural research experienced an increasing shortage of funding from the Department. In the case of potato research, and likely also other crops, researchers approached commercial farmer organizations to donate funds for research projects.

Potatoes South Africa (PSA) (refer to section 15.4), then known as the Potato Producers Organization (PPO), supported the funding of potato research. As the need for funding increased due to decreased departmental funding, PSA decided to appoint a potato research manager (1992) to advise them regarding the numerous funding requests from research institutions. The research manager was tasked to compile a comprehensive research plan for the potato industry and to manage and evaluate research progress being made. He discussed the need for research with potato farmers in all the potato producing areas and prioritized the requests. The research manager reported to a national research committee, consisting mainly of potato producers.

Besides the national research plan, potato working groups were established in all the potato production areas in South Africa. Local agriculturists of commercial companies, researchers at universities and the Department of Agriculture, as well as extension officers in the provinces joined the potato working groups and became involved in regional-specific research. Potato farmers in the various production regions are also involved in the activities of the potato working groups. Field officers of Potatoes South Africa are actively involved in the working group activities.

Funds for research are provided for by the compulsory levy imposed on all bags of potatoes produced for consumption. Every year, the research committee discusses and approves the budget intended for approved and prioritized research projects. The research manager is responsible for the management of the allocated research funds.

The potato section at the ARC-VOPI is actively involved in potato pathology research and worked closely with the local potato breeding programme at the institute to develop resistance against certain potato diseases e.g. common scab. Several new potato cultivars with good resistance against scab were bred and released for local production. Over the years the University of Pretoria and Stellenbosch University became more and more involved with potato pathology, and they currently form an integral part of the national research plan of Potatoes South Africa, the potato industry's organization.

This following section summarises some of the important diseases on potatoes, and research done in South Africa to improve their management.

LATE BLIGHT

Worldwide, late blight (LB) is the most devastating disease on potato. Historically, the centre of origin of *Phytophthora infestans* has been considered to be either Mexico or the Andean region of South America. In the 1840s, the A1 mating type of *P. infestans* was accidentally spread to Europe and North America in infected tubers, and then spread to other potato production areas of the world, including South Africa. The earliest report of late blight in South Africa was in 1913 in Pretoria, in what was then the Transvaal province, with the disease soon reported from other provinces. In the 1970s, a second accidental spread of *P. infestans*, this time the A2 mating type, occurred from Mexico, again *via* the export of contaminated tubers. In some countries where both mating types of the pathogen were present, sexual recombination between the A1 and A2 mating types has resulted in the appearance of more virulent, recombinant genotypes of the pathogen, which have overcome resistance to certain commonly used fungicides.

In South Africa, late blight continues to be a problem on potatoes growing in environments that favour disease development, such as the KwaZulu-Natal midlands, Sandveld and the Mpumalanga Lowveld. Although genetic resistance is available, many producers prefer using varieties with low late blight tolerance, as these varieties are more resistant to other important pathogens.

To better understand the changes that can take place in *P. infestans* populations, a disease survey was undertaken in South Africa in the late 1990s by Adele McLeod at the ARC-VOPI. This study showed that the *P. infestans* population in South Africa was the "old" US-1 population, with only the A1 mating type present. The potato industry remained concerned about the possible spread of the A2 mating type or other more virulent clonal (asexual) genotypes of *P. infestans* to South Africa from northern sub-Saharan African (SSA) countries. A second survey in eight sub-Saharan African countries, including South Africa, was therefore carried out between 2007 and 2009. This large study, under the supervision of Adele McLeod (Stellenbosch University) was done in collaboration with Cornell University (Ithaca, USA) and the Australian National University (Canberra, Australia), with the support of the International Potato Centre (CIP) in Kenya, Uganda and Malawi, the Insitut des Sciences Agronomiques (Rwanda), the Kenyan Agricultural Research Institute and the Department of Agricultural Research Services (Malawi). The countries sampled included Burundi, Kenya, Malawi, Mozambique, Rwanda, South Africa and Tanzania.

Results relating to South Africa have clearly shown the following:

- The A2 mating type of *P. infestans* was not detected in any of the SSA countries sampled, including South Africa, so the chances of its introduction into South Africa *via* migration from northerly SSA countries is extremely unlikely.

- The late blight populations in South Africa, and in the rest of the SSA countries sampled were very similar, and still consisted of the US-1 genotype or variants, with only the A1 mating type detected in all countries sampled.
- Metalaxyl resistant *P. infestans* strains were detected in 2007-2009 in the Western Cape, despite the withdrawal of this product in 1996.

Potato farmers in South Africa rely on fungicides to control late blight. In the late 1990s Freddie Denner at the ARC-VOPI worked with a commercial company to demonstrate how disease forecasting models can be applied to optimise the use of fungicides. In the Sandveld, the spraying programme based on disease forecasting in a demonstration plot was effective and 10% cheaper than the commercial spraying programme.

ALTERNARIA DISEASES

In South Africa, diseases caused by *Alternaria* species are the most devastating foliar diseases on potato. This is especially in regions where potatoes grow into autumn, under irrigation or where the daily minimum and maximum temperatures vary sufficiently to allow a minimum period of leaf wetness. The first recorded case of early blight (*Alternaria solani*) was probably in 1900 in KwaZulu-Natal. The first study on the disease was between 1980 and 1984 by Graham Nevill and included the epidemiology and control of early blight in the mist belt of KwaZulu-Natal. Jacquie van der Waals (University of Pretoria) carried out a comprehensive study during the late 1990s to early 2003, which comprised the development and evaluation of the first decision support system for *A. solani* in South Africa. This included trends in concentration of airborne spores above the plant canopy as affected by weather patterns and characterization of *A. solani* isolates from various regions. A formal survey of potato farmers suggested that crop losses caused by *A. solani* are 20% on average, but can vary from 1% to 60%.

Atypical leaf blight symptoms were observed on potatoes between 2000 and 2010 in various production regions in South Africa. Lesions are observed before early blight and differ from typical early blight symptoms in that they are small and do not show the concentric rings typical of early blight. Yield losses as high as 40% were reported by farmers. Jacquie van der Waals and her team consistently isolated *Alternaria alternata* from the lesions and after conducting Koch's postulates, published a first report of *A. alternata* on potato in South Africa in 2010. Failure to control brown spot with the fungicides used to control *A. solani* led to an investigation on the putative development of resistance among *A. alternata* populations by Jacquie der Waals and her team at UP. The first report of reduced sensitivity among *A. alternata* isolates to QoI fungicides, including azoxystrobin, in South Africa was published in 2014.

Management of Alternaria leaf blight remains a problem. Consequently, current work by Elsie Cruywagen of the ARC-VOPI focuses on identifying species other than *A. solani* and *A. alternata* causing leaf blights. The work includes potato cultivar susceptibility and efficacies of various fungicides to control *Alternaria* diseases.

VIRAL DISEASES

All viral diseases affecting potatoes (PVX, PVM, PVA, PVS, PAMV, TSWV, AMV, PVY, PLRV and TSWV) in South Africa can be transmitted by seed potatoes, and virus infected potatoes generally lead to lower yield. With the exception of Tomato spotted wilt virus, Potato virus Y^{NTN}, Potato virus X and in exceptional cases, Potato leafroll virus, viral infections often cause no noticeable symptoms in potato tubers in South Africa.

South Africa was totally dependent on imported seed potatoes before World War II. Imported seed potatoes were multiplied locally, but deteriorated rapidly due to virus- and soilborne diseases. The development of a healthy seed potato industry started in the early 1950s and progressed to the promulgation of the Potato Certification Scheme in 1995. The work of Graham Thompson and Pieter Prins in the mid-1980s led to the introduction of the ELISA test to identify and quantify viruses in seed potatoes. Extensive validation of these tests was carried out by Neil Theron and Marieta Botha in the early 2000s. Today ELISA testing is routinely used in regional potato testing laboratories to diagnose and quantify PVY and PLRV in seed potatoes.

PVY^{NTN} was first reported worldwide in Hungary in 1983, and within the next 15 years had spread to every European country. PVY^{NTN} was identified in South Africa for the first time in 2005 from potato plants from the Sundays River Valley that produced tubers showing necrotic lesions. Dirk Bellstedt and students at Stellenbosch University subsequently examined the sequences of some of PVY isolates. This research led to the identification of the PVY^{NWilga} strain in South Africa. The final conclusion of this PVY strain assessment was that the strain composition of PVY in South Africa at the end of 2007 was 5% PVY^{O}, 15% PVY^{N}, 25% PVY^{NWilga} and 50% PVY^{NTN}. The phylogenetic analyses on the whole genome sequences indicated that the PVY^{NTN} and PVY^{NWilga} isolates that had been found in South Africa were closely related to European PVY^{NTN} and PVY^{NWilga} strains, and not to local PVY^{N} and PVY^{O} isolates. This points to the possibility that these strains were brought into the country via *in vitro* nuclear plants and were not tested for PVY infection by ELISA on arrival. Consequently, all imported nuclear plants are now tested for PVY and PLRV using RT-PCR. The work of Dirk Bellstedt further showed that the PCR tests for PVY and PLRV are much more sensitive than the ELISA test, particularly in freshly harvested tubers before storage. RT-PCR tests were subsequently validated and established at Plantovita (the controlling laboratory of the potato industry). These tests are currently available for testing for certification, but are seldom requested as they are much more sensitive than the ELISA tests, and are also more expensive.

TSWV was first recognised in South Africa as early as 1905 in the Eastern Cape, and has always been a limiting factor to the production of crops such as tomato and tobacco in the Western and Eastern Cape. However, with the arrival of the Western flower thrip, *Frankliniella occidentalis* into South Africa in 1987/1988, the incidence of this virus has been on the increase in other crops and in other provinces. The Western flower thrip is a very efficient vector of TSWV virus, but is resistant to many insecticide groups. During the summer season of 1997/1998, TSWV posed a severe threat to potato production in the Northern Cape and North West Provinces. Michelle Cloete and Graham Thompson (ARC-VOPI) interviewed affected farmers and concluded that every outbreak of this virus was associated with the production of paprika on the same farm. In most instances paprika seedlings were purchased from an area known to be heavily infested with TSWV and Western flower thrips (the vector for TSWV). They also conducted a survey on weeds in each affected area and found that many weed species acted as reservoirs of TSWV. The infection pressure was reduced when farmers adopted the recommendations of the researchers to either stop growing paprika or produce their own seedlings and to control weeds. Today TSWV is more or less under control and occurs only sporadically on potatoes.

BACTERIAL WILT

The most destructive bacterial disease of potatoes, bacterial wilt, is caused by the pathogen *Ralstonia solanacearum.* After the first report of the disease in South Africa in 1914, it remained relatively unknown to the South African potato industry until the mid-1970s, when there were confirmed visual detections in both seed and commercial potato plantings. This sudden increase in outbreaks was a cause of great concern and subsequently a number of research projects were initiated at ARC-VOPI and the Universities of Pretoria and Stellenbosch. Results of these studies all contributed to the industry's ability to manage bacterial wilt. Currently *R. solanacearum* is a quarantine pathogen in the seed potato industry, with zero tolerance status in the Seed Potato Certification Scheme. In 1995, the potato industry started testing all registered seed potato plantings using an ELISA test kit, developed by Dirk Bellstedt (SU), for the presence of bacterial wilt. This involves the sampling of fields by certification officials according to a sampling method approved for use in the United States of America to combat ring rot (*Clavibacter michiganensis*) disease. Any sample that tests positive for bacterial wilt with the ELISA test is then confirmed by the controlling laboratory by means of a PCR test established by Plantovita, while conventional plating-out techniques are used for strain identification.

Several comprehensive surveys and characterisation studies by Anita Swanepoel (ARC-VOPI) have shown that biovar 2 (race 3) is the most prevalent biovar on potatoes in South Africa, causing infection in cooler regions and in high-altitude locations. Moreover, latent infection of tubers in cooler climates by biovar 2 can result in the increased spread of the pathogen, with potatoes, tomatoes and certain weed species being most susceptible. Lize Stander and Piet Hammes (UP) showed that in South Africa *R. solanacearum* was able to survive in the soil for eight years after the initial infestation. A large number of crops and weed species were tested for their ability to host the pathogen (by Anita Swanepoel, Nico Mienie and Anel Espach). The effect of incubation temperature, storage period and inoculum concentration on the multiplication and survival of *R. solanacearum* in tubers was investigated by Anita Swanepoel. Results of this study refuted a theory that cold storage (4°C) of latently infected tubers for 10 weeks can rid potatoes of *R. solanacearum*. Viable counts dropped and remained relatively low whilst in cold storage, but increased exponentially after removal from storage. These results pointed to the reality and risk of latent infection of tubers infected with *R. solanacearum*. Additional studies included the effect of temperature on wilting and on progeny tuber infection (Anita Swanepoel), survival of the pathogen in the stems and roots of weeds (Anita Swanepoel), the effectiveness of various sanitisers (Nico Mienie, ARC-VOPI) and herbal plant extracts (Wilma van Broekhuizen and Lise Korsten, UP) to kill bacterial cells, biological control (Nico Mienie), bio-fumigation (Lize Stander, UP) and survival of bacterial cells in the digestive tracts of various farm animals (Nico Mienie) to name only a few.

DRY ROT

In 1934, Dippenaar isolated *Fusarium oxysporum, F. coeruleum* (*F. solani*), *F. solani* and *F. sambucinum* from potatoes with dry rot, while Alex Jandrell, Jake Van Reenen and Gavin Hill isolated *F. equiseti*, *F. avenaceum* and *F. merismoides* from diseased potatoes. However, the pathogenicity of these species was not tested. Arno Visser (1975) identified *F. solani* as the main causal organism of potato dry rot in Mpumalanga, one of South Africa's main dryland production areas during this time. These contrasting reports might have been because of the different classification systems followed and the variability of certain species. A comprehensive survey and study was initiated in 1985 under the leadership of Neil Theron (ARC-VOPI). Tubers from 125 farms in ten regions throughout South Africa were used. Fourteen *Fusarium* spp. were isolated from dry rot and stem-end rot lesions of potato tubers collected from 51 farms in two major dryland production regions of South Africa. *Fusarium oxysporum* and *F. solani* were the predominant species isolated. Eight species (*F. oxysporum, F. crookwellense, F. solani, F. sambucinum, F. acuminatum, F. graminearum, F. scirpi* and *F. equiseti*) caused typical dry rot lesions on inoculated potato tubers. *Fusarium oxysporum* was the most pathogenic of the fungi. *Fusarium acuminatum* subsp. *armeniacum* was isolated for the first time in South Africa from potato tubers on 64 farms in eight irrigated regions of South Africa. The optimum temperature for infection by *Fusarium* species causing dry rot was reported to be 15˚C, however, in Neil Theron's study the maximum decay occurred on tubers incubated at 25°C. Local isolates of pathogenic *Fusarium* species are possibly adapted to the high temperatures that prevail in the production regions. Another study showed that fusaric acid production by *F. oxysporum* isolates seemed to play a major role in the development of dry rot in potato tubers of susceptible cultivars. Sonja Venter (ARC-VOPI) showed that *in vitro* culture combined with somaclonal variation for the selection of fusaric acid resistant potato phenotypes showed potential, since somaclonal variation can already be present in the explant or can be induced by the technique.

VERTICILLIUM WILT

Verticillium wilt causes premature death of potatoes, which shortens the growing period and may substantially reduce the number and size of progeny tubers, thus greatly affecting the yield. Subsequent to the first report of Verticillium wilt of potato in South Africa by Doidge in 1950, no new cases were confirmed until 1989. The increased number of recordings since 1989 showed Verticillium wilt to be a growing problem for the potato industry. In a survey conducted between 1995 and 2000 by Cornel Millard (ARC-VOPI), 93 *Verticillium* isolates were characterised, of which 60% were identified as *V. dahliae* and 8% *V. nigrescens. Verticillium dahliae* was present in nine of the then 14 potato-growing regions and *V. nigrescens* in seven. Unidentified *Verticillium* species were isolated from six of the regions. Both *V. dahliae* and *V. nigrescens* were pathogenic to potato *in vivo*, with *V. dahliae* the more virulent of the two species. *V. albo-atrum*, previously reported by Ethel Doidge (1950) was absent, although that probably relates to advances in protocols used to identify fungi.

During 2017 and 2018, Estianne Retief (ARC-PHP) carried out a survey in the Sandveld, using more modern techniques for identification than in the previous survey by Millard. Plants of crops used in rotation with potatoes in the Sandveld were included. From a collection of 82 *Verticillium* isolates, all were identified as *Verticillium dahliae*. Nine *Verticillium* isolates were identified from oats (three isolates), serradella (five isolates) and rye (one isolate) and were confirmed to be *V. dahliae*. These are all crops used in rotation with potato in the Sandveld. The genetic diversity was evaluated for all 91 *V. dahliae* isolates. Three isolates belonged to clonal lineage 4A (VCG 4A, haplotype II, genotype E) and the remaining 88 isolates to lineage 4B (VCG 4B, haplotype I, genotype C). All of the *V. dahliae* isolates from the rotation/cover crops belonged to clonal lineage 4B. A genetic diversity study of the *V. dahliae* isolates collected during the survey indicated that this population has a low genetic diversity. All of the rotation plants tested during this study have the potential to produce microsclerotia within their plant tissue and may, therefore, contribute to the survival and increase of *V. dahliae* inoculum in the soil.

SOFT ROTTING PECTOBACTERIACEAE (SRP)

Soft rotting Pectobacteriaceae (SRP) pose a significant threat to potato production in South Africa and globally. The taxonomy of SRP has undergone several changes in the past few years and, through multiple surveys conducted worldwide, new novel species of *Pectobacterium* and *Dickeya* have been identified. The first report of SRP in South Africa was by Suretha Serfontein (ARC-VOPI) and co-workers in 1991, after a wilt disease appeared in seed-potato crops during the 1988 season. *Pectobacterium carotovorum* subsp. *carotovorum* [Pcc] (= *Erwinia carotovora* subsp. *carotovora)* and *Dickeya dadantii* (= *E. chrysanthemi)* were isolated from wilted plants, but Pcc was the dominant pathogen. There was an indication that *D. chrysantemi* was more virulent at a higher temperature range (28-32°C) and Pcc at a lower temperature range (20-25°C). It was found that the potting compost, irrigation water and some parent tubers used for the propagation of plantlets at the Foundation Seed Scheme, were contaminated with Pcc.

More than 20 years after the first report, during the 2006/2007 potato growing season, outbreaks of blackleg with symptoms similar to those described in Brazil were observed. The causal agent was identified as a new subspecies in South Africa, *Pectobacterium carotovorum* subsp. *brasiliense* (Pb) in 2010 by Hanli van der Merwe, Jacquie van der Waals and co-workers (UP). In a later survey by Jacquie van der Waals and Elizabeth Ngadze, they reported the presence of *Dickeya dadantii* and *Pcc* in the South African potato industry. Occurrence of *Pectobacterium parmentieri* (= *P. wasabiae*) in South Africa was reported by Lucy Moleleki (UP).

A number of studies have subsequently been carried out, as the SRP can cause substantial losses if conditions are conducive to soft rot and blackleg development. Susan du Raan and Jacquie van der Waals (UP) published cardinal growth temperatures for six different species and found that the cardinal temperatures and sensitivity to temperature vary amongst species. It is noteworthy that *Dickeya solani,* which has not yet been found in South Africa, can grow at 42°C and has an optimal temperature of 35°C. Van der Waals and students reported that chlorine-based products showed the most promising results for managing *P. brasiliense* in potato.

Lucy Moleleki and students (UP) established that *P. brasiliense* is the most virulent of the *Pectobacterium* spp. occurring in South Africa. Temperature did not affect the virulence of *P. brasiliense.* The results of a survey of rotting vegetables in South Africa suggest that of the isolates identified, 69% were *P. brasiliense*, 23% *Pectobacterium carotovorum* subsp. *carotovorum* and 8% *P. wasabiae.*

With respect to cultivar susceptibility, Lucy Moleleki found that Mondial and Valor were highly susceptible, while Avalanche, BP1 and Sifra were moderately susceptible. No cultivar was tolerant to soft rot, however the results showed that BP1 is highly tolerant to blackleg. Rinette Gouws and her team evaluated the susceptibility of potatoes after harvest. Their results confirmed that Valor is highly susceptible, and that Sifra is moderately susceptible. More tubers rotted when they were pricked than shaken to remove part of the skin on the tuber. Elizabeth Ngadze and Jacquie van der Waals (UP) found that resistance of a large number of varieties was correlated with high polyphenol oxidase (PPO) and phenylalanine lyase (PAL) enzyme activity, as well as increased concentrations of chlorogenic acid and total soluble phenols. PPO, peroxidase (POD), and PAL activities increased significantly in wounded and inoculated tubers. These findings show that PAL, PPO, peroxidase, chlorogenic acid, and total soluble phenols play a role in imparting resistance to potato soft rot infection. Elizabeth Ngadze, Teresa Coutinho and Jacquie van der Waals also demonstrated that soil amendments of calcium increase concentration of calcium, caffeic and chlorogenic acid in tuber peels, which in turn reduces the maceration effect of pectinolytic pathogens.

SILVER SCURF AND BLACK DOT

The importance of silver scurf (*Helminthosporium solani*) and black dot (*Colletotrichum coccodes*) has traditionally been overlooked by the potato industry. Research by Freddie Denner (ARC-VOPI) from 1991 to 1997 showed that black dot and silver scurf were omnipresent on washed tubers from three major seed production regions, with black dot the most prevalent overall. Results highlighted the fact that *Colletotrichum coccodes* does not merely cause a blemish disease, but that it is a soilborne pathogen with sclerotia able to survive in soil for many years, and that management requires an integrated approach. The most important cultivars in South Africa at the time of the study were all susceptible to both *Helminthosporium solani* and *Colletotrichum coccodes*. Other studies by Freddie Denner showed that infection of seed tubers by *C. coccodes* affected the sprouting, and that the greater the tuber area affected, the poorer the physiological condition of the tuber. Denner's research further focused on control measures such as treatment of seed tubers with prochloraz, fumigation of soil, disinfection of storage facilities, solarization and tillage of soil.

COMMON SCAB

Common scab, caused by *Streptomyces* species, was first recorded in South Africa by Pole-Evans (1906). The aetiology, epidemiology and control of common scab have been investigated extensively in many countries and the disease was the topic of various studies in South Africa during the first half of the previous century. Most potato cultivars grown at that stage were susceptible to the disease, and huge losses were incurred due to a reduction in the cosmetic value of the produce. Research at ARC-VOPI in the 1980s and 90s focused primarily on control using plant protection products and screening of genotypes for resistance in the breeding programme. A screening method was developed by Letitia Marais in 1988. Several cultivars with resistance to common scab were released by Arno Visser (ARC-VOPI) during the 1990s. The value of crop resistance in disease control is well illustrated by the fact that the most popular potato cultivar, BP1, susceptible to common scab, was replaced in a short period of time by Mondial with resistance. Today, common scab resistance is a fundamental requirement for new cultivars.

Surveys and characterisation of *Streptomyces* species causing common scab have been carried out by Reinette Gouws (ARC-VOPI), Estiene Jordaan and Jacquie van der Waals (UP). *Streptomyces scabiei* is largely accepted as the most important causal organism of common scab. Estiene Jordaan and Jacquie van der Waals (UP) published the results of a comprehensive survey of Streptomycetes isolated from common scab lesions in South Africa in 2016. Isolates were characterized morphologically, physiologically and genetically. Most pathogenic isolates were *S. scabiei* and *S. stelliscabiei*. All three pathogenicity/virulence genes (*txtAB*, *nec1*, and *tomA*) were found in South African isolates. Pathogenicity could not be linked to the presence of a single one or any combination of two of the three genes.

The work of Reinette Gouws (2006-2012) focused on aspects of management of common scab. Of nine rotation crops tested for their ability to sustain or suppress *Streptomyces scabiei,* rye, triticale, pea and cabbage showed a marked suppressive effect on *S. scabiei,* whereas pumpkin, maize, soybean, sunflower and spinach had little impact on total densities of the pathogen. Biofumigation with *Brassica* crops, especially cabbage, was found to have the potential to reduce common scab disease. In 2012, Reinette Gouws reported a new symptom on potatoes, which was named 'fissure scab' and repeatedly isolated unknown *Streptomyces* species from the lesions. A team at ARC-VOPI confirmed that a new *Streptomyces* species is the cause of the new symptom.

RHIZOCTONIA DISEASES

Apart from the first recording of Rhizoctoniasis on potatoes by Ethel Doidge in 1918 and subsequent reference to the problem, the first investigative study on the disease was only conducted at the end of the 20th century by Johan du Plessis (1999). He focused on chemical, cultural and varietal control, the effect on inoculum source and temperature on disease. In 2005, Mariette Truter (UP) published results on a study that focused on the aetiology of Rhizoctoniasis in South Africa and strategies for alternative and novel control of the disease. This included disinfection and hot water treatment of tubers, compost from different sources, application of antagonists, and the use of plant protection products. Mariette Truter reported that 99% of the *Rhizoctonia solani* isolates collected from seven potato-production regions belonged to the anastomosis group (AG 3-PT) and that this group was the most virulent of all those tested.

Norman Muzhinji, under the supervision of Jacquie van der Waals (UP), Mariette Truter (ARC-VOPI) and James Woodhall (University of Idaho), conducted a comprehensive study on the characterization and symptomatology of *Rhizoctonia* species associated with potatoes in South Africa, between 2013 and 2016. The study confirmed Truter's results, but also found other AGs including AG 2-2IIIB, AG 4HG-I, AG 4HG-III and AG 5, as well as binucleate *Rhizoctonia* (BNR), AG A and AG R, to be associated with diseased potatoes. Additionally, this study included the first report of AG 4HG-III, AG R causing potato diseases globally, AG 2-2IIIB, AG 4HG-I and AG A causing potato diseases in South Africa, and also AG 3-PT causing elephant hide and growth cracks on potato tubers in South Africa. A population genetic diversity study on *R. solani* AG 3-PT isolates in South Africa showed that they were genetically diverse and differentiated, therefore disease management strategies should be applied accordingly.

The relative importance of seed tuber- and soilborne inoculum of *R. solani* AG 3-PT on potato disease development was also investigated by this team. Seed inoculum was found to be the predominant and most important genotype in inciting potato diseases, although the synergistic effect of the two types of inoculums were evident. In another study, Muzhinji *et al.* evaluated the sensitivity of *Rhizoctonia* AGs to different fungicides *in vitro* and *in vivo*. Their results demonstrated variable sensitivity within and among AGs of *R. solani* and BNR to different fungicides, highlighting the need for continued monitoring of fungicide sensitivity to manage Rhizoctoniasis in potatoes.

DISEASES CAUSED BY *SPONGOSPORA SUBTERRANEA* F.SP. *SUBTERRANEA*

The internationally-recognised James Vanderplank, while Director of the Plant Protection Research Institute in Pretoria between 1953-1971, stated that powdery scab is unlikely to become a problem in South Africa because cool and wet conditions are required for disease development. Unfortunately, this is not the case. The first major outbreak of the disease was in the 1980s in the Sandveld growing region. The pathogen, *Spongospora subterranea* f.sp. *subterranea* (Sss), causes root infection, root galling and unsightly powdery lesions on tubers. It is hypothesised that infected seed potatoes were imported from Scotland in the 1950s and 1960s and then propagated at the Foundation Seed Scheme, subsequently spreading Sss throughout the country on seed tubers.

Today, powdery scab is recognized as one of the most important emerging potato diseases in South Africa. A solid understanding of the biology of the pathogen, epidemiology of the disease, and response of the host is required for development of a successful integrated pest management (IPM) programme. In order to develop a customised IPM for South Africa, various aspects have been investigated by Jacquie van der Waals and her team at the University of Pretoria since 2006. In 2012 they published a novel study that documents the source and possible eradication methods of Sss in a mini-tuber production facility. The susceptibility of the most commonly planted cultivars to Sss was screened in pot and field trials, and the results were collated to produce a susceptibility scale for root and tuber infection of these cultivars. The correct choice of rotation crop is also imperative in the management of diseases. Crops often planted in rotation with potatoes were assessed for their Sss host status. The same was done for weeds commonly encountered in cultivated fields. Crops in which Sss can complete its full life cycle and then form resting spores should be avoided when planting in fields contaminated with Sss, as they may contribute to an increase in Sss soil inoculum. However, crop rotation with trap crops can be an effective long-term mechanism for reducing disease incidence in a field, as the pathogen is unable to complete its life cycle within these hosts, thus reducing the amount of Sss inoculum in the soil. Pot trials in growth cabinets were used to determine optimal soil temperature and moisture levels for root infection by Sss. Pot and field trials showed that application of certain soil amendments or treatments can reduce the final amount of disease encountered.

20.0 Forest Pathology

Any historical account of the field of forest pathology in South Africa is bound to be somewhat incomplete and fragmented. This is firstly because the definition of forest pathology varies amongst those working in this field. For example, some researchers working in this field choose to distinguish between tree pathology and forest pathology. Those defining themselves as tree pathologists include work on trees in natural ecosystems, planted forests (plantations) as well as amenity trees and orchard (fruit) trees. The argument here is that even fruit trees are trees in forests somewhere in the world and their health in the two disparate environments is deeply interconnected. Thus, trees in plantations and orchards are considered collectively and are only different in the products for which they are grown. In contrast, some purist forest pathologists work only on the health of trees in natural woody ecosystems. A second reason why this account will be incomplete is that there are fragmented records of the people that have worked in this field, especially prior to the early 1970s.

Most work on forest tree diseases in South Africa has focused on problems of relevance to the South African forestry industry. This industry relies on intensively managed plantations of non-native tree species, mostly those in the genera *Pinus, Acacia* and *Eucalyptus*. In this regard, it is relevant to note that South Africa has the world's oldest plantation forestry programme based on planting of non-native trees. This emerges from the reality that the country has minimal resources of wood crucial for construction timber and fuel, and where plantations were established to preserve native trees from destruction.

From the earliest days of plantation forestry, disease problems were recognized as a constraint to plantation productivity. This is clear from early papers, such as by P MacOwan in the *Agricultural Journal* of 27 June 1895, commenting on a health problem of *Eucalyptus* in the Fort Cunninghame plantation, reported by TR Sim, the Conservator of Forests, King William's Town. It is clear from that report that very little was known at the time regarding diseases in forest plantations. Likewise, one of the first formal reports of a disease of trees was that by John Fisher in 1912 (Farming in South Africa), recording what appears to be the first record of shoot blight caused by the fungus *Diplodia sapinea*. The intersection of mycology and forest pathology is also relevant in this regard, where various tree-infecting fungi were recorded in the early 1900s by mycologists, most notably Ethel Doidge and her colleagues. Most of these reports were of the fungi without pathogenicity data, and the absence of Koch's Postulates being proven. Thus, the connection to disease was uncertain or unknown.

In the early days of forestry in South Africa, most plantations were the property of the South African government and thus under the jurisdiction of the South African Department of Forestry. Forestry research was based at the Forestry Research Institute in Pretoria West.

A milestone in the history of forest pathology must certainly be the attendance of H Luckhoff at the 6th FAO/IUFRO symposium held in Rome in 1964, where he presented a paper on diseases in South African forest plantations. In that presentation, Luckhoff made the statement that South African forestry had been particularly fortunate in not having been seriously affected by diseases. This was an interesting view, given that some diseases such as leaf blight on *Eucalyptus globulus* caused by *Teratosphaeria nubilosa* (then *Mycosphaerella molleriana*) and needle blight caused by *Dothistroma septosporum* (then *D. pini*) had in fact substantially altered the tree species that could be planted in some areas. It is reasonable to assume that Luckhoff's view captured the possible impact that diseases could have had on plantation forestry, at least in comparison to what had happened elsewhere in the world.

As plantation forestry grew in South Africa, especially in the late 1960s, concern began to grow regarding the negative impact that diseases could have on an important emerging industry. At that time, there was clearly very little capacity to deal with tree disease problems. This led to the American forest pathologist, CS Moses (who retired from the USDA Forest Service in 1978) being appointed as a consultant to the Department of Forestry. It is unfortunate that there appear to be no surviving records as to the duration of this consultancy, or the work that CS Moses carried out.

During the 1960s, commercial forestry was growing in South Africa, with companies such as Sappi and Mondi acquiring land for plantation development and to supply the paper mills that they were establishing. At that time, an interest in forest pathology research began to emerge in university plant pathology departments, mostly linked to contracts with the government's Department of Forestry. For example, Lawrence Marais, a silvicultural forester in the Department of Forestry, was mentored by CS Moses and completed an MSc degree studying mycorrhizae under the guidance of Ballie Kotzé at the University of Pretoria. Marais served as a forest pathologist in the Department of Forestry from 1969 to 1973, after which he joined CapeSpan International (previously Outspan International) as a citrus pathologist. He had obviously been influenced by Kotzé, who was world-renowned for his work on citrus diseases!

At that time, the Department of Agriculture and, more specifically, the Plant Protection Research Institute (PPRI) assumed the responsibility to provide pathology and entomology support to the Department of Forestry. This was motivated by the fact that agriculture had access to reasonable numbers of pathologists and entomologists and as an environment better suited to conducting research in these fields than was true for a forestry department. Thus, in 1971 the plant pathologist Jozsef Darvas, who had come to South Africa after having escaped communist rule in Hungary, was employed by the Department of Agriculture (refer to section 28.8). He completed an MSc degree at the University of Pretoria, producing a dissertation on damping off diseases in South African pine nurseries, before moving to study avocado black rot. This change of direction might also have been linked to his studying under the guidance of Ballie Kotzé, who was deeply involved and internationally recognized for his work on avocado diseases. Jozsef Darvas later became world-recognised for his pioneering work on the wide host-range tree pathogen *Phytophthora cinnamomi* and showing that the disease could be managed by injecting trees with phosphorus acid.

When Joszef Darvas (refer to section 27.8) left research on plantation tree diseases to begin his career (including a PhD) working on avocado disease problems, the PPRI was under pressure to provide forest pathology support to the Department of Forestry. In 1979, Michael (Mike) Wingfield, was completing a BSc Honours degree in plant pathology at the University of Natal in Pietermaritzburg, and was obligated to join the Department of Agriculture and to work back the two years of bursary support. He was posted to the PPRI Plant Quarantine Station in Stellenbosch, supported by the fact that this would place him close to Stellenbosch University, home to the only Faculty of Forestry in South Africa, as well as to the PPRI forest entomology laboratories in Rosebank (Cape Town). Another advantage of starting a new forest pathology base at the quarantine station was that the American plant pathologist Sharon von Broembsen, working on *Phytophthora cinnamomi*, well-known to be an important forest tree pathogen, was based at that research station.

Mike Wingfield was tasked with building the first integrated forest pathology programme in South Africa. He was provided with laboratory facilities and found a working environment and colleagues with whom he could collaborate. Other than the very influential Sharon von Broembsen, these included Mike Morris, who worked on the biological control of woody invasive weeds, Wally Marasas (a globally recognized mycologist), Derek Donald (Professor of Silviculture at the University of Stellenbosch) and Peter Knox-Davies (Professor and Head of the Department of Plant Pathology at the University of Stellenbosch) amongst others. Mike Wingfield then began to survey forest plantations in South Africa, to become familiar with the field and industry and to undertake research that would form part of his MSc degree, registered with the Stellenbosch University.

During his first two years with the PPRI, Mike Wingfield began to build a solid base of forest pathology research in South Africa. He received support and enthusiastic encouragement from leaders in the forestry industry who wished to see the field develop in order to provide long-term support. It also became clear that he needed specific education in the field, and he sought financial support to undertake a PhD degree in the United States. With support from the PPRI, Mike Wingfield left South Africa at the end of 1979 to begin a PhD in plant pathology/entomology at the University of Minnesota.

The departure of Mike Wingfield to study in the United States left the PPRI under pressure to continue providing pathology support for the forestry industry. This resulted in an American plant pathologist, John Lundquist, who had recently completed a PhD at the University of Georgia (1979), being employed in 1982. When Wingfield returned to Stellenbosch at the end of 1983 and with an aim of distributing support to the forestry industry, Lundquist moved with his research group to the Forest Research Station in Sabie. By this time, a reasonably strong base of forest pathology research was beginning to emerge in South Africa.

Once back in Stellenbosch, Mike Wingfield began to establish a research team with a small number of technical staff. He was joined by forestry student Wijnand Swart, who began an MSc degree with him and registered in the Department of Plant Pathology at Stellenbosch University. Mike Wingfield also assumed responsibility for teaching the forest pathology course that was mandatory for all Stellenbosch forestry students. This brought him in contact with Pedro Crous, who also joined the team for an MSc degree in Plant Pathology. Both Swart and Crous went on to undertake PhD degrees with projects on forest pathogens with Mike Wingfield as advisor. This contributed substantially to a growing base of knowledge regarding tree diseases in South Africa. John Lundquist returned to the United States in early 1988 at a time where the political situation under the apartheid government in South Africa had become uncomfortable for him.

In mid-1988, Mike Wingfield decided to move his research to a university environment and assumed a faculty position in the Department of Microbiology at the then University of the Orange Free State (UOFS). The following year, Wijnand Swart also moved to the UOFS and the Department of Plant Pathology. Pedro Crous, having completed an MSc degree at Stellenbosch University was conscripted to military service, but after basic training, moved to the PPRI research facilities in Rietondale, Pretoria, where he pursued research towards a PhD, registered at the UOFS with Mike Wingfield as advisor. Mike Wingfield's move to the UOFS raised concerns for the forestry industry, which via their industry association the Forestry Council (now Forestry South Africa), entered into a negotiation to maintain his support. This arrangement was formalized through the establishment of the Tree Pathology Co-operative Programme (TPCP) at the UOFS in the beginning of 1990.

At the time when the TPCP was established, the Institute for Commercial Forestry Research (ICFR), based on the campus of the University of KwaZulu-Natal in Pietermaritzburg, was aware of the growing need for tree health research to support the South African forestry industry. At that time the ICFR had a small forest entomology section, but no forest pathology programme. Prior to that time and in the late 1960s, the institute, then known as the Wattle Research Institute, employed a physiologist/pathologist FCJ Zeilemaker, who worked on a disease known as "black butt", a disease of *Acacia mearnsii* caused by *Phytophthora nicotianae*. Due to the absence of pathology at the ICFR, the Institute became a formal member of the TPCP. This was also motivated by the fact that the forestry industry funders of the TPCP also provided the core financial support for the ICFR and logically, wished to see collaboration between the groups. This led to the employment of a young pathologist, Nicola Knipscheer, at the ICFR who then undertook an MSc degree with Wingfield and Swart as her advisors. After the departure of Knipscheer some years later, pathology research was terminated at the ICFR and the forestry industry came to rely entirely on the growing TPCP team of forest pathologists for research and extension services.

Establishment of the TPCP marked the first major step towards the establishment of a unified and sustainable forest pathology programme in South Africa. Funding for the TPCP was formalised following a 'leverage' model, with the University of the Free State contributing the salaries of academic staff and physical facilities and the forestry industry covering running costs. This funding base was fortified by a National Research Foundation grant to Mike Wingfield via their Rated Researchers programme. In later years, funding from the forestry industry was matched (various models used) via the Technology and Human Resources for Industry (THRIP) programme of the Department of Trade and Industry. With this base of support, the TPCP grew to include a strong team of mainly postgraduate students and various academic staff at UFS. Research outputs grew substantially, national and international collaborations were strengthened and an international footprint began to emerge. Further details are provided in sections 8.1 and 8.3.

After 10 years at the UFS, the TPCP moved to the University of Pretoria, forming the catalyst for the newly-established Forestry and Agricultural Biotechnology Institute (FABI). This move included four academic staff members (Mike Wingfield, Brenda Wingfield, Teresa Coutinho and Annamaria Botha-Oberholster) moving their research programmes to the University of Pretoria where they were joined by approximately 50 MSc, PhD students and postdoctoral fellows, mostly working on some aspect of tree health. This team continued to grow in number as new funding streams emerged, mostly linked to the growing impact of the research being undertaken, not only in South Africa but globally. In 2003, the forestry industry decided to include their forest entomology research needs within the responsibilities of the TPCP. This was based on the fact that these two fields are closely connected with tree health problems typically emerging from strong associations between insect pests and microbial pathogens. At this time, the Tree Pathology Co-operative Programme was re-branded as the Tree Protection Co-operative Programme (still the TPCP), and it marked a period of further growth and development.

In 2014, the tree health team at FABI was recognized by the Department of Science and Technology (DST) (now the Department of Science and Innovation (DSI)) as one of the first six government-supported Centres of Excellence. This became known as the DSI-NRF Centre of Excellence in Tree Health Biotechnology (CTHB) at FABI and contributed substantially to the growth of the research team. Establishment of the CTHB alongside the TPCP, which was already successful and highly recognized, led to some fundamental changes to tree health research being conducted at FABI. Most important of these was the inclusion of projects focused on the health of trees in native woody ecosystems. The CTHB provided funding for these projects, not only centrally at FABI, but also at various other academic institutions in South Africa. This allowed for substantially greater collaborative research and education linked to tree health in the country.

Details regarding the establishment of FABI, of which Bernard Slippers (also a forest health specialist) became Director in 2018, and its impact on tree health research are captured in other parts of this SASPP history and in a document "The road to research excellence: The FABI story" published on the occasion of the 20th Anniversary of FABI in 2018 and available on the FABI website (www.fabinet.up.ac.za). At the time of compiling this historical perspective, FABI accommodated the single largest group of academics and students (a team of some 150 people) conducting research on tree health problems globally. This ensures that South African forestry has access to world-class forest pathology and forest entomology research support. Importantly, this team has established substantial global collaborative projects with associated satellite research programmes in Australasia, Europe, Latin America and North America.

21.0 Cereal Rust Pathology

South African wheat farmers have battled rust diseases for almost 300 years. The first known documentation of rust on small grain cereals in South Africa dates back to infected rye in 1708. The first reported occurrence of rust on wheat in South Africa, assumed to have been stem rust caused by *Puccinia graminis* f.sp. *tritici* (*Pgt*), was in 1726. This report preceded the first descriptions of rust morphology by Fontana in 1767, as well as the scientific demonstration of fungal parasitism in plants by more than a century. There is no indication of how rust was perceived in those early years of South African agriculture, and if this disease was in any way associated with the mysticism and religious rituals practised in ancient Europe. What has been documented is the regular occurrence of rust and its role in causing crop losses and the demise of many wheat varieties throughout the history of South Africa. The adverse effects of crop failures due to rust on the well-being of farming communities are often mentioned.

The time of the first appearance of wheat leaf rust, caused by *P. triticina* (*Pt*), is not known. The stripe rust fungus, *P. striifo*rmis f. sp. *tritici* (*Pst*), emerged in 1996 in the Western Cape and has since established itself as an important wheat disease. Certain records refer to the occurrence of stripe rust in the former Transvaal province in 1935, but the authenticity of this account could not be confirmed.

A LONG HISTORY OF STEM RUST EPIDEMICS

To put the history of rusts in perspective, some background on wheat breeding is necessary as disease and variety improvement have extensively influenced each other over many years. The first bread wheat (*Triticum aestivum*) varieties grown in South Africa were imported from Europe and India but were poorly adapted in general. Some durum types were also grown. Over time, more productive selections were made and a few successes were evident as varieties such as Du Toit's and Baard (Baart) were exported to Australia and the United States of America (USA). An introduction from Italy, Rieti, is often mentioned as stem rust-resistant when varietal evaluations were initiated in 1891. Union, Darlvan and Nobbs, the first varieties bred in South Africa, were released in 1910. Following these releases, breeding continued under the leadership of Johannes H Neethling at Stellenbosch-Elsenberg College of Agriculture, Stellenbosch University, but most varieties succumbed to stem rust in typical boom-and-bust successions. He also introduced the Australian varieties Primrose and Florence, as well as several Unie selections, to wheat farmers in the Cape province in 1914.

A fact worth mentioning is that Neethling achieved interspecies hybrids by crossing bread and tetraploid wheat in 1912, intending to transfer stem rust resistance. These crosses eventually resulted in the release of the varieties Sterling, Pelgrim and Vorentoe. Neethling's successes should be seen in context with the work of ES McFadden in the USA at more or less the same time. McFadden transferred the durable and non-race-specific *Sr2* gene for adult plant resistance to stem rust from tetraploid to hexaploid wheat and released the acclaimed varieties Hope (line H49-24) and H44-24, both with *Sr2*, in 1925. *Sr2* remains effective to all known stem rust pathotypes and forms the backbone of many "*Sr2* complexes" in varieties with durable resistance.

Despite pioneering race (pathotype) analysis by Len Verwoerd in the 1920s and 1930s, it seems clear that, for many years, wheat breeders continued in practically complete ignorance of variability in the pathogen. However, one variety that did not succumb to stem rust shortly after its release was Hoopvol, which remained popular due to its "horizontal resistance" to stem rust between 1948 and 1971. Today, it is known that stem rust resistance in Hoopvol was conferred by *Sr2*.

During the first half of the 20th century and parallel to the Stellenbosch programme, wheat breeding also occurred at the Potchefstroom College of Agriculture with the focus of combining acceptable milling and baking quality with rust resistance. An important feature of this work was the use of diverse sources of stem rust resistance. Crosses not only utilised the *Sr2* wheat genotypes H44-24 and Renown from the USA, but also Kenyan germplasm and Australian lines with resistance from *Triticum timopheevii*. In 1940-1941 Franciscus X Laubscher crossed *Agropyron elongatum* with wheat in the quest to achieve immune levels of stem rust resistance. While obtaining fertile and stable progeny in wide crosses was a scientific breakthrough in own regard, in retrospect, many of the resistances derived from related grasses were conferred by single, non-durable genes. Virulence for *Sr36* transferred from *T. timopheevii* was first detected in South Africa in 1964, interestingly without any deployment of the gene in commercial production. The varieties Dipka, Gouritz, Flamink, SST 101 and Zaragoza, all carrying *Sr36*, perished in the 1980s. However, pathotypes with *Sr36* virulence never dominated in South Africa and seemed to lack the fitness of their counterparts with *Sr24* virulence.

From 1950 onwards, wheat breeding continued at Stellenbosch University with the newly appointed Franciscus X Laubscher as head of the Department of Genetics. Several influential wheat breeders e.g. KW Pakendorf, JP Jordaan, B Lombard and HA van Niekerk were trained by him, and new varieties were released until his retirement in 1968. Importantly, this period saw a more focused pathology and rust screening programme managed by Jan van der Watt and J Truter. Between 1954 and 1975, WMRE Pieper initiated breeding of winter types at the Bethlehem Agricultural Research Station. With the assistance of B Lombard, they released several varieties, including an introduction 'Klein Impacto' from Argentina, locally named Betta, in 1969, as well as the selection Scheepers 69. Betta was commonly used in variety improvement in the years to follow. Using conventional genetic analysis, Kobus le Roux reported the presence of a single, dominant stem rust resistance gene in Betta. This resistance gene is effective against stem rust pathotypes within the Ug99 lineage currently occurring in South Africa, and is considered the likely source of resistance in several modern-day winter wheat varieties. Phenotyping assays with East African and USA stem rust pathotypes suggested that the Triumph-derived *SrTmp* gene could be the source of stem rust resistance in these varieties.

In 1959, a wheat programme was established at the Roodeplaat Experimental Station near Pretoria to develop varieties for the irrigated regions. Mexican varieties, in particular, were well adapted to these environments and cultivars Elize, Helene and Aerie were released. Although wheat lines used in the development of Green Revolution varieties were provided to the formal South African wheat breeding programmes, one example of germplasm exchange needs elaboration. In 1961, HW Turpin, a farmer from Groblersdal requested "short, stiff-strawed, spring wheat varieties" from Dr Norman Borlaug at the Rockefeller Foundation in Mexico. This request reached Borlaug through the South African Embassy in Washington DC and the United States Department of Agriculture (USDA). An important fact is that Turpin, on his own initiative and without research infrastructure, wanted to "find more productive wheat varieties for this irrigated area – especially high yielders that won't lodge under conditions of high fertility and spray irrigation". Turpin, however, was a qualified agronomist and his experience provided the scientific background for evaluating the introductions.

Yield testing and detailed correspondence between Borlaug and Turpin on new lines and varieties, disease scores, agronomic data, soil fertility, irrigation, quality, and even criticism from the South African Wheat Board, continued until at least 1969. At times, a round of communication took several months to complete. One of the lines (entry number four) had the pedigree "Lerma Rojo-64/Norin10-Brevor//3*Andes" (syn. 8739-4R-1M-1R), which resembles that of a spring variety released as T4 in South Africa. The pedigrees and selection identifiers for T4, T7 and T8, all from the 1962 shipment of 27 entries, occur in Borlaug's handwriting under the heading "Turpin" in his notebook used during a visit to South Africa in 1970. Besides being a popular variety at the time, T4 has been extensively used in variety development in South Africa, and is a significant legacy of the relatively unknown collaboration between the 1970 Nobel Laureate, Norman Borlaug, and a retired agronomist/enterprising wheat farmer. T4 was also the background genotype used to produce the variety SST 44. Incidentally, in 1984, the first breakdown ever of the universally effective *Sr24* gene transferred from *A. elongatum* occurred in the varieties SST 44 and Gamka in South Africa.

In 1975, the Bethlehem Agricultural Research Station was renamed the Small Grain Centre (currently ARC-Small Grain) when all public sector breeding programmes were consolidated in a single institution, with regional trials at experimental farms located in the primary wheat areas. Kobus le Roux and Zakkie Pretorius were appointed as pathologists and instructed to establish a rust research programme. Kobus le Roux spent an internship at the University of Sydney in Australia and Zakkie Pretorius at the USDA Cereal Rust Laboratory and the University of Minnesota, where they were trained in rust research methodology and skills. Access to critical germplasm resources were established at the same time.

Sensako (Pty) Ltd., a private seed company, started a wheat breeding programme in 1970 and has released many rust-resistant spring, winter and facultative varieties over the years. Rust screening is done in field nurseries, whereas advanced lines and commercial varieties are tested at the University of the Free State (UFS). The wheat programme of Pannar (Pty) Ltd. (now Corteva Agriscience™) was initiated in 1987 and has been aided by the excellent environment for rust screening and selection at their Greytown research station.

RUST SURVEILLANCE, NEW FACILITIES AND RESEARCH PROGRESS

The structured surveillance studies instituted in the 1980s provided the much-needed information on race diversity and effectiveness of stem- and leaf rust resistance genes. This paved the way for productive interaction with wheat breeders, more controlled screening of breeding material and genetic analyses of resistance in host varieties. When a dedicated rust laboratory was established by Zakkie Pretorius at UFS in 1989, the earlier foundation was extended in areas such as infrastructure development, continuity, biological resources, student training, centralised evaluation of breeders' lines and internationally-recognised contributions. Willem HP Boshoff took over the rust programme at UFS when Pretorius retired in 2017.

The confirmation of virulence for *Sr9e*, *Sr24* and *Sr36* and demonstration of single-gene resistance in the 1980s resulted in the withdrawal of several varieties. At the same time, virulence for leaf rust resistance genes such as *Lr3ka*, *Lr24* and *Lr26* was common and rendered many varieties susceptible. Fortunately, ARC-SG, with assistance from UFS, has continued surveillance of all wheat rusts, including stripe rust since 1996. The most recent survey studies for *Pt* showed that six new races emerged between 2009 and 2016. This is indicative of an upward trend in wheat leaf rust occurrence and pathogenicity, especially in the Western Cape. An analysis of *Pt* diversity, including microsatellite data, showed that the currently dominant pathotypes differ from the historical population. This points to foreign incursions which subsequently adapt for new virulence combinations, including some adult plant resistance genes.

Pgt pathotype changes continue to influence the local wheat industry with five *Pgt* variants (TTKSF, TTKSP, PTKST, TTKSF+ and PTKSK) belonging to the African Ug99 race group being detected in South Africa since 2000. The occurrence of these pathotypes has traditionally been ascribed to mutation and migration, but a recent study has shown that somatic recombination was responsible for the origin of African Ug99 stem rust. In 2009, B Visser at UFS used microsatellite and amplified fragment length polymorphism marker analyses to prove that a *Pgt* pathotype (TTKSF), collected by WHP Boshoff in the Western Cape in 2000, clustered with the Ug99 race group. This study provided the impetus for genotyping of rust isolates, which has become indispensable in describing and understanding relationships amongst pathotypes.

Triticale production, either as a cover-, silage- and forage crop or as a feed grain, has impacted on the occurrence of wheat rust in South Africa. *Pgt* pathotypes with increased virulence for the monogenic resistance genes *Sr27* (1998), *SrKw* (2003) and *SrSatu* (2005) occurring in South African triticale varieties, have been frequently detected during surveys. Stem rust pathotypes collected from triticale are mostly avirulent to local wheat varieties, but pathotype BPGSC+*Sr27*,*SrKw*,*SrSatu* has shown an increase in virulence. Concerning wheat leaf rust, pathotype 3SA144 (North American race code SDDN) also has broad virulence towards triticale, which indicates pathogenic adaptation to this crop.

Four pathotypes of the stripe rust fungus have been detected in South Africa, but recent sequencing studies have suggested a more diverse population. The detection of a threatening *Pst* pathotype in Zimbabwe in 2018 is of serious concern to the South African industry. This variant belongs to the *PstS1* lineage that is known for broad virulence and adaptation to higher temperature ranges. It is not known if this pathotype survived or migrated to South Africa, where it is expected to attack varieties resistant to the historic *Pst* population.

Cultures of these pathotypes stored at UFS and ARC-SG are used in the screening of all commercial germplasm and lines destined for release. To assist the industry, data from the annual UFS rust evaluations are incorporated in the production guidelines for rust risk assessment. Representative rust isolates are also available for essential phylogenetic studies on local, regional and international scales. An example of such relatedness was provided when the intercontinental dissemination of *Pgt* urediniospores from Africa to Australia was modelled and supported by genotyping of pathotypes occurring on both continents. Likewise, the similar SNP genotypes of some South African and New Zealand *Pt* isolates reinforce the long-distance migration of rust spores. Given the rare rust cultures available in South Africa, numerous phenotyping projects have been conducted at UFS on request by international colleagues.

At present both the Sensako and Corteva programmes employ DNA marker-assisted selection for obtaining durable rust resistance in future varieties. CenGen (Pty) Ltd., a plant and pathogen genomics company in Worcester with R. Prins as director, assists with routine marker application. Funded by the Winter Cereal Trust, the CenGen project tests and confirms the target trait in a donor line, assists breeding schemes by planning crosses to transfer and stack traits, and finally tracks the traits in derived generations. According to CenGen, molecular markers are currently applied to 29 genes and/or quantitative trait loci (QTL) for rust resistance in local wheat lines. Several studies mapping QTL for rust resistance have also been completed with CenGen as a partner. These studies provide valuable information on chromosome regions associated with possible durable rust resistance, in particular stripe rust loci in the varieties Kariega and Capelle Desprez, as well as molecular markers to select for resistance. Likewise, expertise in using genome-wide association mapping was established by analysing an African wheat collection for stem rust resistance.

To improve an understanding of the survival and epidemiology of the wheat rusts, the reaction of pasture crops, including rye, triticale and barley to *Pgt* and *Pt*, as well as to the rye stem and leaf rust pathogens, *P. graminis* f. sp. *secalis* (*Pgs*) and *P. recondita* (*Pr*), respectively, has been determined recently. Selected pathotypes of *Pgt* and *Pt* were avirulent on rye entries planted as forage crops in South Africa. Similarly, isolates of *Pgs* and *Pr* were avirulent on triticale currently grown for forage purposes. It was concluded that leaf and stem rust infections on forage rye and triticale do not pose a threat to commercial wheat production in South Africa. However, the field response of barley forage varieties suggested that both Mobey and SKG9 can serve as hosts for the wheat stem rust pathogen. The almost extinct wild rye (*Secale strictum* var. *africanum*) population of the Roggeveld mountain region has been confirmed as a host of wheat stripe rust. Although only the rye-infecting forms of leaf and stem rust were isolated from wild rye, controlled infection studies confirmed its susceptibility to *Pgt*.

OAT AND BARLEY RUST

Despite their common occurrence and importance, rust diseases of oat and barley have largely been neglected in South Africa. Barley leaf rust, caused by *P. hordei* (*Ph*) became a threat as commercial production expanded in the 1950s. Oat 'rust', presumably stem rust (*P. graminis* f. sp. *avenae* [*Pga*]), was first recorded in 1858, whereas epidemic outbreaks of oat leaf (crown) rust (*P. coronata* var *avenae* f. sp. *avenae* [*Pca*]) were not reported until 1909. In the first study of pathogenic variation in *Ph* in the late 1990s, BD van Niekerk identified only two pathotypes. The lack of pathogenic variation was attributed to the dominant monoculture of the leaf rust-susceptible variety Clipper at that stage. The lack of sexual recombination was also apparent from the low diversity in the pathogen, despite the common occurrence of *Ornithogalum* spp., the alternate host for *Ph*, in the Western Cape. Unpublished results from UFS indicate the presence of new diversity in *Ph*.

In 1931, Len Verwoerd reported pathogenic variation in *Pga*, followed 70 years later by BD van Niekerk, who described four pathotypes. More recently three *Pga* variants were identified from South African field isolates, including the first report of virulence for the *Pg6* and *Pg13* resistance genes. The first report of variation among isolates of *Pca* in 1967 was followed by BD van Niekerk who, in 2001, reported five *Pca* races from field isolates collected during 1997 and 1998. Similarly, six *Pca* pathotypes were typed from field isolates collected from 1998-2017 in a recent study conducted at the UFS. However, these analyses include new pathotypes characterised by increased virulence for several resistance genes when compared to the earlier work of BD van Niekerk. The recent UFS studies further include comprehensive data on oat variety response and genetic analysis of rust isolates using microsatellite markers.

FUTURE PROSPECTS

Since the 18th century, small grain cereals cultivated in South Africa have been threatened by rust diseases. Apart from the negative economic effect of rust outbreaks on farming communities, the loss of key resistance sources and the impact thereof on breeding programmes cannot be reversed. Early breeding efforts were commendable and incorporated field screening to select the most resistant lines, but all programmes, arguably up to the 1980s, worked essentially in isolation of in-depth knowledge of pathogen diversity and resistance durability. Even the scientific innovations of interspecies crosses and transfer of novel resistance genes to bread wheat were rendered ineffective because of the short-lived nature of these single genes. Backcross and topcross breeding delivered several productive varieties, but many of these also contained non-durable rust resistance.

The occurrence of the African *Pgt* race Ug99 (first described by Zakkie Pretorius in 2000) served as a global incentive for meaningful collaboration and progress. Significant financial investments, primarily from the Bill and Melinda Gates Foundation and co-ordinated by Cornell University, have resulted in advances in the rapid detection and identification of new occurrences, a better understanding of wind dispersal patterns, early warning systems, effective germplasm characterisation and resistance breeding, gene cloning, the potential of constructing and transferring resistance gene cassettes, studies on pathogen biology, training, and general awareness of the importance of rust diseases. However, new outbreaks are alarming and, in many parts of the world, the cereal rusts are considered as re-emerging diseases.

From past experiences, it is clear that South Africa is not exempt from new incursions and further adaptation of rust pathotypes. To remain competitive and make progress in battling the cereal rusts it is essential for us to (1) maintain critical biological resources of the pathogens and hosts, (2) remain vigilant and continue surveillance and research on pathogenicity, (3) phenotype key germplasm, (4) understand the genetics of resistance in important varieties, (5) invest in resistance gene discovery, (6) utilise sources of durable resistance in focused breeding, (7) support breeding by appropriate molecular selection strategies, and (8) keep abreast with chemical control options.

22.0 Maize Pathology

Maize was first introduced into South Africa in 1655, and today it makes up more than 40% of all local crop production. The crop is produced in all the provinces of South Africa, but the most significant regions are the Free State, Gauteng, Mpumalanga and the North West provinces, accounting for roughly 85% of overall production. The area planted for commercial maize ranges from 2.5 to 2.8 million hectares annually.

Maize breeding, under the auspices of the Department of Agricultural Technical Services, has been conducted in Potchefstroom since 1925. Hybrid maize development in South Africa commenced in the 1940s with the introduction of lines from the United States of America by CO Grogan, and with this grew an awareness of the need to include disease resistance in the crop improvement programme. Subsequently, in the 1970s, maize research was centred at the Potchefstroom Research Institute from where all research was co-ordinated. This led to the establishment of the Summer Grain Centre, later to become part of the ARC-Grain Crop Institute in 1992.

According to SA Hulme, Chief Director for Crops and Pastures in 1974, emphasis in the breeding programme focused on boil smut (*Ustilago maydis),* cob and tassel smut (*Sphacelotheca reiliana*), cob rots (*Stenocarpella maydis*; *Fusarium* spp.) with special attention given to root rots caused by a complex of soilborne pathogens and stem rots. Initially stem rot, caused by *Colletotrichum graminicola sensu lato,* was the focus of the research, but this was superseded by Diplodia stem rot (*Diplodia maydis sensu lato; Stenocarpella maydis*), and more recently by Fusarium stem rot caused by the *Fusarium graminicola* species complex. Emphasis was primarily placed on inoculation techniques. In the Natal programme under the leadership of Hans Gevers**,** screening for

Northern corn leaf blight (*Exserohilum turcicum* syn. *Helminthosporium turcicum*) resistance based on the HtN gene, and cob and tassel smut resistance based on the N6 gene for resistance was undertaken.

BOIL SMUT

Common or Boil smut of maize is caused by the dimorphic Basidiomycetous biotroph *Ustilago zeae* (previously known as *Ustilago maydis*). The disease was already well documented in South Africa by Ethel Doidge in 1927. Boil Smut was a problem on maize plants in the 1950s, 1960s and early 1970s when in dry seasons, incidence tended to be higher. Boil Smut resistance breeding in the 1970s was conducted by a programme established by HJ Maree. He used a tissue-invasive inoculation method, which involved injecting 0.5ml of a suspension of chlamydospores into the meristematic tissue of each stem, approximately 40 days after planting. Later, a less invasive method, where chlamydospores were suspended in a Tween 80 solution and sprayed into the leaf whorl pre-flowering, was optimised by Marietjie Ferreira. This was used successfully to select lines and develop resistant hybrids to the point where the disease has declined in local importance.

COB AND TASSEL SMUT

Cob and tassel smut is caused by the basidiomycete biotrophic fungus, *Sphacelotheca reiliana* (syn. *Ustilago reiliana*). The disease was documented in South Africa by Ethel Doidge in 1927 and was a major threat to the maize industry in the 1970s and early 1980s, reducing yields due to serious epidemics. It was bought under control due to the development of resistant maize cultivars. From 2006 onwards, Cob and tassel smut epidemics were reported as sporadic and occurred when high yielding susceptible cultivars were planted, and the season was favourable for disease development.

Cob and tassel smut screening became an integral part of the breeding programmes and the initial inoculation technique, developed by Zaag de Beer**,** under the leadership of Jan van der Watt**.** This involved mixing of spores with potting soil in small paper bags, planting of seed and maintaining the bags in the greenhouse under cool temperatures until the four-leaf stage. Bags were subsequently moved to field plots until flowering and disease incidence, based on visible sori in the heads or tassels, was determined. Subsequently, this procedure was simplified by Ingrid Wythe, where early planting ensures cooler conditions during the seedling stage and chlamydospores in soil were added to planting holes. This procedure is still applied today in cultivar evaluations, currently under the leadership of Bradley Flett. Interest also grew in the potential use of fungicides to control Cob and tassel smut. Carboxin was subsequently registered as a seed dressing to reduce the risk of infection during the critical seedling stage.

STALK ROT

Stenocarpella maydis stalk rot resistance breeding was evaluated in sweetcorn breeding programmes by Jean du Plessis. This technique involved injecting spores into the third internode, followed by splitting of stems three to four weeks later and rating internal lesion length. This was done in collaboration with Strauss Ferreira**.** This programme was extended and further research was conducted by Kevin Chambers and later by Bradley Flett during the 1990s.

More recently, Fusarium stem rot has emerged as a production constraint, particularly in the Northern Cape irrigation areas and KwaZulu-Natal, and has been studied by Bradley Flett and Aneen Schoeman in Potchefstroom. Sandra Lamprecht at PPRI, Stellenbosch, has also worked on this problem, concentrating on the aetiology. Emphasis by the Potchefstroom group has been on the interaction between production practices and disease incidence, including the role of tillage practices, crop rotation, plant nutrients and irrigation on plant defence responses. Since mycotoxins are associated with the causal complex, the study of potential translocation of the mycotoxins Deoxynivalenol, Nivalenol and Zearalenone has also been studied, although this source of mycotoxins has not been shown to be a major health threat.

ROOT ROT

Root rots received attention in the 1970s to early 1990s. In early studies, Mof le Roux attributed this disease complex to more than 40 pathogens, and a similar wide range of organisms was confirmed by Wouter Jooste in a country-wide survey in 1978/79. The complexity of the root rot complex was further studied by Sandra Lamprecht and her team at ARC-PPRI, and 75 fungal species were isolated from different growth stages of maize displaying diseased crowns and roots in KwaZulu-Natal production systems. The most important soilborne pathogens were identified as species in the *Fusarium graminearum* complex *(F. boothii* and *F. graminearum),* *Phaeocytostroma ambiguum, Phialophora zeicola, Pyrenochaeta terrestris, Pythium* spp. (eight species were associated with diseased plants), *Rhizoctonia solani* and *Stenocarpella maydis*.

Early emphasis was on the identification of resistance, and Mof le Roux considered root pulling strength to be the only reliable and practical method to be used as a selection criterion. This was then applied in breeding programmes to select for root rot resistance as well as for determining root regrowth potential, an important criterion in the drier areas where severe moisture stress predisposes roots to severe die-back. Subsequently, Kevin Chambers introduced a technique whereby plants were simply shaken *in situ* and anchorage in the soil was rated, and this proved successful in selection of improved lines. Subsequently, however, interest in this disease complex has waned, due to difficulties associated with selection for stable resistance associated with the multiplicity of host x pathogen x environment interactions.

Interest in the aetiology of root rots has continued. Kevin Chambers indicated that soil-inhabiting fungi rapidly infect maize roots as soon as they begin to differentiate. He observed that the first tissues to develop were the seminal roots and mesocotyls and as their function became superseded by that of the adventitious roots, they rapidly became completely rotten. Adventitious root rot developed more slowly and the roots did not become as severely rotted. Numerous fungi were isolated from the roots. The most frequently isolated were *Helminthosporium pedicellatum* and *Fusarium moniliforme*. *Trichoderma* sp. was the next most frequently isolated fungus. Elbe Hugo showed that that the spectrum of fungi differs over localities, as well as their relative frequencies. Fungi isolated from discoloured root tissue and root tissue without visible discolouration were classified as root pathogens and root colonizers, based on their isolation frequency from the respective samples. *Exserohilum pedicellatum, Macrophomina phaseolina* and *Fusarium oxysporum* were classified as the major root pathogens and *Phoma* spp., *Curvularia* spp. and *F. chlamydosporum* as root colonizers. Fungi classified as root pathogens tended to occur early in the growing season in juvenile tissue, as opposed to root colonizers which occurred later. Elbe Hugo also suggested that root pathogens were isolated at higher frequencies under no stress and normal rainfall treatments than in the total stress treatment in a long-term water stress trial. A positive linear relationship between the water stress index and the isolation frequency of *M. phaseolina* was obtained. She also noted differences between isolation frequencies in tillage and rotation systems.

FOLIAR DISEASES

The 1970s led to greater attention being focused on maize foliar diseases, in particular, Northern Corn Leaf Blight (NCLB) and a short-lived concern that Southern Corn Leaf Blight, caused by *Bipolaris maydis* (*Helminthosporium maydis*), might be a threat. This was linked to race T susceptibility associated with the T-cms gene used to induce male sterility in hybrid seed production. A programme aimed at identifying the T-cms gene in local maize hybrids under the leadership of Jan van der Watt led to a withdrawal of these hybrids from production, resulting in this disease not becoming established.

NCLB was a major threat to maize production in South Africa from the 1950s to the early 1970s, particularly in the high rainfall areas of KwaZulu-Natal. A disease screening programme was initiated in Potchefstroom by Jan van der Watt in the late 1970s and emphasis on resistance breeding was undertaken in Pietermaritzburg (Cedara and Ukulinga) under the leadership of Hans Gevers. More recently, severe outbreaks have been reported from Kwazulu-Natal, Mpumalanga and irrigated maize throughout the maize production area of South Africa.

In the late 1970s, interest gradually shifted towards studying mechanisms of resistance and epidemiology of maize diseases. Mick Lloyd studied pre- and post-infection inhibitors and suggested that these, primarily phenolics and flavonoids, were the dominant underlying basis of disease resistance. In recent years, six *E. turcicum* races have been identified in studies by Maryke Craven, using differential sets of varying backgrounds. The races were primarily classed based on the phenotypic response as obtained with the V26 and A632 backgrounds. Races identified were Race 3, 3N, 23, 23N, 13N and 123N. As cultivar yield potential improved, attention has shifted to chemical control, and effective fungicides have been identified and application strategies were developed under the leadership of Maryke Craven.

Grey Leaf Spot was initially observed in KwaZulu-Natal in 1988, after which the disease spread rapidly northwards where maize was grown under warm and humid conditions. An intensive research program conducted and co-ordinated by Julian Ward was initiated**.** Studies on the epidemiology led to the development of an integrated disease management system using fungicides as the primary control system, together with resistance, crop rotation and ploughing-in of maize stubble. Disease risk modelling and the effect of stubble management was evaluated by Neil van Rij at Cedara.

The increasing incidence of Maize Streak in the Highveld region in the 1970s, and producer demands for improved germplasm, led to germplasm screening for MSV resistance. This was conducted at the Vaalharts Research Station, a natural hotspot for the disease. However, in the late 1970s, studies conducted by George van Rensburg enabled the culture of the vector *Cicadulina mbila* on artificial media and the development of a greenhouse and field inoculation technique. His studies also demonstrated the relationship between wheat and maize and the back-and-forth movement of the vector and virus, which enables persistence between maize seasons. Risk prediction based on vector traps was developed by Johnie van den Berg.

DIPLODIA EAR ROT

Diplodia ear rots are caused by the maize-specific pathogens *Stenocarpella maydis* and *S. macrospora*. Symptoms of both ear rots are almost identical, but occur under different climatic and epidemiological conditions. Macrospora ear rot appears more dominant in KwaZulu-Natal, whereas Maydis ear rot occurs throughout the entire maize production area of South Africa. Diplodia ear rot results in yield loss, grain grade reductions and toxicity to animals. Toxins are difficult to identify. Initial toxicity in ducks and sheep was demonstrated by Chris Rabie and diplodiosis was reported by Fanie Kellerman.

Diplodia ear rot became a major production threat in the eastern Free State and North West provinces in the early 1980s with the increased application of minimum tillage. The incidences and severities of the disease in the 1980s initiated a large research programme in Potchefstroom. This involved Kevin Chambers, who resigned in 1987. Subsequently, Adrian Snyman and Bradley Flett became actively involved, and with the resignation of the former in the early 1990s, this research became the sole responsibility of Bradley Flett. Diplodia ear rot management is achieved by an integrated management system that includes maize stubble reduction, crop rotation, early harvesting and host plant resistance. Stubble reduction is achieved by means of ploughing-in of the previous season's maize stubble in monoculture maize systems, and this interaction was extensively studied by John Mallet at Cedara and Bradley Flett in the 1990s. A linear relationship was recorded between maize stubble concentration and incidence of Diplodia ear rot. *Stenocarpella maydis* was found to overwinter on maize stubble retained on the soil surface from where spores released from pycnidia become airborne and infect maize ears. Crop rotations were effective in reducing Diplodia ear rot, as they reduce initial inoculum levels and maize being the only host of the causal organism. In South Africa, maize ears are left to dry on the plants in the field. Early harvesting reduces the time that the fungus can grow on the maize ear. *Stenocarpella maydis* can grow on maize kernels in the field until 11% moisture. Although no hybrids are totally resistant to Diplodia ear rot, they do vary in resistance. A regression methodology developed by Bradley Flett**,** based on sorghum ergot methodologies used by Neil McLaren, is now widely used to quantify the relationship between ear rot potential and observed disease incidence, and identify cultivars more tolerant of higher disease potential. Less susceptible hybrids play an important role in reducing Diplodia ear rot. The result of these studies is that Diplodia ear rot has declined in importance.

FUSARIUM EAR ROT

Since the 1990s, interest in Fusarium ear rots has increased, particularly in light of the work conducted by the PROMEC group of Chris Rabie, Wally Marasas, John Rheeder, G Shepphard and W Gelderblom, who illustrated the importance of mycotoxins in *Fusarium*-contaminated grain. Initial emphasis was on *Fusarium verticiliodes* (*F. moniliforme sensu lato*) and the health implications of fumonisins. Resistance evaluation of germplasm was initially conducted by Bradley Flett who, together with Koos van Rensburg, also highlighted the role that stalkborer plays in dispersal and infection by the pathogen. Belinda Janse van Rensburg surveyed the natural occurrence of fumonisin-producing *Fusarium* spp. and fumonisin contamination of maize in 29 maize production areas of South Africa and recorded higher fungal biomass and fumonisin concentrations in warmer production areas. High fumonisin levels, in excess of 2ppm recorded at 10 localities are of concern, because of possible mycotoxicoses in animals and carcinogenic effects in humans. Additional concerns are reduced yields, grain discoloration, physical breakdown of grain structure and reduction of grain nutritional value. In collaboration with Neil McLaren from University of the Free State, Janse van Rensburg was able to develop a provisional epidemiological model to predict the risk of maize kernel colonisation by *Fusarium* spp., and fumonisin contamination based on meteorological data. An attempt was also made to determine the potential of prophylactic fungicides, generally applied for the control of foliar diseases, to reduce Fusarium ear rot of maize and fumonisin synthesis, but with limited success.

More recently, attention has shifted to ear rots associated with the *Fusarium graminearum* species complex and the mycotoxins Deoxynivalenol, Nivalenol and Zearalenone. Al Boutigny and colleagues from Stellenbosch University and PPRI showed that *F. boothii* was the primary isolate from maize kernels and is distinct from other species in the complex due to the production of 15A-DON. This was confirmed in a subsequent study by M Muvhango at the University of the Free State. Control and cultivar evaluation studies have been conducted by Bradley Flett and Belinda Janse van Rensburg.

FUTURE PROSPECTS

It is clear that maize has been affected by numerous important plant pathogens during the past century. Although many research projects have contributed to the management of these diseases, much work is still required. The constant adaptation of the pathogens to planting stock, the emergence of new races of the pathogens, environmental issues and economic concerns will continuously require the screening and development of new germplasm, chemicals and production practices to address the threat of disease.

23.0 Mushroom Pathology

Commercial mushroom cultivation in South Africa was established in the early 1950s. The first documented farm, Silver Stream, flourished and was sold in the 1960s to Denny, which is still a household brand name in the country. Commercial cultivation expanded and in 1979, one of the largest privately-owned mushroom farms, Highveld Mushrooms, was established. In 1989, the South African Mushroom Farmers' Association (SAMFA) was established. The number of members fluctuated over time, and in 2003 the industry had 179 members, which represented 98% of the industry. More recently, membership has dwindled to the current 10 members. The aim of SAMFA is to support commercial white button and brown mushroom farming throughout South Africa, and to promote quality and consumption through effective research and marketing. The volume of commercial mushrooms cultivated in South Africa remains around 21 000 tonnes and *Agaricus* constitutes roughly 90% of the market and the other types (mainly Oyster and Shiitake), the rest.

Mushroom pathology research at the University of Pretoria started more than 75 years ago with Barend J Dippenaar, the second head of the "Departement van Plantsiekteleer" (Department of Plant Disease Studies). Between 1945-1959, his research focused on mushroom and maize diseases, as well as common scab of potatoes. In 1975, Albert Eicker in the Department of Botany started his research programme on mushrooms, which he continued until his retirement in 1999. Albert Eicker trained several prominent plant scientists, who focused their initial studies on various aspects of white button and to a lesser extent, oyster mushrooms. These students became well known in their own right, such as the mushroom spawn specialists Martmari van Greuning (General Manager of Sylvan Africa, who completed her PhD in 1990), Wilma du Plooy (who completed her MSc in 2007) and Isabella Rong (who completed her PhD in 2005). Albert Eicker was extensively funded by SAMFA.

An interesting fact regarding mushroom pathology at the University of Pretoria is the long-standing 'difference of opinion' between Albert Eicker and Ballie Kotzé about the domain of mushroom research. This, according to Kotzé, was considered "part of microbiology", an aspect that at the time caused considerable stress between the Departments of Microbiology and Plant Pathology, and the Department of Botany. After Albert Eicker's retirement, SAMFA contacted Lise Korsten (Department of Microbiology and Plant Pathology), to establish a new mushroom research programme.

Initial mushroom research conducted by Lise Korsten's group was directed towards the development of an alternative mushroom casing material to replace locally used peat. This was mainly due to a change in legislation restricting commercial mining of peat in South Africa (Act No 107 of 1998). The industry had thus to urgently find a replacement or rely on expensive imported peat from Europe. It is relevant to note that in South Africa, the industry focusses on a production system that is reliant on commercial poultry manure in the composting process, rather than horse manure which is used in other countries such as the Netherlands. To fast track the development of an alternative casing material, a mushroom growing unit was established at the University of Pretoria Plant Pathology laboratories in a converted shipping container. This was done to enable the team to run mushroom growing trials at a semi-commercial level. Funding matching that from SAMFA was obtained from the Technology and Human Resources for Industry Programme (THRIP), managed at the time by the National Research Foundation (NRF) which made a significant impact on resources and funding for research.

By 2005, the mushroom research programme expanded to include a research focus on mushroom diseases. This included the development of a rapid diagnostic system for the industry, focused on the detection of all fungal pathogens in mushroom farms. A benchmarked food safety management system and a series of pathogen detection methods were developed for the industry. The system includes an ongoing pathogen surveillance and diagnostics service for mushroom farms.

Lise Korsten has, over the past 15 years, established a small nucleus of mushroom researchers consisting of postgraduates, postdoctoral students and industry-funded assistants. The initial alternative casing project resulted in a patent and licensing agreement with MABU casing (Linda Meyer). The second focus shifted to the detection of mushroom pathogens in growing environments and growing rooms. A series of modern detection methods has been developed, optimised and implemented to assist rapid detection and diagnosis of the pathogens. This resulted in the Mushroom Disease Outbreak Prevention Service (MushDrOPS) programme, through which the farms of all mushroom growers are sampled once a year, to monitor the spread of pathogens. The programme also provides advice to growers dealing with improved production systems and disease control measures. A further expansion includes the assessment of food safety systems focussing on the presence of potential foodborne pathogens.

During the course of the past 10 years, several scientists have been involved in the mushroom research programme at UP. These include Elna van der Linde, Linda Meyer and Ane van den Heever. The current core group of researchers includes senior researcher Nazareth Siyoum and numerous postgraduate students that have completed their studies or are currently involved in the programme. Nine postgraduate students have been trained through this programme and published 10 peer reviewed papers. The MSc and PhD students have included Zelda Pieterse, who worked on *Mycogone perniciosa* for her MSc in Plant Pathology (2005); LP van Jaarsveld, who worked on chemical, physical and microbiological properties of casing materials used in the commercial production of white button mushrooms for his MSc Agric in Plant Pathology (2011); Nazareth Siyoum, who worked on the microbial dynamics of different casing materials in the production of white button mushrooms for her PhD in Plant Pathology (2013); Gary Dzingirayi, who developed a Mushroom Good Agricultural Practices (MGAP) system for the white button industry, achieving his MInst Agrar Crop Protection degree in (2016); Alinesie Chakwiya, who worked on the identification and resistance profiles of *Cladobotryum* spp. for her PhD in Plant Pathology (2018) and Werner Rossouw, focusing on the mushroom microbiome and prevalence of foodborne pathogens and mycoparasitic fungal pathogens in white button mushroom production systems for his PhD in Plant Pathology (2020).

The Plant Pathology Mushroom Health and Safety team at the University of Pretoria is the only South African industry-funded research group that provides analytical data, diagnostic services and health management solutions to the white button mushroom producers. The research focusses on improving yield, quality and preventing diseases, as well as ensuring safety of fresh mushrooms using innovative technologies. The group has well-established international links with Ralph Noble (United Kingdom) and John Peccia at Pennsylvania State University in the United States.

Ross Richardson, chairperson of SAMFA, has said that the South African mushroom industry is proud to recognise seven world-firsts. These include major deliverables that have been achieved by the Plant Pathology mushroom research group at the University of Pretoria:

1. First mushroom Alternative Casing Material patented (PCT/IB2011/055183), licenced and internationally distributed by Mabu casing.
2. Development of the Global Mushroom Fungal Collection (142 isolates of the four fungal species: *Cladobotryum, Trichoderma, Mycogone* and *Lecanicillium*) and running the international

collection with the University of Wageningen and the Agricultural Research Council since 2008.

3. Development of a Rapid Fungal Disease Diagnostic System for the industry since 2012.
4. Development of a MushroomGAP for the industry based on GlobalGAP and the ISO 22000 Food Safety Management System (2015).
5. Development of a mushroom farm disease and health checks system (initially called Health Checks, 2012-2016) MushDrOPS (2017) monitoring between ten and sixteen farms over eight years giving a total of 96 farm visits.
6. Monitoring of foodborne pathogens in the mushroom supply chain with a focus on *Listeria monocytogenes* and *Staphylococcus aureus*.
7. The development of a mushroom microbiome project aligned with Penn State University to study microbial succession in casing, compost and white button mushrooms in the growing room and under postharvest conditions.

24.0 Mycotoxin Research

Our ancient ancestors became accustomed to the use of edible mushrooms in their diets. Throughout the ages their knowledge included the fact that foodstuffs, specifically grain crops, could become mouldy and unfit for human consumption, but they were unaware of the existence of micro-organisms. The old Roman and Greek societies were, however, well-aware of the dangers and uses of poisonous mushrooms, and these were sometimes used in assassination plots.

Mycotoxigenic fungi did not originate with human society, but were probably prominent when prehistoric animals and rodents stored seeds in their burrows. It is likely that conditions of food storage by humans from the Neolithic era onward became conducive to such fungi, and that as agricultural societies developed, so did mankind's awareness of mouldy food spoilage.

Classic, yet in some cases speculative, examples of historically-significant episodes of mycotoxicosis have been discussed by many authors. Examples of such accounts include the great plague of Athens during the Peloponnesian War, which was possibly either linked to *Fusarium*-contaminated wheat associated with alimentary toxic aleukia or with ergotism, several Biblical incidents involving the sufferings of Job, the impact of mycotoxins on human lifespan after Noah's flood and possible mycotoxin links with the plagues of Egypt. During the Middle Ages, gangrenous ergotism, also known as "St. Anthony's Fire" or "Holy Fire", ravaged many parts of Europe for several centuries and was later ascribed to the consumption of rye grain contaminated with ergot sclerotia.

Against this historic backdrop, South African mycotoxin research is relatively recent, the foundation being made during the early 1900s with the establishment of the Onderstepoort Veterinary Research Institute (OVI) in Pretoria in 1908. This was under the leadership of Arnold Theiler, and the appointment of Illtyd B Pole-Evans in 1905 as Head of Mycology and Plant Pathology in the former Transvaal Department of Agriculture. This led to the first South African mycotoxin-related research publication in 1918, which paved the way for a dynamic future for South African mycotoxicology.

FIELD MYCOTOXICOSES IN ANIMALS

The first two animal mycotoxicoses reported in South Africa were diplodiosis (cattle and sheep) and *Paspalum* staggers (cattle) during the period 1918-1920. This was followed in the 1940s by a publication describing bean hay toxicosis in horses, with a possible association with *Fusarium*-infected hay. Soon after the discovery of aflatoxin in 1960 in Great Britain, outbreaks of aflatoxicosis in livestock in South Africa were reported in 1964 and later in 1989. Further field outbreaks among livestock included facial eczema (caused by *Pithomyces chartarum*) in sheep; stachybotryotoxicosis (*Stachybotrys atra*), also in sheep; tremorgenic mycotoxicosis (*Aspergillus clavatus*) in cattle; ergotism (various *Claviceps* species) in cattle; hyperestrogenism or vulvo-vaginitis (*Fusarium graminearum*) in pigs; and leukoencephalomalacia (LEM; *Fusarium. verticillioides*) in horses. All these published reports were accomplished through the excellent collaboration between scientists from the OVI, the Council for Scientific and Industrial Research (CSIR) and the Medical Research Council (MRC). Recent reports outlined outbreaks of canine aflatoxicosis in South Africa in 2011, when more than 220 dogs died after consuming pet food that was contaminated with high levels of aflatoxin B_1.

THE CHEMISTRY ERA

The isolation and elucidation of novel mycotoxigenic compounds in South Africa began in the 1960s with the isolation of ochratoxin A from laboratory cultures of *Aspergillus ochraceus*. This was followed by work done on cultures of *Phomopsis leptostromiformis* in the 1970s, shown to reproduce the disease lupinosis in sheep, with the chemical characterisation of phomopsin A in 1983.

In 1983, WCA (Blom) Gelderblom and the research team at the former PROMEC Unit of the MRC isolated the compound Fusarin C from cultures of *Fusarium verticillioides* (strain MRC 826), followed by structure elucidation. This work, involving the famous MRC 826 fungal strain, isolated from rural maize in the Eastern Cape province, was commenced because of the search for the elusive mycotoxin(s) responsible for LEM in horses. Although Fusarin C was shown not to be responsible for LEM, these research efforts ultimately resulted in the discovery of the fumonisins in 1988. This led to the start of a dynamic era in South African mycotoxin research, which reverberated worldwide.

THE EARLY FUMONISIN ERA (1988-2011)

Beside the causative link between the fumonisins and various animal diseases, the fumonisin B analogues have also been associated with several human disease syndromes. This is in addition to several sporadic outbreaks of human disease linked to fumonisin and/or aflatoxin contamination, especially in Africa.

MYCOTOXINS IN RURAL SUBSISTENCE CROPS

One of the most important aspects of mycotoxin research in South Africa is in relation to human health in rural communities where subsistence farming is the norm. As is typical of many developing countries, subsistence farming households in South Africa are primarily concerned with food security, whereas food safety concerns tend not to be emphasised during years of drought and crop failure. The provinces of the Eastern Cape, KwaZulu-Natal, Limpopo and Mpumalanga have been shown to have high levels of fumonisin and/or aflatoxins in maize during crop seasons with favourable environmental conditions for fungal contamination. Deoxynivalenol has also been detected as a human urinary biomarker in the Eastern Cape.

Transgenic insect-resistant (*Bt*) maize emerged during the late 1990s as a potential means of reducing fumonisin exposure worldwide. Consequently, a field study in northern KwaZulu-Natal was undertaken to examine whether the adoption of *Bt* maize seed in rural areas could reduce rural consumers' fumonisin exposure to levels considered safe by the international health community. In this study, maize samples from four consecutive crop seasons represented the use of traditional, open-pollinated varieties, non-genetically modified hybrids and transgenic *Bt* hybrids. The results indicated a clear advantage of *Bt* maize over conventional hybrids and traditional maize seed. *Bt* maize had 40% less fumonisin than the traditional seed. Relative to the non-*Bt* commercial hybrids, *Bt* maize had on average 16% less fumonisin. Based on these results, a simulation run on Eastern Cape mycotoxin data found that a possible 62% reduction in fumonisin exposure levels could be achieved within rural communities.

It is widely recognised that the enforcement of international regulatory maximum levels (MLs) is not practical under subsistence farming conditions, since the food produced is consumed directly in the households, or traded within the local community. The problem of excessively high fumonisin exposure in these populations cannot be addressed by regulation, but requires a multifaceted approach to address these issues. The promotion of dietary diversity is seen as one of the best tools to alleviate high fumonisin exposure rates in those communities with excessively high maize consumption patterns.

One of the most important issues when doing field work in rural areas lies in the constraints associated with taking adequate and reliable grain samples, because these situations are completely different to the statistically-based sampling plans for commercial bulk foods and feeds. No elaborate technical sampling plan can work in South African rural situations because there are too many practical and culturally-sensitive variables that must be taken into consideration. These include limited and varying sample sizes between rural households, varying grades of postharvest sorting, and different varieties and/or hybrids. It is, nevertheless, imperative that sampling and surveillance studies be conducted among subsistence farmers to determine the extent to which they are being exposed to mycotoxin contamination. Such data can then be used to plan detailed intervention studies, which are better suited to the needs of rural communities than are mycotoxin regulations.

MYCOTOXINS IN COMMERCIAL SOUTH AFRICAN CROPS

The agricultural marketing boards for grains and oilseeds (e.g. the Maize Board and the Oilseeds Board) were closed in 1997, as South Africa moved to a free-market system for the production and marketing of crops. This led to the establishment of the Southern African Grain Laboratories (SAGL) in the same year - an independent, non-profit industry laboratory to conduct annual quality surveys on locally produced and imported crops. To deliver this service on an internationally recognised level and to act as a reference laboratory for the industry, SAGL was accredited in 1999 by the South African National Accreditation System (SANAS) and is under the ISO/IEC 17025:2005 international standard for testing laboratories.

SAGL's customer base includes the entire grain value chain from breeding, production, storage, processing, baking, milling, trading, imports and research. SAGL began using Vicam test kits for wheat and maize in 2004, changed to the ROSA (Rapid One-Step Assay) quantitative test in 2008 and since 2010, implemented their UPLC-MS/MS multi-mycotoxin method. Since 2015, SAGL has also been conducting a survey on post-storage, pre-processed maize collected at the processing plants for human consumption and animal feed. Prior to 1997, the South African Maize Board conducted an extensive mycotoxin monitoring programme (including aflatoxin, fumonisin, moniliformin and deoxynivalenol) on local and imported grain using different techniques such as thin-layer chromatography, high-performance liquid chromatography and gas chromatography.

Currently, the list of mycotoxins tested for by SAGL in maize, wheat and sorghum are aflatoxins (B1, B2 B3); fumonisins (B1, B2, B3); deoxynivalenol; 15-ADON; ochratoxin A; zearalenone; HT-2 toxin and T-2 toxin. The services provided by SAGL are an integral part of the South African mycotoxin research infrastructure and it is one of only a few highly-skilled testing laboratories in the country.

A study conducted in 2013 investigated the effect of experimental dry milling on the reduction of fumonisin, deoxynivalenol and zearalenone in maize. Reduction of mycotoxins in the milling fractions was accomplished by a significant removal of all three mycotoxins in the total hominy feed fraction. This result was expected since this fraction contains the germ, hull, pericarp (bran), tip cap and some kernel endosperm. Of the other commercial dry milling fractions destined for human consumption, fumonisin was mainly concentrated in the SPECIAL fraction, deoxynivalenol in the semolina, whereas zearalenone was equally distributed between these two milling fractions.

Enzymatic detoxification has become a promising postharvest approach for control of mycotoxins through modification of chemical structures determining toxicity. In 2019, a commercial fumonisin esterase was applied on fumonisin-contaminated subsistence maize to test the enzyme's efficacy. The enzyme treatments resulted in a significant reduction (≥80%) in fumonisin-contaminated maize, indicating that this approach could have both commercial and rural applications to reduce mycotoxin exposure.

FUTURE PROSPECTS

The closure of the PROMEC Unit by the Medical Research Council in 2013 was a major down-turn for mycotoxicology research in South Africa. This was a globally-recognised research programme, in later years run by Wally Marasas, who was fundamentally involved in the discovery and characterisation of Fumonisin (refer to section 28.7). Although this research team was able to survive for another six years under the umbrella of the Cape Peninsula University of Technology, the field of mycotoxicology was finally dropped from a restructured research institute at the end of 2019. This has left South Africa with the important question as to whether mycotoxin research will survive and in what form that might be. It can only be hoped that a new generation of molecular mycotoxicologists will take up the challenge and acquire the needed financial backing for this crucially important field of research.

25.0 Disease Outbreaks that had a Significant Impact on the Agricultural and Forestry Sectors

Some of the diseases that have significantly impacted either the agricultural or forestry industry over the years are listed below. Others are discussed in more detail elsewhere in this book (sections 18.0 to 24.0).

25.1 CITRUS CANKER

In the 1905/06 growing season, Marsh grapefruit trees were imported from Florida, USA and planted in the government's Experimental Orchard in Warmbaths (Bela-Bela). Symptoms of bacterial canker were noticed in 1908 and due to very wet conditions that year, the pathogen *Xanthomonas citri* subsp. *citri* spread exceptionally rapidly. Nursery stock was burnt and distribution of trees and scions was immediately stopped. Both orange and lemon trees became infected and attempts to control the disease were made by applying copper carbonate or bordeaux mixture and removing infected parts of the trees. Some level of success in controlling the disease was achieved, and it was eventually eradicated from this farm.

In 1916, serious outbreaks of the disease appeared in two nurseries in the Rustenburg area (North West province). In one nursery, nearly all of the approximately 87 000 newly-budded trees were infected. The disease was then reported in another nursery where 10 000 budded trees were infected. These infections were traced back to the 1908 outbreak in Warmbaths, unfortunately, before the serious nature of the disease was realised and the distribution of the nursery stock could be discontinued. All trees were destroyed. During 1917-1918, a further outbreak occurred in the region, and the inoculum for this outbreak was found to have been *Citrus trifoliata* seedlings imported from Japan.

In 1917, quarantine restrictions were placed in the area where citrus canker occurred. The disease was detected on 33 farms and all infected trees were destroyed. No trees were allowed to be planted within three miles (4.8km) of an infected orchard without a permit. This eradication campaign required exceptional efforts and involved compliance and co-operation from not only the farmers, but also the scientists and regulatory bodies operating at that time. By the end of 1927, citrus canker had been eradicated, and it was noted by JE Vanderplank that this was "the first successful eradication of a plant disease in the world". The success of the campaign has largely been attributed to the tenacity of two plant pathologists, Ethel Doidge, a trained phytobacteriologist, and the mycologist Illtyd Pole-Evans.

25.2 FRUIT AND FOLIAR DISEASES OF CITRUS INCLUDING BLACK SPOT

The most economically-important fruit and foliar diseases of citrus are Alternaria Brown Spot of mandarins, Alternaria Core Rot of navels, Botrytis ridging on lemons, and Citrus Black Spot (CBS). Ethel Doidge described Citrus Canker in South Africa in 1916, but through effective collaboration between stakeholders at that time, this dreaded bacterial disease which causes unsightly fruit and leaf spots, was successfully eradicated in 1927. For many years CBS, caused by *Phyllosticta citricarpa,* has been the most important disease. This is due to the zero tolerance for CBS lesions on citrus exported to the European Union, which is South Africa's largest market. This historical overview is largely focused on CBS.

Ethel Doidge discovered CBS in the Pietermaritzburg area in 1922. In 1940, Vincent Wager described how this disease had spread inland as far as the northern Transvaal with nursery material. In 1953, he proved, using infected fruit in baskets mounted on citrus trees, that asexual spores (conidia) from fruit lesions needed running water to infect lower hanging fruit. Vincent Wager conducted the first research on chemical control of CBS by spraying Bordeaux mixture. He was also the first researcher to determine that *Alternaria*-infected navel oranges develop black core rot under extremely hot and dry conditions during blossom. In the 1960s, Loest conducted spray trials with different fungicides for citrus black spot control, with the aim of replacing Bordeaux mixture. The latter chemical had detrimental effects on cosmetic appearance of fruit, darkening blemishes caused by wind and insect damage. James Vanderplank wrote about CBS in the "Control of disease by fungicides" chapter of his famous book *Plant diseases: Epidemics and control* published in 1963.

Cameron McOnie and Ballie Kotzé initiated research on the epidemiology of citrus black spot disease in early 1960. Both determined that windborne ascospores were the main source of inoculum produced from leaf litter on the orchard floor. They also detected mature pseudothecia on leaf litter 30 to 180 days after leaf fall, depending on prevailing temperatures, and found that pseudothecia are dependent on wetting and temperatures of above 18°C for maturation. They determined the critical period for fruit infection (October through February) and recommended spray programmes, consisting mainly of copper. They found that asexual spores (conidia) were not a major source of inoculum for fruit infection, mostly serving as an additional source of inoculum where there is an overlap of late hanging fruit and the new fruit set. Cameron McOnie also described speckled blotch lesions on citrus as a new form of CBS lesion expression.

Cameron McOnie was the first to determine that there were two *Phyllosticta* species infecting citrus fruit. He found that *Phyllosticta citricarpa* was restricted to the summer rainfall regions, and another *Phyllosticta* sp. was commonly found on various plant species and in various growing regions. This fast-growing *Phyllosticta* sp. produced both pycnidia containing conidia, and pseudothecia with ascospores in culture. *P. citricarpa* was not able to produce ascospores in culture. In later years, researchers learnt that *P. citricarpa* is heterothallic and needs both mating types to form sexual reproductive structures.

Cameron McOnie, along with JH Smith, was the first to demonstrate effective control of CBS with four successive dithiocarbamate applications. These fungicides replaced copper fungicides, which resulted in fruit rind stippling after successive applications.

In 1970, Harry T Brodrick investigated the effects of light and temperature on sporulation of *P. citricarpa* on artificial culture media. He found that incubation of isolates under continuous light resulted in significant higher counts of pycnidiospores produced than under alternating light/dark or continuous dark. Incubation at 27°C resulted in more conidia produced on citrus peel segments than at lower temperatures.

The citrus black spot research programme at University of Pretoria has an extensive history with Ballie Kotzé and later Lise Korsten. Ballie Kotzé's 1963 DSc dissertation on CBS epidemiology and control became a landmark study that provided a foundation for the citrus industry to effectively control the pathogen. His 1981 review article on CBS in the journal *Plant Disease* is also one of the most important references used world-wide. Ballie Kotzé's contributions in this field also includes research collaboration on the citrus nematode (with Hennie le Roux at OCC), citrus rootstocks and soilborne diseases (with Fritz Wehner and Nico Labuschagne at the University of Pretoria).

In 1977, Chris Kellerman, an MSc student of Ballie Kotzé, found that a single application of benomyl sprayed in mid-summer resulted in effective control of CBS as a curative treatment. In some areas, these attributes of benzimidazoles were, however, short-lived, because resistance to the benzimidazoles emerged. This was detected within five years of extensive use, as reported by Tom H de Wet. In 2001, Hennie Korf published research on the effects of postharvest treatments on CBS, and demonstrated a five- to seven-fold reduction in lesion viability.

In 1995, Tian Schutte developed new spray programmes using strobilurin fungicides, resulting in the formation of registered multi-fungicidal spray programmes against CBS. In later years, Schutte was part of a German team under the leadership of Gert Stammler that determined the risk of resistance to strobilurins in *P. citricarpa* to be low. This was due to an intron immediately after codon 143 in the cytochrome *b* gene. In 1997, Schutte determined that successive copper fungicide treatments resulted in stippling of the rind and could be overcome if spray intervals are stretched beyond 60 days. In the same year, he developed a method to detect latent infections in citrus fruit using ethephon. He also developed various other spray programmes for Alternaria brown spot control and developed a new volumetric spore trap (Quest), which was used for trapping ascospores of the CBS pathogen.

Tian Schutte was part of the Dutch team working with Robert Baayen that described the non-pathogenic strain of *Phyllosticta* in 2002 using PCR. In 2001, Linda Meyer and Lise Korsten did similar work at the University of Pretoria, but the species of *Phyllosticta* was not described.

In 1998, Lise Korsten, collaborating with Ballie Kotzé, took over the CBS research programme at University of Pretoria and established a core research group with Petra Labuschagne and later Linda Meyer (2000-2007). This team focused on the life cycle of the pathogen, addressing specific questions posed by the European Union and developing a rapid diagnostic test method for the industry and inspectors. Mariette Truter described an air sampler (Kotze-Quest Inoculum Monitor) to determine available *P. citricarpa* inoculum on citrus leaf litter. Mariette Truter also described the failure of *P. citricarpa* conidia to infect Eureka lemon leaf litter, described the period of susceptibility of citrus leaves, and also demonstrated the relevance of infected leaf litter as a major inoculum source. Other notable outputs include an impact assessment study of CBS in southern Africa, including alternative management approaches (Lorna Halueendo), and a framework for effective agricultural practices, *inter alia* for control of CBS, in citrus nurseries (Thomas Mutengwa). In 2004, Ida Paul determined the potential global distribution of citrus black spot and its likelihood of establishment in the European Union. An improved CLIMEX model of global distribution of CBS was published by Tanya Yonow in collaboration with Vaughan Hattingh in 2013.

In 2012, Elma Carstens, CRI colleagues and representatives from the Department of Agriculture conducted a national survey to provide scientific evidence that CBS does not occur in the Western Cape, Northern Cape and Free State provinces. In a ground-breaking study, Elma Carstens, in collaboration with Adele McLeod (University of Stellenbosch), Celeste Linde (Australia National University, Canberra), Paul Fourie and researchers in Australia, Brazil, China and USA, used microsatellite markers to analyse global and local *P. citricarpa* populations. This study demonstrated that Chinese populations of the pathogen were distinct from the 'new-world' populations from Australia, Brazil, South Africa and the USA. They also demonstrated clonal persistence and a more important role of the asexual conidia than previously understood.

Fanus H Swart, in collaboration with Kobus and Suretha Serfontein, established QMS AgriScience in Letsitele in 1998, which provided research and technical services to citrus and subtropical fruit growers. QMS used spore traps to quantify ascospore inoculum levels in citrus orchards. Many growers subscribed to this service which led to a better understanding and control of CBS. In 2013, CRI obtained the ascospore trap and linked weather data from QMS, and Paul Fourie and colleagues modelled the conditions required for pseudothecium maturation and ascospore dispersal. In collaboration with Roger Magarey from North Carolina State University (USA), these models were later integrated with CBS infection models and used to demonstrate that warm summer rainfall areas are more suitable for CBS. Importantly, they showed that most of Europe is not under threat of CBS, with only a few locations in the south of Europe likely to have a low to marginal risk of *P. citricarpa* establishment. These publications, along with those of Ida Paul and Tanya Yonow, provided critical evidence in subsequent technical engagements with the EU on the CBS regulatory measures.

The EU's pest risk assessment on CBS led to the culmination of many years' technical interactions with the EU on the zero-tolerance regulations for fruit with CBS lesions, which were promulgated after the formation of the EU and subsequent harmonisation of standards. Prior to formation of the EU in 1993, South African citrus had varying levels of market access to countries of Europe, with CBS lesions regarded as blemishes in quality assessments. However, the citrus-growing EU member states perceived CBS as a risk and the EU declared *P. citricarpa* as an A1 quarantine pest. They then adopted a zero-tolerance approach without conducting a pest risk assessment (PRA). After several bilateral engagements failed to resolve the matter, South Africa compiled a PRA in 2000, which concluded that fruit is not a pathway for CBS introduction, and that the EU's CBS regulations were without adequate technical justification and excessively trade restrictive. This PRA was compiled by Vaughan Hattingh, Hennie le Roux and Tian Schutte, in consultation with the Department of Agriculture and other CBS experts, Jan Kotze, Hennie Korf and Chris Kellerman. This led to several technical exchanges between South Africa and the EU from 2001 to 2009, which did not resolve the matter. South Africa then called on the International Plant Protection Convention (IPPC) for dispute settlement in 2010. The EU mandated EFSA to conduct a CBS PRA, which was published for public comment in 2013.

Vaughan Hattingh convened an international panel of CBS experts from South Africa (Paul Fourie, Tian Schutte, Hennie le Roux, Elma Carstens, Mariette Truter, Chris Kellerman, Fanus Swart, Kobus Serfontein, Alice Baxter, Mashudu Silimela, Mike Holtzhausen, Jan Kotzé, Ida Paul and Lise Korsten), USA (Tim Gottwald, Jim Graham, Megan Dewdney, Timothy Schubert, Michael Irey, Edwin Civerolo, Timothy Riley, Stephen Garnsey), Brazil (Geraldo José Silva Junior, Renato Beozzo Bassanezi, Eduardo Feichtenberger, Marcel Bellato Spósito and Armando Bergamin Filho), Australia (Andrew Miles, Pat Barkley, Nerida Donovan, Tania Yonow and David Daniels) and Argentina (Gabriela Fogliata, Fernando Carrera, Hernan Salas and Daniel Ploper). The 37 panel members collectively amassed 545 years' experience with CBS and submitted a detailed 55-page technical response to the 359-page draft PRA. Apart from highlighting many discrepancies and interpretations contrary to practical experience and published science, the panel concluded that it was in agreement with earlier South African and USA PRAs, which concluded that fruit is not a realistic pathway for CBS to enter, establish, spread and have significant economic impact within the EU. EFSA, however, maintained its position and effectively ignored many of the technical inputs and criticisms. The end result of these engagements was that the EU maintained its regulatory measures, and even imposed emergency measures to protect its territories from CBS.

Vladimiro Guarnaccia, under the supervision of Pedro Crous, director at the Westerdijk Fungal Biodiversity Institute in the Netherlands, found *P. citricarpa* on leaf litter under old backyard trees in Portugal, Malta and Italy, and described a new species *Phyllosticta paracitricarpa* from leaf litter in Greece. No CBS disease symptoms were detected, indicating the persistence of *P. citricarpa* in the absence of disease, as a foliar endophyte. More recently, CBS was reported from lemons and Maltese oranges in Tunisia, which is the first report of CBS disease in a Mediterranean climate area.

Using Alternaria Brown Spot (ABS) as model pathogen, Paul Fourie and Gideon van Zyl conducted research on spray application technology in citrus orchards. Traditionally, citrus fungal diseases (such as CBS and ABS) are controlled by means of high-volume sprays which is very costly in terms of time and losses to run-off. A novel spray deposition assessment protocol was developed which involved using a fluorescent pigment in the spray mixtures. This made it possible to assess deposition quantity, quality and uniformity by analyses of digital macrophotographic images of individual leaves sampled at various positions in the tree canopy. This research clearly demonstrated the potential of reduced-volume spray application and its concomitant cost-saving benefits. Jan van Niekerk, Charl Kotze and Tertia van Wyk continued this work to validate reduced-volume applications for disease and pest control in citrus orchards. They found that reduced-volume sprays generally achieved higher deposition quantities on fruit and leaves in comparison with the high-volume applications. However, the higher spray volumes achieved better deposition uniformity and had better pest and disease control. They concluded that deposition uniformity throughout the tree canopy strongly influenced the biological efficacy.

In 2016, Mareli Kellerman, Gideon van Zyl and Paul Fourie developed PhytRisk, a web-based disease forecasting platform for CBS. Infection models for Alternaria brown spot and Botrytis were also added in later years and are used by growers as a decision support tool, and to assess the CBS risk in orchards prior to harvest and export.

The CBS research programme at CRI is currently led by Providence Moyo. Recent research outputs include the validation and improvement of the pseudothecium maturation models, demonstration of ontogenic CBS resistance in fruit in a collaborative project with Brazilian researchers, and demonstration of the low reproductive potential of CBS lesions on fruit or citrus rind segments. The latter project complements earlier work by Hennie Korf (MSc student of Ballie Kotzé at University of Pretoria) and Wouter Schreuder (MSc student of Erasmus du Plooy and Paul Fourie at Stellenbosch University) that demonstrated the effective control of *P. citricarpa* by the combination of postharvest treatments typically applied to export fruit, which further supports the argument that fruit is not a pathway for spread of CBS to new areas.

Extension services in the form of grower workshops, study groups and guidelines were prioritised to support growers with effective CBS control to meet the zero- tolerance requirements in certain markets. Industry often involved researchers from OCC/CRI, as well as universities.

25.3 SOILBORNE DISEASES OF CITRUS

As noted in section 16.0, the South African citrus industry was initially established on Rough Lemon rootstock due to its vigorous nature. Unfortunately, it is also highly susceptible to soilborne pathogens, such as the citrus nematode, *Tylenchulus semipenetrans*, *Phytophthora nicotianae* and *P. citrophthora*, *Fusarium* spp. and *Pythium* spp.

Pressure from growers mounted for researchers from SACCE and CSFRI to provide solutions to the increasing problems due to soilborne diseases. Numerous rootstock screening trials were initiated to provide growers with alternative options. Over time the predominant reliance on Rough Lemon rootstock declined (from 80% to 10% of plantings) as trifoliate hybrids, most notably Carrizo Citrange and Swingle Citrumelo, were shown to be more tolerant to *Phytophthora* and the citrus nematode. However, tolerant rootstocks alone did not solve the problems. At the time, citrus trees were produced in open soil nurseries, often situated amongst old citrus trees used for commercial production. Consequently, the citrus nematode, which was not endemic to South Africa, spread via infected trees to all production areas. Poor quality trees, infested with nematodes and *Phytophthora*, was one of the factors that led to the establishment of the CIS. Control measures and certification guidelines were developed over time, and these were implemented as part of the CIS to ensure that citrus trees were grown in disease-free conditions.

In 1974, Anton Hough established that contaminated irrigation water derived from rivers was a source of infestation by oomycete pathogens, as well as plant parasitic nematodes. Commercial systems to clean irrigation water through flocculation, filtration and/or chlorination were consequently developed and tested with the assistance of various companies. Through the CIS guidelines, it became mandatory to grow nursery trees in containers raised above the soil surface to prevent contamination. A protocol for seedbed fumigation with methyl bromide was established with the aim to rid seedbeds of oomycete propagules. The basic principles of using pathogen-free potting media and irrigation water, combined with the prevention of infection in nurseries, resulted in a significant improvement in the phytosanitary quality of nursery trees.

Citrus researchers also focused on management of *Phytophthora* gummosis, specifically in orchards. Fritz C Loest working at the CSFRI in the 1970s, conducted research on the relation between orchard practices and disease development and investigated tree surgery as a control measure. At that time, John Moll focused on discovering tolerant or resistant rootstocks.

The primary research focus of Nigel Grech at CSFRI was on the production of *Phytophthora*-free nursery trees for the industry. His research led to published guidelines on the chlorination of nursery irrigation water to eliminate oomycete pathogens. At the time, RT Frean and Rob Wood from CSFRI also conducted research on *Phytophthora* and *Pythium* species and their effect on citrus trees in nurseries and in the orchard.

As the citrus industry grew, old orchards were removed and replanted with new citrus trees. Whilst nursery trees were largely free from *Phytophthora* and nematodes, growers started to experience problems with replant disease when replacing old orchards. Initially various abiotic soil problems were regarded as the cause of the replant problems. To address this problem, Hennie le Roux was appointed as soilborne researcher at SACCE. His findings confirmed those from other parts of the world, that the citrus nematode was the most commonly encountered parasite associated with the replant problem. Hennie le Roux's work demonstrated that exclusion of pathogens when planting or replanting trees was essential, and that the main source of spread of the citrus nematode was by means of infested nursery trees. Strict implementation of the CIS guidelines and a move away from tree production in soil to production in treated substrates in pots ensured nematode-free nursery plants. Improved orchard management practices and the change from flood-irrigation to micro- or drip-irrigation further ensured that orchards on virgin soils could theoretically be managed nematode-free for many years. Pre-plant fumigation with methyl bromide on replant soils proved to be very successful.

In 1989, MC Pretorius was appointed at SACCE as Hennie le Roux's research technician and later developed his own nematology and soilborne disease projects. Together they evaluated and registered a number of nematicides. They determined a threshold of >1000 *T. semipenetrans* females per 10g of roots, justified the use of a nematicide and further demonstrated that multiple applications of a nematicide can break the life cycle of the nematode. Nematicides are still recommended to be applied in a programme of at least three applications. Certain nematicides were found to be more prone to accelerated microbial degradation (aldicarb and fenamiphos), and alternation between different active ingredients was recommended. Le Roux and Pretorius also researched the benefits of using phosphonates to control *Phytophthora* infections in citrus trees which led to the registration of new phosphonate products for control of Phythophthora root, collar and brown rot.

In 1992, Tian Schutte compared different application techniques for the effective control of Phytophthora root rot on citrus. Using liquid-gas-chromatography, he determined that foliar spray applications were the best method of application, and determined spray intervals at which phosphonate treatments should be applied. In later years, Tian Schutte researched Phytophthora branch canker caused by *P. citrophthora,* which was an emerging problem mostly on Clementine trees in the Western Cape province. He showed the epidemiological significance of snails as vectors of the pathogen into trees, and showed that the disease was not limited to Clementines, and that navels and lemons were also severely affected. Schutte developed a highly effective management strategy for the pathogen, using repeated trunk sprays of captan and a quaternary ammonium compound.

Nico Labuschagne of the University of Pretoria began his more than 20-year involvement in citrus pathology with a doctoral study on *Fusarium solani* as a root pathogen of citrus. This pathogen was associated with dry rot of scaffold roots and extensive feeder root rot in citrus trees exhibiting decline symptoms. He demonstrated the important role that stress and carbohydrate depletion in roots play in the root rot syndrome. Labuschagne supervised various students on citrus pathology projects. Johan Janse van Rensburg demonstrated a link between *Fusarium*-produced naphthazarin toxins (isomarticin) and the citrus blight syndrome. In that study, a ranking of rootstocks indicated that trees with observed tolerance to blight in the field generally had higher tolerance to isomarticin in hydroponic culture, whereas trees susceptible to blight were more sensitive to the toxin. This finding had important implications for screening of citrus rootstocks for tolerance to citrus blight. Deon Joubert investigated the role of soil compaction in the citrus decline syndrome in the Eastern Cape, and demonstrated the aggravating effect of soil compaction on Phytophthora root rot in a greenhouse study. Deep ploughing as a means of soil profile modification was shown to be an effective means of alleviating the problem in the Sundays River Valley. Masiyiwa Sakupwanya investigated *Phytophthora* resistance in citrus rootstocks by using a metabolomics approach, and identified three marker compounds, putatively identified as wyerone, 4'-prenyloxyresveratrol and pulverochromenol, which were associated with resistance of citrus rootstocks to *P. nicotianae*. This finding revealed the potential for development of a rapid screening procedure for rootstock tolerance against Phytophthora root rot.

Presently, the soilborne diseases research programme is led by Jan van Niekerk who has built on earlier work to improve preventative and curative measures for *Phytophthora* control in citrus nurseries. Outcomes of this research have been implemented with success in nurseries. These include alternatives to methyl bromide fumigation using metham sodium, and improved guidelines for chlorination of irrigation water which was necessitated when reduced chlorine sensitivity was found in *Phytophthora* and *Pythium*.

After his appointment as CRI's programme coordinator for soilborne diseases in 2013, Jan van Niekerk assumed responsibility for a project investigating *Armillaria* root rot of citrus in Eastern Cape citrus orchards. Extensive field investigations and isolations from declining trees, however, yielded no *Armillaria* isolates. Instead, Jan van Niekerk and Charl Kotze isolated mostly *Fusarium*-like species causing dry root rot, which appears to be an important component of a new citrus decline syndrome referred to as Valley Bushveld Decline. The stressors leading the decline syndrome appear to be the predominant use of trifoliate hybrid rootstock that are sensitive to the high soil and water pH in these growing regions. Over time, it seems that the soilborne diseases programme has returned to its early beginnings, where new rootstock options are again being investigated.

25.4 CITRUS GREENING

Citrus greening was first observed by PCJ Oberholzer as a yellow branch disease in the western Transvaal in 1928/29. In 1937, it was postulated by AJ van der Merwe and FG Anderson that chromium or manganese toxicity might be the cause of the Transvaal citrus greening. From field observations, WJ Basson reported in 1965 that greening was more prevalent in cooler climate areas at altitudes exceeding 700m. At the time, Citrus greening was thought to be caused by a virus, after McLean, in collaboration with Oberholzer, demonstrated that greening was graft transmissible. They later proved that the greening pathogen (then thought to be a virus) was transmitted by the African citrus psyllid, *Trioza erytreae*. This important finding led to the realisation that psyllid populations could no longer be tolerated in commercial citrus orchards. This led to some pioneering research on the population dynamics of this insect in citrus orchards by HD Catling at the Malkerns Research Station in Swaziland. RE Schwarz, who also worked on citrus blight and CTV at CSFR in the late 1960s, collaborated with McLean to demonstrate the greening susceptibility and symptomatology in different citrus species following graft and insect vector transmission. It is important to recognise that during the late 1960s and early 1970s, greening practically eliminated citrus production in three major citrus-growing areas, with an estimated four million out of seven million trees infected with the disease.

In 1973, John Moll and Mike Martin were the first researchers to observe the bacterium causing citrus greening in its *Trioza erytreae* vector, using electron microscopy. John Moll's *in planta* electron microscopy studies published in 1974 concluded that the cause was most probably a prokaryote organism. This laid the foundation for later studies to identify the causal organism as a Gram-negative bacterium.

The vector pathology of greening was studied by John da Graça and Fanie van Vuuren, and the ecology of *T. erytreae* by Michael Samways, Barry Manicom and MA van den Berg at CSFR in the late 1970s and 1980s. MA van den Berg wrote several papers and reviews on *T. erytreae*. Various workers (Schwartz, DL Milne, John Moll, Fanie van Vuuren and GS Bredell) studied the use of antibiotics to control greening in infected trees, whilst it was later realised that vector control is also required. In this period, van Vuuren and colleagues at CSFR (LJ van Lyleveld and G Visser) studied metabolites in greening-infected trees, which could be used as markers for assessment of tolerance.

In 1985, Helen Garnett, a medical microbiologist at the University of the Witwatersrand, and students (Richard Chippendall, Hortelano Gonzalo, Dvora Ariovich and F Duncan) published on the successful isolation of the greening bacterium, and described the serological similarities of the isolated bacterium with the bacterium in greening-infected trees. Garnett developed polyclonal antibodies to diagnose greening-infected trees using ELISA assays. However, Garnett's work was controversial. Most notably, Jose Bove and Monique Garnier from Bordeaux (France) disagreed with her findings, leading to fierce debates on the international stage. In 1994, Bove and Garnier's group was the first to identify the organism as a non-culturable Gram-negative bacterium, in the alpha subdivision of the class Proteobacteria, provisionally called *Liberobacter*. In South Africa, Lise Korsten and Adriaan Botha (University of Pretoria) and Barry Manicom (CSFR) largely agreed with Bove, after years of failed attempts to isolate the organism. Korsten spent a sabbatical in Bove's laboratory learning the techniques required to develop monoclonal antibodies against greening. Lise Korsten and her student Laura Smith collaborated with Jan Verschoor from the University of Pretoria's Biochemistry department to successfully develop monoclonal antibodies to an organism isolated from greening diseased citrus.

It was widely agreed that African citrus greening was not as aggressive as Huanglongbing (HLB, Asian Citrus Greening), largely because of the temperature sensitivity of the bacterium and its vector. Nonetheless, greening destroyed citrus orchards in cooler climate areas. In the late 1980s to early 1990s, excellent research was conducted at the OCC by Carel Buitendag and colleagues on the control of *Trioza,* using systemic insecticides applied by means of novel patented stem-applicators, leading to effective vector and greening control. For many years, growers in warmer climates were able to tolerate greening by planting certified disease-free trees from the CIP, controlling the vector, and reduction of inoculum by removing infected young trees and symptomatic branches in older trees. The latter approach was heavily criticised by Bove, who subscribed to the Brazilian approach of completely eradicating infected or symptomatic trees.

Gerhard Pietersen continued greening research at the University of Pretoria from 2004. Notably, a survey was conducted of citrus greening in South Africa in collaboration with South African colleagues, as well as experts from Fundecitrus in Brazil, including Silvio Lopes and Pedro Yamamoto. In 2010, they published that only *Candidatus* 'Liberibacter africanus' (CLaf) occurs in South Africa, and that the Asiatic strain, *Candidatus* 'Liberibacter asiaticus' (CLas), was absent.

In 2000, Bove and Garnier observed greening-like symptoms in a Cape chestnut tree (*Calodendron capense*) outside a restaurant on a wine farm in the Western Cape, from which a sub-species of CLaf, *Candidatus* 'Liberibacter africanus subsp. capensis' was described. Gerhard Pietersen continued with this research, and his student, Ronel Roberts, subsequently described four subspecies in native Rutaceae trees, but could not demonstrate cross-infection to citrus. In later years, this work proved to be fundamental when a reported CLas from citrus in Uganda and Tanzania was shown to be a first report of a subspecies of CLas in citrus. Ronel Roberts, currently working at ARC-PPR, consequently improved the standard diagnostic protocols in collaboration with Glynnis Cook, since the CLas protocols used worldwide resulted in non-target amplification of this Liberibacter sub-species.

Huanglongbing, which is caused by CLas and vectored by the Asian citrus psyllid (ACP, *Diaphorina citri*), is by far the disease most feared by the South African citrus industry. Both the pathogen and vector are not heat sensitive, and have proven to be devastating to citrus industries where they have been poorly controlled. This is most notable in Florida (USA) where HLB destroyed 75% of a once thriving citrus industry.

Various forums, including the CIS's Advisory Committee and the Department of Agriculture's Phytosanitary Risk Forum, have supported citrus industry researchers who have worked closely with government officials to strengthen biosecurity measures and thus prevent an incursion of CLas or ACP. In collaboration with the Department of Agriculture officials, CRI has driven biosecurity awareness and HLB and ACP surveillance in South Africa, but also in neighbouring countries. These countries are encouraged to participate in the CIS to prevent the inadvertent incursion of exotic pests and diseases, and also to participate in surveillance efforts.

In 2015, Hennie le Roux was appointed as CRI's Biosecurity Manager with the responsibility to identify biosecurity threats facing the southern African citrus industry, and to advance the development and implementation of actions to mitigate risk and consequences of exotic pest or disease incursions. Following Hennie le Roux's untimely passing in 2016, Solomon Gebeyehu was appointed in this position, along with Elma Carstens as Biosecurity/Phytosanitary Specialist and Wayne Kirkman as Operations Co-ordinator. CRI also established a Biosecurity Advisory Committee which consisted of industry plant pathologists and entomologists to support the newly-formed Biosecurity Division. This committee supported CRI to lead in the development of the official HLB and ACP Action Plan which describe the preparedness and response actions required for early-detection, delimitation as well as containment or eradication of CLas and/or ACP. This plan was formally adopted by an HLB Steering Committee in 2019, and promulgated as a regulation under the Agricultural Pest Control Act in 2020.

CLas has been reported in Kenya and Ethiopia in Africa, and ACP has been reported as far south as southern Tanzania. CRI is involved in surveillance efforts in Mozambique, and is collaborating with researchers in Tanzania and Kenya regarding surveillance, training, awareness and response actions.

25.5 GRAFT TRANSMISSIBLE DISEASES (GTD) OF CITRUS

The graft transmissible (virus and virus-like, including citrus greening) diseases research programme co-ordinator for industry is currently Glynnis Cook at CRC. Glynnis Cook and her Nelspruit GTD research team study viruses, viroids and bacterial diseases. They collaborate with Elize Jooste at ARC-TSC, specifically on diagnostics services in support of the CIS. A strong research collaboration was built between CRI and Ronel Roberts at ARC's Plant Protection Research Institute (ARC-PPRI) in Pretoria and Hano Maree, a CRI researcher seconded to Stellenbosch University.

Past contributions of South African virologists are highlighted in section 9.0 of this book. The research conducted on citrus viruses is highlighted in this section, and research on citrus greening in the section above.

The failure of sour orange (*Citrus aurantium*) as a rootstock for most citrus cultivars in South Africa in 1896 is probably the earliest recorded evidence for the presence of Citrus tristeza virus (CTV). The CTV-sensitive sour orange rootstock was abandoned because of CTV quick decline, and was replaced by CTV tolerant rootstocks such as rough lemon (*C. jambhiri*).

Along with the successful eradication of citrus canker, researchers from CFSRI (Loest and Stofberg) assisted in the mandatory eradication of citrus psorosis virus. Unfortunately, the regulation enforcing eradication was repealed before psorosis was completely eradicated. Nonetheless, following the establishment of the CIP and use of disease-free propagation material, psorosis virus has been effectively controlled.

In 1930, Ethel Doidge and James Vanderplank wrote an article on a disease known as concentric ring blotch of citrus, which resembled leprosis symptoms reported from Argentina and Florida. BJ Dippenaar of the Agricultural Research Institute in Pretoria ascribed the aetiology of this disease to Eriophidae mites, specifically the grey mite.

Almost 80 years ago, APD McLean, while working at the Department of Agriculture, PPRI, conducted the first research on citrus viruses. In the late 1950s, some work was done by A van Oostroom that led to publications on citrus exocortis. McLean first reported citrus vein enation virus, citrus xyloporosis virus, citrus exocortis "virus" (later reclassified as viroids) and citrus tristeza virus (CTV). His initial work on CTV included demonstrating transmission by the citrus aphid *Toxoptera citricida* and, importantly, identifying CTV sources to be used in cross protection studies.

John da Graça worked at the CSFRI in Nelspruit between 1974 and 1979. Da Graça and his colleagues

John Moll and Fanie van Vuuren worked on the control of citrus greening, citrus impietratura, citrus blight, as well as the virus indexing of citrus trees as part of the CIP. In 1979, John da Graça returned to the Department of Microbiology and Plant Pathology, UKZN, and supervised several students working on citrus virology. Da Graça's notable contributions to citrus virology include identification of mild CTV strains that were first used for cross-protection, characterization of the citrus vein enation virus, involvement in characterization of citrus psorosis and helping to establish the indexing programme for the CIP. Da Graça moved to Texas A&M University in 1999, but has maintained involvement with South African citrus virology and the CIP/CIS.

After obtaining his DSc on the CTV complex, Lawrence Marais was the first industry-appointed citrus virologist at the Outspan Citrus Centre. Marais studied CTV, citrus blight, citrus psorosis and citrange stunt virus. During this time, the CTV cross-protection program for grapefruit was established, thus saving the grapefruit industry. He developed a rapid-diagnostic test for citrus blight and described the viroid-induced gum pocket disease of trifoliate orange. In 1999, Lawrence Marais relocated to the University of California, Riverside, USA.

Fanie van Vuuren became one of the 'legends' in citrus virology after dedicating 57 years of service to citrus virology in the South African industry. His career began in 1960 as a learner technician at the Department of Agriculture, stationed at the CSFRI in Nelspruit. In 1966, he obtained a National Diploma for Agricultural Technicians and worked with RE Schwarz. During the 1970s, he assisted de Lange and da Graça in establishing the STG laboratory at CSFRI. In 1992, van Vuuren obtained an MSc and in 1998 a PhD under da Graça at UKZN. He worked at the ARC until 2003 and joined CRI as programme co-ordinator for research and services on citrus graft-transmissible diseases. Fanie van Vuuren had a substantial impact on the citrus industry by training several people in the skills of STG, cross-protection and virus indexing. These include Jacolene Meyer, the current Citrus Foundation Block manager, and Kobus Breytenbach, the CIS facilities manager at CRC in Nelspruit, where cultivar introduction, STG, diagnostics and gene source repository services are conducted for the CIS.

In 2004, Gerhard Pietersen joined CRI from ARC-PPRI and was seconded to the University of Pretoria (UP). His research programme focused on CTV and greening, and he trained several students. This work continued after 2009 when he returned to the employment of the ARC-PPRI, while remaining seconded to the University of Pretoria, before relocating to Stellenbosch University in 2018.

Glynnis Cook's career at CRI commenced in 2009 as programme co-ordinator of graft-transmissible diseases at CRI in Nelspruit. Her research focused on the CTV cross-protection programme implemented to mitigate the effects of this virus. Glynnis Cook developed techniques for CTV strain genome characterization and studied biological expression of CTV strains. Her work advanced the understanding of this complex disease and cross-protection mechanisms. Glynnis Cook actively collaborated with her ARC-TSC counterparts on the CIS diagnostic services, formerly Barry Manicom, Desmond Ncango and, currently, Elize Jooste, resulting in significant improvements to the diagnostic processes and systems used by the CIS.

Hano Maree joined CRI as a biotechnology researcher, seconded to Stellenbosch University. Maree's research team (Rachelle Bester, Marike Visser and Dirk Aldrich) and collaborators (Johan Burger and Glynnis Cook) applied high throughput sequencing for the detection and discovery of new viruses and virus variants to the study of plant pathogen interaction and its use in diagnostics. Other citrus viruses or virus-like disease studied included psorosis virus, citrus viroids (Glynnis Cook and Chanel Steyn) and Impietratura disease. In 2019, new viruses were discovered in South Africa, including orchid fleck virus, which is part of the citrus leprosis complex (Glynnis Cook and team at CRI), and citrus virus A (Hano Maree and Rachelle Bester).

25.6 FUSARIUM WILT OF BANANA

Bananas were first introduced into South Africa by labourers from India who worked on sugarcane farms in KwaZulu-Natal (KZN) around the turn of the 19th century. It is, however, possible that some banana plants were also introduced from countries north of the Limpopo River, where cultivation is known to have occurred since at least the 14th century. The first commercial production took place in KZN, from there banana suckers were taken to Limpopo and Mpumalanga, probably around the 1950s. By the 1970s, the Kiepersol area in Mpumalanga became the centre of banana production in South Africa, with bananas also produced in the Onderberg, Tzaneen and Levubu districts. By the 1990s, banana Fusarium wilt became so severe in Kiepersol, that banana plantations were replaced on a large scale by avocado and later, macadamia trees. Onderberg has since become the main banana-producing area in the country.

Fusarium wilt was first verified in South Africa when the disease affected approximately 100 Cavendish banana plants near Durban in the 1940s. The disease then spread to Pinetown and Anerly in the 1950s, and by 1966 reports of the disease in KwaZulu-Natal had become regular. Fusarium wilt was first observed in Kiepersol in the 1970s, and rapidly became problematic. The disease was detected in Onderberg and Tzaneen in 2000, but there are no reports of Fusarium wilt in Levubu. The pathogen responsible for banana Fusarium wilt in South Africa is called *Fusarium oxysporum* f. sp. *cubense* (Foc), a diverse soilborne fungus that consists of three pathogenic races and 24 vegetative compatibility groups, which can survive in infested soils for decades. The strain in South Africa is Foc 'subtropical' race 4 (STR4; VCG 0120), so named because of its ability to cause disease to Cavendish banana in the subtropics but not the tropics.

The impact of Foc STR4 on banana in South Africa has been considerable. Production in Kiepersol declined from approximately 2 500 hectares in 1980 to less than 800 hectares in 2018. The disease was more damaging in Kiepersol than in KwaZulu-Natal, most likely due to the colder winters and the sharing of irrigation sources. Many disease management strategies against Fusarium wilt in Kiepersol and KwaZulu-Natal were explored, without much success. These include containment efforts, the planting of tissue culture bananas in disease-free areas, soil fumigation and the use of fungicides and growth stimulants, the treatment of soil with organic materials and the planting of Cavendish somaclonal variants and FHIA hybrid bananas. Where Fusarium wilt became inordinately severe, bananas were replaced with other crops. Because the occurrence and source of Foc TR4 in the Onderberg and Tzaneen was verified early, both cases were contained. From 1990 to 2018, banana production has decreased by 50% to approximately 8 000 hectares. This reduction is not only due to Fusarium wilt, but also to land claims, the profitability of exporting avocado and macadamia nuts, and the importation of large volumes of bananas from southern Mozambique.

25.7 EMERGENCE OF CRYPHONECTRIA CANKER OF *EUCALYPTUS*

In the early 1980s, a serious stem canker disease emerged on *Eucalyptus* trees in Brazil. The disease was one of the first considered a threat to a forestry industry, an enterprise that was growing rapidly in the tropics and southern hemisphere to provide a source of pulp for paper production. The cause of the disease was shown to be a fungus. It was very similar to the canker pathogen *Cryphonectria parasitica* that was accidentally introduced into Europe and North America which had virtually wiped out the American chestnut. There was obviously great concern amongst forestry companies that the same fate might befall *Eucalyptus.*

In the mid-1970s, a fledgling forest pathology programme was being established in South Africa. This was to support a forestry industry that was growing rapidly in the country. One of the best-known forest pathologists of the time was Ian Gibson. He was based in London and employed by what was then the Commonwealth Mycological Institute (CMI), with laboratories in Ferry Lane close to Kew Gardens. Ian Gibson had worked in Kenya and travelled to many countries in the tropics and southern hemisphere to advise on tree disease problems. On one of these missions, he reported Cryphonectria canker on *Eucalyptus* in the Congo and suggested to Mike Wingfield, at the time engaged in an MSc study and establishing a forest pathology programme in South Africa, that he should be on the lookout for this disease.

Some years passed before, in the mid-1980s and just back from a PhD at the University of Minnesota, Mike Wingfield was alerted to a problem where *Eucalyptus* trees were dying during their first year of growth on the KwaZulu-Natal coast, which that has a sub-tropical climate. This climate was similar to that well-suited to the pathogen, which at that time was known as *Cryphonectria cubensis*. Surveys conducted on affected plantations showed that trees had distinct basal cankers. Asexual fruiting structures of a *Cryphonectria* sp. were obvious on the bark. Isolations were made from these structures and they were subjected to pathogenicity tests on trees of an apparently susceptible *Eucalyptus* clone. The results, read about six months later, were dramatic. A highly aggressive pathogen of *Eucalyptus* had been discovered in South Africa. A first report of *C. cubensis* in South Africa was published in 1989 and active research began on this problem. This was also linked to the establishment of the Tree Protection Co-operative Programme (TPCP) (refer to sections 6.1 and 6.3).

The emergence of Cryphonectria canker in South Africa was closely linked to the onset of clonal *Eucalyptus* forestry in the country. The local forestry industry had been alerted to the problem in Brazil and they were understandably concerned that a similar problem would emerge in South Africa. It was also known that the disease in Brazil affected clones of *Eucalyptus grandis,* but in trials some hybrids of this species and *Eucalyptus urophylla* were apparently not affected. In order to capture the opportunity to use these disease-tolerant hybrids, unaffected trees were cloned using vegetative propagation, a technology that had been developed by French researchers in then Belgian Congo. It is an important and often overlooked fact that vegetative propagation, which rapidly emerged as a driving force in *Eucalyptus* forestry, was initially adopted in order to resolve a serious disease problem.

The discovery of Cryphonectria canker on *Eucalyptus* was one of the fundamental reasons for the establishment of the TPCP in South Africa. This was the first disease to be studied by students in the programme, and it led to many other disease problems being recognised and tackled in subsequent years. This development also had a substantial impact on plant pathology education, with a large number of MSc and PhD students working on Cryphonectria canker and assisting the forestry industry to select planting stock that would not be affected in areas conducive to infection.

When Cryphonectria canker was first discovered in South Africa, it was assumed that the pathogen had entered the country accidentally. The hypothesis at that time was that *C. cubensis* had probably originated in South East Asia on cloves that had been brought to Brazil as part of the spice trade. This was connected to the fact that Brazil had introduced cloves from Zanzibar and a canker disease had been observed on plantings of these trees in this country.. This view changed dramatically when researchers in the TPCP discovered cankers caused by the same fungus on native Myrtaceae (*Syzigium cordatum*) growing naturally in KwaZulu-Natal. This discovery was made at a time when DNA sequencing technology was emerging as a powerful tool to accurately identify fungi. It became obvious that, while the canker pathogen was very similar to the one killing trees in Brazil, it was clearly of a different species. Furthermore, both fungi were shown to be of species fundamentally different to those in the genus Cryphonectria (eg. *C. parasitica*). The new genus *Chrysoporthe* was described, with *Chrysoporthe cubensis* occurring in South America, and the South African pathogen was given the name *Chrysporthe austroafricana*. Two of the most important drivers of this early research were TPCP students Marieka Gryzenhout, who later wrote an important monographic book on the topic, and Cassi Myburg (incidentally the sister of Zander Myburg, who specialises on forest molecular genetics at FABI, University of Pretoria).

Some years later, a fundamentally important discovery was made regarding the origin of *Chrysoporthe* species and related canker pathogens in the Cryphonectriaceae. This emerged from an observation by the Colombian forest protection specialist Carlos Rodas., Primarily an entomologist, Carlos had established a strong working relationship with Mike Wingfield and other members of the TPCP. What Carlos had seen (initially observed by his daughter Juliana) were infections very similar to those on *Eucalyptu*s, killing various species of *Tibouchina* in Colombia. Juliana had been attracted not to the cankers on the trees but to their remarkably beautiful flowers.

The discovery of Cryphonectria canker on *Tibouchina* was at first confusing and hard to believe. This was because *Tibouchina* is a tree in the Melastomataceae and not the Myrtaceae, which was at that time thought to represent the hosts of *Chrysoporthe* species. Purely by serendipity, George Carroll, an accomplished botanist, was visiting the TPCP on sabbatical from the University of Oregon. While attending a seminar where Mike Wingfield presented the strange discovery of Cryphonectria canker on a non-Myrtaceae host, George Carroll noted that the Melastomataceae reside in the same order (Myrtales) as the Myrtaceae. This small but important realization initiated a series of studies showing that these fungi, as well as their relatives, were undergoing host shifts from native trees, not only in the Myrtaceae but also the Melastomataceae. This discovery opened up many new lines of research on one of the most important groups of tree pathogens in the tropics and southern hemisphere. In subsequent years, researchers in the TPCP and their collaborators globally discovered many new species of pathogens in the Cryphonectriaceae. Some of these resided in the genus *Cryphonectria*. But they also included obviously novel genera described as *Celoporthe*, *Immersiporthe*, *Holocryphia*, *Chrysifolia* and others. Most of these are significant pathogens of the host plants on which they were first found. Importantly, much in the same way that chestnut blight has emerged as a devastating tree pathogen, many are likely to threaten tree species in the Myrtales in the future, as they are accidentally and inevitably introduced into new areas of the world.

The threat of *Chrysoporthe austroafricana* as a *Eucalyptus* pathogen has been significantly reduced through intensive research. For many years, the TPCP team provided South African forestry companies with intensive screening trials in order to select *Eucalyptus* clones tolerant to infection. This programme was highly successful and the disease is now seldom encountered as a problem. However, it is also clear that the pathogen is continuously adapting to the local environment and that strains could easily emerge that are aggressive on newly developed *Eucalyptus* planting stock. Consequently, the many studies that have been conducted on the pathogen, including those promoting an understanding of its genetics (numerous genomes had been sequenced by 2020) will be important to South African forestry in the future. Furthermore, research excellence on this and other important tree pathogens has resulted in the TPCP being recognised as a global leader in the field of tree health. This has in turn resulted in great numbers of important collaborations and a substantial global research footprint, not only in the field of forest protection but also in mycology in the broadest sense.

25.8 PITCH CANKER OF PINES

The fungus *Fusarium circinatum* has emerged as the most serious pathogen of *Pinus* spp. in South Africa. The pathogen is very well known, particularly in the United States of America, for the disease known as pitch canker which first emerged as a problem in the eastern part of that country in the 1940s. The disease name refers to the dense accumulation of resin (referred to as 'pitch' in the USA) in the wood associated with infections.

The emergence of the pitch canker fungus in South Africa was a surprise. This was because its first discovery was as a nursery pathogen, very different to where it is best known as the causal agent of cankers on the branches and stems of established trees. The first discovery of *Fusarium circinatum* in South Africa occurred when the largest forestry nursery in the country began to experience a very serious disease problem and huge losses of plants in 1990. A consultant hired by the affected company managing the Nelspruit nursery in 1990, sampled plants and suggested that the problem was being caused by the well-known pine nursery pathogen, *Fusarium oxysporum*. This was an unusual diagnosis as the disease was very different to that typically caused by *F. oxysporum*, which is more typical of damping off. The new problem was on well-established plants and affected not only the roots, but also the root-collars. There was also a very clear difference in the susceptibility of plants, where *Pinus patula* was highly susceptible whereas *Pinus elliottii* was hardly affected. Such differential host susceptibility is atypical of damping off of pine seedlings in nurseries.

A follow-up inspection of plants in the affected nursery by the emerging Tree Protection Co-operative Programme (TPCP) team resulted in a large collection of isolates morphologically different to *F. oxysporum*. This was also the time when DNA sequencing technology was emerging as an important technique to confirm the identity of fungi. And thus, further work showed that the cause of the seedling disease was due to the pitch canker fungus, then known as *Fusarium subglutinans* f.sp. *pini*. The name *F. circinatum* for the pathogen emerged some years later, also connected to the rapidly-growing DNA-sequence based techniques to identify fungi.

Discovery of the pitch-canker fungus in South Africa led to many years of research on this topic. This was mainly conducted by students linked to the Tree Protection Co-operative Programme (refer to sections 6.1 and 6.3). The first of these studies was a MSc project by Altus Viljoen, who conducted the first nursery and field pathogenicity tests. Later, in his PhD studies, he began to consider the population genetics of the pathogen. That work provided the first firm evidence that *F. circinatum* had been accidentally introduced into South Africa.

Fusarium circinatum as a nursery pathogen rapidly became one of the most important constraints to pine propagation in South Africa. Within a few years, the pathogen was found in every pine nursery in the country, and it began to impart hugely negative economic impacts. The problem was most serious on *Pinus patula*, then the most widely planted pine species in the country and thus fundamentally crucial to the local industry, which at the time had some 250 000 hectares of pine plantations. But the disease on mature trees known as pitch canker remained absent from pine plantations. This resulted in substantial confusion regarding the name of the disease, which was clearly a nursery problem and not a canker disease on established trees.

Leaders of the TPCP believed strongly that *F. circinatum* would eventually move from being a nursery problem and become established on trees in plantations. This happened in 2007, when a serious canker disease appeared on *Pinus radiata* in the Tokai plantations close to Cape Town. Later population-genetic studies showed that the pathogen had most likely been transported to Cape Town with infected seedlings from a nursery in the southern Cape. This also fuelled speculation that the disease would begin to appear on established trees in other parts of South Africa.

By 2010, the disease of established *Pinus* spp. known as pitch canker had appeared in plantations in all the major pine-growing areas of South Africa. By this time, it had already become clear that planting the important *P. patula* as a pure species in the country was rapidly becoming unprofitable. The most important driver of this problem was not the canker disease on mature trees, but the fact that the pathogen was being transported with apparently healthy plants from nurseries to plantations. These 'healthy' plants either had minor infections on their roots, which were insufficient to result in obvious symptoms, or the fungus was present in the growing medium surrounding the roots. When these seedlings or rooted cuttings were planted in lands being established as plantations, large numbers would die. This was either shortly after planting but also during the first year or two of growth. The inability of forestry companies to cost-effectively establish plantations of *P. patula* led to a major change to pine propagation in South Africa.

Infection of *P. patula* nursery plants by *F. circinatum* was one of the major drivers in the South African forestry industry's change from planting pine seedlings to planting pine hybrids produced from rooted cuttings. For example, hybrids between *P. patula* and *Pinus tecunumanii* (high elevation source) were found to have relatively low levels of susceptibility to the pathogen. Other than tolerance to the pitch canker pathogen, these hybrids could also be selected for traits associated with wood quality and growth. Thus, by 2020, most companies propagating *Pinus* spp. had begun to convert to pine hybrid forestry.

A very substantial body of research has been conducted in South Africa on the pitch canker fungus and the diseases it causes. Almost all of this has been by students and academics linked to the TPCP and funded by the South African forestry industry. Arguably, the greatest number of research papers on the topic globally have come from this team. These include the first sequencing of the whole genome of the pathogen, the first eukaryotic genome to be sequenced in Africa, by a team led by Brenda Wingfield. In all, by 2020, approximately nine PhDs and five MSc degrees by the TPCP team, were on some aspect of *F. circinatum* and the disease that it causes. At the time of writing this historical account, at least 52 scientific papers had been published by team members on the topic. Given the importance of the pathogen and the disease that it causes, research on *F. circinatum* in South Africa is likely to remain a high priority. This will also underpin an understanding of genetic changes likely to occur in the pathogen, and associated changes in the susceptibility of new and emerging pine planting stock.

25.9 MYRTLE RUST

The myrtle rust pathogen, *Austropuccinia psidii* (synonym *Puccinia psidii*) was first reported and described from a native *Psidium* sp. (Myrtaceae) in Brazil in the late 1800s. Until the early 1900s it was known only from native Myrtaceae in South America. In 1912, it was, however, reported from an Australian *Corymbia* species in Brazil and then in the 1940s it was reported to have made a host jump to Australian *Eucalyptus* species grown in the same country. Since then, it has spread from its hypothesised native range in Central and South America and is now present in nearly 30 countries globally, affecting several native hosts in the Myrtaceae.

Austropuccinia psidii was first detected in South Africa in 2013. A forester recognized the disease on a non-native *Myrtus communis* tree in his garden after attending an industry feedback session of the Tree Protection Co-operative Programme (TPCP) at the University of Pretoria. In this meeting, one of the presentations highlighted the risk that the myrtle rust pathogen poses not only to the South African forestry industry, but also to native Myrtaceae in the country. Upon his return home he collected material for analyses by the TPCP, resulting in the confirmation of the disease in South Africa. The discovery set in motion extensive awareness creation campaigns with plantation forestry companies. Articles were published in local newspapers along the KwaZulu-Natal coast where the pathogen was first detected and private ornamental nurseries in the area were visited to survey for the disease.

The second discovery of *A. psidii* in South Africa was, surprisingly, made from a wilderness area in the Limpopo province in 2014, during surveys of cycad diseases conducted by Jolanda Roux. This discovery represented the first record of the rust pathogen on a native South Africa Myrtaceae, *Eugenia natalitia*. This led to increased awareness campaigns about myrtle rust with articles in magazines such as 'The Gardener' and 'Veld and Flora' and stimulated reports of the disease from ornamental nurseries on the south coast of KwaZulu-Natal and Gauteng, and even a private residence in Parys in the Free State. Focused surveys were undertaken by Jolanda Roux and her students to areas shown to be high risk for the occurrence of the disease, and where native Myrtaceae occurs, based on climatic modelling exercises.

Population genetic studies have shown that the genotype of *A. psidii* present in South Africa is unique. It is different to what is known as the pandemic strain of the pathogen, as well as to other localized strains from South America.

Myrtle rust has now been reported from seven of the nine provinces in South Africa. Non-native hosts include ornamental plants such as *M. communis* (the most common non-native host to date), *Callistemon* species, Australian *Syzygium* species and lemon myrtle species. Native South African hosts include *Eugenia natalitia, E. capensis*, *Heteropyxis natalensis*, the endemic and near threatened species *E. erythrophylla* and *E. verdoorniae* and the endangered *E. umtamvunensis*. To date, despite the impact of *A. psidii* on eucalypts in South America and Australia, it has not been found on these trees in South Africa. Artificial inoculation studies in the greenhouse have shown that a number of other South African myrtaceae can be infected by the pathogen and are at potential risk. Of concern to the plantation forestry industry is the fact that some of their key genotypes were found to be susceptible to *A. psidii*.

The detection of the myrtle rust pathogen in South Africa has led to in-depth studies into the genetics and reproduction of this important fungus. Amongst other discoveries are the fact that, contrary to common belief, basidiospores of the pathogen can infect its host. Sexual recombination was also identified in invasive populations of the pathogen. *Austropuccinia psidii* can thus rapidly adapt to new environments and native hosts, and thus represents a significant future threat to South African native biodiversity and industries relying on myrtaceous crops.

25.10 DISEASES CAUSED BY *PHYTOPHTHORA* SPECIES

The first report of a species of *Phytophthora* in South Africa was by Eric Nobbs who reported *P. infestans* as the causal agent of blight of potato at the Cape of Good Hope in 1903. Ethel Doidge also recorded the disease in 1913, but it was only in 1922 that *P. infestans* was found to cause late blight of tomato. This was soon followed by reports of other *Phytophthora* species in South Africa, namely *P. nicotianae* as the causal agent of crown rot of rhubarb and *P. citrophthora* causing brown rot on seedling oranges. In the 1930s there were reports of *P. cactorum* as the causal agent of wilt on a variety of ornamental plants by Margaretha Mes (1934) and Everdina Wijers (1937), and of *P. cambivora* causing root rot of avocado, although the identification in the latter report was later corrected to *P. cinnamomi*. Vincent Wager was the first South African plant pathologist to publish accounts of *Phytophthora* (then included in the Pythiaceae) in South Africa, first in 1931 and then again in 1941. In addition to the five species mentioned above, he reported *P. citricola* causing brown rot of grapefruit, *P. cryptogea* causing wilt of *Clarkia amoena*, and *P. syringae* causing fruit rot of oranges. This brought the total to eight species of *Phytophthora* that had been associated with wilt, blight, fruit rot, gummosis and root rot of 14 different plant hosts by 1941.

There were no new reports of *Phytophthora* species in the country during the subsequent three decades and only five new host reports were made. It was only in the 1970s that the number of host reports started picking up again, largely due to the discovery of *P. cinnamomi* on grapevines, peaches, eucalypts, pines and a variety of indigenous flora in the Western Cape by J van der Merwe. During this time, Sharon von Broembsen started investigating the occurrence of *P. cinnamomi,* mainly in the Western Cape, but also in other parts of the country. Her surveys identified more than 100 new hosts of *P. cinnamomi* in South Africa from 1976–1983. In the 1980s, new records of *Phytophthora* species in South Africa were made, with the first being of *P. porri* on onions, and *P. drechsleri* and *P. medicaginis* on lucerne.

Reports of *Phytophthora* species on forestry trees such as species of *Eucalyptus, Pinus* and *Acacia* accounted for most of the new host and species records during the

1990s and 2000s. These reports mostly emerged from research conducted as part of the Tree Protection Co-operative Programme (refer to sections 6.1 and 6.3) and also include the first new *Phytophthora* species to be described from South Africa, i.e. *P. alticola* and *P. frigida*. Surveys of *Phytophthora* species on buchu (*Agathosma*), the native plant harvested for a tea-like infusion, and *P. capsici* on a variety of vegetable crops resulted in a considerable jump in the number of new host reports in 2010. The survey by Bezuidenhout and her colleagues in 2010 also led to the description of a third new *Phytophthora* species from South Africa. This species, *P. capensis*, which was isolated from indigenous trees (*Curtisia dentata* and *Olea capensis*) and stream water, had previously been identified as *P. citricola*.

The first hybrid *Phytophthora* species from South Africa were reported in 2013 from soil and water from natural environments from research conducted by Jan Nagel. In addition to the four hybrid species reported in his publications, *P. chlamydospora* was recorded for the first time, along with four putative new species. A study by Bose and colleagues in 2018 was the first South African study to make use of a metabarcoding approach to investigate *Phytophthora* diversity in native and non-native South African forests. This study identified 11 additional *Phytophthora* species not previously recorded in South Africa. These and some additional publications not referred to above bring the total number of *Phytophthora* species or hybrids known in South Africa to 61, and their associated hosts or substrates to approximately 309 (Table 2 and Fig. 1).

Avocado Root Rot and Wilt

The story of Phytophthora root rot and wilt on avocados in South Africa is an interesting one that was recently treated in detail by Bezuidenhout (section 34). *Phytophthora* was first associated with this disease in the eastern Transvaal. The species was then identified as *P. cambivora*, but a later re-evaluation revealed it to be *P. cinnamomi*. By the 1970s, *Phytophthora* root rot was a major concern for the local avocado industry. In 1973, Jan Toerien was appointed as horticulturist at Westfalia Estate and was given the task to address the problem. In 1976, Joe Darvas, and later, in 1979, Lindsey Milne joined the team, and Ballie Kotzé from the University of Pretoria became an important collaborator. During the 1970s and 1980s, these researchers and their colleagues conducted ground-breaking work on the successful management of the disease. An integrated approach was followed with attention to soil quality (drainage, nutrition, etc.), tolerant rootstocks, clean nursery material, and chemical control.

The most striking success in managing root rot of avocado was obtained through chemical control. Jan Toerien, Joe Darvas and their co-workers were the first in the world to apply trunk injections of fosetyl-Al and phosphorous acid for the management of *Phytophthora*. This practice was taken up globally and is still applied today (additional information can be found in section 28.8). The team was also the first in the world to achieve management of the disease under field conditions through the application of metalaxyl. During the late 1980s and the 1990s, Ballie Kotzé's research focused on more environmentally friendly management strategies, such as suppressive soils, biological control and tolerant rootstocks. Over the last two decades there has been a considerable decrease in research on Phytophthora root rot of avocado in South Africa. However, some ongoing research is being conducted by Adéle McLeod's team at Stellenbosch University on the timing and application methods of phosphonates for optimal management of *P. cinnamomi.* Supported by a long-term grant from the Merensky Foundation, Noëlani van den Berg and her co-workers at FABI are investigating the mechanisms and gene expression pathways responsible for avocado rootstock resistance to *P. cinnamomi.*

Citrus-Root Rot, Gummosis and Trunk or Branch Cankers

Phytophthora species have been associated with a variety of citrus diseases in South Africa, including brown rot of fruit, gummosis, root rot, crown rot and trunk and branch cankers. Gummosis had already been "attracting attention in the Cape colony" in 1891, although *Phytophthora* was only recorded as the causal agent in South Africa in 1930. Brown rot of citrus fruit was first recorded in 1925 by Ethel Doidge when an epidemic of the disease affected parts of what was then known as the Transvaal (Gauteng, Limpopo, and Mpumalanga), and the Cape (Western, Eastern and Northern Cape). Surveys conducted during the 1980s, 1990s and 2000s have shown that the various citrus diseases caused by *Phytophthora* in South Africa are caused mainly by *P. nicotianae* and *P. citrophthora.*

Research in the 1950s indicated that soil from about one third of the sampled citrus orchards were infested with *Phytophthora*, although the pathogen could not be detected in adjacent virgin soil, suggesting its possible introduction along with the citrus trees. In the early 1970s, the citrus industry relied heavily on the *Phytophthora* susceptible rootstock, Rough Lemon, which contributed in part to the problems that *Phytophthora* was causing in new plantings and the poor condition of South African citrus orchards in general. During this time, the Citrus and Subtropical Fruit Research Institute (CSFRI) and the Citrus Exchange established the Citrus Improvement Scheme (CIS), a research and extension programme that focused on *Phytophthora* control in citrus nurseries. The primary aim was to improve the quality of nursery material supplied to producers and limit the distribution of pathogens via nursery material. Recommendations to the nursery industry that have subsequently been made, include growing plants in raised containers and using clean irrigation water to prevent contamination from soil and water sources respectively. Implementation of these recommendations have reduced the incidence of *Phytophthora* in nursery samples from 78% to less than 2.5%. Currently, the CIS includes a certification scheme that ensures certified trees are of high quality, true to type, and free from harmful pathogens, including *Phytophthora.*

Research on the management of Phytophthora root rot and gummosis in South African citrus orchards has investigated a variety of methods to reduce and prevent disease, with varying success. Hough, in 1979, actually applied heat treatment using a kerosene blowtorch to eliminate *P. nicotianae* from trunk cankers. The treated areas reportedly healed rapidly and the trees recovered. However, treatment of badly affected trees and trees with trunk diameters of less than 5cm usually resulted in extensive damage to unaffected bark. Other researchers applied chlorine in micro-irrigation systems to eliminate *Phytophthora* dispersal through irrigation water, and also illustrated a reduction of *Phytophthora* propagules in the soil in glasshouse assays.

Following the success of phosphonate trunk injections against *Phytophthora cinnamomi* on avocado trees, this technique was also applied on citrus with promising results. However, wounds from trunk injections were slow to heal on older trees, providing opportunities for infection by opportunistic plant pathogens and this practice was consequently abandoned. Current recommendations for the management of root rot using fungicide treatments include metalaxyl applications to the soil, phosphonate stem paints and foliar sprays. Systemic phosphonate treatments have the added advantage of also being effective against brown rot of citrus fruit. Soil solarisation has also been investigated and showed some promise for the management of *Phytophthora*, but results were inconsistent. Nico Labuschagne and his co-workers at the University of Pretoria have been investigating citrus rootstock resistance or tolerance to important fungal root pathogens, including *Phytophthora*, from the late 1990s. Additional information on this disease is also available in sections 16.0 and 24.3.

Grapevine Root and Crown Rot and Apple Replant Disease

Sudden death and decline of grapevines was observed in South Africa since the 1930s. However, it was only in the early 1970s that J van der Merwe reported the frequent recovery of *P. cinnamomi* from such vines and illustrated its ability to cause root and crown rot. This discovery paved the way for an extensive study on the disease and its management, including surveys of vineyards and nurseries, investigations of the chemotactic responses of *P. cinnamomi* zoospores, root exudates of different cultivars, the penetration of grapevine roots, the spread of the pathogen in a vineyard, as well as management through rootstock resistance, heat treatment, and chemical treatment. This study made up the PhD thesis of Pierre Marais. The surveys conducted by him indicated a high incidence and distribution of *Phytophthora* (mainly *P. cinnamomi*) in South African vineyards and grapevine nurseries in the 1970s. However, follow up surveys in 2001–2002, 2005–2007 and 2013–2015 recovered almost no *Phytophthora* isolates in nurseries and vineyards, presumably due to the increased use of phosphonate foliar sprays for the management of downy mildew and/or recommendations made by Pierre Marais during his investigations of the disease.

Soon after J van der Merwe reported *P. cinnamomi* on grapevines, he also reported *P. cactorum* as the causal agent of root and crown rot of apple trees in South Africa. At the time, he reported the recovery of *P. cactorum* from "approximately 10-15% of the isolations". Celeste Linde reported the death of up to 20% of apple trees in some orchards due to crown rot in 1998. This pathogen has more recently also been recognised as an important contributor to apple replant disease in South Africa. Over the past decade Adéle McLeod (Stellenbosch University) and her co-workers have investigated a variety of aspects of apple replant disease, using qPCR assays to monitor the levels of *Phytophthora* and other pathogens. These studies considered nursery material and irrigation water as possible inoculum sources, and the use of soil fumigants and different applications of phosphonates to manage the disease.

Late Blight of Potatoes and Tomatoes

By 1945, late blight caused by *P. infestans*, had been recorded in the Eastern Cape, Gauteng, KwaZulu-Natal, Limpopo and the Western Cape provinces on potato, and in KwaZulu-Natal on tomato. This disease featured frequently in James Vanderplank's ground-breaking research on plant disease epidemiology and breeding for host resistance. Potato cultivars developed by Vanderplank were so successful that they accounted for about 60% of planted potatoes at the time of his death in 1997.

Late blight was not prevalent in most South African potato production regions prior to 1995 when severe late blight epidemics occurred in almost all potato and some tomato production regions. An investigation of the *P. infestans* isolates causing these epidemics showed that the South African population of *P. infestans* still belonged to the historical clonal lineage (US-1) that had previously been distributed globally. This ruled out new introductions of the pathogen as the cause of the epidemics. In contrast, epidemics were rather ascribed, in part, to conducive weather conditions, high levels of fungicide resistance in the *P. infestans* populations, and incorrect fungicide spray programmes. Characterisation of isolates collected a decade later during 2005–2007 showed that the population still remained very much the same, with the US-1 clonal lineage dominating, and the A2 mating type being absent.

Phytophthora on Tobacco, Vegetables and Other Agricultural Hosts

Phytophthora species have been associated with a variety of diseases of vegetables and other agricultural crops in South Africa. With the exception of black shank disease of tobacco, most records of these diseases are limited to single disease notes or reports. One of the main contributors to available records of these diseases is Alistair Thompson, who authored or co-authored reports of *Phytophthora* species on banana, cabbage, lucerne, paprika, pumpkin, tomato, and a variety of other vegetables from the 1980s until as recently as 2010. The first official report of *P. nicotianae* as the causal agent of black shank disease on tobacco in South Africa dates to 1970. However, the disease was already widespread in local tobacco producing regions in 1968. Gerrit Prinsloo spearheaded initial black shank research in the 1970s with a characterisation of the races of the pathogen and the evaluation of fungicides for management of the disease, while later research investigated fungicide resistance of the pathogen, and cultivar resistance.

Phytophthora Diseases Impacting Forestry

The first record of *Phytophthora* affecting forestry trees in South Africa is that of *P. nicotianae* on black wattle trees (*Acacia mearnsii*) with black butt. This name referred to the blackening of the basal part of the trunk and the production of copious amounts of gum. Two different symptom types were associated with the disease and pathogen, and it was hypothesised that there was a link between the symptom types, climatic conditions and the infective propagules of the pathogen. In some cases, mottled lesions appeared on young, green bark, while in other cases lesions of dead bark or sunken areas extended upwards from the base of the trunk. For the mottled symptom type, it was proposed that cool nights and rain stimulated the production of zoospores that could swim in the water film covering the trunk and infect the bark, presumably through lenticels, to cause distinct lesions. When conditions were unfavourable for zoosporic dispersal, the pathogen had to rely on hyphae as infective structures, leading to the formation of dark, sunken lesions that extend upwards from the base of the trunk. Twenty-four years later Jolanda Roux recovered *P. nicotianae* from similar symptoms on black wattle, but also isolated *P. boehmeriae* and *P. meadii* from basal cankers, and she was able to illustrate their pathogenicity.

Initial reports of *Phytophthora* on eucalypts and pines in the 1970s were limited to *P. cinnamomi* in forestry nurseries. Shortly thereafter, Mike Wingfield and Peter Knox-Davies also recovered the pathogen from diseased established pines and eucalypt trees in various parts of the country. Celeste Linde was the first to report additional species of *Phytophthora* that were also highly virulent, i.e. *P. boehmeriae* and *P. nicotianae*, on eucalypts, although these species were recovered at much lower incidences than *P. cinnamomi*. Some years later, Bongani Maseko found an outbreak of Eucalyptus collar and root rot to be associated with *P. nicotianae* rather than *P. cinnamomi*, and six years later two new species, *P. alticola* and *P. frigida*, were consistently associated with the disease.

A recent survey by Tanay Bose from the University of Pretoria made use of soil baiting and metabarcoding to investigate the diversity of *Phytophthora* species in plantations of *Eucalyptus grandis* and *Acacia mearnsii*, as well as natural forest sites. His studies suggest that the diversity of *Phytophthora* species on forestry trees in South Africa is much higher than previously reported. A follow-up study investigated the pathogenicity of the most commonly isolated species from *A. mearnsii* and *E. grandis* using a soil inoculation technique that allows for a more natural infection process than the severe under-bark inoculation technique that had been applied in previous South Africa studies on *Phytophthora* on forestry trees. The results suggested that *P. multivora* may also be responsible for root diseases of these trees in addition to known pathogens such as *P. cinnamomi* and *P. nicotianae*.

Early research on the management of *Phytophthora* diseases on forestry trees focused on the use of soil fumigants to control *Phytophthora* in nurseries**.** Sharon von Broembsen made several recommendations towards the control of soilborne diseases in forest nurseries, including the use of clean propagation material, different methods of eliminating pathogens from soil and water, and general sanitation. Differences in host susceptibility has also contributed to the overall management of *Phytophthora* in *Eucalyptus* plantations with more tolerant species such as *E. grandis* favoured over highly susceptible ones, such as *E. fastigata.* Recent work at the Forestry and Agriculture Biotechnology Institute (FABI) at the University of Pretoria has investigated host-pathogen interactions at the gene level in order to facilitate the development of tolerant or resistant varieties.

Phytophthora on Indigenous Hosts and in Natural Environments

Phytophthora was first recorded as a pathogen of South African indigenous vegetation by J van der Merwe and Pieter van Wyk in 1973. They reported *P. cinnamomi* on species of *Erica*, *Leucadendron*, *Leucospermum*, *Protea* and *Serruria*, along with some non-indigenous fruit and forestry hosts. In the following years, *P. cinnamomi* was increasingly associated with the death of indigenous flora in the Western Cape, to such an extent that some feared extinction of sections of fynbos, such as the *Proteaceae*, in their natural habitat. In the 1970s and 1980s, Sharon von Broembsen investigated the occurrence and management of *P. cinnamomi* on cultivated and naturally occurring indigenous hosts. Her work identified an extraordinary wide range of hosts of the pathogen in South Africa, and indicated the widespread distribution and frequent occurrence of this pathogen in rivers in the Western Cape. *Phytophthora cinnamomi* was also found to be problematic in *Protea* nurseries. Early research had identified varying levels of susceptibility among different genera and species of *Proteaceae* indicating the possibility of disease management through the use of resistant varieties or species. Accordingly, Sandra Denman evaluated a stem inoculation technique to assess the resistance of *Leucospermum* cultivars to *P. cinnamomi,* and illustrated the importance of standardising methods to reduce variability over time. Initial research on the use of fungicides found fosetyl-Al to be ineffective and metalaxyl to be unusable due to problems with phytotoxicity. However, several years later, Lizelle Swart and Sandra Denman illustrated the efficacy of metalaxyl-M against *P. cinnamomi* on *Leucospermum* cultivars without observing any phytotoxicity.

Aside from investigations into the decline and dieback of stinkwood (*Ocotea bullata*), the 1990s saw almost no published research on *Phytophthora* associated with indigenous South African plants and environments. However, over the last 10-15 years, there has been renewed interest in this topic. In 2010, Bezuidenhout investigated the diversity and pathogenicity of *Phytophthora* species associated with symptomatic buchu (*Agathosma* spp.) plants from commercial plantations and nurseries and recovered seven different *Phytophthora* species. *Phytophthora cinnamomi* was recovered from rooibos (*Aspalathus linearis*) soil collected from a natural site and was found to cause 100% damping off in pathogenicity assays. During this time, researchers and students at FABI also began investigating the occurrence of *Phytophthora* in natural ecosystems, streams and rivers in South Africa, leading to the first reports of *Phytophthora* hybrid species in South Africa. An initiative called Cape Citizen Science (https://citsci.co.za/disease/) by Joey Hulbert endeavoured to enlist the help of the general public to survey and monitor the occurrence and diversity of *Phytophthora* species in natural and urban environments.

Phytophthora Species Native to South Africa

There are currently no available data to conclusively point to South Africa as the centre of origin of any known *Phytophthora* species. The most likely candidates are species that have been recovered in South Africa, such as *P. capensis* and some putative new species. Other species initially recovered in this country, such as *P. alticola* and *P. frigida*, have been reported in additional countries, and it is uncertain whether these were introduced from South Africa to those countries or *vice versa*. The widespread occurrence of *P. cinnamomi* in remote, undisturbed natural sites in the Western Cape led to speculation that this species may be indigenous to South Africa. However, later investigations by Celeste Linde into population structure and genetic diversity of South African *P. cinnamomi* isolates suggested that this pathogen was introduced into the country and supported New Guinea as a possible centre of origin. *Phytophthora multivora* is a more-recently described species that was originally described from collections in Australia, but is believed to have been introduced to that country. This species is also frequently found on various introduced and indigenous hosts in South Africa, with early records (identified as *P. citricola*) dating back to collections from lupins (*Lupinus* species) and white stinkwood (*Celtis africana*) by Sharon von Broembsen, raising the possibility that it could be an indigenous South African species.

Future Prospects

Over the past 120 years, South Africa has established a rich base of knowledge on the diversity, distribution, impact and management of *Phytophthora* species. Industry-driven research, especially on fruit crops such as avocado and citrus, along with collaborations with academic institutions, government research councils and consultations with international authorities, have resulted in the development of disease management strategies that have preserved the economic viability of some crop production enterprises threatened by *Phytophthora*. Nevertheless, many aspects of the South African *Phytophthora* story remain unexplored. Despite the substantial contributions of Sharon von Broembsen and more recent surveys of *Phytophthora* species in natural environments, relatively little information is available on the diversity and distribution of *Phytophthora* in natural ecosystems of South Africa. Furthermore, knowledge of the ecological roles of species and hybrids that have been discovered is mostly lacking. From an agricultural point of view, little information is available on *Phytophthora* diseases of small-scale crops and newly introduced crops. Even in the case of larger industries where much work has been done to investigate and manage *Phytophthora* diseases, the pathogen still remains relevant. In light of ongoing changes in agricultural trends and global climate change, *Phytophthora* is likely to remain an important pathogen to contend with in the future.

25.11 VIRAL DISEASES OF GRAPEVINES

Grapevine virus research in South Africa was initiated by DJ Engelbrecht of the Plant Protection Research Institute (then in the Department of Agriculture) in support of the Wine Grape Certification Scheme established in 1976 and initially focused on grapevine fanleaf virus (GFLV, first reported by Engelbrecht in 1961), but later on grapevine leafroll disease (GLD). The nematode vector of GFLV, *Xiphinema index*, was found to be limited in its distribution in South Africa, and in regions where it was absent no natural spread of GFLV occurred. By using the antisera to GFLV developed by Engelbrecht to detect the virus in planting material, and avoiding the propagation of grape planting material in areas where the nematode is found, the virus has been reduced to one of limited importance in South Africa. Grapevine leafroll disease is a disease resulting in significant economic losses due to lower yields, poor quality berries and premature replanting of vineyards. Internationally, the disease was shown to be due to a graft-transmissible entity in 1936. It was first described in South Africa by du Plessis in 1950. The cause of the disease remained unknown until the early 1980s when virus particles were observed under the electron microscope in infected material by a number of laboratories worldwide.

In 1984, the so-called grapevine leafroll associated viruses type 1, 2 and 3 had been identified. In South Africa this was shown by Ken Corbett, a virologist from the USA visiting DJ Engelbrecht and his group at the Plant Protection Research Institute (PPRI). Electron microscopist extraordinaire, Kassie Kasdorf and Johan Wiid, then from Stellenbosch Farmers Winery (SFW) assisted in this discovery. Internationally, it was shown that the disease could be eliminated from grapevine planting material through heat therapy and meristem tip culture. This was incorporated into the Wine Grape Certification Scheme and nuclear plants, free of the then-known viruses, were established and maintained under vector-free conditions. In 1985, Piet Goussard, Johan Wiid and Kassie Kasdorf demonstrated that the virus could also be eliminated by somatic embryogenesis. Transmission of GLRaV-3 by the mealybug *Planococcus ficus* was demonstrated in Italy in 1987, and at the same time remained unpublished, by DJ Engelbrecht and Kassie Kasdorf in South Africa.

TABLE 2: LIST OF *PHYTOPHTHORA* SPECIES AND HYBRIDS AND THEIR ASSOCIATED HOSTS OR SUBSTRATES THAT HAVE BEEN REPORTED IN SOUTH AFRICA FROM 1903-2020

Phytophthora species	Host/substratea
Phytophthora aff. *meadii*[b]	*Eucalyptus grandis*, natural forest (soil)
Phytophthora alticola	*Acacia mearnsii*, *Eucalyptus* spp., natural forest (soil)
Phytophthora amnicola	Soil, water
Phytophthora amnicola × *chlamydospora*	Pond water, river water
Phytophthora arecae	Unknown
Phytophthora asparagi	Soil, natural forest (soil)[b]
Phytophthora boehmeriae	*Acacia mearnsii, Eucalyptus* spp.
Phytophthora cactorum	*Antirrhinum majus, Centaurea* sp., *Cussonia paniculata, Dianthus caryophyllus, Fragaria* sp., *Malus* spp., *Prunus persica, Solanum* spp., *Verbena* spp., *Vitis* spp.
Phytophthora cambivora	Natural forest (soil)[b]
Phytophthora capensis	*Acacia mearnsii*[b], *Curtisia dentata*, natural forest (soil)[b], *Olea capensis,* soil
Phytophthora capsica	*Capsicum* spp., *Cucumis melo*, *Cucurbita* spp., *Solanum lycopersicum*
Phytophthora chlamydospora	River water, soil
Phytophthora cinnamomi	*Acacia mearnsii* (soil), *Agathosma* spp., *Ananas comosus, Araucaria angustifolia, Aspalathus linearis, Aulax* spp., *Banksia* spp., *Berzelia intermedia, Brabejum stellatifolium, Castanea sativa, Casuarina cunninghamiana, Cedrus deodara, Centaurea* sp., *Chamaecyparis lawsoniana, Cliffortia grandifolia, Curtisia dentata, Encephelartos transvenosus, Erica* spp., *Eucalyptus* spp., *Hakea sericea, Leucadendron* spp., *Leucospermum* spp., *Macadamia* sp., *Mimetes* spp., natural forest (soil), *Nymania capensis*, *Ocotea bullata, Orothamnus zeyheri, Paranomus reflexus, Persea americana, Pinus* spp., *Priestleya* sp., *Protea* spp., *Prunus persica, Pyrus communis, Quercus cerris, Rhododendron* sp., *Serruria* spp., *Telopea speciosissima, Thuja nana, Vitis* spp., *Widdringtonia* spp.,
Phytophthora citricola	*Citrus* spp., *Medicago sativa*, natural forest (soil)[b]
Phytophthora citrophthora	*Citrus* spp.
Phytophthora colocasiae	*Protea* sp.
Phytophthora cryptogea	*Agathosma betulina, Chrysanthemum cinerarifolium, Clarkia amoena,* natural forest (soil)[b], *Osteospermum* sp., *Pinus radiata, Prunus persica, Vitis vinifera*
Phytophthora drechsleri	*Acacia mearnsii* (soil), *Agathosma betulina, Brassica oleracea var. capitata, Eucalyptus grandis* (soil), *Medicago sativa*, natural forest (soil)
Phytophthora elongata[b]	*Acacia mearnsii* (soil), *Eucalyptus grandis* (soil), natural forest (soil)

Phytophthora frigida	*Acacia* spp., *Eucalyptus* spp., natural forest (soil)
Phytophthora gondwanense[b]	*Acacia mearnsii* (soil)
Phytophthora gregata complex[b]	*Eucalyptus grandis* (soil), natural forest (soil)
Phytophthora hibernalis	*Citrus* sp.
Phytophthora humicola[b]	*Eucalyptus grandis* (soil)
Phytophthora hydropathica × sp. maryland	Water
Phytophthora infestans	*Petunia × hybrida, Solanum* spp.
Phytophthora inundata[b]	Natural forest (soil)
Phytophthora lacustris	River water
Phytophthora litchii[b]	Natural forest (soil)
Phytophthora meadii	*Acacia mearnsii*
Phytophthora medicaginis	*Medicago sativa*
Phytophthora megasperma	*Medicago sativa*
Phytophthora multivora	*Acacia mearnsii* (soil), *Agathosma* spp., *Citrus sinensis × trifoliata, Eucalyptus grandis* (soil), *Medicago sativa,* natural forest (soil), *Ocotea bullata,* soil
Phytophthora nicotianae	*Acacia mearnsii, Agathosma betulina, Chamaecytisus palmensis, Citrus* spp., *Cotyledon* sp., *Delphinium* sp., *Eucalyptus* spp., *Gypsophila paniculata, Musa* sp., natural forest (soil)[b], *Nicotiana tabacum, Passiflora edulis, Rheum rhaponticum, Solanum lycopersicum, Vitis vinifera*
Phytophthora niederhauserii	*Acacia mearnsii* (soil)[b], *Eucalyptus grandis* (soil)[b], natural forest (soil)[b], *Vitis vinifera*
Phytophthora palmivora	Natural forest (soil)[b]
Phytophthora parvispora	*Acacia mearnsii* (soil)[b], *Agathosma betulina, Eucalyptus grandis* (soil)[b], natural forest (soil)[b]
Phytophthora plurivora	*Acacia mearnsii* (soil)[b], *Eucalyptus grandis* (soil)[b], natural forest (soil)[b], river water
Phytophthora porri	*Allium cepa*
Phytophthora pseudocryptogea[b]	*Acacia mearnsii* (soil), *Eucalyptus grandis* (soil), natural forest (soil)
Phytophthora pseudocryptogea × cryptogea	Soil
Phytophthora sp.	*Cichorium intybus*
Phytophthora sp. AUS2A[b]	Natural forest (soil)
Phytophthora sp. *canthium*	Soil
Phytophthora sp. emzansi	*Agathosma betulina,* soil
Phytophthora sp. hennops	*Eucalyptus grandis* (soil)[b], natural forest (soil)[b], water
Phytophthora sp. *kelmania*	Natural forest (soil)[b]
Phytophthora sp. *Kununurra*	Soil
Phytophthora sp. RSA1A[b]	*Acacia mearnsii* (soil), *Eucalyptus grandis* (soil), natural forest (soil)
Phytophthora sp. RSA2A[b]	*Acacia mearnsii* (soil)

Phytophthora sp. RSA3A[b]	*Acacia mearnsii* (soil), natural forest (soil)
Phytophthora sp. RSA5A[b]	*Acacia mearnsii* (soil), *Eucalyptus grandis* (soil), natural forest (soil)
Phytophthora sp. RSA7A[b]	*Acacia mearnsii* (soil), *Eucalyptus grandis* (soil), natural forest (soil)
Phytophthora sp. RSA10A[b]	Natural forest (soil)
Phytophthora sp. nov. 9A[b]	Natural forest (soil)
Phytophthora sp. *stellaris*	Soil, water
Phytophthora sp. *Umtamvuna*	Water
Phytophthora sp. × WS	Water
Phytophthora syringae	*Citrus sinensis*
Phytophthora taxon Sisuluriver	*Citrus sinensis,* river water
Phytophthora thermophila × *amnicola*	River water
Phytophthora tropicalis	Soil

[a] Where multiple species or hybrids of the same host genus have been reported, these are not listed individually but indicated as spp.

[b] Record based on next generation sequence data only.

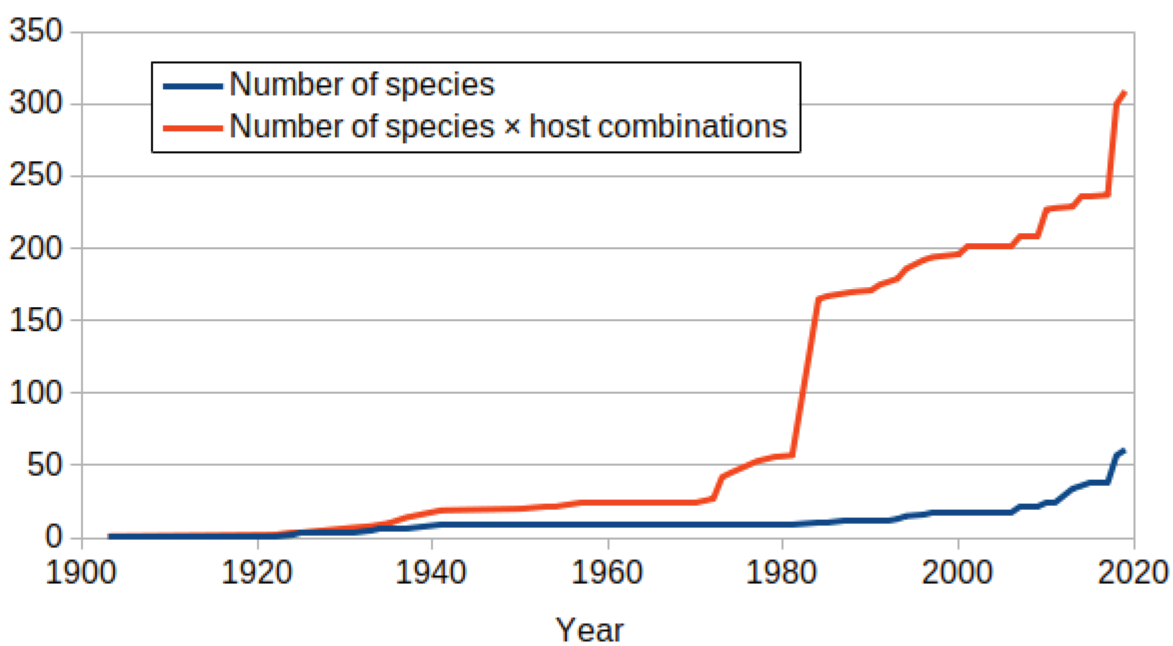


Fig. 1: Cumulative number of *Phytophthora* species and host reports in South Africa from 1903-2020

By 1989, DJ Engelbrecht's group (Kassie Kasdorf, Linda Pretorius and Roleen Carstens) had produced antisera and developed ELISA techniques for the detection of GLRaV-1, GLRaV-2 and GLRaV-3. In 1990, DJ Engelbrecht retired and the Stellenbosch virology laboratory of PPRI was closed and amalgamated with the PPRI laboratory in Pretoria, headed by Gerhard Pietersen. Kassie Kasdorf relocated to Pretoria to continue with the research. By 1993, Dariusz Goszczynski from Poland (who had joined the group at PPRI), Kassie Kasdorf and Gerhard Pietersen had identified multiple sources of GLRaV-1, -2, and -3 and had produced antisera and developed a GLRaV-1, -2, -3 directed, single test, ELISA. At the same time, Gerhard Pietersen and Kassie Kasdorf also developed an immuno-electron microscopy (IEM) technique to detect GLRaV-1, -2, -3 and the subsequently detected -4, -7 and GFkV. Both techniques were utilised for routine detection of these viruses in certification schemes for over 20 years. Using these techniques, Kassie Kasdorf and Gerhard Pietersen also demonstrated that GLRaV-3 was by far the most important leafroll-associated virus locally. While elimination of leafroll-associated viruses from nuclear material was very effective, propagation of this material in the field resulted in it rapidly becoming re-infected again. To address this issue, Gerhard Pietersen embarked on a spatio-temporal analysis of the spread of leafroll in 55 vineyards in South Africa between 1998 and 2005. Contemporaneously, Kerstin Krüger, an entomologist at the University of Pretoria, did studies on the transmission characteristics of GLRaV-3 by *Planococcus ficus* while Vaughan Walton, an entomologist with K Pringle at Stellenbosch University, conducted biological studies of the vector for a PhD degree. By combining the vector studies and spatio-temporal spread analyses, Gerhard Pietersen formulated a control strategy based on mealybug control and roguing of leafroll-infected vines. This was assessed experimentally in Stellenbosch at Grondves vineyards with the collaboration of Nico Spreeth and Tobie Oosthuizen of Vititec. The integrated control strategy was implemented on a commercial scale at Vergelegen wine estate and has led to the near-eradication of leafroll on Vergelegen, a farm that had produced the world's first commercial wines from grapevine leafroll virus-free vineyards by 2010. This control strategy is now widely applied within the wine grape certification scheme foundation and motherblocks, as well as on most leading South African wine estates.

In parallel with the epidemiological studies, attempts to produce transgenic plants resistant to GLRaV-3 were initiated. The first such plants were established by Michael-John Freeborough during his PhD studies under the supervision of Johan Burger at Stellenbosch University (SU). Several transgenic grapevine lines that expressed a mutated version of the GLRaV-3 HSP-70 gene showed excellent resistance against the virus in greenhouse trials. Jacques du Preez, another one of Burger's PhD students, conducted a comprehensive study on Grapevine virus A and also assembled an infectious clone of this virus for use in host-pathogen studies. In 2008, Hano Maree determined the first complete nucleotide sequence of GLRaV-3 as part of his PhD studies, while Renate Lamprecht did the same for a South African isolate of Grapevine fanleaf virus in 2012 for her PhD. In 2010, Beatrix Coetzee, using the then novel technology of next-generation sequencing, determined the virus status ("virome") of a leafroll-diseased vineyard during her MSc study, confirming the dominant status of GLRaV-3 in the aetiology of GLD.

Subsequently, postgraduate students of Johan Burger and Hano Maree, Elize Jooste (PhD), Rachelle Bester (PhD) and Dirk Aldrich (MSc) studied GLD. Collectively they showed the presence of different GLRaV-3 variants and characterised their properties and spread. They also used high-throughput sequencing to study plant virus interactions, establishing the group as international leaders on GLRaV-3 variants and host-pathogen interactions. Burger and Maree's group was also the first to report Grapevine Syrah virus-1, Grapevine virus E and Grapevine virus F in South Africa. In 2017, Gerhard Pietersen joined the Burger-Maree group at Stellenbosch University. The larger group remain seriously involved in grapevine virology and were the first to recently create genome-edited vines, ultimately with the aim to establish resistant plants.

While leafroll disease and fanleaf disease were the diseases on which the bulk of the research in South Africa was done, other virus diseases also received some attention. EF Beukman conducted a study on corky bark disease in the late 1960s, G le Roux Kriel studied stemgrooving (legno reggio) of grapevine in the mid 1970s and Nico Spreeth did an MSc study on grapevine fleck disease which he completed in 1985. At PPRI, Dariusz Gosczcynski conducted research primarily on grapevine virus A and B in South Africa, characterising the variation of the viruses in the country, determining the whole genome sequence of various isolates of these and producing infectious clones to various isolates. Dariusz Gosczcynski also conducted research on determining the aetiology of grapevine corky-bark disease, Shiraz decline disease and Shiraz disease.

25.12 VIRAL DISEASES OF CEREALS

While it was not known as a virus disease at the time, work in 1899–1900 by the government entomologist of Natal, Claude Fuller, was the first to identify a new disease agent in maize causing "mealie variegation". The legendary HH Storey did extensive work on characterising the disease agent of what was renamed maize streak disease (MSV) and its transmission in South Africa in the 1920s and 1930s, including the formal demonstration that it was a virus. Interestingly, this was also the first characterisation of any plant virus agent in South Africa, including the fact that sugarcane- and maize-infecting viruses were different to one another.

Barbara von Wechmar, working with Marc von Regenmortel in the Paul van der Bijl Laboratory at Stellenbosch University in the 1960s, isolated a number of viruses including brome mosaic (BMV) and barley yellow dwarf (BYDV) from wheat and barley, as well as MSV from various cereal hosts. Von Wechmar continued this work at the University of Cape Town in the early 1970s and helped initially by Alfred Polson and Robert "Bob" Milne from Torino. She went on to demonstrate transmission of BMV by the Russian wheat aphid *Diuraphis noxia*. Later work included finding cucumber mosaic virus (CMV) and tobacco necrosis virus (TNV), usually in association with several different potyviruses, in diseased cereals from around the country. Pieter Cronje of ARC-Small Grains in his 1990 PhD thesis reported that, despite widespread occurrence, BMV was not a limiting factor in wheat production in the summer rainfall area.

Barbara von Wechmar was joined by Ed Rybicki for his PhD project (1980-1984), in which he explored the purification and characterisation of BYDV, BMV and other viruses from wheat and barley plants as individual and mixed infections implicated in the "Free State streak disease" of wheat. He also pioneered the use of western blotting as an analytical tool in plant virology. From 1988 onwards Rybicki worked mainly on MSV, initially with Barbara von Wechmar. By 1989, Rybicki and his student Beverley Clarke and colleague Ralph Kirby had characterised three novel maize strains of the virus, and applied restriction map-based phylogenetic analysis techniques to investigate their relationships with other MSVs. From 1988 Rybicki's group, including PhD students Wendelin Schnippenkoetter, Eric van der Walt, Darren Martin, Janet Willment and Aderito Monjane, used genomic cloning and sequencing and PCR to detect and characterise new cereal-infecting geminiviruses, and, by means of making artificial recombinant viruses, they also investigated the determinants of viral pathogenicity. Achievements of this study included proving that maize-infecting MSVs were all very closely related, that streak viruses of other grasses and sugarcane were all distinct species of mastreviruses (including sugarcane-infecting viruses from Natal and Mauritius), and that directed recombination was an excellent tool for investigating geminivirus virulence and evolution. Darren Martin and Arvind Varsani as independent researchers, with Dionne Shepherd (née Miles) and PhD student Aderito Monjane in Ed Rybicki's group, have continued to characterise many novel geminiviruses infecting grasses and maize throughout Africa. An unpublished PCR study conducted by Bradley Flett of ARC-Grain Crops at Potchefstroom and Ed Rybicki on more than 100 000 maize seedlings proved conclusively that MSV was not seed transmitted which had not previously been reliably shown.

Ed Rybicki and his PhD student Kenneth Palmer started using MSV for "molecular farming", or the production of high-value biologics in plants, in the mid-1990s. Work on MSV as an expression vector in cultured maize cells was especially useful, as it laid important groundwork for later molecular farming developments with another geminivirus, bean yellow dwarf mastrevirus (BeYDV, from Pietersen). They were able to show stable, long-term (three years) high-level expression of foreign genes in cultured maize plant cells from plasmid-like circular dsDNA replicating forms of engineered MSV genomes.

The early molecular biological work on MSV also led to investigations of the potential of using MSV-derived genes and sequences for engineering maize for resistance to MSV. In work initially done by Ed Rybicki in collaboration with Jennifer Thomson at the University of Cape Town, Tichaona Mangwende and then Dionne Shepherd successfully demonstrated that a MSV Rep gene-derived construct was effective in significantly limiting the replication of MSV, first in suspension cultured maize cells, and later (in work funded by Pannar South Africa (Pty) Ltd) in transgenic maize.

In recent years, with the outbreak of maize lethal necrosis in Tanzania, research on viruses of maize in South Africa has received new impetus, especially regarding potyvirus. Pietersen, Roberts and an MSc student, E. Schulze (at PPRI and UP) conducted surveys that indicated that sugarcane mosaic virus is prevalent only in limited regions of the maize production areas.

25.13 VIRAL DISEASES OF LEGUMES

Research on viruses and virus-diseases of legumes has been led by Patricia (Pat) Klesser of the Vegetable and Ornamentals Crops Institute (previously then from DAFF). She did an enormous amount of transmission, host range and symptomatology studies on beans, broadbeans, cowpeas, lucerne, peanuts, peas, soybean, sweetpeas and sunhemp in the late 1950 and throughout the 1960s, where she identified a number of viruses for the first time in South Africa. From 1980 this work was continued at PPRI by Gerhard Pietersen and his co-workers Christine Vroon, Tertia van Tonder, Glynnis Cook and Elize Jooste, who detected and identified local viruses on lucerne, soybeans, beans, lupins and peas, and produced antisera and developed ELISA for surveys on these crops to determine viral distribution and importance. Following this approach, the group confirmed the presence of a number of viruses reported previously, primarily by Klesser, in South Africa and identified some on new crops, including a number previously unreported in South Africa. This group also discovered four internationally-important and previously undiscovered legume viruses (soybean blotchy mosaic virus, groundnut ringspot tospovirus, bean yellow dwarf geminivirus and peanut chlorotic blotch potyvirus). Very little work on viruses of legumes was done subsequent to that recorded above, with the exception of a PhD study by Elrea Strydom in 2018, who determined the inter-seasonal persistence of soybean blotchy mosaic virus on soybeans as well as the current and historic variability of this virus on soybeans in South Africa.

26.0 Development of a Biological Control Agent for the Port Jackson Willow (*Acacia saligna*)

The first biological control programme against an invasive alien plant (IAP) in South Africa was the release of the cochineal insects against the cactus *Opuntia monacantha* in 1913, followed by two more similar releases in the 1930s. This was followed by a hiatus of work until the 1960s, when biological control of IAPs was revitalised by the Plant Protection Research Institute (PPRI), the Department of Agriculture (now in the Agricultural Research Council as ARC-Plant Health and Protection), and the additional assistance of a number of entomologists.

Amongst the first weed targets for biological control were a number of aggressively invasive Australian *Acacia* species, including *Acacia saligna*. Although surveys for suitable insect biocontrol agents were conducted in the native range of *Acacia saligna* in Western Australia in the 1970s, it was observed that the gall-forming rust fungus, then known as *Uromycladium tepperianum*, was a highly damaging, and sometimes lethal, pathogen of this tree. In early 1979, the team leaders of the Biological Control of Alien Invasive Plants team (all entomologists at this stage) decided to appoint a plant pathologist to the team to research this gall rust fungus. Thus in 1979, Mike Morris received a phone call from Stefan Neser, inviting him to join the team. This was on condition that he was prepared to complete a PhD within three years and then move to Australia for an extended period of time. At the time, Mike was a lecturer/researcher at the Cedara Agricultural College (in Hilton, KwaZulu-Natal), but he joined the team at PPRI and undertook a PhD (1979-1982), conducting research on three different local plants that were invasive weeds elsewhere in the world in order to gain experience in working on biological control of IAPs.

Between 1979 and 1982, seeds of representative species of African *Acacias* (now in the genera *Senegalia* and *Vachelia*) were sent to Australia and grown at the quarantine station in Brisbane, Queensland (now Queensland Department of Agriculture and Forestry). In 1982, Mike Morris, together with his wife Mavis and three-month old daughter Fay, moved to Canberra, Australia, where they lived until 1985. Mike was hosted at the CSIRO laboratories and was given laboratory and glasshouse space to conduct his work for the next three years. During this time, seeds were collected of selected *Acacia* species representative of all taxonomic groups, and seedlings were grown. The gall rust fungus was collected from various Australian *Acacias*, and then cross inoculations were made on all the different Australian *Acacia* species grown in order to study the development of the different rust collections on the inoculated plants. In addition, the African *Acacia* seedlings were collected from Brisbane and were inoculated. During this time, Cristina Sands, an Australian, was employed to help with the research. But when more experienced help was required, Jessica Scholtz, Mike's previous laboratory assistant in South Africa, was sent to Australia to provide support.

Following the successful completion of Mike's research which proved that the gall rust fungus collected on *Acacia saligna* was safe to introduce into South Africa, teliospores of the fungus were collected from “clean” glasshouse plant galls and brought back to South Africa when the Morris family (now expanded with a son, David) returned in 1985. These were stored in liquid nitrogen. During 1986, a report detailing the completed work was written and submitted to various experts (including Wally Marasas of the Medical Research Council) for an assessment of the benefits and risks of introducing the fungus into South Africa. The fungus was regarded as sufficiently host-specific by these experts and cleared for release.

In 1987, glasshouse-grown seedlings of *Acacia saligna* were inoculated with the teliospores of *Uromycladium morrisii* from liquid nitrogen. These were grown and inoculated in the newly-constructed plant pathogen quarantine facility on the PPRI Stellenbosch campus. Galls subsequently developed and fresh spores were harvested and used for releasing the fungus onto field-growing plants around Stellenbosch. Only a single release was made that year, but the number of releases rapidly increased over the following years, reaching a peak in 1996. By that year, the rust fungus had largely spread throughout the range of its host in South Africa, from north of Clanwilliam on the west coast to Port Elizabeth on the south-east coast. Initially, Gwen Samuels and Netta Uys assisted with the releases, but later they carried out all releases themselves. They still remember the excitement of going back to the first release sites a year after inoculating and then seeing galls present. A total of 174 releases were made.

In 1992, Mike set out permanent transects at ten sites in the Western Cape, to record the impact of the rust on host plants. The infection levels and tree populations have been monitored on an annual basis at these sites since then. There has been attrition of the sites due to various factors, but three of the original ten sites are still in existence. In 2020, these sites was monitored for the last time, giving a total of 30 continuous years of data on a pathogen and its host tree, which is a unique record. The data shows that, despite a lot of variation due to site characteristics and disturbance regimes, overall, the impact of the gall rust fungus has been severe on populations of its host tree, except where frequent disturbance (e.g. fires that kill galls) occurs. Gwen Samuels is still involved in this monitoring and is responsible for making sure it is carried out correctly, having been involved from the very beginning.

In evaluating the impact of the biological control of *Acacia saligna* with *Uromycladium morrisii*, it is worthwhile recalling Mike’s original prediction of impact. “Initial spread is expected to be slow, and it may be five to ten years before the fungus reaches an exponential rate of spread and any influence on populations of the weed can be observed”. In fact, the levels of tree mortality that were experienced shortly after establishment of the gall rust, particularly in mature populations in the Swartland (Western Cape), were so high by 1992-1994, that a controversy erupted in the local press, and even internationally, with an article in *New Scientist*. This was driven by people who feared complete eradication of the tree within just a few short years. This controversy rapidly faded, however, as a new predator–prey type relationship was established with annual recruitment of host trees that compensated for some mortality, resulting in stands that had a lower density but were still persistent. Overall, the introduction of the gall rust fungus has been incredibly successful against a plant that in the 1980s was considered to be the greatest threat to the survival of the fynbos posed by any invasive plant.

The taxonomy of the *Uromycladium tepperianum* complex was recently revised, and the gall rust on *Acacia saligna* was recognised as a host-specific species, and given the name *Uromycladium morrisii* in recognition of the work done by Mike on this species. This work also led to the expansion of the weed pathology group in the ARC-PHP, with between two and four researchers employed at any time over the last three decades working in collaboration with entomological colleagues who have typically been more numerous in number. Research carried out has been aimed at the control of many of the worst, and some important emerging, invasive alien plants in South Africa. A total of 11 species of fungi have been investigated for their biocontrol potential and have been successfully established on their target hosts. Two fungal products have been produced and are available on request. In addition, permission for release was granted for a further two species, but these failed to establish.

27.0 Bibliographies of Selected Leading Plant Pathologists

27.1 PAUL ANDRIES VAN DER BIJL (1888-1939)

Paul van der Bijl was the youngest son of Andries Christoffel van der Bijl and his wife Aletta Catharina Johanna, also born van der Bijl. He attended the Boys' High School in Wynberg, Cape Town, continued his studies at Victoria College in Stellenbosch (later Stellenbosch University) and was awarded the degree Bachelor of Arts (BA), with honours in botany, by the University of the Cape of Good Hope in 1909. After a short period as a science teacher in Bethlehem in the Free State, he joined the staff of the Division of Plant Pathology and Mycology of the Department of Agriculture in Pretoria on 1 August 1911. During the next four years, he continued his studies and obtained the degrees Master of Arts (MA) in botany in 1913 and Doctor of Science (DSc) in 1915 from the University of the Cape of Good Hope, the latter with a thesis entitled *A study of the dry-rot disease of maize caused by* Diplodia zeae. The thesis was published by the Department of Agriculture in 1916. In September 1915 he was transferred to Durban as mycologist in charge of the phytopathological laboratory and Natal Herbarium, where he worked on the destruction of trees by fungi and diseases of citrus, sugarcane and other subtropical crops.

In August 1921, van der Bijl became the first professor of phytopathology and mycology in the Faculty of Agriculture, University of Stellenbosch - the first and for many years the only such position in South Africa. He was a clear and capable lecturer and was tireless in his efforts to do the best for his students. His post-graduate students later filled a number of senior positions in their field. From 1927 he served as dean of the Faculty of Agriculture, and he was a member of the university council from 1927 to his death. He did his best to extend the university's influence on agriculture, and in particular he promoted the amalgamation of the Faculty of Agriculture and the Agricultural School at Elsenburg, to form the Stellenbosch-Elsenburg College of Agriculture. In 1928, he succeeded CK Brain as principal of the college, a post he held until his death 11 years later. His work was appreciated by the agricultural community of the Western Cape, and at their special request the Department of Agriculture appointed him chairman of the newly-established Dried Fruit Board shortly before his death. He was also one of the first and strongest advocates of advanced forestry training in South Africa, until the first chair of forestry was instituted at the University of Stellenbosch in 1932.

Van der Bijl specialised in the collection and study of South African fungi and lichens and with his students described many new species of plant pathogenic fungi. He soon became interested in the larger fungi, especially the Polyporaceae found on indigenous trees. With JDM Keet, the Director of Forestry, he made an extensive collection of fungi in the forests of the Eastern Cape conservancy in 1915. During his years at Stellenbosch, he and AV Duthie studied the fungi of the Western Cape and later those of the Knysna forests. Subsequently, he paid attention to the taxonomy of South African fungi. He produced approximately 60 publications, many of them in Afrikaans. They included the first local textbook of its kind, *Plantsiektes; hul oorsaak en bestryding* (Plant diseases, their causes and control; 1928). He also wrote *The fungus flora of the Western Province of the Cape* (1929). His first scientific paper dealt with a mottled disease of the black wattle trees and many later papers with the decay of indigenous forest trees. A number of his papers were published in the *Transactions of the Royal Society of South Africa* and dealt with topics such as heart rot of Sneezewood (1917), South African *Xylarias* occurring around Durban (1921), a fungus which causes powdery mildew on the leaves of the pawpaw plant (1921), a new species of fungus on a spider (1922), fungi of the Stellenbosch district (1922), and notes on some South African *Xylarias* (1924). Many more papers appeared in the *South African Journal of Science*, on topics such as die-back of apple trees (1915), fungi affecting the wood of the willow (1916) and the wood of black ironwood trees (1917), the fungus causing root disease in sugar cane (1919), host plants of the Loranthaceae (1919, 1920), and descriptions of new South African fungi (1925, 1926, 1927, 1928, 1929). A number of papers, most with descriptions of the South African fungal species residing in several different families, were published in the *Annale van die Universiteit van Stellenbosch* during the period 1923 to 1935. These were all written in Afrikaans.

Van der Bijl was elected a Fellow of the Royal Society of South Africa in 1924 and served on its council for some years. He was a Fellow of the Linnean Society (London), a member of the Suid-Afrikaanse Akademie vir Wetenskap en Kuns, and a member of the South African Association for the Advancement of Science, serving as president of Section C in 1926. During 1914-1915 he delivered three papers to the Transvaal Biological Society and in 1916 became a foundation member of its successor, the South African Biological Society.

Van der Bijl left his collection of fungi and lichens to the University of Stellenbosch. The university named the Paul van der Bijl Laboratory for the Study of Plant Diseases after him. He is also commemorated in the names of the fungal genus *Byliana* and the species *Physalospora bylii, Acarospora bylii, Cerospora byliana, Lecanora bylii, Uromyces byliana* and *Puccinea byliana*.

In January 1923, he married Anna Elisabeth Schreuder. They did not have children.

Source: S_2A_3 biographical database of southern African science, www.s2a3.org.za/bio/Main.php (as on 10 November 2020)

27.2 ILLTYD BULLER POLE-EVANS (1879-1968)

Illtyd Buller Pole-Evans, botanist and mycologist, was the son of Reverend Daniel Evans, an Anglican clergyman, and his wife Caroline J Pole. At some time, he changed his surname from Evans to Pole-Evans, but his name is often given as either Evans, IB Pole or Pole-Evans IB. In 1903, he obtained the degree Bachelor of Science (BSc) at the University College of South Wales and Monmouthshire at Cardiff. He continued his training as a research student under HM Ward at Selwyn College, University of Cambridge, working on problems connected with rusts on cereals. In 1905, he graduated with a Bachelor of Arts (BA) degree, but a few years later was awarded the degree Master of Arts (MA). In July 1905, he was appointed as the first mycologist and plant pathologist in the Department of Agriculture of the Transvaal Colony (Pretoria) under the head of the Division of Botany, J Burtt Davy.

Pole-Evans soon established a mycological laboratory and initiated research on cereal rusts and on the life history and development of local fungi, reporting his findings in a series of papers and popular articles. His work laid the foundation for all future mycological work in South Africa. A paper on "The South African rust fungi: 1. The species of *Puccinia* on Compositae" was published in the *Transactions of the Royal Society of South Africa* (Vol. 5) in 1916. Several other mycological papers containing descriptions of interesting fungi appeared in various journals between 1907 and 1918. Approximately 20 notes and articles by Pole-Evans on matters of interest to farmers, were published in the *Transvaal Agricultural Journal* during 1905-1910, followed by several more in the *Agricultural Journal of the Union of South Africa* during 1911-1913. In 1908 Ethel M Doidge was appointed as his first assistant and a mycological herbarium was established, which later became the leading collection of its kind in South Africa. As the work increased other mycologists were appointed, the following two being Paul van der Bijl (1911) and AM Bottomly (1913).

After the formation of the Union of South Africa in 1910, Pole-Evans became head of a newly-created Division of Mycology and Plant Pathology in the Union's Department of Agriculture in 1912. When Burtt Davy retired during the following year the two divisions were combined under Pole-Evans as the Division of Botany and Plant Pathology. From about this time, he began to give more attention to the flowering plants of the country, concentrating at first on the aloes.

In August-September 1913, Pole Evans visited Mozambique at the request of the governor-general of that territory to study and report on the diseases affecting palms. A full account of this work was published only in 1918. At times, he and his staff had to implement unpopular measures in combatting plant diseases. For example, when citrus cancer began to spread in the Transvaal in 1916, threatening to devastate the citrus industry, he ordered the complete destruction of infected nurseries and orchards at great cost in the form of paid compensation to the growers. After a long and ruthless campaign the disease was eradicated, and his actions came to be appreciated by those affected. From 1919, he studied the serious wastage in shipments of citrus and other fruit and formulated requirements for the cold storage of export fruit. This work led to the establishment of a low temperature laboratory in Cape Town in 1925, as part of his division. After 1918, Pole-Evans no longer had time for the study of fungi, though this work was continued by members of his staff.

Pole-Evans was elected a Fellow of the Linnean Society in 1907 and became an active member of several local scientific societies. In 1906, he joined the South African Philosophical Society and remained a member when it became the Royal Society of South

Africa in 1908. In 1911, he was elected a Fellow and served on its council for several years. He joined the South African Association for the Advancement of Science in 1905, served as president of Section C (which included botany) in 1916, as president of the Association in 1920, and received its South Africa Medal (gold) in 1922. In 1905, he joined the South African Ornithologists' Union. A few years later he became a foundation member of the Transvaal Biological Society, before which he delivered several papers. He served as its honorary secretary in 1909 and as president in 1911. This society amalgamated with the South African Ornithologists' Union in 1916 to form the South African Biological Society. He served as president of the latter society in 1926, and in 1918, he received its Captain Scott Memorial Medal. He was also a member of the South African Geographical Society. From 1905 to 1916 he served as an examiner in botany at the Bachelor's and Master's level for the University of the Cape of Good Hope.

After retiring in September 1939, Pole-Evans continued to collect indigenous plants and described his expeditions to Botswana and Kenya in *Memoir No. 21* (1948) and *No. 22* (1948) of *The Botanical Survey*. He settled in Mutare, Zimbabwe in 1955. South Africa owes Pole-Evans a debt of gratitude for his farsightedness and drive in bringing together and inspiring a large and active body of researchers, and for his important contributions to botany, mycology, agriculture and soil conservation. In 1918, his former university in Wales conferred upon him the degree Doctor of Science (DSc). The British government honoured him as a Companion of the Order of St Michael and St George (CMG) in 1921, and in 1933, the University of the Witwatersrand awarded him an honorary Doctor of Laws (LLD) degree. In 1922, he married Mary RH Thompson, a mycologist on his staff, with whom he had a son and daughter. The grass genus *Polevansia*, based on a grass he discovered in the mountains of Lesotho, was named in his honour, as were the plant species *Aloe pole-evansii, Dinteranthus pole-evansii, Gladiolus pole-evansii* and *Albizia evansii*, and the fungi *Puccinia pole-evansii* and *Ravenelia evansii.*

Source: S_2A_3 biographical database of southern African science, www.s2a3.org.za/bio/Main.php (as on 4 March 2020)

27.3 ETHEL MARY DOIDGE (1887-1965)

Ethel Doidge, mycologist and plant pathologist, was the daughter of Henry Doidge, an analytical chemist, and his wife, Elizabeth Craven. In 1897 (or 1895), the family moved from England to Pietermaritzburg, where Ethel attended Epworth High School and matriculated in 1903. The next year she continued her studies at Huguenot College, Wellington, studying botany under Bertha Stoneman, with mycology as her main interest. She received the degree Bachelor of Arts (BA) from the University of the Cape of Good Hope in 1907. The next year she moved to Pretoria to take up an appointment as assistant to Illtyd Pole-Evans, mycologist and plant pathologist in the Division of Botany, Department of Agriculture, of the Transvaal Colony. Continuing her studies privately, she was awarded the degree Master of Arts (MA) in botany by the University of the Cape of Good Hope in 1909, for her thesis on "The flora of certain kaffir beers". For this thesis she won the university's Cornwall and York Prize for 1909. It was published that same year in the *Science Bulletin* (No. 8) of the Transvaal Department of Agriculture.

After the formation of the Union of South Africa in 1910, Doidge was promoted (in 1912) to professional assistant in the Division of Botany and Mycology. Two years later she was awarded the degree Doctor of Science (DSc) by the University of the Cape of Good Hope for her thesis "A bacterial disease of mango". This newly-described disease had caused considerable damage to mango crops in South Africa during the previous few years. Her doctoral degree was the first ever to be awarded to a woman in South Africa. In 1919 she was promoted to assistant chief of the Division of Botany and Plant Pathology, and in 1924 attended the Imperial Botanical Conference and the first Imperial Mycological Conference in London. She was appointed principal plant pathologist to the mycological section of the newly created Division of Plant Industry in 1929, a post she held until her retirement in 1942 at the age of 55. After her retirement she was employed in the division for several more years in order to complete the research for her most extensive and important publication, "The South African fungi and lichens to the end of 1945". This work was eventually published in *Bothalia* (1950, Vol. 5, pp. 1-1094) and for decades remained the most important publication on the topic. After its completion she retired to the KwaZulu-Natal south coast.

Doidge's work in the division consisted mainly of pioneering research in taxonomic mycology and studies of the bacterial and fungal diseases of crop plants. The results contributed much to the success of South African agriculture, particularly of the citrus industry. In the course of her work she made extensive collections of fungi and the host plants on which they occurred. During the early years her collecting expeditions were often with horse and cart. Most of her specimens are in the National Herbarium and the National Collection of Fungi of the Plant Protection Research Institute in Pretoria, and the Selmar Schonland Herbarium of the Albany Museum in Grahamstown.

Ethel Doidge's research was published in about 50 scientific papers between 1915 and 1950. Many of these appeared in the *Transactions of the Royal Society of South Africa* (including a series of six on plant parasites of the order Perisporales, of the group Ascomycetes, 1915-1921), the *South African Journal of Science* (including a series of four "Descriptions of some previously unnamed South African fungi", 1925-1928) and, from 1921 onwards in *Bothalia*. Her papers in the latter journal included a series of four with descriptions of South African Ascomycetes in the National Herbarium (1921-1922) and a series of six dealing with the South African rust fungi (1927-1948). In addition, she wrote more than 100 semi-popular articles and pamphlets aimed mainly at farmers, including "Potato diseases" (Johannesburg, 1919, 49p), "Some common diseases of the tomato" (Johannesburg, 1919, 24p), and "Diseases of the apple, pear and quince" (Johannesburg, 1919, 50p). As a leader in her field, she did much to inspire younger scientists by her example and with her advice.

Doidge was elected a Fellow of the Linnean Society (England) in 1912. She was a member of the Royal Society of South Africa and in 1918 was elected one of its Fellows. In 1915, she became a member of the South African Association for the Advancement of Science, serving as president of Section C (which included botany) for 1918/9. Her presidential address dealt with "The role of bacteria in plant diseases". She became a member of the Transvaal Biological Society and read papers at its meetings in February 1909, July 1910 and April 1915. In 1916, she became a foundation member of its successor, the South African Biological Society and served on its council. In 1920 she was awarded this council's prestigious Senior Captain Scott Memorial Medal in recognition of her work in plant pathology. From 1920 to 1921 she was Editor-in-Chief of the society's publication, the *South African Journal of Natural History*. The plant species named after her included *Aplanodes doidgeana, Crotalaria doidgeae* and *Nitella doidgeae*, as well as the fungi *Meliola doidgeae, Phyllachora doidgeae* and *Eutypella doidgeae*.

Outside botany, Doidge practiced gardening and bred Pekinese dogs. As a licentiate of Trinity College of Music (London), she was a competent pianist and singer, and was a member of the Pretoria Music Society for many years. She was a member of the council of the University of South Africa from 1918 to 1924.

Source: S_2A_3 biographical database of southern African science, www.s2a3.org.za/bio/Main.php (as on 4 March 2020)

27.4 JAMES EDWARD VANDERPLANK (1908-1997)

James Edward Vanderplank was born in 1908 in Eshowe in Zululand, South Africa to British parents. Despite this, he spelt his surname in a traditional Dutch way, as van der Plank, until the mid-1970s, after which he changed it to Vanderplank. This certainly resulted in a fair amount of confusion for plant pathology scholars, when citing his work. Although Vanderplank is often fondly referred to as the "Father of Plant Disease Epidemiology", he did not hold a formal tertiary qualification in plant pathology. After school, Vanderplank completed a BSc in botany and chemistry from the University of South Africa in 1927, an MSc in botany in 1928, and another MSc in chemistry in 1932. In 1935, he was awarded a PhD in botany by the University of London, and subsequently a DSc in chemistry by the University of South Africa in 1944.

In 1941, Vanderplank joined the South African Department of Agriculture and worked his way up to Chief of the Division of Plant Protection in the Department in 1953. He was later appointed as Director of the Plant Protection Research Institute in Pretoria, and held this position until his retirement in 1971. During Vanderplank's career he was closely involved with the development of potato varieties and is credited with developing a highly successful potato breeding program in South Africa. Many of his potato varieties are still grown. His involvement in the potato industry clarifies why many of his books include potato virus and late blight examples.

Vanderplank's ideas and hypotheses changed the course and thinking of both plant pathology and plant breeding, bringing them together with epidemiological principles. His first ideas were outlined in the 1960 paper "Analysis of epidemics" and his 1963 book, *Plant diseases: Epidemics and* *control* which is generally regarded as the formative text on plant disease epidemiology. This was followed by five other books including *Disease resistance in plants* (1968), which was an expansion of the ideas in the previous book, and *Principles of plant infection* (1975), a collection of selected topics. In 1978, the more controversial *Genetic and molecular basis of pathogenesis* was published. Vanderplank wrote his final book, *Host-pathogen interactions in plant disease* (1982) after analysing more papers. This book expands on some of his basic principles and strengthens his ideas for the bases of resistance and epidemic development.

Vanderplank was renowned for being a 'reviewer of evidence', rather than using examples from his own work. He re-analysed and assessed published data to arrive at conclusions different from the original author. Some of his findings were controversial and challenging, and often instigated lively, heated or even acrimonious arguments. Despite this, Vanderplank's immense and influential contribution to plant pathology was recognised when, in 1979, the University of Giessen honoured him with an Honorary Doctoral degree. He received two further Honorary Doctoral degrees, as well as the Captain Scott medals of the South African Biological Society, the medal of the South African Association for the Advancement of Science, a Fellowship and the Ruth Allen Award of the American Phytopathological Society, and the Stakman Award of the University of Minnesota (1985). He was also the first recipient of the Christiaan Hendrik Persoon Gold Medal of the Southern African Society for Plant Pathology. In addition, a special issue of *Journal of Plant Diseases and Protection* (Vol. 93) edited by Jorgen Kranz was produced as an 80th birthday tribute to Vanderplank. These honours pay tribute to the shy and retiring James Edward Vanderplank, one of the most influential figures in plant pathology.

27.5 SUSARAH JOHANNA TRUTER (1910-2007)

Susarah Johanna Truter was born on a farm in Aliwal North. In 1931, she obtained her BSc degree, majoring in botany and zoology from Grey University College in Bloemfontein and was awarded the Junior Captain Scott Medal for achieving the best marks in zoology. She then acquired a Diploma in Education and for five years taught biology at Durban Girls' College to repay, as she later said, her considerable student loan. In 1939, she was awarded an MSc degree in mycology *cum laude* by Stellenbosch University. She then applied for an overseas scholarship under the auspices of the cultural agreement between South Africa and the Netherlands and became the first woman student to gain admission to this programme. In 1939, Truter went to Het Willie Commelin Scholten Phytopathologisch Instituut in Baarn, in the Netherlands, and registered for a PhD degree under the supervision of Johanna Westerdijk (the first woman professor in the Netherlands). The outbreak of World War 2 compelled her to remain in the Netherlands for a total of eight years and, as a South African, she was even interned by the Nazis for four months. She always considered herself very fortunate that she was released the day before the internees were transported to Germany.

On 10 July 1947 she was awarded her PhD degree by the University of Utrecht after defending her thesis on the die-back of a European tree, the alder, and then returned to South Africa on the Dutch liner, Oranjefontein. She always retained close contact with her mentor, Johanna Westerdijk, who later, in 1953, visited South Africa for an extended holiday.

On her return to South Africa in 1947, Susarah Truter was appointed as a plant pathologist at the Western Province Fruit Research Laboratories at Stellenbosch and it was there that, in 1949, she was persuaded by the Secretary for Agriculture to take up the post of Senior Lecturer in Plant Pathology in the new Faculty of Agriculture at the University of Natal. When she arrived in Pietermaritzburg that faculty was housed in Oribi village, so she was offered the old war hospital dispensary from which she proceeded to fabricate her sterile student practical laboratory.

In 1956, she was promoted to the new chair of Plant Pathology and Microbiology at the University of Natal, her elevation being approved by the Minister of Agriculture, as happened in those days. During 1961-1962 her male colleagues elected her to the position of Dean of the Faculty of Agriculture and in doing so made her the first female dean in a faculty of agriculture in the world. This led to an entry in the *Guinness Book of Records*. On 30 June 1976 Susarah Truter retired, leaving behind her a department that had grown to five academic staff members and a number of technicians and laboratory assistants.

Susarah Truter was a formidable, no-nonsense woman, even at the age of 97. Yet behind the tough façade, there was kindness and consideration. She was meticulous in all she did and exacted that from those who worked with her, or studied under her guidance. She was a superb organiser, a very efficient administrator, and unstintingly gave of her time, devoting many of her evenings and weekends to assisting those she supervised with thesis drafts or with the writing of articles.

Source: Written by FHJ Rijkenberg and published in Natalia 36-37 (2007) Copyright © Natal Society Foundation 2010 (with permission)

27.6 PETER SIDNEY KNOX-DAVIES (1929-1999)

Peter Knox-Davies was born on 7 December 1929 at Elandsputte in the Lichtenburg District, Transvaal, and passed away in Stellenbosch on 25 March 1999. In October 1938, his family moved to Pietermaritzburg in Natal where he completed his schooling at Maritzburg College. He received a BScAgric degree from the University of Natal in Pietermaritzburg. While occupying a post as lecturer in horticulture, he attended courses in plant pathology under the guidance of Susarah Truter. He was appointed lecturer in plant pathology and microbiology at the University of Natal in 1952.

In 1956, he undertook postgraduate studies at the University of Wisconsin. He returned to South Africa in 1959 after receiving MSc and PhD degrees. His PhD thesis was titled: "The cytology and genetics of *Helminthosporum turcicum* and its ascigerous stage, *Trichometasphaeria trucica*". He resumed his post as lecturer in plant pathology and microbiology at the University of Natal and was later promoted to the post of senior lecturer. In July 1962 he was appointed to the post of senior lecturer in the Department of Plant Pathology at the Stellenbosch-Elsenburg Agricultural College of the University of Stellenbosch. He became professor and head of the Department of Plant Pathology in 1970, a post he held for over 20 years until his retirement on 31 March 1991.

After a period of intensive research, Knox-Davies became involved in the training of numerous postgraduate students, many of whom would later hold influential positions at various South African Universities and agricultural research institutes. Knox-Davies was the South African representative at the inaugural meeting of the International Society for Plant Pathology in London (1968) and remained a council member until 1983. He was a founding member of the South African Society of Plant Pathology (and Microbiology) in 1962, and acted as president in 1968, 1969 and again from 1977 to 1979. During his term of office, he laid the groundwork for the formation (1981) of two societies: The South African (now Southern African) Society for Plant Pathology (SASPP) and the South African Society for Microbiology. In 1985, he was also the first person to be elected a Fellow of the SASPP and in 1993 was elected as honorary member.

During his career he refereed innumerable papers for various journals, reviewed several books, and served on the editorial committee of the journal *Phytophylactica* (now *African Plant Protection*) for 15 years. He published more than 70 research papers in peer-reviewed journals, and was the promoter of 32 postgraduate students. He is remembered by his students and colleagues as being highly energetic, sharp of wit, and having a great mind. His enthusiasm for plant pathology impressed all of those who crossed his path.

Source: Written by PW Crous and published in Phytopathology News 33, 7 July 1999

27.7 WALTER FRIEDRICH OTTO MARASAS (1941-2012)

Walter Friedrich Otto Marasas was born on 25 October 1941 in Boksburg, South Africa. In 1962, he graduated from the University of Pretoria with a BScAgric (plant pathology and botany), followed by an MScAgric (plant pathology) in 1965, while lecturing and conducting research in the field of mycology. Having developed an interest in the mycotoxins produced by fungi, as well as the human and animal diseases associated with these toxins (a topic which had not yet been researched extensively in South Africa), he enrolled for a PhD in plant pathology at the University of Wisconsin in the USA, graduating in 1969. In 1975, the family relocated to Cape Town, upon Marasas's appointment as chief specialist scientist of the Programme on Mycotoxins and Experimental Carcinogenesis (PROMEC). This was based at the Medical Research Council (MRC) in Tygerberg, where Marasas was able to develop his research focus on mycotoxins with the potential to affect human health. He later became Programme Leader and in 2001, was promoted to the position of director of the PROMEC Unit. He would remain at the MRC until his retirement in 2006.

A leading authority in the field of mycology and mycotoxicology, Marasas focused particularly on the taxonomy and biology of the genus *Fusarium*, a common maize-infecting fungus, and the range of diseases that could be transferred to humans and animals in food and feed as a result of *Fusarium* toxins. In addition to this, he was able to contribute to the classification and description of numerous other toxigenic fungi - both in South Africa and internationally. Over the course of his career, he was instrumental in the classification of 34 taxa. Two taxa were also named in his honour: *Mycosphaerella marasasii* and *Pseudocercospora marasasii*.

His initial interest in the mycotoxins of *Fusarium* began when he observed cases of equine leukoencephalomalacia (LEM), leading to brain damage of diseased horses. This he believed to be the result of the ingestion of infected maize. Many years of intensive research at the MRC laboratories in Tygerberg enabled this hypothesis to be proved, although the specific toxin responsible had not been identified. After over 20 years of concentrated research by Marasas and his team, the mycotoxin named Fumonisin (from *Fusarium moniliforme* toxin) was identified and characterised. This momentous discovery led to international recognition of the team responsible, and fumonisin became the subject of much research across the globe.

Having identified Fumonisin, the next phase in Marasas's career was to investigate its potential consequences for human health. Findings pointed to the likelihood of this toxin being related to oesophageal cancer, pinpointing cases within the population of the Transkei, where the rate of occurrence was shown to be one of the highest in the world. These cases appeared to be linked to infected maize supplies, a dietary staple in the region, as well as traditionally being used to brew beer. Subsequently, these findings played a definitive role in the advancement of human health in South Africa and other emerging regions, assisting in the development of risk analyses of food standards for groups such as the World Health Organisation (WHO).

While Marasas spent most of his career as an active researcher at the MRC, he also held a number of visiting appointments. From 1977-1978, he was a visiting scientist at the Bundesanstalt für Fleischforschung based in Kulmbach, Germany. In 1981, Marasas was acting as a visiting professor at the Department of Plant Pathology of Pennsylvania State University in the USA. This was followed by an appointment as a Pawlett visiting scholar in the Department of Plant Pathology of the University of Sydney, Australia. He returned to the USA in 1992 as a visiting professor at Kansas State University in their Department of Plant Pathology. He maintained close ties with Pennsylvania State University where he was named adjunct professor in the Department of Plant Pathology, as well as Kansas State University. He was also appointed as a distinguished professor in the Department of Microbiology and Biochemistry at the University of the Free State in 1989. In 1998, he was recognised by his *alma mater*, the University of Pretoria, where he was appointed as extraordinary professor in the Faculty of Natural and Agricultural Sciences. This honour was also accorded to him by Stellenbosch University, as extraordinary professor in the Department of Plant Pathology. Although not based at an educational institution, he was able to make an important contribution to the training of a new generation of scientists in this manner through supervising, and sometimes co-supervising, some of the leading students of microbiology and plant pathology. He also played an active role in encouraging students from other African nations to continue their studies in this field.

Throughout his career, Wally Marasas was esteemed by the scientific community, and held a number of honorary positions. In January 1991, he was made a Fellow of the South African Society for Plant Pathology. International exposure following his work in describing the effects of mycotoxins led to his appointment in 1995 as expert consultant to the Joint Food and Agriculture Organisation (FAO)/ WHO Expert Consultation on the Application of Risk Analysis to Food Standards Issues by the World Health Organisation, based in Geneva, Switzerland. He participated in various other professional societies including the International Society for Plant Pathology, where he was involved in committees on mycotoxicology and *Fusarium,* respectively; the Southern African Society for Plant Pathology; the South African Council for Natural Scientists. He was also deeply involved in the Pan-African Environmental Mutagen Society (PAEMS), of which he was president between 1995-1999.

Wally Marasas published extensively on his research and attended a variety of conferences, delivering more than 190 papers throughout his career. He authored three monographs on the topic of *Fusarium* and mycotoxins. These are generally considered to be definitive works in their field. In 2002, data from the Institute of Scientific Information (ISI) showed that he was one of the most cited scientists in the world in two categories: agriculture, and plant and animal sciences.

Wally Marasas's longstanding contributions to plant pathology were recognised locally and abroad when, in 2001, he was made an honorary member of the Southern African Society for Plant Pathology. A fellowship of the American Phytopathological Society followed in 2005 of which he is one of only three South Africans who have achieved this honour. He is also only one of a very small number of South African scientists to have been elected as a foreign honorary fellow of the American Academy for the Advancement of Arts and Sciences.

In spite of his great success as a scientist and the numerous accolades garnered throughout his career, Wally Marasas is remembered as a humble man of integrity with a "typical South African sense of humour". He was passionate about his chosen profession and worked hard to make a contribution to the community. Together, he and his wife were frequent visitors to the Nieuwoudtsville area of the Namaqualand, where he enjoyed studying the indigenous flora. He passed away in 2012 at the age of 70.

Wally Marasas was also a passionate philatelist, collecting large numbers of stamps, particularly focusing on those depicting fungi and flowering plants. At the time of his death, he had been compiling a book with some of his most cherished specimens, a project which was then taken up by his wife Rika in collaboration with Mike Wingfield and Pedro Crous. Rather than organising the book according to the usual philatelic method of country and year of issue, over 1 000 stamps were classified according to the taxonomic groups to which the depicted fungi belong. The book, titled *Philatelic mycology: Families of fungi*, was completed in 2013. It was published by the CBS-KNAW Fungal Biodiversity Centre in the Netherlands – a fitting tribute to this distinguished scholar, bringing together the love of the man for the field to which he dedicated his career.

Source: Written by MJ Wingfield and published in Legends of South African Science (2017) Academy of Science of South Africa, Pretoria, pp. 130-131.

27.8 JOZSEF DARVAS (1945-2011)

Joe (Jozsef) Darvas was born in Hungary in 1945. He completed his elementary school in a small village on lake Balaton and his high school in Kesthely. After he matriculated, he studied crop protection sciences at the Agricultural University of Kesthely and graduated in 1966. He worked at the Plant Protection Station in Kaposvar on insect forecasting systems for the province of Somogy. In 1971, he left Hungary and spent time in Italy before immigrating to South Africa. He started working at Rietondale Plant Protection Research Station in 1972, but soon left for full time study at the University of Pretoria where he earned BSc (Hons) and MSc (Agric) degrees. In 1977, he joined Westfalia in the Limpopo province and began working on avocado diseases. This research eventually led to a DSc degree that was awarded in 1982. He was advised by Ballie Kotzé at the University of Pretoria and the topic of his thesis was on pre-and postharvest diseases of avocado. In 1985, he joined Letaba Estates and began working on mango and citrus diseases. He eventually left that organisation to start his own business as a consulting plant pathologist.

While at Westfalia, Joe Darvas's primary objective was to find a cure for Phytophthora root rot of avocado which was devastating orchards in Limpopo. At the time, Westfalia was the first to treat young and mature avocado trees with Ridomil, and Joe's prediction that *Phytophthora* would develop resistance to this compound was proven correct. Aliette foliar spray treatments were developed but were soon replaced with the phosphorus acid injection technique. He played a major role in the development of the technique and conducted intensive studies to ensure a safe and efficient treatment that would achieve long term control of *Phytophthora*. He was also involved in, and contributed to, the selection of root rot tolerant rootstocks such as Dusa, Jovo and Latas.

He received international recognition for his research on avocado diseases and was invited to speak at many meetings. He was honoured with an award for excellence at the World Avocado Congress in 1991 and with the Golden Avocado Award by the South African Avocado Society.

27.9 JOHANNES MARTINUS (BALLIE) KOTZÉ (1928-2019)

Johannes Marthinus Kotzé was born on 18 November 1928 in the district Vanrhynsdorp. He often described his formative years as growing up on a farm and his many adventures in nature. His grandfather played an important part in his upbringing, providing him with direction, a moral code, and a value system that proved to be very important later on in his life. He often spoke about his experiences of horseback riding on the farm that is known today as Weltevrede Estate in Somerset West. The foundation for his illustrious career in agriculture and more specifically plant pathology, was most certainly established in those formative years.

Ballie Kotzé studied BSc (Agric) Plant Pathology at Stellenbosch University and graduated in 1953. His first job was at a chemical company, African Explosives and Chemical Industries (AECI), Modderfontein. He worked for AECI for 11 years as a lead researcher. He often spoke about precision measurements and his experience in developing new chemical formulations. It is, therefore, not surprising that he remained a chemical control expert and classical applied plant pathologist throughout his career. Crop protection remained an important aspect for him in plant pathology, something he practiced throughout his career. Kotzé retained his network in the chemical industry and often interacted with companies in the mining sector. He for instance explored clay minerals (kaolin) and copper formulations for disease control.

Ballie Kotzé completed his DSc (Agric) degree in 1963 with a thesis entitled "Studies on the black spot disease of citrus caused by *Guignardia citricarpa* Kiely, with particular reference to its epiphytology and control at Letaba" at the University of Pretoria. This landmark study became one of the most valuable documents used by the industry and contributed to effective black spot control. His groundbreaking work allowed the citrus industry to ensure effective control of citrus black spot and strengthen exports.

Ballie Kotzé worked with the citrus industry for more than 45 years, focusing on epidemiology and control of diseases, most importantly, citrus black spot. This disease later became one of the most important phytosanitary risks for the South African citrus export industry. One of his most important contributions was the establishment of the critical infection period, which is still used in principle in the industry, to effectively control the disease. In 1959, when 80% of the crop was lost due to black spot, an effective spray program using copper was developed. He discovered that Dithane could be used to control black spot with less damage. He also introduced a single late seasonal Benlate spray that provided effective control. Additionally, he developed a spore trap and was the first person to use this in combination with aerial spraying. He proved that by the removal of litter, he could break the life cycle of the pathogen. At one stage, he studied the removal of litter using snails in orchards and contributed to the development of citrus compost to reduce inoculum levels on the orchard floor. In later years, he developed a new spore trap (the Kotzé inoculum monitor) that is still used by the industry to detect spore release periods and to adjust spraying cycles more effectively.

In 1966, Ballie Kotzé became the managing director of Westfalia Estate and was appointed to several director positions. His close relationship with Westfalia lay the foundation for a strong industry relationship that benefitted the avocado growers in South Africa. In 1967, Westfalia exported their first avocados that were initially planted by Hans Merensky. Ballie Kotzé thought highly of Alexander Merensky (1837-1918), a noted ethnographer who undertook geological surveys in the then Transvaal, and who was a famous prospector, philanthropist, the founder of Westfalia Estate and author of *Beyond the wind*. This is a book that Kotzé said "everyone should read".

During the late 1960s and early 1970s, it was clear that avocados were not yet popular in Europe and the export market had to be developed. *Phytophthora* was a further challenge in older orchards at Westfalia Estate and a new management strategy was required. Westfalia also had extensive citrus plantings that were not performing as expected due to citrus greening. Kotzé, therefore, had to make the difficult decision to remove 40 hectares of citrus orchards and decided to replant this area in 1967-1968 with the avocado cultivar Fuerte. This was a cultivar showing potential on the European markets at the time. Later, with the introduction of more plantings of the cultivar Hass in South Africa, it was found that the fruit had better shipping qualities and was growing in popularity on the export markets. Kotzé established the first avocado nursery based on disease-free planting material, and this laid the foundation for a strong industry focus on exports. During this time, Kotzé was also instrumental in establishing the South African Avocado Growers Association (SAAGA) in 1967 and was the first chair of SAAGA (1967-1968). His close relationship with Westfalia and SAAGA remained throughout his career, and he was awarded the SAAGA Golden Avocado Award in 1987 and finally a lifetime membership of SAAGA in 2016.

The University of Pretoria head-hunted Kotzé and he moved to Pretoria in 1969. He continued his strong relationship with the avocado industry and trained many students in this field of study. His training approach was unique and always had a strong field component to his projects. In 1977, SAAGA appointed him as research co-ordinator for the industry, a position he retained for 10 years. During this period, he established the *Avocado Growers Annual Yearbook* which, to this day, is widely cited in international industry circles. To date, 43 volumes have been published. It is notable that, at the time in academic circles, the journal and industry-specific publications were heavily criticized by his colleagues and other academics conducting more basic research. Nevertheless, it fulfilled an extremely important niche and made South Africa one of the leading avocado research countries in the World.

Ballie Kotzé appointed Eileen Kushke in 1981 who, amongst others, assessed South African avocado fruit quality on the export markets. This was a significant strategic decision, since it paved the way for improved production and postharvest practices, to improve market end fruit quality. Another major contribution to the avocado industry was the doctoral studies of Joszef Darvas in 1982 (Aetiology and control of some fruit diseases of avocado "*Persea americana Mill"* at Westfalia Estate). Although his thesis covered fruit control, he was mostly involved in the development of phosphoric acid as a trunk injection with Kotzé and Jan Toerien. This revolutionised the industry and brought Phytophthora root rot under control.

Ballie Kotzé played an important role in a biotechnology research program at the University of Pretoria at a time when molecular biology and its application in agriculture was not well established. Importantly, he had the foresight to introduce this emerging field of science in the Faculty of Agriculture, laying the foundation for the emerging field of molecular biology in the department of Plant Pathology. As part of this initiative, Kotzé invited a prominent researcher from the Volcani Centrum, Moshe Bar Joseph, to visit the University in 2000 and present a series of lectures in molecular biology.

Ballie Kotzé was well known for his ability to attract major funding. For example, in 1979, he raised funding from the Wheat, Maize, Citrus and Tobacco Boards to erect a greenhouse on campus and to establish an electron microscopy facility in plant pathology. It took persistent negotiations to get the greenhouse erected on campus, and the building remains a testimony to his leadership and vision. He thus expanded the plant pathology research programs on campus to include a wheat research unit, at which several postgraduate students studied under his guidance utilising the world class facilities.

Other important contributions of Kotzé include his involvement in the South African tea industry, where he established the tea council for South Africa and coordinated their research activities. The industry also published an annual report similar to that published by SAAGA. The South African Mango Industry (SAMGA) was similarly established by Kotzé following the SAAGA model, and later a similar initiative was the South African Litchi Growers' Association (SAALGA).

An interesting story associated with Kotzé's career pertains to a fire in 1983 which started in Lab 2-13 and spread to five labs, the electron microscopy, scanning electron microscopy units, and five offices. The cause of the fire was methane bacteria stock cultures prepared by Jurg Bezuidenhout for his soil microbial ecology studies. Besides equipment such as the Gilson apparatus and microscopes that melted, Hennie le Roux lost the typed draft of his thesis and had no backup copies.

Ballie Kotzé received the Agricultural Researcher of the Year Award in 1989 from the South African Agricultural Industry, recognising his important role in the continent and internationally. He also received a 1990 University of Pretoria medal for an exceptional performer. Although Ballie Kotzé was extremely active in the agricultural sector, he never applied for a National Research Foundation rating, a system that he believed was flawed and only based on peer-reviewed publications. His view was that system never considered the impact of a researcher and their industry or community contribution.

During his career, Kotzé was the author or co-author of more than 200 scientific publications and promoter or co-promoter of 41 MSc and PhD students. He served as a consultant in several African and European countries and was coordinator of four major interdisciplinary research projects between six universities. This reflects the fact that he was ahead of his time, since transdisciplinary research is now considered the platform to provide real-time sustainable solutions in a post-COVID-19 world. Kotzé was director of the Zebediela Estate (previously one of the world's largest citrus farms), the Lisbon Estate, a well-known citrus and mango farm alongside the Kruger National Park, the Bavaria Estate, which is the largest mango farm in South Africa, the Hans Merensky Technological Services and the Tea Council of Southern Africa. He also played a key role on several Ministerial advisory and international committees.

Ballie Kotzé had a special presence; when he entered a room, everyone looked up to this tall, impressive-looking person, meticulously dressed and one who could strike fear in the hearts of any student, at any time. He did not tolerate fools lightly and it was well known that no student could get away with woolly stories or excuses. Many students recall how Kotzé would instruct them to read all of Vanderplank's books. These were amongst his favorite books in his extensive private library. Kotzé was a brilliant lecturer, a man with extensive experience and practical knowledge, someone the industry respected and regarded highly. Students feared him, yet appreciated his fairness, knowledge, and wisdom. He was a personal friend of James Edward Vanderplank, and many students had the privilege to meet Vanderplank in his office or in the passages of the Department.

In 2018, Ballie Kotzé's health was deteriorating rapidly. From time-to-time, some of his past students visited or phoned him and he always said that those were the best moments and most meaningful discussions he ever had. During this time Gerhardt Nortje, Andre Ernst, and Kosie Eloff visited him and presented him the avocado industries life-long honorary membership, an award that was dear to him. Other close friends such as Dave Litter, previous head of Capespan and a life-long friend, visited him as well as other notable prominent people in the avocado industry such as Louis Voster, Paul Fourie and Vaughn Hattingh from Citrus Research International. Every one of these visits mattered and were special, appreciated and meaningful.

Ballie Kotzé's 90th birthday party was a small event, the way he wanted, with his children and grandchildren, celebrating his life in a dignified manner. He always said "getting older is not for the fainthearted". For him, it was a part of his life that he did not appreciate. His final days were spent in the high care unit in Kokanja where he was kept for more than a month. For Kotzé, his own spiritual journey crossed the pivotal point between science and religion, something he always discussed and explored, at least for those brave enough to debate the topic with him. He passed away peacefully on 8 May 2019. For him, this was the end of a meaningful, wonderful, fulfilling life, where he had a significant impact on the people around him, his students, who really respected him, and the broader agricultural community at large. Kotzé was a strategist, and an applied plant pathologist. He was a natural leader, a man with presence and was admired by many in the agricultural industry

SECTION II: SOCIETY

1.0 The South African Society for Plant Pathology and Microbiology (1962–1980)

1.1 ESTABLISHMENT OF THE SOCIETY

The founding meeting of the South African Society for Plant Pathology and Microbiology (SASPPM) was held at the University of Pretoria on 25 October 1962. Chris Rabie, the head of the Transvaal region: plant pathology and microbiology, issued the invitation and organised the first meeting. The following matters were discussed: establishment of the society by formulating the constitution, the first symposium (later in 1969 the name changed to congresses), financial arrangements, rules related to presentations at the symposium and the nomination of a managing committee. This *ad hoc* committee included PM le Roux (University of Pretoria), Chris Rabie (Department of Agriculture), PM Lategan (University of the Free State) and JJ du Toit (School of Agriculture, Potchefstroom). Piet Steyn (University of Pretoria) was co-opted later that year. In 1987, these founding members of the SASPPM were awarded with a certificate at the annual congress held in Bloemfontein.

The first symposium was held over two days, 25-26 October 1962 at the University of Pretoria. The welcoming address was presented by PM le Roux and the opening lecture by BJ Dippenaar (Stellenbosch University). There were 72 attendees and 26 presentations, with 17 on plant pathology topics.

During the following year (1963), the SASPPM committee and members met on 31 October after the two-day symposium. The draft constitution drawn up by the *ad hoc* committee was accepted. The next venue for the symposium was discussed (Stellenbosch) and the new committee elected (Table 3). Provincial members were elected for the first time, their primary role being regional representatives. The decision to elect provincial members, later known as branch chairs, continued throughout the next 50 years. WJ Lütjeharms (UCT) and Ethel Doidge were invited to become honorary presidents (later changed to honorary members). Ethel Doidge declined the invitation. The list of honorary membership expanded in 1963 to include SJ du Plessis (Head Director of Agricultural Research), BJ Dippenaar (Stellenbosch University), James Vanderplank (Plant Protection Research Institute), J de Ley (Rijksuniversiteit van Belgie, Gent), JHS Gear (Director South African Institute for Medical Research), BC Jansen (Chief, Veterinary Research Institute, Onderstepoort) and APD McClean (Department of Agriculture).

At the symposium held in Pretoria on 29-30 October 1963, there were 14 presentations, of which nine were plant pathogen-related, interestingly with the majority being on viruses. The welcoming address was presented by PM le Roux and the opening address by James Vanderplank. At that time, there were 62 members of SASPPM.

1.2 1964–1980

Symposia, or congresses as they became to be known, were held annually in the then four provinces of South Africa (Table 3). There was one exception, in 1973, when the congress was held in Harare (then known as Salisbury), Zimbabwe (formerly Rhodesia). A managing committee (council) was appointed each year, with all members coming from the same province. One of their tasks was to organise the next congress. In 1969, a congress organiser handbook was compiled which was updated three times over the years, and it still contains information that would be useful today.

Symposia of the SASPPM were held either at the end of October, or early in November each year. In 1969, the date was changed to the end of January. In some years, this was in the second week of January and later, in 1975, the third week of January. The meetings have remained at this time since 1978.

In 1972, when it was decided that the next congress was to be held in Harare (Salisbury), politics, i.e. laws linked to apartheid, reared their head. A proposal to change the constitution to allow people of all races and nationalities to join was accepted by the majority of members (with one vote against).

Problems also arose when congresses were held in Bloemfontein. The organisers had to arrange special permits for attendees of Indian descent and, on one regrettably memorable occasion, plant pathologists from KwaZulu-Natal were not permitted to attend.

The first sponsorship for a congress was obtained in 1965 from the Wild of South Africa (Pty) Ltd. The next year, Susarah Truter and her team actively sought sponsorship and 16 companies provided a total of R140 (a significant amount in those days). In 1964, South African Breweries accepted the invitation to become a patron of SASPPM. This was followed in 1971 by African Explosives and Chemical Industries Ltd (AECI), Bayer Agro-Chem (Pty) Ltd, Fedmis (Edms) Bpk, Ko-operatiewe Wijnbouwers Vereninging van Zuid Africa Bpkt, Stellenbosse Boere Wynmakery Bpk, Triton Chemicals (Pty) Ltd, the Bristol Myers Group (Pty) Ltd and Triomf Kunsmis (Edms) Bpk.

J de Ley, professor of microbiology from the Rijksuniversiteit van Belgie, Ghent, was the first international speaker at a SASPPM event, and he presented the opening address at the congress held in Pietermaritzburg in 1966. The title of his address was "New approaches to bacterial taxonomy". It was not until 1979 that an overseas speaker was again invited to present the opening address. AR Hooker, from Illinois University, spoke on "Helminthosporium leaf blight of maize – an adventure in science and technology" at the congress held at the University of Durban-Westville. J de Ley again presented the opening address in 1980 at the congress held in Bloemfontein, with a talk entitled "Similarities between bacterial ribosomal RNA cistrons as a measure of phylogeny and a new tool for taxonomy and identification".

The first bulletin of SASPPM was published in 1967. Its purpose was to be a newsletter and a forum for exchanging ideas. It included short articles and congress abstracts. Unfortunately, it appeared irregularly. In 1970, a publication secretary was appointed to council (HJ Potgieter), and his role was as editor of *The Bulletin*. *The Bulletin* was eventually discontinued and replaced by *Studia Microbiologia*. This newsletter was suspended in 1974 and replaced by another entitled *SASPPM Bulletin*. In the 1976 edition, with Martin Hattingh as editor, interesting and relevant topics were included, for example, safety measures when using genetic engineering. Two volumes were produced each year until 1981.

The first excursion to be held as part of a congress was in 1969, and was organised by the Council in the Cape Province. This was a visit to the KWV Plant Quarantine Station in Paarl and to the Paul van der Bijl Laboratory for Virology in Stellenbosch. In 1970, the excursion was to the Triomf fertilizer factory. The next excursions only occurred after the society had split, separating plant pathology and microbiology. At the 1980 congress a fermentation workshop was offered at the University of OFS.

In 1965, RKS Wood from the Imperial College in London and the president of the International Society of Plant Pathology at that time, contacted the society to request the contact details of plant pathologists who would be interested in attending the 1st International Congress of Plant Pathology (held in Edinburgh, Scotland). In 1969, SASPPM became affiliated with this International Society, as well as the International Union of Microbiological Societies. In 1974, the society became a member of the Joint Council of Scientific Societies.

In 1970, the constitution of SASPPM was changed and the council was appointed for a three-year term. All council members had to reside in the same province. Another change to the constitution was that an organising committee for the next congress was to be appointed at the annual general meeting, and this committee needed to include at least three members.

James Vanderplank and Susarah Truter were elected honorary members of SASPPM in 1973 and 1978, respectively. At the 1978 congress held at Stellenbosch University, rules were drafted on the procedure that would be followed for honouring scientists with the Christiaan Hendrik Persoon Medal. The first recipient of this gold medal was James Vanderplank in 1979. He was awarded the medal at a gala dinner held at the University of Durban-Westville. In 1978, a year prior to receiving this award, James Vanderplank opened the congress with an address entitled "Host pathogen specificity and the new biology". It was published in the SASPPM Bulletin and is available in section 31.0 of this book.

At the 1979 congress held at the University of Durban-Westville, posters were introduced for the first time. There were a total of 34 presentations and 27 posters. At the congress held in Bloemfontein the next year, there were 83 presentations held in concurrent sessions where plant pathology and microbiology were clearly separated. Seventeen posters were also displayed.

TABLE 3 COUNCIL MEMBERS OF SASPPM, SYMPOSIA/CONGRESS ORGANISING COMMITTEE AND VENUE OF THE SYMPOSIA/ CONGRESSES

Year	Council Members	Organising Committee	Venue
1962	Chairman: PM le Roux Members: PM Lategan CJ Rabie JJ du Toit	Council	Pretoria
1963	Chairman: PM le Roux Vice-chairman: JJ van der Watt Secretary/treasurer: CJ Rabie Assistant secretary/treasurer: PL Steyn Additional member: JJ du Toit Provincial members: PS Knox-Davies (Cape) PM Lategan (Orange Free State) KT van Warmelo (Transvaal) Additional provincial member: JM Kotzé	Council	Pretoria
1964	Chairman: HA Louw Vice-chairman: MH van Regenmortel Secretary: PS Knox-Davies Treasurer: AC Nel Additional member: DJ Engelbrecht Provincial members: PM le Roux (Cape) GD Pauer (Orange Free State) DO Senekal (Transvaal) JJ Joubert (Natal)	Council	Stellenbosch
1965	Information unavailable Secretary: GD Pauer Treasurer: SW Baard	Council	Bloemfontein
1966	Information unavailable Chairperson: SJ Truter Secretary: JJ Joubert Treasurer: ME Stiles	Council	Pietermaritzburg
1967	Information unavailable Secretary: KT van Warmelo	Council	Pretoria
1968	Information unavailable Secretary: GD Pauer	Council	Bloemfontein

1969	Chairman: PS Knox-Davies Vice-chairman: MH van Regenmortel Secretary: MB von Wechmar Treasurer: AC Nel Additional member: JJ du Toit Provincial members: GD Pauer (Orange Free State) MM Martin (Natal)	Council	Stellenbosch
1970	Chairman: D van Eeden Vice-chairman: MJ Jooste Secretary: PAJ Brand Treasurer: JN Louw Additional member: JJ du Toit Publication secretary: HJ Potgieter Provincial members: MB von Wechmar (Cape) SW Baard (Orange Free State) GCA van der Westhuizen (Transvaal) JJ Joubert (Natal)	Council	Potchefstroom
1971-1973	Chairman: GCA van der Westhuizen Vice-chairman: JM Kotzé Secretary: PL Steyn Treasurer: PG Thiel Publication secretary: HJ Potgieter Provincial members: MJ Hattingh (Cape) S Lategan (Orange Free State) JJ du Toit (Transvaal) JJ Joubert (Natal)	1971 University of the Orange Free State	Bloemfontein
		1972 University of Natal	Pietermaritzburg
		1973 Information unavailable	Salisbury, Rhodesia[4]
1974-1976	Chairman: BW Strydom Vice-chairman: CJ Rabie Secretary: WH Holtzapfel Treasurer: FC Wehner Publication secretary: PL Steyn Provincial members: DR Woods (Cape) AJ van Rensburg (Orange Free State) KT van Warmelo (Transvaal) MA Loos (Natal)	1974 Potchefstroom University	Potchefstroom
		1975 Department of Agriculture	Pretoria
		1976 Rhodes University	Grahamstown

1977-1979	President: PS Knox-Davies Vice-president: MA Loos Secretary: AB van Jaarsveld Treasurer: PG Marais Provincial members: G Holz (Cape) BA Prior (Orange Free State) HT Brodrick (Transvaal) JM Erskine (Natal)	1977 Information unavailable	Pretoria
		1978 Stellenbosch University ARC-Plant Protection Research Institute	Stellenbosch
		1979 University of Durban-Westville	Durban-Westville
1980	SASPPM split into SASPP and SASM Joint council for one year: President: GDC Pauer Vice-president: PM Lategan Secretary: MJ de Kock Treasurer: HJJ van Vuuren Publication secretary: BA Prior Provincial members: S von Broembsen (Cape) PJ Jooste (Orange Free State) AS Greeff (Transvaal) HJ Lloyd (Natal)	University of the Orange Free State	Bloemfontein

For the period 1964-1969, the majority of presentations were on plant pathogens. From 1970 onwards, presentations on microbiological topics dominated the congresses. At the 1975 and 1979 congresses, separate sessions were devoted to either microbiology or plant pathology. This led to two heated debates, in 1975 and 1979, regarding the name of the society from South African Society for Plant Pathology (SASPPM) to the South African Society for Microbiology and Plant Pathology (SASMPP) (emphasising the role of microbiology) or to the South African Society of Microbiological Studies.

In 1980, the SASPPM was split into the South African Society for Plant Pathology (SASPP) and the South African Society for Microbiology (SASM). The split was amicable, assets were divided and members were asked to choose their society of preference. It was decided that a new, joint council would be appointed for the period 1 April 1980 to 31 March 1981. The final joint congress was held in Pietermaritzburg in January 1981, where the first council of SASPP was then elected.

2.0 The South/Southern African Society for Plant Pathology (1981-2019)

2.1 CONSTITUTION

At the joint congress of the SASM and SASPP held in Pietermaritzburg in 1981, a constitution was drafted, largely based on the SASPPM constitution. It was then distributed to members for comment. The constitution was accepted at the annual general meeting held in 1982. Wording and different sections were changed over the years. In 1983, the category 'fellows' was included under membership with the procedures for electing fellows formulated and included. In 1990, and in compliance with Statute 5 of the ICSU (International Council of Scientific Unions), the principle of non-discrimination on the basis of race, religion, political philosophy, ethnic origin, citizenship, language or sex was accepted and the constitution was amended accordingly. In 1994, the name was changed to the Southern African Society for Plant Pathology. That year it was decided that English would be used in all forms of national and international communication, whereas in previous years all communications had been in both English and Afrikaans. In 2011, the constitution was reorganised and henceforth only dealt with the governance of the society. The policies and procedures, previously included in the constitution as by-laws, would deal with all other matters, such as society awards and honours, publications and congress organisation. In this year, it was also decided that the congress would be held biennially. Interestingly, in 1989, a similar request had been submitted to the AGM, and it was vehemently opposed. In 1983, the emblem of the society was designed by a graphic design firm, and in 1994 it was modified to include only the English abbreviation.

2.2 COUNCILS

Since the establishment of the SASPP, the Council always consisted of a president, vice-president, treasurer and secretary (Table 4). In the early years, an 'additional member' was added. From the early days of the combined societies until 1999, a publication officer was part of the council. His or her responsibility was editing the newsletters. After 1999, a webmaster was appointed, but once commercial companies were employed to design the webpages, this function disappeared.

TABLE 4 COUNCIL MEMBERS OF SASPP, CONGRESS ORGANISING COMMITTEE AND VENUE OF THE CONGRESSES, 1981-2019

Year	Council Members	Organising Committee Institution	Venue
1/04 1981 - 31/03 1984	President: GCA van der Westhuizen Vice-president: MA Holtzhausen Secretary: J Nieuwoudt Treasurer: S Visser Publication secretary: KT van Warmelo Provincial members: S von Broembsen (Cape) SW Baard (Orange Free State) JN Moll (Transvaal) JC da Graça (Natal)	1981: University of Natal 1982: Dept of Agriculture 1983: University of Fort Hare	 Pietermaritzburg Pretoria Wilderness
1/04 1984 - 31/03 1987	President: HL Lloyd Vice-president: FHJ Rijkenberg Secretary: JC da Graça Treasurer: A Hall Publication secretary: C Roux Provincial members: S von Broembsen (Cape) SW Baard (Orange Free State) G Thompson (Transvaal) A Hall (Natal)	1984: University of the Witwatersrand 1985: University of Fort Hare 1986: ARC-Grain Crops	 Johannesburg Hogsback Golden Gate

1/04 1987 - 31/03 1990	President: CJ Rabie Vice-president: WFO Marasas Secretary: JC Combrink Treasurer: JF Fourie Publication secretary: M Passmoor Provincial members: M Wingfield (Cape) J le Roux (Orange Free State) RY Annelich (Transvaal) M Laing (Natal)	1987: University of the Orange Free State 1988: ARC-Tropical and Subtropical Crops 1989: University of Cape Town	 Bloemfontein Berg-en-Dal, Kruger National Park Cape Town
1/04 1990 - 31/03 1993	President: MJ Wingfield Vice-president: J le Roux Secretary: ZA Pretorius Treasurer: W Swart Publication secretary: M Passmoor Provincial members: S de Kock (Cape) G Kemp (Orange Free State) P Crous (Transvaal) M Laing (Natal)	1990: University of Pretoria 1991: University of Natal 1992: University of Fort Hare	 Pretoria Pietermaritzburg Cintsa West
1/04 1993 - 31/03 1996	President: IMM Roos Vice-president: E Rybicki Secretary: HJ du Plessis Treasurer: K van der Merwe Publication secretary: R Brand Provincial members: S de Kock (Cape) R Kloppers (Orange Free State) G Pietersen (Transvaal) M Laing (Natal)	1993: ARC-Infruitec 1994: ARC-Grain Crops 1995: University of the Free State	 Club Mykonos Christiana Thaba 'Nchu Sun
01/04 1996 - 31/03 1999	President: L Korsten Vice-president: R Anelich Secretary: E Lubbe Treasurer: G Thompson Publication secretary: N McLaren Provincial members: P Crous (Southern Branch) W Boshoff (Eastern Branch) N Labuschagne (Northern Branch) M Laing (Central Branch)	1996: Stellenbosch University 1997: University of Pretoria 1998: University of KwaZulu-Natal	 Stellenbosch Pretoria Champagne Sports Resort

01/04 1999 - 31/03 2003	President: P Crous Vice-president: SC Lamprecht Secretary: C Lennox Treasurer: P Fourie Webmaster: PW Hanekom Provincial members: C Lennox (Southern Branch) Z Pretorius (Central Branch) T Coutinho (Northern Branch) M Laing (Eastern Branch)	1999: University of KwaZulu-Natal 2000: Rhodes University 2001: ARC-Tropical & Subtropical Fruit 2002: FABI, University of Pretoria	 Pietermaritzburg Grahamstown White River Dikololo
01/04 2003 - 31/03 2005	President: Z Pretorius Vice-president: W Swart Secretary: D Fourie Treasurer: A Cilliers Webmaster: J Appelgryn Provincial members: P Fourie (Southern Branch) W Botes (Central Branch) T Aveling (Northern Branch) P Caldwell (Eastern Branch)	2003: University of the Free State 2004: University of KwaZulu-Natal 2005: Stellenbosch University ARC-Weeds Pathology Unit	 Bain's Game Lodge Cathedral Peak Hotel Hartenbos
01/04 2006 - 31/03 2011	President: K Jacobs Vice-president: W Swart Secretary: D Fourie Treasurer: F Halleen Provincial members: L Mostert (Southern Branch) W Botes (Central Branch) J van der Waals (Northern Branch) P Caldwell (Eastern Branch)	2006: ARC-Grain Crops 2007: ARC-Biosystematics Division 2009: Stellenbosch University 2011: University of Pretoria	 Magalies Country Park Kopanong Gordon's Bay Berg-en-Dal
01/04 2011 - 31/03 2014	President: TA Coutinho Vice-president: J Roux Secretary: W Kriel Treasurer: S van Heerden Provincial members: C Lennox (Southern Branch) D Fourie (Central Branch) L Moleleki (Northern Branch) S Yobo (Eastern Branch)	2013: Council 2015: University of the Free State	 Klein Kariba Baines Lodge

01/04 2014 - 31/03 2019	President: M Laing Vice-president: A Gubba Secretary: B Sivparsad Treasurer: S Yobo Provincial members: C Lennox (Southern Branch) D Fourie (Central Branch) L Moleleki (Northern Branch) I Bosdew (Eastern Branch)	2017: Council 2019: Stellenbosch University ARC-Weeds Biocontrol Unit	 Champagne Sports Resort Club Mykonos
01/04 2019 - 31/03 2022	President: W Swart Vice-president: W Boshoff Secretary: C Bender Treasurer: G Marais Provincial members: C Lennox (Southern Branch) D Fourie (Central Branch) L Moleleki (Northern branch) S Yobo (Eastern Branch)	2022: FABI, University of Pretoria	 Pretoria

The process of electing the council has not changed significantly over the years. Nominations must be received by the current council two months prior to the General Meeting and signed by the proposer and seconder. On one occasion, in 2009, this process was not followed, and a council was elected at the General Meeting. As this was not constitutional, the council was immediately disbanded, and the prior council was invited to serve an additional two years. In 2001, the constitution was amended, and the manner in which the council was elected was changed to a rotating schedule from the four regions: Northern (Gauteng, Limpopo, North West and Mpumalanga), Eastern (KwaZulu-Natal), Central (Free State) and Southern (Northern, Western and Eastern Cape).

Since 1962, provincial or branch chairs were appointed in each of the then four provinces, later changed to regions. Their role was to act as regional facilitators and to organise regional meetings. The success of the branches has been strongly linked with the chairperson and his/her level of motivation.

2.3 MEMBERSHIP

Any person can become a member of SASPP, as long as they possess a bachelor’s degree in plant pathology or an equivalent degree in a related discipline from a recognised university. There are a number of membership categories: ordinary, affiliated, student, honorary, fellows and patrons. The membership number has increased over the years, starting from 72 in 1962, 102 in 1981 to 309 in 2019. Members that were awarded honorary membership and became fellows of the society are listed in Table 5. South African Breweries was the first patron of SASPPM. The number of patrons steadily increased and in the late 1980s, there were 27 patrons, the majority of which were agrochemical companies. Currently (2020), there are only four patrons: Inqaba Biotech, Syngenta, Bayer and an anonymous American plant pathologist. Throughout the history of the SASPP, efforts have been made to invite plant pathologists from neighbouring countries to join. *Ad hoc* committees were appointed on two occasions to address this issue. Plant pathologists known to members were invited on numerous occasions to the congresses, but rarely joined the society. Funding was always problematic for these plant pathologists. Today, the SASPP has 17 non-South African members, 15 of which reside in other African countries.

TABLE 5 HONORARY[1] MEMBERSHIP AND FELLOWS[2] OF THE SASPP FROM 1981-2019

Date	Name	Category
1981	GJMA Gorter	Honorary
1986	GDC Pauer	Fellow
	CJ Rabie	Fellow
	BW Strydom	Fellow
1988	P Knox-Davies	Fellow
	MM Martin	Fellow
1989	VA Wager	Honorary
	GCA van der Westhuizen	Honorary
	J Mildenhall	Fellow
1991	MJ Hattingh	Fellow
	WFO Marasas	Fellow
1993	P Knox-Davies	Honorary
	FHJ Rijkenberg	Fellow
1995	MJ Hattingh	Honorary
	MJ Wingfield	Fellow
1996	B von Wechmar	Honorary
1997	CJ Rabie	Honorary
1999	Z Pretorius	Fellow
2001	WFO Marasas	Honorary
2002	MJ Morris	Fellow
2004	FHJ Rijkenberg	Honorary
2013	P Crous	Fellow
2015	S Lamprecht	Fellow
	TA Coutinho	Fellow

[1]Honorary membership is awarded to members who have served the SASPP for extended periods of time, usually throughout their career.

[2]Members of the SASPP may be elected as a fellow for outstanding contributions to plant pathology, as well as support for, and service to, the SASPP and plant pathology in southern Africa

2.4 FINANCES

Some of the documents most often retained in the archives of the SASPP are the audited financial statements of the society. Since 1982, the finances have been meticulously managed and appropriately invested by the various treasurers. However, the first evidence of auditing and investments was only in 1987. Today, the SASPP has a "healthy" investment portfolio, and the hope is that this continues into the future.

Membership fees have increased on a yearly basis, usually based on inflation, and ratified at the AGM. In 1982, the membership fee was R10 per year for an ordinary member, and in 2020 this had risen to R244. Student members have always paid less, usually 50% of the ordinary membership fee, but it has differed over the years. In 2020, student membership fee was R133 per year.

2.5 CONGRESSES

Once an organising committee had been elected at the General Meeting, either voluntarily or involuntarily, their first task was to find an appropriate and affordable venue for the next congress. In the early days, a formal proposal was presented which included details on the venue and costs involved. This has often led to heated debates. On one memorable occasion, it was proposed that the congress be held on a cruise ship. The costs had been carefully calculated, but it was agreed that it would be beyond the budget of students. Initially the venues were at the Universities, but this changed in the 1980s and congresses were most often held at resorts. The reasoning behind this decision was that attendees would be forced to remain in the same place and be less inclined to participate in non-plant pathological activities. This decision has not been accepted unopposed over the years. Some members have felt that the costs of resorts were exorbitant and that more attempts should be made to host the congresses at the Universities, using the residences for accommodation. Nonetheless, wherever the venue, each congress has had its own ambiance, and all have been hugely successful, including the one held in a marquee tent at Cintsa.

In 1981, after the split between the societies of microbiology and plant pathology, there was some confusion as to whether the next SASPP congress was to be the 2nd or the 20th congress. It was eventually agreed that this should be the 20th Congress and in 2019, the SASPP celebrated its 50th Anniversary meeting. Initially the congress was held over three days, with delegates arriving on the Sunday afternoon and departing on the Tuesday after lunch. In 2015, this was extended by an afternoon, and the congress is now concluded with a gala dinner on the Wednesday evening. It is at this event that the awards are presented.

In 1984, a poster category was included in the congress for the first time. The numbers of posters at congresses have steadily increased, and over the past five congresses have overtaken the number of presentations (Figure 2). At the majority of congresses poster viewing took place during the tea and lunch sessions. At congresses held between 1990 and 1992, a section 'introduced posters' was included in the programme. Presenters were given five minutes to introduce their posters. A similar approach was attempted at later congresses, but was never a very popular option by the congress organisers.

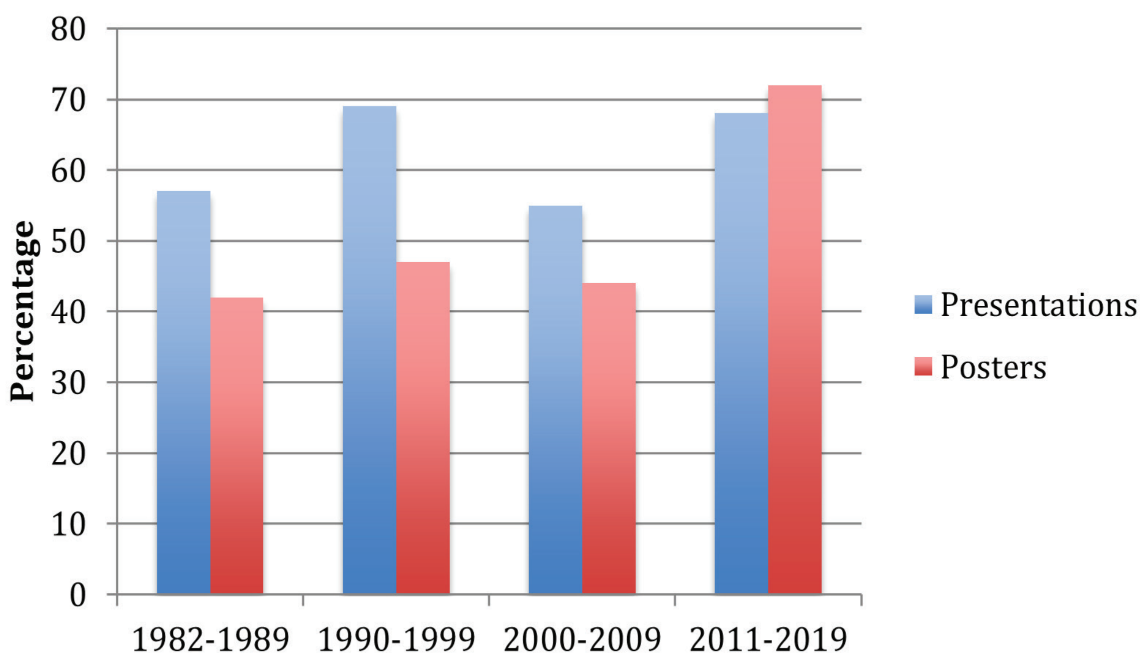


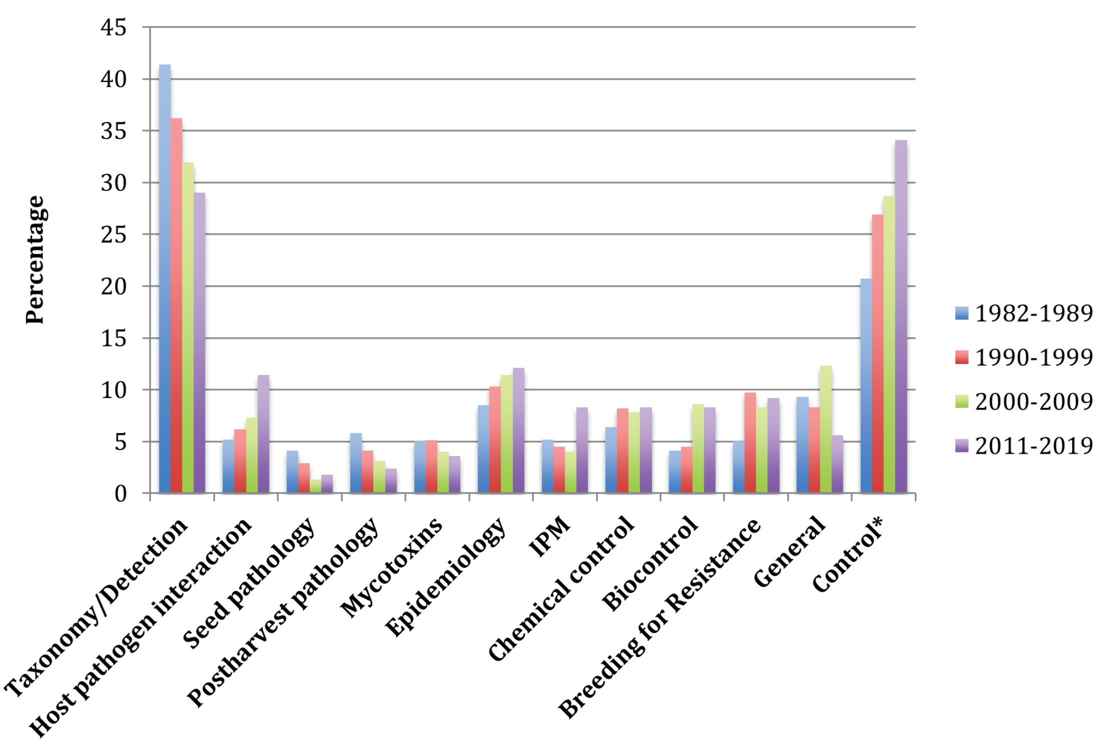
Fig. 2 Average number of oral and poster presentations at congresses held between 1982-2019

Congresses were initially held annually, until 2007, when it was agreed that they would be held every two years. The congress venues and organising committees were then rotated from region to region, each taking a turn. This approach has worked well, with the burden of organising the meeting shared more fairly by members of the society. One of the challenges in organising the congresses, and a contributing factor to having these every two years, was the costs involved. To organise an affordable congress, the organising committee needed to obtain substantial sponsorship that usually came from the agrochemical and laboratory equipment companies. Over the past 40 years, the SASPP has had significant support from the commercial sector.

Concurrent sessions were included in the programme of a number of congresses (in 1987, and 1991-1993). They were eventually discontinued, as the session topics were usually very specific, with the audience usually consisting almost entirely of research groups of the presenters themselves.

Efforts have been made to hold joint congresses with other societies. In 1984, an invitation was issued to the Nematology Society of South Africa to have a joint meeting with them in Hogsback the following year. They declined the invitation. In 2000, a hugely successful joint meeting was held between the Societies of Plant Pathology, Biochemistry and Molecular Biology, and Microbiology in Grahamstown (BIOY2K).

The imbalance between applied research (disease management) and basic research (diagnostics/detection) has been an agenda item at the general meeting for many years. A comment often heard is that there was "too much taxonomy". On one occasion an *ad hoc* committee was appointed to try and address this perceived imbalance. Members, particularly from the commercial sector, felt that the presentations were of limited value to them. However, as shown in Figure 3, when all management categories are grouped, and compared to taxonomy/detection (which includes fungi, viruses and bacteria), the numbers are not vastly different. In fact, between 2011-2019, there were more presentations on management than taxonomy/detection.



* combined figures for IPM+chemical control+biocontrol+breeding for resistance

Fig. 3 Oral presentations at SASPP congresses between 1982–2019 grouped into categories and presented as a percentage of the total number of presentations (based on congresses/terms)

Another concern raised within the SASPP in the early 2000s was that there were very few presentations on plant pathogenic bacteria. However, in the analysis performed here, the numbers of presentations on both bacteria and viruses have remained more or less the same over the years (Fig. 4). For obvious reasons (most plant diseases are caused by fungi), presentations on fungal pathogens dominate the presentations.

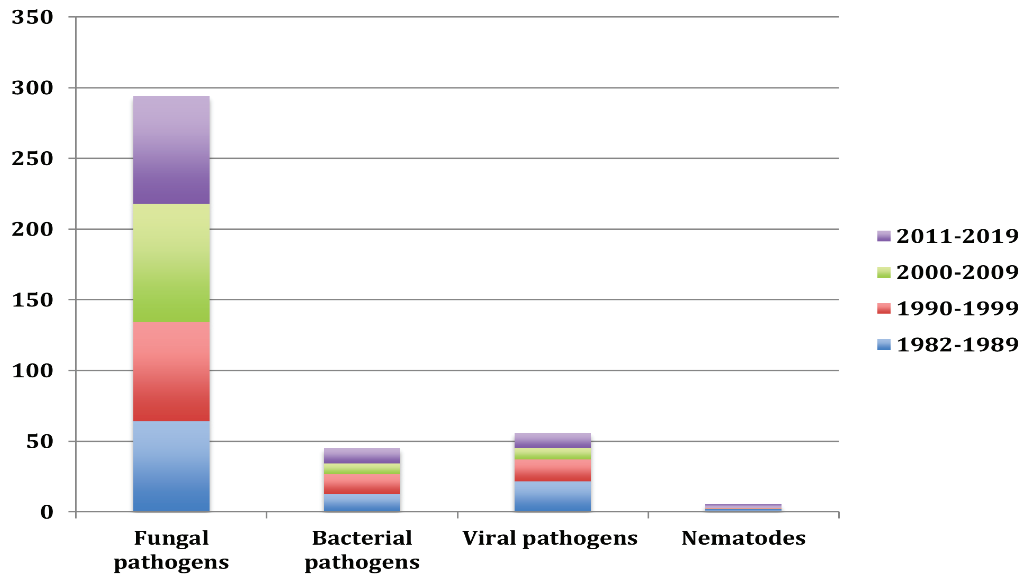


Fig. 4 Number of oral presentations at congresses between 1982-2019 on different plant pathogens

2.6 AFFILIATIONS

In 1981, SASPP was already affiliated with the International Society of Plant Pathology (ISPP), the International Society of Microbiological Societies (ISMS) and the Joint Council of Scientific Societies (JCSS). Since 1981, the society became affiliated with the International Mycology Association (IMA), the International Union of Microbiological Studies (IUMS) (in 1996), the National Science and Technology Forum (NSTF), the International Society of Viral Taxonomy and the SGB/NSB 10 standards generating body of SAQA. Membership of IUMS was terminated in 2003.

In 1982, the South African Council for Natural Scientists (SACNAS) (known today as SACNASP, the South African Council for Natural Scientific Professions) was established. That year, SASPP played an important role in registering plant pathology as a profession, by providing information to SACNAS in a document entitled "Responsibilities of the professional plant pathologist" (available in the SASPP archives). However, the organisation was never formally affiliated with the SASPP, even though this suggestion had been proposed and accepted at a general meeting.

Throughout the years, efforts were made to formally link the SASPP with international societies, such as the British Society for Plant Pathology (BSPP), the Australasian Plant Pathology Society (APPS) and more recently with the American Phytopathological Society (APS). Some success was achieved with BSPP and a joint Grace Waterhouse Fellowship for early career plant pathologists was established. In 2020, a memorandum of understanding was put into place with APS.

2.7 KEYNOTE AND PLENARY LECTURES

Once SASPP had become an entity in its own right, international keynote or plenary speakers were invited each year. They are listed in Table 6. In the 1980s, political unrest in South Africa was widespread and sanctions were enforced. Scientists from overseas were thus reluctant to attend congresses. However, each year the SASPP was able to invite at least one international speaker, mostly international leaders in their fields at the time, and members, including students, were given the opportunity to network with them.

TABLE 6 KEYNOTE ADDRESSES AT SASPP CONGRESSES FROM 1981-2019

Date	Speaker	Address	Title of Presentation
1981	Arthur Kelman	University of Wisconsin, USA	Information unavailable
	CL Hennebert	Catholic University of Louvain, Belgium	Information unavailable
	Jim Deacon	Edinburgh University, UK	Information unavailable
1982	Donald H Smith	Texas A&M University, USA	Management of groundnut diseases in the United States
1983	PH Williams	University of Wisconsin, USA	Information unavailable
1984	G Loebenstein	Israel	Active resistance to plant virus infection
	R Wood	UK	Information unavailable
1985	T Staub	Ciba-Geigy Ltd	Progress in coping with fungicide resistance
	D Hagedorn	University of Wisconsin USA	Information unavailable
1986	RA Frederiksen	Texas A&M University, USA	Transitions in the practice, theory and experimentation in plant pathology
1987	I Chet	Hebrew University, Israel	Information unavailable
	R Williams	Ciba-Geigy Ltd, Switzerland	Information unavailable
1988	No information available		
1989	R Koening	Plant Virus Laboratory, Germany	Antibodies and cDNAs in the identification, differentiation and classification of plant viruses
	J Thompson	University of Cape Town	Plant genetic engineering: the current status
	W Marasas	MRC	*Fusarium moniliforme* and fumonisins. A review of 18 fascinating, frustrating, frantic and fantastic years
	MJ Wingfield	University of the Orange Free State (now Free State)	Future trends in forest pathology
	CH Dickinson	New Castle-upon-Tyne University, UK	Microbiology of aerial plant surfaces
	M Hattingh	Stellenbosch University	Systematic invasion of deciduous fruit trees by *Pseudomonas syringae*
1990	PE Nelson	Pennsylvania State University, USA	Taxonomic misadventures in *Fusarium*

1991	D Cole	University of Zimbabwe	The prevalence of aflatoxins in groundnuts in Zimbabwe
	HW Kirby	University of Illinois, USA	The role of extension in a developed country
	Y Elad	Volcani Centre, Israel	Biocontrol, physiological and chemical approaches to control grey mold
	CM Brasier	Forest Research, UK	Current questions in *Phytophthora* systematics
	WAJ de Milliano	Sorghum and Millet Improvement for Southern Africa, Zimbabwe	Collaboration in plant pathology in southern Africa
	JF Webber	Forest Research, UK	Dutch elm disease – a model of an insect-vectored disease
1992	N Keen	University of California, Riverside, USA	Molecular approaches to the study of host-pathogen interactions
	BD Wingfield	University of the Orange Free State (now Free State)	Future prospects for the molecular characterisation of plant pathogenic fungi
	I Roos	ARC	Application of biotechnology in breeding for resistance against bacterial diseases of deciduous fruit trees: challenges and prospects
	E Rybicki	University of Cape Town	Molecular taxonomy of the Potyviridae
1993	CJ Lamb	The Salk Institute, USA	Plant defence mechanisms: elucidation and manipulation
	S Beer	Cornell University, USA	Molecular genetics of *Erwinia amylovora*
	SA Hill	Central Science Laboratory, UK	Plant health issues for the United Kingdom and the single European market
	B Kendrick	University of Waterloo, Canada	A retrospective analysis of mycorrhizal research: where have we been, where shall we go?
1994	F Nutter	Iowa State University, USA	Epidemiological studies concerning *Cercospora zeae-maydis* on maize
	R Spotts	Oregon State University, USA	An integrated strategy for control of postharvest decay of fruit
1995	R Johnson	John Innes Centre, UK	Durable resistance to diseases and its successful exploitation in plant breeding
	J Lucas	University of Bristol, UK	From simple to complex – the evolving story of cereal eyespot disease
	T Harrington	Iowa State University, USA	Clonal development of root-rotting Basidiomycetes in forest stands
	ME Stanghellini	University of Arizona	Foes from below: expect the unexpected

1996	KA Seifert	Centre for Land and Biological Resources Research, Canada	Do you believe in species?
	HC Evans	IIBC, UK	Biological control of weeds using fungal pathogens
	JI Pitt	CSIRO, Australia	*Penicillium* systematics and ecology: the current status
1997	J Cook	Washington State University, USA	Biological control of soilborne plant pathogens: integration of traditional and emerging technologies
	AA MacNab	Penn State University, USA	[1] Tomato blight forecast systems: FAST, TOMCAST and BLITECAST [2] Tomato blight forecasting: some experience with implementation
	T Tabhavi	University of Queensland, Australia	Molecular phylogeny of *Ralstonia solanacearum* and related bacteria
	G Carroll	University of Oregon, USA	Fungal endophytes in vascular plants: pathogens, mutualists, or both?
	CL Wilson	USDA ARS Appalachian Fruit Research Station, USA	Synergistic biological control of postharvest diseases with biological, physical and chemical elicitors
	T Staub	Ciba Crop Protection, Switzerland	Systemic acquired resistance: a new option to protect plants against diseases
	JM Gouot	Rhone-Poulenc Agrio, France	Fungicide resistance management: how to retain a variety of disease control options
	H Steva	BIORIZON S.A., France	Evaluating anti-resistance strategies for control of *Uncinula necator*
1998	TJ Gulya	USDA Northern Crop Science Laboratory, USA	Integrated disease management strategies for sunflower
	JA Lucas	University of Bristol, UK	Revealing the villain: new approaches to analysing fungal pathogenicity
	MG Milgroom	Cornell University, USA	The transmission of hypovirulence in populations of the chestnut bight fungus
	A Drenth	University of Queensland, Australia	The role of fungal genetics in plant pathology
1999	M Palm	USDA/APHIS/PPQ, USA	Systematics, plant pathology and the global agricultural market
	SV Thompson	Utah State University, USA	Using epidemiological data to develop innovative control strategies for fireblight
	G Adams	Michigan State University, USA	Cytospora canker of hardwood and conifer trees
	D Wilson	Arizona State University, USA	The endophyte-pathogen enigma
	D Guest	University of Melbourne, Australia	New confrontations with *Phytophthora*

2000	O Petrini	Swiss Federal Institute of Technology, Switzerland	Endophytes: past and present knowledge and a research agenda
	J Taylor	University of California, Berkley, USA	Nucleic acids, phylogenetics and the revolution in fungal evolution
	I Toth	Scottish Crop Research Institute, Scotland	Novel approaches to study the pathogenicity and host range of the bacterial pathogen *Erwinia carotovora*
	G de Lorenzo	University of Rome "La Sapienza", Italy	PGIPs: leucine-rich repeat cell wall proteins involved in plant defense and development
	T Brenneman	Coastal Plains Experimental State, Georgia, USA	Integrated management of plant diseases in the south eastern United States
	A El Ghaouth	Micro Flo Company, Memphis, USA	Biological alternatives to synthetic fungicides for the control of postharvest diseases of fruit and vegetables
	F Cervone	University of Rome "La Sapienza", Italy	Studies on the PGIP (polygalacturonase-inhibiting protein) family of *Phaseolus vulgaris*)
	J Dale	Queensland University of Technology, Brisbane, Australia	Plant virus variability and transgenic resistance: can we cope?
	C Straker	University of the Witwatersrand	The status of arbuscular mycorrhiza (AM) on gold and uranium slimes dams in relation to slime characteristics, and the use of slime-tolerant AM fungal strains for inoculum production
	J Brown	University of Arizona, USA	Molecular tracking of new and emergent Begomoviruses and genic variation of the whitefly vector *Bemisia tabaci*
	O Preisig	FABI, University of Pretoria	The mycoviruses: a focus on recent discoveries and opportunities in South Africa
2001	W Marasas	MRC	Will the real *Fusarium moniliforme* please stand up
	PE Russell	Aventis Crop Science, France	Trials and tribulations of managing fungicide resistance in industry
	HC Evans	CABI Bioscience, UK	Fungal pathogens for the classical control of invasive weeds: recent case studies
	P Larignon	UMRSV, France	Biology of *Phaeomoniella elianthinre* and *Botryosphaeria elian*, two fungi involved in grapevine declines
2002	D Shtienberg	Volcani Centre, Israel	The contribution of epidemiological research to plant disease management
	J Burdon	CSIRO, Australia	Diseases in space and time – co-evolutionary patterns in natural plant-pathogen associations

2003	BM Moerschbacter	University of Munster, Germany	Pathogenicity factors: do obligate biotrophs do it differently?
	BJ Steffenson	University of Minnesota, USA	Combating *Fusarium* head blight of wheat and barley in the USA
	P Lecomte	INRA-ENITA, France	Present status of Eutypa dieback of grapevine in Europe and research in progress in France
	A Liobell	University of Sevilla, Spain	From spores to genes: *Trichoderma* strains as a source of biotechnological applications
	WAJ de Milliano	University of KwaZulu-Natal	Sorghum and pearl millet, jewels of Africa this millennium
2004	A Liobell	University of KwaZulu-Natal	A high throughput molecular biology platform for South Africa
2005	P Crous	Westerdijk Fungal Biodiversity Institute, the Netherlands	*Mycosphaerella*: morphologically unified but phylogenetically diverse
	TJ Wicks	South Australian Research & Development Institute, Australia	Sustainable control of grapevine powdery mildew in southern Australia
	N Hallenberg	Gottenburg University, Germany	Biogeography and taxonomy in wood-inhabiting Basidiomycetes
	D Six	University of Montana, USA	How important is pathogenicity in fungus-bark beetle symbioses?
2006	T Gulya	ARS-USDA	Recent advances and novel concepts in managing Sclerotinia diseases on sunflowers and other crops
	D Cole	Harbour Island, Gordons Bay	Trends in plant disease management research
	GA Kong	Department of Primary Industries and Fisheries, Australia	Virulence dissociation and pyramiding genes for resistance to *Puccinia elianthin* in sunflower
	R Buruchara	CIAT, Uganda	Strategies to overcome disease constraints in common bean (*Phaseolus vulgaris* L): case study of Pythium root rot
2007	R Charudattan	University of Florida, USA	The useful side of pathogens: development and application of commercialisation of bio-herbicides
	RF Park	University of Sydney, Australia	Eighty five years of cereal rust pathology and resistance breeding in Australia; are we winning?
	M Wolfson	SANBI	The National Environmental Management Biodiversity Act: implications for research

2009	CMJ Pieterse	Utrecht University, the Netherlands	Plant immune responses triggered by beneficial microorganisms
	SE Lindow	University of California, Berkeley	Life of microbes on a leaf
	DW Minter	CABI, UK	Fungi, the orphans of Rio
	PW Crous	Westerdijk Fungal Biodiversity Institute, the Netherlands	Phycomycology embracing cybertaxonomy
	L Palou	IVIA, Spain	Fungicide-free management of postharvest citrus
	SJD Midgley	Stellenbosch University	Climate change and agriculture in South Africa: the future is not what it used to be
	D Prusky	Agricultural Research Organisation, Israel	Mechanisms modulating fungal attack in postharvest pathogen interactions and their modulation for improved disease control
2011	G Brodal	Bioforsk, Norway	*Sydowia polyspora* and other seedborne fungi on conifers
	KD Hyde	Mae Fah Luang University, Thailand	The need to carry out re-inventory of plant pathogens
	W Janisiewicz	ARS-USDA, USA	Biological control of postharvest diseases of fruits: from wound to latent infection
	P Birch	James Hutton Institute, UK	The host targets and virulence factors of RXLR effectors from the potato late blight pathogen *Phytophthora infestans*
	BH Bluhm	University of Arkansas, UK	Grey leaf spot of maize: two pathogens, two continents
2013	HB Deising	Martin Luther University Halle-Wittenberg, Germany	Fungal strategies to escape recognition and evade plant defense
	D Hodson	CIMMYT, Ethiopia	Enhancing knowledge to protect future harvests: tracking wheat rust pathogens in Africa
2015	P Fourie	Citrus Research International	Citrus black spot: a scientific and political conundrum
	GE Harman	Advanced Biological Marketing, USA	Emerging opportunities for use of plant beneficial microbes: Demystifying the interaction between beneficial microbes and plants
	MJ Wingfield	University of Pretoria	Global tree health: new developments and emerging challenges
2017	A Robertson	Iowa State University, USA	How my experience as a corn pathologist in Iowa taught me to appreciate the disease triangle
	R Jackson	University of Reading, UK	Identification and characterisation of new aphid-killing bacteria for use as biological pest control agents
	D Arnold	University of the West of England, UK	A persistent reservoir of a genomic island in *Pseudomonas syringae* pv. *Phaseolicola*

2019	PW Crous	Westerdijk Fungal Biodiversity Institute, the Netherlands	Resolving the taxonomy of coelomycetes
	C Bull	Pennsylvannia State University, USA	Translational taxonomic investigations to control diseases caused by *Pseudomonas syringae*
	J van der Waals	University of Pretoria	Quarantine pathogens and certification systems: a potato perspective
	P Fourie	Citrus Research International	The Southern African Citrus Improvement Scheme: balancing biosecurity and commercial citriculture
	J Wiles	Corteva Agriscience, UK	Designing and developing integrated disease management solutions to improve crop performance, efficacy and durability
	A Stensvand	NIBIO, Norway	Alternative means to control powdery mildews
	Z Pretorius	Free State University	Are cereal rusts still important?

2.8 WORKSHOPS, PRE- AND POST-CONGRESS EXCURSIONS

In 1983, the first workshops (termed discussion sessions) were held as part of the congress. Topics that year included antibiotics and plant disease control, techniques for virus detection and identification, new approaches to the control of soilborne pathogens, and "the plant pathologist and photography". That same year, a pre-congress tour was organised to vegetable farmers in the George area. A list of workshops and excursions that have taken place over the years are presented in Table 7.

TABLE 7 WORKSHOPS AND FIELD EXCURSIONS LINKED TO SASPP CONGRESSES FROM 1981 TO 2019

Year	Workshop	Field Excursion
1983	Discussion on new approaches to the control of soilborne diseases - Dr PG Marais Discussion on antibiotics and plant disease control - M Hattingh	
1984	Workshop on root diseases and soilborne pathogens	
1985		Foray into the rich and varied flora of the Hogsback Excursion to the Katberg
1986	Methods of isolating common rot fungi - S von Broembsen New techniques in plant virology - J Thompson Seed pathology - H Lloyd	
1987	Virology, Soilborne pathogens and seed pathology workshops	

1989	Virus epidemiology - B von Wechmar Nucleic acids techniques workshop run over three days after the congress at UCT - E Rybicki and R Koenig	Tour of Franschoek included a tour of a cellar making champagne, wine tasting, tour of packing shed
1990	*Fusarium* Indaba - W Marasas Root disease indaba - N Labuschagne Virology indaba - G Pietersen	
1991	Virus workshop	
1993	Plant protection working group: Regulatory strategies relating to the importation of plant harmful organisms - V Siebert	
1994	Wheat pathology: current status and future prospects - Z Pretorius	
2005	One day devoted to presentations by members of the AMA	
2007	Constructing a perfect conference poster - an interactive workshop - M Laing Photographic competition - adjudicated by A Hall and C van der Merwe	
2013	Field trial design, inoculation trials and breeding strategies - Z Pretorius & N McLaren New Technologies in plant pathology - B Wingfield	Visit to a granadilla farm - G Pietersen
2015	Fungicide technology for plant disease control - P Fourie New technologies in the identification of fungi - C Schoch	Trip to the planetarium
2019	Professional development workshop - C Bull	

2.9 AWARDS

The Christiaan Hendrik Persoon Medal is the highest honour of the society. Persoon was born in South Africa and is regarded as the "Father of Mycology". The award and the selection criteria for this award were first included in the constitution in 1978, while still under the auspices of SASPPM. When split in 1980, the award became part of the SASPP constitution by-laws. The gold medal has been awarded five times since 1982 (see Table 8).

In 1992, a new award category, the JE Vanderplank Award, was included in the policies and procedures of the SASPP. The first recipient was Bernard Slippers from FABI, University of Pretoria, in 2015. This award is given to an outstanding "young" plant pathologist based on an evaluation of his or her research.

The Applied Plant Pathology Award and the Publicity Award were formally included in 1992. The Applied Plant Pathology Award recognises the contribution of members who have made significant contributions, specifically in applied aspects of plant pathology. The Publicity Award in given in recognition of the contributions of members to promoting the general public awareness of plant pathology and related issues. A record of the recipients of both these awards was never kept.

In 2003, an award for the best article on the SASPP website featuring a disease was accepted as a new category. It is unclear whether or not this award has ever been given to a member of the society.

The Young Plant Pathologist Award was initiated in 2002 and awarded to 10 student members of the society. Selection was based upon a nomination by the student's primary advisor. In 2008, this award was replaced by the John and Petakin Mildenhall Award. John Mildenhall and his wife, Petakin, donated funds for this purpose. The purpose of the award is intended to stimulate interest and advance excellence in postgraduate students, especially doctoral students in the field of plant pathology. The awardee is selected based on academic excellence and potential of the applicant. A record of the recipients of this award has not been kept.

In 2015, the Grace Waterhouse Fellowship was established to encourage links between the SASPP and the British Society of Plant Pathology (BSPP), with a particular focus on plant pathologists in the early stages of their careers. There have been two recipients of this award, both from the University of Pretoria.

TABLE 8 SASPP AWARDS (1979-2017)

Award	Date	Recipient
Christiaan Hendrik Persoon Medal: Awarded for outstanding achievement in plant pathology or any other field approved by Council	1979	JE Vanderplank
	1987	WFO Marasas
	1999	MJ Wingfield
	2005	PW Crous
	2009	ZA Pretorius
	2015	BD Wingfield
The John and Petakin Mildenhall Award: Awarded for academic excellence and potential	2009 - 2017	No records available
JE Vanderplank Award: Awarded to an outstanding "young" (within 10 years of receiving a PhD) plant pathologist based on an evaluation of his/her research	2015	B Slippers
Applied Plant Pathology Award: Awarded to plant pathologists who have made a significant contribution specifically to applied aspects of plant pathology	2002	S Denman
	2003	No records available
	2004	No records available
	2005	L Mostert
	2006	No records available
	2007	No records available
	2009	N McLaren
	2011	J Roux
	2013	F Haleen
	2015	B Flett
	2017	No records available
Publicity Award: Awarded to plant pathologists in recognition of their contributions towards promoting general public awareness of plant pathology and related issues	2002 - 2004	No records available
	2005	T Coutinho
	2006 - 2008	No records available
	2009	JE van der Waals
	2010 - 2017	No records available
Best Disease Feature Award for the website	2003	No records available
Grace Waterhouse Fellowship: The Grace Waterhouse Fellowship has been set up to encourage links between the SASPP and the British Society for Plant Pathology (BSPP), with a particular focus on plant pathologists in the early stages of their careers	2015	P Madupe (UP) to the University of Exeter
	2017	J Dube (UP) to FERA

Since 1996, Pannar has awarded a trophy to, respectively, the best oral presentation and research poster by student members of the SASPP (Table 9). Both awards included a cash prize. Since 2007, Inqaba Biotec has awarded a book prize to the best molecular presentation by a student member of the society. Again, the names of recipients of this award have not been kept.

TABLE 9 RECIPIENTS OF THE PANNAR STUDENT AWARDS AND INQABA BIOTEC BOOK PRIZES

Award	Year	Recipient
Pannar Student Trophy:	1996	C Viljoen, UFS
Awarded for the best student paper presented at the congress	1997	L du Toit, UKZN
	1998	J Roux, UFS
	1999	K Cradock, UKZN
	2000	I Barnes, UP
	2001	I Barnes, UP
	2002	ZW de Beer, UP
	2003	E du Preez, UKZN
	2004	L Matsaunyane, ARC
	2005	L Mostert, Wageningen University
	2006	J Moldenhauser, UFS
	2007	B Sivparsad, UKZN
	2009	I Barnes, UP
	2011	L Esterhuyzen, UJ
	2013	D Herron, UP
	2015	IL du Plessis, SU
	2017	N Robbertse, UP
	2019	SL Masekane, SU
Pannar student poster Award:	1996 -	No records available
Awarded for the best student poster presented at the congress	2017	
	2019	H Schreuder
Inqaba Biotec book prize:	2007 -	No records available
Awarded for the best student molecular paper presented	2019	

2.10 JE VANDERPLANK AND ETHEL M DOIDGE MEMORIAL LECTURES

The JE Vanderplank lecture is presented in recognition of his contribution to the field of plant pathology and to science in general in South Africa, and the world. The lecture is presented as the opening address at the congress. The address is intended to be thought-provoking in the spirit of James Vanderplank's philosophy. Preference is given to inviting leading South African scientists to deliver the address.

In recognition of the outstanding contribution of Ethel Doidge to the field of mycology in South Africa and the world, the keynote address in the systematics session of the congress has been named in her honour. Preference is given to inviting leading South African systematists to deliver this address. Although Ethel Doidge is mainly recognised for her contributions to mycology, she contributed significantly to phytobacteriological research in South Africa between 1900 and 1930. It is for this reason that two of the presenters of this lecture have been phytobacteriologists (Table 10).

TABLE 10 PRESENTERS AND TITLE OF THE JE VANDERPLANK AND EM DOIDGE MEMORIAL LECTURES

Presentation	Year	Presenter	Title
JE Vanderplank lecture	1999	W Marasas, MRC	Risk assessment of fumonisins in maize
	2001	FHJ Rijkenberg, University of KwaZulu-Natal	Plant pathology in SA: whither or wither
	2002	Z Pretorius, University of the Orange Free State (now Free State)	Challenges in breeding for durable resistance in plants
	2003	N McLaren, ARC	Beyond the pathogen
	2004	M Laing, University of KwaZulu-Natal	Two current anomalies in plant pathology, subsequent to Vanderplank's legacy
	2005	G Holz, Stellenbosch University	The ecology of *Botrytis* on plant surfaces
	2006	G Pietersen, University of Pretoria	Tackling the grapevine leafroll disease problem in South Africa
	2007	M Holtzhausen,	Agricultural, global trade and international standards on phytosanitary measures
	2009	SP van Vuuren, CRI	Management of graft-transmissible diseases of the southern African citrus improvement scheme
	2011	MEC Rey, WITS	Twenty-eight years of host pathogen interactions in plant disease: where to next?
	2013	R Kloppers, Pannar Seed	Managing risk for plant diseases in agronomic crops - a breeding perspective
	2015	S Lamprecht, ARC	Confessions of a serial soilborne plant pathologist - 30 years of digging holes and finding my way out of them
	2017	L du Toit, Washington State University, USA	Spinach seed crop pathology research and extension efforts at Washington State University: engaging principles of the US Land Grant Mission to enhance production of a minor acreage, high value crop
	2019	A Viljoen, Stellenbosch University	Global effects to mitigate the impact of banana *Fusarium* wilt caused by *Fusarium oxysporum* f.sp. *cubense* TR4

EM Doidge Memorial lecture	2002	D Geiser, Pennsylvania State University, USA	Using multilocus phylogenetics to figure out *Fusarium* species
	2003	I Rong, ARC	Are anamorphs and taxonomists becoming extinct?
	2004	A Wood, ARC	From whence commeth the rust of our land?
	2005	MJ Wingfield, University of Pretoria	Forest pathology and forest pathogens in South Africa. The past and the future
	2006	JLW Rademaker, NIZO Food Research, the Netherlands	Construction, calibration and application of a comprehensive species to strain taxonomic framework for *Xanthomonas* based on rep-PCR genomic fingerprint typing
	2007	J Dames, Rhodes University	Characterisation of mycorrhizal fungi, their associations and related taxonomy
	2009	GJ Marais, University of the Free State	The value of applied mycology in a changing world
	2011	M Gryzenhout, University of the Free State	How good is our pathology library?
	2013	P Crous, Westerdijk Fungal Biodiversity Institute, the Netherlands	Names of fungal pathogens in plant pathology: starting over
	2015	C Schoch, National Institute of Health, USA	Do names still matter for fungi?
	2017	C Bull, Pennsylvania State University, USA	Translational bacterial taxonomy: from field to phylogeny and back again
	2019	S Denman, Forest Research, UK	A holistic approach to investigating a complex decline-disease syndrome: acute oak decline

2.11 THE SOUTH AFRICAN PLANT PATHOLOGIST/PATOLOOG

In 1982, the newsletter "South African plant pathologist/patoloog" was produced for the first time. The publication secretary, as part of the council, was given the role as editor. Two editions were produced each year (ISSN 1018-4309) until 1999. They were what can be considered as social newsletters and included interesting events in the lives of members of the society, for example new appointments, promotions, awards and retirements. They often had sections on letters to the editor, presidential reports, new members, new council members, personality profiles, international congress/workshop reports, and occasionally popular scientific articles, such as "Woman in science – helping women to realise their full potential in science". In the June 1993 edition, all the culture collections and their respective curators are listed. In reflecting on these bulletins, one of the most interesting experiences is trying to identify people in the photographs. All editions of the Newsletter are available in the archive of the SASPP. The intention is to scan all of these (and related) documents and to feature them on the SASPP website, such that members can enjoy aspects of the early social history of the SASPP.

2.12 THE MILDENHALL STAKES AND OTHER FUN ACTIVITIES

John Mildenhall has, since he joined in 1966, been a key member of SASPPM and later SASPP. He left for the USA in 1967, returning to South Africa in 1971. While in the USA, he performed a trick, now known as the Mildenhall Stakes, to earn free drinks. This trick involves placing a bottle of beer upon one's forehead in the standing position, then lowering the body to the ground, rolling backwards, gripping the bottle between one's knees or lower legs and then placing it on the ground behind one's head. It concludes finally with turning around and drinking the beer without touching the bottle. A challenge, and no mean feat! This event now takes place, rain or shine, clothed (or clothed only in underwear) at every congress. There are a number of categories – male and female beginners, male and female veterans and the plenary/keynote presenters. This event has been performed in under 19 seconds; a record held by a UKZN female student.

At the 2015 congress, a quiz evening was included in the programme. The event is sponsored by the seed company Starke Ayres and facilitated by Wilmarie Kriel. Members are placed in teams of their own choosing and are shown photographs of between 20 and 30 diseases or pathogens that need to be identified. Prizes are then awarded to the top teams.

3.0 Keynote Address Presented by James Vanderplank at the 1975 Congress

This address appeared in the 1976 SASPPM Bulletin. It is included here, because it clearly illustrates the thought provoking and insightful nature of JE Vanderplank's philosophy.

Host-Pathogen Specificity and the New Biology

The first points I want to make in this address are:

First, host-pathogen recognition in gene-for-gene disease takes place between the primary coded protein of the pathogen and the primary coded protein of the host. In other words, this address is about proteins, and about gene-for-gene diseases.

Second, the proteins are brought together by polymerisation which is thermodynamically controlled. In other words, a topic is the thermodynamics of protein polymerisation.

Third, the host-pathogen recognition which is a protein-by-protein recognition is the same as the antigen-antibody recognition in animals. The pathogen uses the same principles to recognise its host as the body does when it fights off disease or as you do when you identify a virus or bacterium in the laboratory with rabbit antiserum. The same basic process crops up in both the plant and the animal kingdom, but is twisted to different needs in different circumstances.

Fourth, the phenomenon of common antigenic surfaces in plant host and parasite is a particular manifestation of the general protein-by-protein recognition system.

Fifth, vertical resistance is unstable because the pathogen can make exactly the same type of amino acid change as the host makes in changing from susceptibility to resistance.

The Storage of Variation

Consider stem rust of wheat. At least 20 resistance genes, call *Sr* genes, are known in wheat. This means that there are potentially at least 2^{20}, or more than a million, races of *Puccinia graminis*. The fact that no laboratory will ever be able to collect the potential million races is beside the point. If there are 20 *Sr* genes, there is a potential for at least a million stem rust races, i.e., for at least a million phenotypes of *P. graminis*, and for at least a million differential wheat lines, i.e., for at least a million wheat phenotypes. Put differently, there is a potential for contact between wheat and *P. graminis* in at least a million ways.

All this variation must be stored and must be manifested after infection. Here is the core of the problem. How can molecules of the pathogen come into contact with molecules of the host in at least a potential million permutations and combinations? That contact must be close enough to be within the range of chemical bonds. And how do the appropriate molecules recognise one another?

Genes, i.e. DNA, can store the variation. So much is axiomatic. But the genes of wheat and those of *P. graminis* never come into contact. They are tightly bound in their respective chromosomes; and these in turn are contained in nuclei surrounded by a nuclear membrane. This is true of all diseases caused by eukaryotes. We can rule out genes as being the points of host-pathogen contact. We must look to the phenotype for the contact.

Proteins are the indicated points of contact. It is in the host protein and pathogen protein that the variation is stored, and it is in host protein – pathogen protein contact that the variation is manifested as host-pathogen specificity.

Observe two points. Proteins are almost as good stores of variation as DNA itself. Variation in the DNA, i.e. mutation, is very largely passed on as variation in the coded protein. To put the matter quantitatively, approximately three quarters (more exactly, 17/24) of the variation in DNA in the form of base substitution is passed on as variation in the coded protein in the form of amino acid substitution. A change in the order of bases in the DNA becomes a change in the order of amino acids in the protein.

The second point to observe is that protein molecules readily come together, in appropriate conditions, to form protein polymers. A polymer consisting partly of host protein and partly of pathogen protein makes ordinary chemical sense. Indeed, such composite protein polymers are known in bacteriophage combinations and have been reported in barley infected with brome mosaic virus (Hariharasubramanian *et al*, 1973).

There are other large molecules able to store such variation, particularly the complex carbohydrates (including the glycoproteins and glycolipids) and nucleic acid-protein complexes. But for reasons too long to go into now, they can be ruled out.

Protein-Protein Recognition

Our hypothesis then is that the relevant susceptibility/resistance variation in the host and the relevant virulence/avirulence variation in the pathogen are stored in their relevant proteins. For the pathogen to recognise the host as compatible, i.e. susceptible, the pathogen protein must recognise the host protein as a compatible partner in polymerisation.

Protein-protein recognition has recently been studied in detail (Chothia & Janin, 1975; and Pauling & Pauling, 1975). The forces holding the surfaces together in a polymer are weak and non-covalent. To be effective, the surfaces must pack very closely together. That is, they must be so contoured that the one fits the other. The packing must be so close that the distance between the surfaces must be less that the diameter of a H atom. Only over these very short distances are the forces adequate to hold the polymer together. Further, there must be hydrogen bonds between the surfaces. These bonds form between O, N and S atoms at the protein surface. They too are weak, except at close range, so the atoms must be positioned opposite one another in the two combining surfaces.

In summary, protein molecules (monomers) will tend to associate with polymers if they have complementary surfaces that pack very closely together and have O, N and S atoms positioned to make hydrogen bonds across the interface. These precise requirements make for a high degree of specificity.

Antibodies are proteins, and when the antigen is also a protein (as it commonly is) the great specificity between antigen and antibody is due to this complementary packing and hydrogen bond formation.

This same specificity is, in our hypothesis, the basis of host-pathogen specificity in plants. To use wheat stem rust again as an example, wheat is susceptible when the relevant coded proteins in *P. graminis* can polymerise with the matching coded proteins of wheat, because of complementary packing and hydrogen bond formation.

Thermodynamic Evidence

It is one thing to propose a hypothesis, but another thing to substantiate it. The most interesting evidence comes from thermodynamics.

Protein polymerisation is an endothermic process, which means that protein polymerisation is increased by high temperatures and decreased by low temperatures.

Two examples will suffice.

The protein coat of tobacco mosaic virus is a tubular polymer. If one extracts the protein from the virus and examines it with an electron microscope, all steps being carried out at room temperature, the protein is seen to be polymerised into tubes of the same diameter as that of TMV itself. But if the protein solution is held at low temperatures, say 4°C, sprayed, dried, and examined at this same low temperature, it is seen to be dissociated. There are no longer tubes. All that one sees is the individual protein molecules, completely scattered and dissociated. TMV protein in solution exists as a polymer at 25°C, but as a monomer at 4°C (Lauffer et al., 1958).

The second example concerns the mechanism of mitosis. The mitotic spindle to which the chromosomes are attached is a head-to-tail polymer, mainly of the protein tubulin. The protein is in the form of fibres when it is polymerised: the fibre structure depends on polymerisation, and disintegrates when the polymer disintegrates. The parallel arrangement of the fibres makes the spindle birefringent; and the amount of spindle in the cell, and hence the amount of polymerisation, can be studied with a polarising microscope. Inoué (1959), working with the pollen mother cells of *Lillium* and with other organisms, found that the spindle is in a temperature-sensitive equilibrium. At 4–6°C the spindle birefringence is destroyed completely. When the temperature is raised, birefringence returns. The process is reversible, and nuclear division proceeds only at temperatures showing birefringence.

Here then is the first test of our hypothesis. If temperature affects resistance to disease, it should take the form of resistance at lower temperatures and susceptibility at higher temperatures.

The test is simple; and there is at hand a large amount of experimental evidence. I traced, through the *Review of Applied Mycology* and other means, every reference I could on the effect of temperature on resistance in a gene-for-gene system. I cannot possibly in this address review the evidence in detail; it is far too bulky. Let me say that it solidly supports the hypothesis, and that it concerns fungus, bacterial and viral diseases and nematode infections. I would however like to elaborate a few points.

The breakdown of resistance as one goes from low to high temperatures has apparently nothing to do with the optimum temperature for disease. E.g., the gene *Sr*6 in wheat gives resistance to appropriate races of stem rust at 20°C but not at 25°C or higher. There is much evidence, both from laboratory and field, that in susceptible varieties 20°C is near the optimum for stem rust attack and 25°C is well above that optimum. At 25°C wheat stem rust is sharply on the wane. In other words, the *Sr*6 gives resistance when the pathogen is at its strongest, and becomes ineffective when the pathogen has lost much of its aggressiveness. Taking the evidence as a whole, there is no relation between the turning-point from resistance to susceptibility and the optimum temperature for disease. Sometimes the turning-point is below the optimum, sometimes near the optimum, and sometimes about it.

Secondly, note the conditional if in the test: If temperature affects resistance, it is in the direction of reduced resistance at higher temperatures. There is nothing in the test to say that temperature will affect disease. The point is material. Polymerisation makes for susceptibility. Polymerisation is endothermic and therefore proceeds furthest at higher temperatures. But thermodynamics concerns processes anywhere on the Kelvin scale of temperatures. We, in plant pathology, are confined to the relatively narrow range from the minimum cardinal temperature for disease at the bottom to the maximum cardinal temperature at the top. There is no thermodynamic reason why the change to polymerisation should occur within this range. It depends on the dissociation constant of the polymer. Haemoglobin is a protein polymer with a small dissociation constant; it is tightly bound and remains associated at all relevant temperatures. If TMV protein had a smaller dissociation constant it too would have been stable at all relevant temperatures. So too the gene *Sr11* is as effective at 25°C as at 20°C, unlike gene *Sr6*. We infer, very obviously, that the proteins concerned with *Sr11* polymerise less readily, i.e. they have a higher dissociation constant, than those concerned with *Sr6*.

Lastly, there are three reports in the literature that could, if uncritically accepted, be regarded as contrary evidence. They concern stripe rust and leaf rust of wheat and *Xanthomonas malvacearum* in cotton. Close examination disposes of them. I shall illustrate this only with wheat stripe rust. There is an old report in the literature that wheat susceptible to *P. striiformis* at ordinary temperatures becomes resistant above 24°C. This report is widely cited, which is the only reason why I cite it. *P. striiformis* is a low temperature fungus, the optimum for disease being about 11°C. Even at 16°C spores germinate poorly, and at 23°C they do not germinate at all. Reports then of resistance at 24°C mean nothing but that belief in artifacts has been carried to absurdity. This report of high temperature resistance is just junk that clutters up the literature.

To return to essentials, there are other tests that can be used to probe the hypothesis.

If temperature affects the dominance of resistance (note the conditional if again), it affects it in the direction of a change from dominance to recessivity with rise of temperature. The available evidence in the literature is 100% in support of this. Particularly interesting evidence of this can be obtained by analysing the data given by Cirulli & Ciccarese (1975) about the infection of tomatoes by TMV.

Another test deals with sugars and polyhydric alcohols. Sucrose and glycerine in solution strongly promote protein polymerisation (Shelanski *et al,* 1973). Young wheat plants are high in sugar, adult plants low. Hence one would expect proteins to dissociate and resistance to develop in wheat. Sugars have long been suspected to play a part in susceptibility; but because the sugar content of susceptible and resistant wheat varieties is much the same, the involvement of sugar concentration has been obscure. Now we see the sugar effect as indirect, involving only certain resistance genes through influencing protein polymerisation. When the resistance or susceptibility of a cultivar is strong, i.e. the protein polymer has a markedly high or markedly low dissociation constant, the sugar concentration cannot influence resistance. In intermediate cases, it does.

Another manifestation I ascribe to sugar, is the susceptibility to rust of the soft tissues of wheat enclosed by the leaf sheaths. These tissues are high in sugar, and even in field resistant cultivars, can be infected if the leaf sheaths are removed. In the field these susceptible tissues are protected from spores by the enveloping sheath, so the resistance is not apparent.

Feeding the Pathogen

Susceptibility means that the host feeds the pathogen. As we see it (in gene-for-gene systems), protein polymerisation is the means the pathogen uses to extract protein from the host. The phenomenon of autoregulation is now widely discussed in molecular biology. It is a system of feedback inhibition: The primary coded protein represses the gene that codes it, and so prevents more protein being produced. Polymerisation, as we see it, is the means by which the pathogen makes the host continue to produce the relevant protein: As fast as the host produces the protein, it is removed as a polymer and hence takes no part in feedback inhibition.

Here we see the difference between how animals use protein-protein recognition and how plant pathogens use it in a gene-for-gene system. Animals make protein antibodies to immobilise the pathogens. Plant pathogens make the host produce "antibodies", which they eat.

Biotrophy and Necrotrophy

All the gene-for-gene pathogens are biotrophic for at least part of the time. They start biotrophic even when they end necrotrophic. Often, in fungus disease, the biotrophic phase lasts long. E.g. in wheat, *P. recondita* continues to produce spores for a week or more, without killing the host cells it has invaded.

In biotrophy, all the indications are that the pathogen gets its protein as protein, not as amino acids. Swollen nucleoli and increased RNA point that way. The problem then is how the pathogen can extract protein without damaging the host. Extraction by polymerisation is the obvious answer.

In necrotrophy, the pathogen excretes protein-digesting enzymes. These inevitably destroy the nucleus and cytoplasm of the host cell. Hence the necrotrophy.

In summary, we see the differences between biotrophy and necrotrophy as the difference between protein polymerisation, which decatalyses the protein, and protein hydrolysis, which catalytically destroys the cytoplasm.

At a guess, the host proteins that the fungus extracts by polymerisation in biotrophy are wound proteins, possibly peroxidases. There is circumstantial evidence about this. In addition, wound proteins are not normal constituents of the healthy cell. Their production can be turned on, by interfering with autoregulation, and then removed as polymers, without depriving the cell of its normal constituents.

As another guess, the host proteins that the virus uses are RNA replicases.

Common Antigenic Surfaces of Host and Pathogen

Doubly *et al* (1960) extracted globular proteins from spores of *Melampsora lini* and from plants of flax (*Linum*). From these proteins they prepared antisera in rabbits. The proteins from fungus and from flax were found to share antigens when the rust race and the flax variety were compatible (i.e. when the flax variety was susceptible), but not when they were incompatible. This work has been confirmed, and similar results have been found with other host-pathogen combinations, especially by de Vay and his colleagues.

At first sight, these results seem to contradict the hypothesis of protein polymerisation. Polymerisation demands complementary surfaces; common antigen surfaces are identical surfaces; and identical surfaces ae unlikely to be complementary. But the contradiction is only superficial. Most polymerisation involves both complementary surfaces and similar surfaces. Consider the simplest case of a head-to-tail polymer, as in flagellin, the protein polymer that makes flagella. There is complementarity between head and tail. But there is also similarity between head and head, and between tail and tail. This combination of complementarity and similarity can be expected in all polymers greater than dimers.

Granted then that the polymers are more than dimers, common antigenic surfaces become just a corollary of the protein polymerisation hypothesis.

The theory of common antigenic surfaces discussed in the literature is the mimicry theory. The closer the surface of the parasite mimics the surface of the host, the less likely the host is to detect it as foreign and initiate defence mechanisms against it. This is all very well for parasites of animals which have active defence mechanisms. But mimicry makes no sense for plant parasites, because (on all the evidence) plants have no system of active immunity. The alternative to the mimicry is the protein polymerisation hypothesis, which as we have just seen requires common surfaces, i.e. mimicry, as a corollary.

And protein polymerisation, our hypothesis suggests, is a mechanism of parasite nutrition. In short, we interpret common antigenic surfaces in plant disease as a facet of protein polymerisation which in turn is a mechanism of parasitic feeding.

A final question arises. Why have common antigenic surfaces not been demonstrated more widely? The answer is, I believe, simply in the mechanism. To use the work of Doubly *et al.* on flax rust as an illustration, common antigens were found in the fungus spores and in the flax plant, but only in very small amounts. This seems to fit in with all we know of developmental biology. Genes are normally turned on only when they are needed. On the pathogen's side, the appropriate proteins are unlikely to be turned on in quantity in the spores, but only in the intracellular mycelium and haustoria. And the host proteins they turn on by polymerisation will be turned on only after infection. Common antigens in ungerminated spores and healthy plants cannot therefore be expected to be abundant. The antigenic proteins can only be expected after infection; and the identification of which protein in a diseased plant comes from the host and which from the parasite is technically difficult. Apart from that, the polymers, because they are food, will be consumed almost as soon as they are formed, without building up large concentrations convenient for chemical analysis.

The Hydrophobic Effect

What makes proteins polymerise? In solution in water, the molecules of the monomer are surrounded by water. When these monomers come together as polymers, part of their surface exchanges contact with water for contact with another protein. That is, in polymerisation a protein-water surface is exchanged for a protein-protein surface. The protein surface prefers contact with protein rather than with water. Hence, the term hydrophobic effect. Protein polymerisation is the result of a hydrophobic effect.

Protein polymerisation occurs because there are at the surface of the monomer amino acids with hydrophobic side chains. (These amino acids are alanine, phenylalanine, leucine, isoleucine, methionine, valine, proline, tyrosine and tryptophan). Polymerisation does not occur when the amino acids at the surface are predominantly those with hydrophilic side chains. (These are side chains containing OH, SH, NH_2, and COOH groups).

On the hypothesis of susceptibility through protein polymerisation, one need only assume that mutation from susceptibility to resistance in the host involves a change from an amino acid with a hydrophobic side chain to one with a hydrophilic side chain. Correspondingly, mutation in the pathogen from avirulence to virulence involves a change from a hydrophilic side chain to a hydrophobic side chain.

A Hypothesis of Vertical and Horizontal Resistance

The primary coded protein which is an enzyme or sub-unit of an enzyme can react in one of two ways. It can polymerise (given the necessary hydrophobicity), it can catalyse (given the necessary substrate), or it can do both, when the catalyst is itself a polymer.

Vertical resistance or susceptibility is determined by polymerisation. Horizontal resistance or susceptibility is determined by catalysis or the products of catalysis.

The hypothesis fits the facts. But I do not want to go into detail, except to follow up the matter of amino acid change. Mutation from avirulence to virulence in the pathogen involves a change from a hydrophilic to a hydrophobic side chain. Mutation from susceptibility to resistance in the host involves a change from a hydrophobic to a hydrophilic side chain. The mutations in opposite directions are of exactly the same kind: a change or an amino acid side chain. What the host can do, the pathogen can do, by a counter mutation. Herein lies the instability of vertical resistance: The pathogen can make a matching change to beat the host, by exactly the same mechanism as the host uses trying to beat the pathogen through resistance.

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4.0 Reflections by Selected Plant Pathologists

4.1 CHRIS RABIE

The founding of the Society for Microbiology and Plant Pathology in 1963 was preceded by the actions of an *ad hoc* committee at the University of Pretoria during 1962. This committee was initially formed by PM le Roux, CJ Rabie, PM Lategan, JJ du Toit and PL Steyn (who was co-opted later in 1962).

The aim was to provide a body that would liaise with scientific societies both locally and in other countries; invite overseas specialists to visit and thus be available to people locally; help in setting training standards; co-ordinate research projects; have an input in establishing and promoting local scientific journals; and to promote plant pathology and microbiology in general. Over the years, many people played a part in the promotion and development of our society, and I will refrain from mentioning names, as inevitably someone will be left out. Names of people will only be used where absolutely necessary for historical purposes.

At the start, we had three problems to overcome:

- Firstly, to convince the authorities that we had the members to sustain a society over the long run (there were approximately 80 plant pathologists and microbiologists in the employment of the Department of Agriculture and at University faculties). It must be remembered that at the time the agricultural faculties formed part of the Department of Agriculture and were funded and administered by the Department of Agriculture.
- Secondly, to get permission from the Department of Agriculture for personnel to take time off to attend congresses. The Department was bound by the rules of the civil service, and this created problems as far as transport, subsistence, travel and such matters were concerned. Travel was by train and could for instance add four days to attend a three day congress.
- Thirdly, we needed to secure funding for postage, writing materials, telegrams, telephone calls, etc.

Fortunately, the Chief Director of Agricultural Technical Services at the time was SJ du Plessis, a former head of the Department of Plant Pathology at Stellenbosch University. He was sympathetic to our cause and he eventually gave permission that two people from each of the five agricultural regions and two from each of the seven institutes could attend the annual meetings at state cost. (We made him our first honorary vice-president.) Some of the conditions imposed included that both the directors of regions, as well as the deans of faculties had to approve papers of delegates chosen by them to attend. Travel was by train and only second-class fares were paid according to civil service regulations.

In order to attain convincing numbers to assure a viable society, we not only contacted scientists in the Department of Agriculture and at university faculties, but also approached institutes such as the faculty and research institute at Onderstepoort, the Institute of Virology, the Bureau of Standards, the CSIR, medical schools of Pretoria and Witwatersrand universities, the Chamber of Mines, mycologists in botany departments at universities, plant pathologists working for private firms in the crop protection industry, and nematologists and protozoologists at universities. During the first 10-15 years, many individuals at the medical schools and Onderstepoort Veterinary School supported us and regularly contributed at our congresses, and they were of great help in getting our society started.

Our financial problems were overcome by obtaining sponsors from the pharmaceutical, fertilizer and crop protection companies. If not for their contributions, we would have had a tougher time getting started. Sponsors were co-opted as associate members and formed an integral part of our society. Unfortunately, the names of these various companies and firms changed over time, due to amalgamations, take-overs etc., and it is impossible to name and thank them all.

The *ad hoc* committee, formed in early 1962, organised the first congress which was held in Pretoria in October 1962 with 72 attending participants. This first congress was thus held before the society existed (the *ad hoc* committee had appointed themselves and no constitution existed at the time of the meeting in 1962). At a general meeting at the end of the 1962 congress, the meeting decided that the same committee should organise a congress in 1963 and that a preliminary constitution should be drawn up and presented at this second meeting. The first constitution was adopted at the second congress was held in Pretoria during October 1963.

The society rapidly grew in numbers during the next 10-15 years, but it became apparent that the society was too diverse in nature and gradually scientists in the fields of nematology, protozoology and the medical fields drifted away, finding niches in other societies more suitable to their needs. This was a natural phenomenon and culminated in people in the field of microbiology forming their own society in 1981. This resulted in the Plant Pathology Society being reborn in 1982 with a membership of 212 growing to 263 in 1986. I am sure that in true Darwinian style, our society will continue to adapt and change again in future.

The composition of the membership of the society has also changed over the years. At the start the society was dominated by men, and the first woman (Helen Garnett from the University of the Witwatersrand) was only elected in 1984 as president of the society. Plant pathology gradually became more attractive as a career for women and in 1989, the male-to-female ratio of members was approximately 50:50.

In 1972, political problems emerged after we started reaching out to colleagues in neighbouring countries. This came to a head in 1972, when we started planning to hold our congress in Salisbury (now Harare), Rhodesia (now Zimbabwe). A proposal to change our constitution to allow people of all races and nationalities to become members was accepted by the national assembly with only one vote against. The negative vote was by a well-respected professor who was probably confused by the ballot form.

In 1965, when RKS Woods of the Imperial College in London contacted us regarding the organisation of the first International Congress in Plant Pathology in 1966, we were able to supply a complete list of plant pathologists with their affiliations and addresses. We were one of only a few commonwealth countries and the only one in Africa who had an active plant pathology society going at the time.

The format and contents of the presentations at congresses also changed over time, reflecting tendencies overseas. Poster presentations were first used in 1979 and these were an immediate success. Presentations on mycotoxins, biotechnology and molecular aspects also became more frequent.

In 1963, we asked Ethel Doidge to become an honorary member of our society. For reasons that she did not disclose, she declined this invitation. In 1964, Ethel Doidge was convinced to become a member, but six weeks later she resigned again, stating that she had lost contact with the discipline and felt that she could no longer make a contribution.

Looking at the membership lists over the years, it is disconcerting to see how many of the younger members leave the discipline. Many of these people leave to retrain and follow a career in other fields. The reason why they studied plant pathology in the first place is unclear.

Another interesting observation when looking at titles of research papers presented at congresses over the years, is than many problems seem to remain unsolved after 50 years. Are they unsolvable or are we keeping them alive?

The society did not only keep itself busy with serious and stodgy matters; many funny things also occurred over the years. One of the funniest titles of a paper at a congress was probably that by a professor who worked on bacteria in sewerage ponds: “To P or not to P?” Another incident was that of a member who sent a telegram to the organising committee two months prior to the 1979 congress: “Please change the date of the congress so that I can attend.” A prominent member spent a lot of time and effort to produce a lengthy memorandum on graduate training at South African universities. The following gem occurs in this epistle: “In many cases, both student and lecturer do not understand the research problem sufficiently”.

In the 1970s, I was tasked to determine to which race group the name sake of our most prestigious award, Jan Hendrik Persoon, belonged. This involved not only going to the national archives in Cape Town, but also to archives of the Dutch Reformed Church. I was not only able to confirm what was generally known about Persoon, but also discovered some juicy details about my own clan.

Looking back, it seems as if things were cheap when we started off. For instance, at the first social event held at Stellenbosch in 1964, a total of 82 people attended the braai, and the total cost came to R54.00, i.e. R0.64 per person. During the meeting in Pietermaritzburg in 1967, one could stay at the Hilton Hotel (bed and breakfast) for R3.50. By 1986, prices had soared and the committee paid R95.00 for the two sheep for the braai. The annual membership fees of the society were two shillings and six pence in 1963, rising to R1.00 in 1966 and to R20.00 in 1983.

What does the future hold for plant pathology in South Africa? Most progress in the past 50 years seemed to have occurred in the fields of resistance breeding/biotechnology and in the field of chemical control. Should our syllabuses at universities then place more emphasis on these areas and where does it leave classical plant pathology?

With big increases in student members and rapidly-escalating costs of training, it will become imperative that we rethink the structures of our universities. One possibility is that undergraduate training be done by selected lecturers, and these lectures could then be transmitted to other centres. This would eliminate a lot of duplication and would allow more time and money for university personnel to concentrate on graduate students and research. It will perhaps be prudent to allow time during congresses to discuss matters such as these. In this way, everybody, from students to the clients of plant pathologists, could be involved to determine what the real needs of the industry are in this regard.

4.2 JOHN MILDENHALL

When tasked with writing a history of the SASPP, one's mind recollects the people, places and events that characterised one's association with the society over a 40-year period. In hindsight, it is also important to document what contribution one has made to the well-being of the society. A society functions because of the input from its members. Regretfully, there are occasions where conflicts have arisen between members, and which have led to resignations from the society.

My own association with the SASPP goes back 45 years to 1966 when I presented a paper at the January meeting held at the University of Natal, Pietermaritzburg. There were about 70 delegates and I felt very nervous addressing senior people, many of whom had been overseas and had an in-depth knowledge of plant pathology. At that time, SASPP was an umbrella organisation for a number of disciplines and the name was the South African Society for Plant Pathology and Microbiology (SASPPM). In addition to these disciplines, there were parasitologists and nematologists in attendance. Indeed, the keynote speaker that year was Ebson-Dew and his talk was entitled "Temper in excreta" when he presented his work on amoebic dysentery in Natal. In 1966, a second keynote address was by J de Ley (Ghent University, Belgium).

In September 1967, I departed for the United States to enrol for PhD studies at the University of Wisconsin. This institution trained a fair number of our scientists in plant pathology, genetics, biochemistry and microbiology. Upon my return to South Africa in 1971, I accepted a position at the University of Fort Hare, where I remained for the next 29 years. Before the era of computers, communication was by mail and telephone. Fort Hare was a lonely outpost in the Eastern Cape. No other university in the Eastern Cape had a plant pathology department and the nearest related discipline was the microbiology department at Rhodes University, some 110km away. At that time, membership of the SASPPM was of great benefit since the annual meetings afforded the opportunity to become acquainted with the work of fellow plant pathologists. It was at these annual meetings where events took place of which the memory remains rivetted in one's mind. At one meeting a professor gave a paper on a topic that he had presented for the two previous years. At question time a professor in the audience stood up and told the speaker to refrain from presenting this information again. There was a silence in the auditorium and no further questions were asked.

During the 1970s the funds of the SASPPM were relatively limited, and most of the keynote speakers were local academics, or they were foreign academics working on research projects in South Africa. Furthermore, South Africa was becoming more and more politically isolated during the 1970s and 1980s and several prominent overseas academics refused to visit South Africa on political grounds.

During the late 1970s, turmoil occurred when a number of microbiologists opted to form their own society for microbiology. Given the relatively small size of the SASPPM, it seemed strange that the microbiologists wanted to opt out. As a plant pathologist, I enjoyed presentations on basic bacteriology and general virology, even if they had no connection with plant diseases. At the meeting of January 1980, held at the campus of the University of the Orange Free State, the president of the SASPPM declared that the society would split into plant pathology and microbiology, respectively. Initially, there was concern whether plant pathology had sufficient membership to maintain a viable organisation. As time has shown, the SASPP continued to flourish as a vibrant and energetic society. Agriculture had also undergone a significant change with the introduction of novel irrigation systems, notably drip and microjet. These systems significantly improved yields, but they also created problems of a pathological nature, especially root diseases. The failure of organo-phosphate insecticides to control insects due to resistance created major challenges to crop production until a new generation of chemicals was available. The need for scientific expertise to address the problems in agriculture stimulated the growth of plant pathology.

Having separated from microbiology, the fledgling

SASPP was able to devote the annual congresses to topics pertaining solely to plant pathology. Therefore, I suggested to the SASPP committee that we invite speakers from the University of Wisconsin. In 1981, Arthur Kelman presented the keynote address, followed by Paul Williams, my major professor, in 1983 and D Hagedorn in 1986. Noel Keen, a former fellow student of mine at the University of Wisconsin, presented the keynote address in 1992. He was a faculty member of the Department of Plant Pathology at the University of California, Riverside.

Apart from the business/academic side of SASPP meetings, there were other activities associated with the congress that are worthy of mention. The midnight swimming club is an anonymous, informal *ad hoc* gathering of plant pathologists at the meetings. There was no agenda nor time for the meeting. My first exposure to the midnight swimming club was at the SASPPM meeting held at Rhodes University in 1976. After the gala dinner, I was retiring to my room at about 11pm, when I noticed a group of people moving in the direction of the university swimming pool. I decided to follow them, and to my surprise there was a fair number of delegates enjoying a swim. At the 1983 congress, held at the Wilderness, the aquatic plant pathologists descended the stairway down to the beach and headed into the sea with gay abandon for the threat of shark attack. There is a greater likelihood of shark attack at night, because these animals move close inshore to feed. The sea was delightfully warm (about 22°C), and it was a memorable sight to see a group of plant pathologists body surfing at midnight. The other notable gathering of the midnight swimming club was at the Cintsa congress held in 1992. The resort has a concrete tidal pool that excludes the possibility of shark attack. Since I had organised that congress, I was overcome with exhaustion and at midnight I was in dreamland. This congress was held in a tent, probably the first and last ever to be held in such a venue.

The other event that has become a regular feature of the meetings is the “Mildenhall Stakes”. It is worth recounting the origin of this “species”. The challenge of the stakes is to place a bottle of beer upon the forehead in standing position, then lower the body down on to the ground, roll backwards and grip the bottle with knees or lower legs and place it behind the head on the ground. Then turn around and drink the beer down without touching the bottle with one’s hands. The person who does this trick the fastest, is the winner. There is also the proviso of minimum spillage of beer. Where did I first see this trick? In 1964, when I was an undergraduate at the University of Natal, I returned home in November for the Christmas vacation. A local farmer, Ernest de Villiers, who had seen this trick while on a cricket tour in Rhodesia, was demonstrating this act in a bar at my hometown, Fort Beaufort. Having caught my attention, I decided to practice the trick until attaining perfection. When I enrolled at the University of Wisconsin in 1967, I joined the UW rugby club, and by doing this trick in bars after rugby matches, I earned free drinks from the opposing team. Upon my return to South Africa in 1971, I used to do it for fun at the congress, in the evening after the barbeque (but before the swimming club meeting). Other plant pathologists soon took up the challenge, and within a few years my colleagues were able to do it faster than I could. Notable, one female student at the Golden Gate congress in 1985 drank the beer from standing up in 19 seconds. Formidable!

The most bizarre challenge for the beer trick was at a congress held at the Hogsback, when an academic from overseas challenged a local plant pathologist. It was held outside in drizzle in semi-darkness. The contestants were clad only in their underwear! The other memorable event that occurred at the Hogsback congress was the intoxication of an African grey parrot in the cage at the bar. A certain delegate fed the parrot with an alcohol-laced drink and suddenly the bird fell off the perch. The owner of the hotel (and the parrot) was furious. He called me to one side and said that he did not want plant pathologists at his hotel ever again!

Having organised two congresses for SASPP at Hogsback in 1991, I offered to organize the 1992 congress at Cintsa resort, 25km northeast of East London. The SASPP committee accepted my offer, however, upon inspecting the resort, I subsequently discovered that there was no auditorium for presentation of papers. I was truly in a fix and cost-wise I was not able to find alternative accommodation at the price quoted at Cintsa resort. As time went by, I became more and more agitated. I racked my brains for a solution to the dilemma. Moreover, I had invited Noel Keen from the University of California, Riverside to be the keynote speaker. A suitable auditorium had to be found. After attending a wedding reception in a marquee, I decided this was the only solution. I contacted a marquee tent rental company and arranged to hire one for a week. Two days before the congress began, we erected it at Cintsa. Then I realised I needed an elevated platform for the speaker and a microphone system! The marquee had to be darkened for showing slides. The platform was made from packing crates, and bales of hay were used for steps. This was much to the consternation of the delegates in high heels. Darkening the marquee was achieved by making a structural framework using aluminium irrigation pipes and draping black plastic sheeting over the frame. Cooling the marquee was achieved by a series of strategically-placed fans. Believe it or not, nothing failed, and all the presentations went smoothly.

4.3 FRITS RIJKENBERG

This book is replete with the great story of almost 60 years of contributions by magnificent men and women, and this is what a book such as this should be about. We need to salute them and express our unbounded appreciation, admiration and gratitude for their wonderful legacy. While the uplifting lives and achievements of several of our eminent societal forebears and colleagues have been sketched in these pages, I thought that, rather than contributing along similar lines, I would present some early glitches I had with the discipline. The brief reminiscences that follow are just presented to indicate that the pursuit of plant pathology is not always plain sailing, and perhaps you can learn some lessons from them. I wistfully smile as I remember!

In 1964, my fourth and final BSc (Agric) year, Susarah Truter gave this keen budding scientist the task of isolating the causal organism of strawberry leaf spot, and having isolated it, she wanted me to fulfil Koch's Postulates. Everyone knew (including Susarah Truter, who had taught me this in her lectures) that the causal organism of strawberry leaf spot is the fungus *Ramularia tulasnei*. So, excitedly, I started my first assignment of applied coursework! Using PDA as a growth medium, and, when one in nine Jik (sodium hypochlorite) did not seem to work as a surface-sterilant, moving to diluted ethanol, I tried my hand at isolating. And I isolated and re-isolated, but instead of producing petri dishes full of fluffy *Ramularia* conidiophores, the mycelium that issued from the leaf spots was appressed and had black pycnidia. Susarah Truter and I knew this to be very wrong, probably ascribable to the shoddiness of my isolating procedures, or to the relatively advanced level of necrosis of the leaf spots I was isolating from. So I started afresh, meticulously, with younger spots. But always the same result. I knew I was doing something very wrong, but, as an inexperienced undergraduate, I was not able to solve my predicament and was kicking myself for being very stupid. Perhaps I wasn't cut out for this damn profession after all…?

By absolute serendipity I was in the library, paging through an issue of *Canadian Journal of Botany*, when my eyes caught an article by a Joan Fall on a strawberry leaf spot in Canada, caused not by *Mycosphaerella fragariae* / *Ramularia tulasnei,* but by a member of the Sphaeropsidales, a pycnidium-producing *Dendrophoma obscurans.* Suddenly a panoply of lights came on, my conundrum was solved. And thus, one of my first lessons that I really took to heart at that early stage in my career development as a plant pathologist, was: "Believe in yourself"!

The story did not end there. A well-known British mycologist, Brian Sutton, almost at the same time, published an article averring that *Dendrophoma obscurans* should in fact be renamed *Phomopsis.* In my inexperience, I now committed my second mistake. I was naively furious: how could someone take the fungus to which by now I had become quite attached, and rename it? I had seen *Phomopsis* spp. in culture, and they were white and fluffy, nothing like the appressed growth of this fungus. Please be understanding and remember I was still an undergraduate. Indignantly I hand-wrote (as there were no computers then, and fourth-year students certainly had no access to the regional typist pool!) a letter to the editor of *Taxon*, giving what I later learned to be taxonomically absurdly inept reasons for asking how someone could just willy-nilly decide to rename a fungus? And I hoped that someone as experienced as the editor of *Taxon* would help me understand, and perhaps might even reprimand this fly-by-night mycologist, who had the temerity to rename 'my' fungus. The editor of *Taxon,* however, had other ideas, and took my hand-penned missive and published it in *Taxon* as a "Letter to the editor"! So my first publication became my hand-written letter, with its ingenuous content, to *Taxon*. Till the end of time, it will remain in print for all and sundry to smile and shake their heads over!

Years later, visiting Kew, my friend Derek Reid introduced me to the famous Sphaeropsidales taxonomist, Dr Brian Sutton. Ouch! I looked at him rather sheepishly and said, "So you are that Sutton?". He didn't bat an eyelid and countered with, "So you are that Rijkenberg?".

And one thinks: early lessons might have sufficed? Forget it. For my Masters, I conducted an ultrastructural study of the poplar rust. I was proud of what was then, in the early days of electron microscopy, pretty good work, even if I say so myself. I looked in *Bothalia V* (the mycological bible, which, in those days, all Susarah Truter's students had to purchase), and saw that only one poplar rust had been recorded in South Africa: *Melampsora aecidioides.* So, with utter belief in Ethel Doidge, it was completely obvious to me that this had to be the fungus I was working on! I submitted my Master's thesis under the title "A study on rust parasitism", and the binomial I used throughout was *Melampsora aecidioides.*

I then submitted my very first conference paper to our conference organisers under that binomial, and was very pleased that it was accepted. When I arrived at the venue and received the conference programme, I saw that, immediately before my paper, was a contribution by a GCA van der Westhuizen, at that stage entirely unknown to me, entitled; "A new poplar rust in South Africa, *Melampsora larici-populina".* My heart sank, surely it couldn't be…? Surely not! During Van der Westhuizen's presentation I saw immediately that indeed I was in trouble; I had taken *Bothalia V* as gospel without bothering to confirm the identity of the fungus I had worked on. Those of you in the know realise only too well how many enormous butterflies were fluttering in me anyway for having to present my first conference paper, and here I had to start by saying that the title and rust of my first presentation ever, was wrong, that I had in fact worked on *M. larici-populina*! I will never forget my first conference presentation! My supervisor, who obviously did shoulder a small amount of blame for such a basic flaw made by a relative novice (supervisors take note!) confided in me much later that this *faux pas* had cost me my *Cum Laude*. So, the next lesson in my budding phytopathological career was: Check and re-check, and even check the "obvious".

Just as well that later there were also one or two success stories, to take some of the sting out of the foregoing, but I won't bore you with those.

I thought I should pen these lessons down for aspirant plant pathologists. Be confident in yourself, but not overconfident! And if mistakes are made (and you will make them), smile; you are usually in good company, because your supervisors will have made them too, and most errors can be corrected. Even if they were to cost you a distinction!

There is one other valuable lesson I have always passed on to my students. Fortunately, this true story is one that does not involve me, but it bears relating in the above context. It is the story of an excellent young plant pathologist, who shall remain unnamed, in another country, which shall also not be specified. Years after the event I will describe in the next paragraph, I arrived in that country, and asked after him, because his publications had impressed me greatly. And then I was told his story.

He had attended a conference and had presented two excellent papers. That night (celebrating?) at the formal conference dinner, he had imbibed entirely too much, and made a complete ass of himself. Friends and other congress-goers, who had included several eminent plant pathologists, had eventually managed to get him to bed. And here comes the lesson: I was told by several people that he had in consequence never been able to find good employment; his behaviour that one night had ruined his reputation for life.

The moral of that story is clear: one silly thoughtless mistake can be exceedingly costly!

This is as good a place and time as any to conclude these meanderings of an old plant pathologist.

Derive as much fun and satisfaction as you can from working in one of the finest professions this world has to offer. And all blessings on your endeavours and your future!

4.4 MIKE WINGFIELD

My first memory of the SASPP dates back to my BSc Honours year (1977) in Pietermaritzburg. My professor, Frits Rijkenberg, persuaded me that I should submit an abstract for a presentation at the January 1978 meeting of the South African Society for Plant Pathology and Microbiology (SASPPM) to be held in Stellenbosch. My honours project had been on peanut diseases, and I had produced an electron microscopic study on the infection biology of rust and "cercospora" leaf spot. It happened that I had co-incidentally been posted to the plant quarantine station (then under the management of the Department of Agriculture) as my first formal employment. I was to start working in Stellenbosch in January 1978, and thus just in time to attend the SASPPM meeting held there. I clearly remember almost missing my talk due to having just arrived in Stellenbosch, and not knowing how to find the meeting venue. I must have looked very stupid running into the lecture room in the "Neelsie" just in time. I don't remember much about that meeting, other than being very inexperienced, nervous and intrigued by the title of Jennifer Thompson's talk that included the words "jumping genes". Jenny was one of South Africa's first leading molecular biologists, in the days when Dave Woods was a leading figure in that rapidly emerging field.

I attended all of the subsequent meetings up to and including 1980, when I left for the USA to undertake a PhD at the University of Minnesota. I have special memories of the meeting in 1979 held at the University of Natal (Durban Westville). I learned an important lesson at that meeting. Drink alcohol with great circumspection the night before one has to stand up and talk. The gala dinner was held the night before my presentation; the first in the morning of the final congress day. I remember the party, a lot of wine and some strong curry. James Vanderplank was awarded the first ever Christiaan Hendrik Persoon Gold Medal. I believe that my talk, one of the first ever in South Africa dealing with tree diseases, was fine. But I felt terrible!

The 1980 meeting was held in Bloemfontein. This was the only meeting that I have attended where beer was on-tap continuously. Piet Lategan, a visionary microbiologist, had established an impressive team working on *Saccharomyces cerevisae* and particularly, on fermentation biology. They had good funding from the South African Breweries, and this accounted for the copious supply of beer. But a more important element of that meeting was the decision of the microbiologists to split off from the plant pathologists. I remember the AGM well. It was a meeting full of acrimony and anger. Some microbiologists felt that their work was incompatible with the (in my view perceived) more practical "bucket and spade science" of the plant pathologists. As a young scientist, I remember feeling dismayed at the behaviour of people that I considered to be great leaders. I will not digress into sharing my views regarding the splitting of the two societies, but it was interesting to me that for many years, the new South African Society for Microbiology (SASM) was less well supported than the SASPP. And, ironically, some years later, as a plant pathologist, I joined the faculty of the Department of Microbiology at the University of the Orange Free State. I was then able to benefit from the commonalities between microbiology and plant pathology and particularly to integrate molecular genetic techniques into my work and that of my students. I still believe that the two societies belong together, or at least that they should hold regular meetings together.

I returned to South Africa to my position with the Plant Protection Research Institute (PPRI) in Stellenbosch in early 1984, having completed a plant pathology PhD in Minnesota. I had kept track of the SASPP meetings (1981-1983) from a distance, with regular news from my close friend and mentor, Wally Marasas. I remember some interesting stories, the most controversial was of the meeting held at Wilderness (not sure of the year) and the gala dinner "toga party". I will not report here on the stories told to me, as they were probably somewhat exaggerated (or perhaps even fictitious!). Suffice to say that the rumour mill went wild, and I believe that after that event, some members changed their behaviour patterns totally.

My first SASPP meeting after returning to South Africa was at the Golden Gate National Park. I was not at all keen to attend. I had perhaps been spoiled by the large APS meetings that I could attend in the USA. I remember my wife, Brenda, scolding me, and impressing on me how important it was to engage with local plant pathologists and to provide mentorship for the younger generation. She was perfectly correct, and I was glad that she pushed me to attend. I learned a lot, established new collaborations, and made many new friends. Perhaps most importantly, I resolved to make a serious effort to attend all future meetings of the society.

There are interesting stories to be told about every meeting of the SASPP. It is a relatively small society, and this means that attendees are deeply engaged with each other; there are few secrets. I will not attempt to tell too many of these stories, but let me share a few of them. One of the meetings that stands out in my memory, is that held in 1985 at Hogsback. This was the meeting where I first met Teresa Coutinho, Terry Aveling and Cheryl Crookes, who had just completed their BSc Honours degrees with Frits Rijkenberg in Pietermaritzburg. I remember meeting them one early morning, sitting on a bench together, enjoying the sun. The prior evening, a number of us, including Ed Rybicki and Ferdi van Zyl, were part of a group that had been drinking in the bar. A bar that had a tank of fish and a parrot (living) on a perch. One member of the group (could it have been Ferdi?) questioned whether some alcohol might make the fish swim upside down. All I remember after that is the hotel owner having a fit and sending us off to bed. I shared a room with Ferdi; He has a story about my swallowing an effervescent vitamin pill and producing orange foam from my mouth. I am not sure that I ever believed him. But I do recall a team of us going out in search of Jim Deacon, a visiting British plant pathologist, who had disappeared into the night and not returned in the morning.

I believe that it was also at the Hogsback conference where Wally Marasas presented a plenary lecture on some of his ground-breaking mycotoxin research. Wally was a wonderful and very perfectionistic scientist. He did not suffer fools lightly. In his talk, he referred to the association of some mycotoxigenic fungi with the grasses, for which he used the generic term, *Gramineae*. When question time came, a hand went up in the audience and a shrill comment was made, "it is not the *Gramineae* but the *Poaceae*". As an exceptional botanist, Wally was of course well aware of the current taxonomy of the grasses, and he did not need to be corrected in such a way. I don't think I have ever seen a colleague so mad. I was sure that he was going to jump from the stage and throttle the person involved. His face went blood red. And then he seemed to calm and quietly left the stage without answering further questions.

I am inclined to bet that our meeting held in Cintsa (1992) is amongst those best remembered by South African plant pathologists of the time. This meeting was organized by John Mildenhall, who lived in the area and had not been able to raise much sponsorship for the gathering. I remember arriving at the congress site, a campground in Cintsa, together with Noel Keen and his wife Di, who had flown in from the USA as our guest speaker. I am sure that I had played-up (perhaps exaggerated!) the successes of our meetings as we drove to Cintsa. I was shocked to see that a circus tent had been erected at the campground in which we were to meet. John had erected a stage fabricated from citrus packing cases (at the time he was a part-time citrus farmer) and the loudspeaker was one that I believe was used at horse gymkhanas. At the start of the meeting, it was realized that the tent was not dark enough to show slides, so black plastic sheeting was sourced to line the walls. It was without doubt the craziest, but most amazing meeting that I have ever attended. At times the wind howled from the adjacent sea, and we wondered whether the tent would survive for the duration of the meeting. Yet attendees rapidly absorbed the rather different atmosphere, laughed at the shortcomings, gasped when a gust of wind passed and revelled in some great science.

I had the honour of becoming the president of the society in 1992. This was some years after I had moved to the University of the Free State. In those days, the presidential term continued for three years. This was a fun time, and I learned a great deal about leading a significant society. And the experience in diplomacy and managing board and other meetings provided me with some most useful skills as my career advanced. The last meeting of my presidential term was held at Club Mykonos in 1993 - another toga party! And the meeting where dear Peter Knox-Davies (my MSc advisor and early mentor) received honorary membership. We perhaps did not know it at the time, but Knox was already suffering from memory loss. He really battled to make his acceptance speech. It was hard to watch this and very sad. Many years passed, and I was excited to return to that venue in 2019. Nothing much had changed, yet it was very different - perhaps more formal, and of course I was much older and less engaged in some of the frolics of the younger members.

An important structural issue that I have battled with during my long association with the SASPP has been the periodicity of our meetings. It is well recorded that I have been a vocal advocate of the view that we should meet annually. Most of my mentors, members of the 'old guard' that I respected and admired, including Wally Marasas, Ben Strydom, Chris Rabie, and John Mildenhall felt very strongly that our society should meet annually. Their view was that South Africa is a large country with a relatively small plant pathology community that depends on regular, in- person, meetings. I promoted this argument during my term as SASPP president, and was sorry to see a motion pass to hold meetings only every second year in 2007. This is not to say that I don't understand the counter arguments, such as the cost of more regular meetings, and that our members might like to attend meetings of other societies in alternate years. I must also admit that there is no clear evidence that the SASPP has weakened since our move to meetings every second year. Perhaps the fact that we now have internet, email, websites and many other rapid forms of communication has replaced the need for more regular in-person gatherings.

I often worry that the value of the SASPP is not fully appreciated by some of its members, particularly our younger members. Especially in a country such as South Africa, with a relatively small plant pathology community. It is easily forgotten that structures such as a national society that bind us are incredibly important. There are many elements of this value, not least the fact that the society provides a foundation for newly-emerging plant pathologists in the country to connect with and learn from experienced members. A platform that provides for sharing knowledge of emerging new disease problems and the techniques to deal with these cannot be underestimated. Meetings of this kind bring together plant pathologists from many different areas, those working in industry, employed by statutory organizations, academics and students. Interactions between all of these groups is critically important to the future of the field in our country.

From a personal perspective, and looking back on my 30 years of SASPP membership, it is hard to imagine having achieved my various goals without the society. It has brought me great career opportunities, significant knowledge and, most of all, very special friendships. I know that this is also true for many of my colleagues, as it was for my mentors no longer with us. It is my sincere hope that the younger members of the SASPP will make the effort to promote and grow the society in the future. And in doing so, they will not only grow as plant pathologists and contribute to plant health and food security in South Africa, but also have enormous fun doing so.

4.5 ZAKKIE PRETORIUS

The first congress I attended was a combined SASPPM meeting in Pietermaritzburg in 1981. I recall talks on, for example, mycotoxins, *Agrobacterium*, plant virology, mycology, sugarcane diseases, and *Phytophthora*, all themes that would become synonymous with individuals for many years. As a young plant pathologist, the social side took me by surprise, more so the fact that my university lecturers and other senior members of the society were actually normal people. Peers that I remember from that congress include Sandra Lamprecht, Cobus le Roux, Ferdi van Zyl, Mark Laing and Graham Thompson. I attended most congresses after that, with exotic locations such as Hogsback, Golden Gate, Club Mykonos, Thaba 'Nchu, Berg-en-Dal, Badplaas and Cintsa coming to mind. I tried to support the congresses wherever possible and reported on field crop diseases, mostly the wheat rusts. However, one thing I could never manage was the Mildenhall Stakes beer drinking exercise.

I served the society as a council member (secretary) from 1990-1993, and again as president from 2003-2006. When I read my presidential reports, I cannot help to notice my concerns at the time. Points raised were an over-emphasis on the social side of things, a lack of scientific depth, too few presentations in important sub-disciplines, the absence of industry, and my perception that few studies addressed the solving of real problems (I mentioned *Fusarium graminearum* and *Sclerotinia sclerotiorum*). Several explanations were offered at the time, such as different expectations by different role players, many early to mid-career pathologists leaving research for management or other jobs, a shortage in senior scientists to mentor the new generation, students not seeing plant pathology as a career, the absence of applied research, and the relatively short one-year cycle between congresses. I also pleaded for more resources for diagnostics, extension, training and the agro-chemical industry. The possibility of setting up specialist committees to look after neglected areas within the broad scope of plant health was mentioned, but never happened. Other aspects I touched upon were university curricula and equipping future plant pathologists with the necessary skill sets, integrated disease management and biosecurity.

Personally, I think the biennial meeting has been a huge step forward. The congresses and individual sessions are well attended, the standard of presentations high, and there is ample opportunity for networking. This aspect is very likely the most important outcome of our meetings. The international delegates seem to value the SASPP congress, and the keynote lectures are generally informative. Financially, the two-year cycle is less harsh on budgets, in particular for larger research groups attending and for organising committees. I am not sure that we do enough to sell our science, but believe that controlled social media reports could solve that problem. The digital world is well designed to inform people about the importance of healthy plants and what we as a society are doing about it.

The society is in good hands and will continue to grow and support the stakeholders and industries it serves. The emphasis will undoubtedly be on multidisciplinary approaches to ensure plant health.

4.6 LISE KORSTEN

Plant pathology is a calling that goes beyond microbiology, plant science, host response, disease expression and control. It is a truly complex field of study that requires innovative, adaptive, and integrated thinking. It also requires a broad-based approach; considering the environment, humankind, and socio-economic factors including biotic and abiotic aspects that may influence plant health. The plant remains the epicentre of the universe (at least for me) providing food, feed, and fibre and encapsulates the seed to plate/fibre context, where systems thinking has replaced traditional silo-structured plant pathology. The circular economy captures the current state of thinking and provides a critical niche for plant pathologists. We can actively engage and shape the future, or remain captured in the past and narrow purist thinking. The future of science will be shaped by the footprints of the past, and we will all be required to influence the public and private discourse and actively engage at a community level, to contribute to a new, post-COVID-19 world and to make it a better place for all. Our collective social responsibility will squarely lie on the shoulders of the next generation of plant pathologists and how they can address the United Nations Sustainable Development Goals in their projects and daily lives.

Let us never forget that 2020, as the United Nations International Year of Plant Health (IYPH), remains a key turning point in the history of our discipline, and has been instrumental in opening up our field of study, taking it beyond obscurity to a global and public level. Sadly, this year has also been "hijacked" by COVID-19. So, the challenge lies in how we still draw enough public attention to this very important field of science, without downplaying the importance and impact of COVID-19. For a start, both the United Nations' IYPH 2020 and the World Health Organization's hot topic, COVID-19, happened in 2020 and afforded the world the opportunity to rethink the way we function, interact and prioritize our work, science, and lives. Plant health thus provides a broader platform for plant pathology to address inequalities of the past, in terms of access to education, obtaining collectively shared research funding and becoming part of broader programs. Plant health should thus be recognized in the broader context of one health, which has until now been the exclusive domain of human health and animal health. The realities of climate change also force us to re-think the inevitable link with environmental health.

How do all of these global challenges affect us in Africa, and, more specifically, southern Africa? How can we as plant pathologists make a difference and help shape the future? I believe reflecting on the past, understanding the drivers that shaped us, recognising the ones who walked the path before us and identifying our strengths and failures can help us shape a better future. The footprints of the past provide a roadmap for the future. I will therefore briefly reflect on my personal journey as previous president of the society (1996-2000) and highlight some of the lessons learned and mistakes made. It is said that "standing on the shoulders of giants" helps pivot us into the future, and we, therefore, need to give due recognition to those that came before us and made a difference. My father once said "be a road builder, never only a road user" and that very much summarises my take on life. Make a difference where it matters, be a champion for a cause and, as Louis Nel once said, "choose your battles wisely".

Sometimes, a single word at the right time, can change the course of history or make a difference in someone's life. Standing in a row, having to hold the hand of another first-year student, and, at the time being a bit insecure and not knowing exactly what to study, I asked the question, "What are you going to study?" "Plant pathology" said the young student next to me. My fate was sealed, plant pathology it would be for me too. Thinking back, that was the greatest decision I ever made! I have thus been privileged to have been exposed at the right moment in time to inside knowledge, someone who had an uncle who was a plant pathologist. Today, I am truly proud to call myself a plant pathologist, and can only say "thank you" to that young man with the piercing blue eyes, who later became a good friend (Johan Ferreira) and his uncle (Gustav Holz).

Our lecturers not only shape our thoughts and mould our minds, but they also lay the foundation for our future careers and impart tremendous wisdom that we should nurture with an open mind. Martin Hatting and Peter Knox-Davies clearly made an impact on my life, and so too on many others who studied at Stellenbosch University. Many will remember their facial expressions when they lectured, and their passion for plant pathology that they so willingly shared with us. Martin Hatting could vividly describe how plant pathogenic bacteria invade plants and Peter Knox-Davies dreamingly talked about powdery mildew and the big old oaks in Stellenbosch's Dorp street. Who could ever forget how Peter Knox-Davies walked across the lecture room, while slightly chewing or sucking the one end of his glasses, deep in thought? Many also fondly recall the evening at our Southern African Society for Plant Pathology function, when Peter Knox-Davies, dressed in a white sheet with a thorny crown, received the society's special lifetime award. Perhaps the noisy crowd at the time did not appreciate the significance of the moment, and were already engulfed in the fun of the evening dancing on the tables.

Another, often big, decision many young students have to make, is whether they should switch between universities when doing their postgraduate studies. Moving to another university to do my MSc and

PhD degrees can only be described as enriching and broadened my scope. Experiencing the reclusive, funny, and brilliant classical mycologist, Fritz Wehner and at the same time, the stylish, impressive, and very knowledgeable classical plant pathologist Jan (Ballie) Kotzé, enriched my career journey. Ballie Kotzé became more than a mentor, he became my stepfather and a person I will always deeply respect. Needless to say, I started my career at University of Pretoria and opted for academia, a soft option that affords us the freedom to think, dream, and create without boundaries. But as my father always said, "don't make dreams your master", and sometimes, we need to go out and make a real difference. Some important lessons that I have learned is to never to get involved in office politics, neither burn your bridges and keep your eye on the ball as long as you can, before branching out and moving into a horizontal career path.

Over the years, discipline-specific thinking in plant pathology was concentrated around mycology, phytobacteriology, plant virology, nematology and crop protection, and although several new fields of study closely aligned with plant pathology emerged, i.e. plant microbiomes, food safety agroecology, food security, and molecular biology, our core discipline remains intact. So too will our society, which has gone through difficult times with dwindling membership numbers and the loss of our annual conference, and the closing down of our own journal *African Crop Protection*, which now, in hindsight, should not have been allowed to happen. This is the responsibility of our leaders and people placed in the caretaker position of our society, and jointly our discipline.

Being part of the alumni of Stellenbosch University and the University of Pretoria is a privilege and an opportunity that I would like to explore. We need more active engagement and mentoring support from our alumni and society members to ensure that the next generation of plant pathologists finds their path in an ever-changing world, which will require different sets of tools and skills. I, therefore, encourage all plant pathologists to actively engage and play a more leading role in our society and alumni, particularly in the post-COVID-19 world, where we will need to train more agricultural scientists to ensure that food is available for all. One very unique and important role plant pathologists can play in the future, is to address the historic imbalances of the past. South Africa is a country with immense inequalities and a unique dual economy. We have to acknowledge the mistakes of the past, be sensitive to the needs of all South Africans, and actively engage with each other to make this a better country for all. I challenge each and every plant pathologist to go out and make a difference. The future is in your hands!

4.7 PEDRO CROUS

Although I started my career in forestry, I switched to plant pathology after listening to my first lecture on tree diseases, given by a youngish, enthusiastic Mike Wingfield, who had just graduated his PhD in Minnesota, and was determined to build a forest pathology programme in South Africa. This career switch was easier said than done, as I then had to essentially do all the agricultural courses, since I was in the forestry faculty at the time. I ended up doing a combined honours and MSc degree at the Department of Plant Pathology, at Stellenbosch University. I did this under the guidance of Peter Knox-Davies (the head of department at the time), but spent a lot of time working at the Plant Protection Research Institute (PPRI), in the laboratory of Mike Wingfield. There was no budget for my MSc, which is why I ended up doing mostly microscopy, which became my passion in later life. The first meeting I ever attended was of the Western Cape branch of the SASPP in 1988, where I also joined the SASPP as a member. Because I had a lot of data as an MSc student, I was asked to give a short 10-minute lecture, which was the first scientific lecture of my career (on *Eucalyptus* leaf diseases). Sitting in the front row was Peter Knox-Davies and Walter (Wally) Marasas. I always experienced Marasas as a larger-than-life and rather intimidating figure. Wally Marasas asked me "why do colonies of *Aulographina eucalypti* differ in morphology - could these be more than one species?". I replied that I did not know why they differed (I had observed grey and black colonies), but that they were cultures derived from single ascospores. Knox-Davies mumbled "touché", and that was it. I felt like I had crossed the Rubicon, and there would never be any going back. Regardless of this fact, however, it took me more than 30 years before I resolved the taxonomy of "*Aulographina*", now known to be several species of *Thyrinula*. I still ponder the question and my confident (naïve) reply. In 1990, Mike Wingfield and I named *Mycosphaerella marasasii* after Wally Marasas, which signalled the start of a long friendship and collaboration. Still, it came as quite a surprise when he involved me as co-author on his final book *Philatelic mycology: Families of fungi*, which we published in 2014, shortly after his untimely death.

After completion of my MSc in 1988, I had to do compulsory military service, which saw me having to confine my mycology to weekends studying books in my car, hidden under a tarpaulin in the parking yard of the military base at Kroonstad. After a subsequent stint at PPRI on the experimental farm at Rietondale, Pretoria (representative of the Northern Transvaal branch of the SASPP, 1990-1992), where I did most of my PhD research on *Calonectria* nursery diseases, I was given the option to return to Stellenbosch University as lecturer in 1992, succeeding Peter Knox-Davies at the Department of Plant Pathology (chairman of the Western Cape branch of the SASPP, 1993–1994), with the mandate to develop a programme on diseases of small grain crops in the Western Cape province. However, Knox's love for indigenous crops was something that stayed with me, and eventually led me to spend several years studying diseases of Proteaceae cut flowers, together with Sandra Denman, who focused more on root diseases, and later Cheryl Lennox, who developed a programme on postharvest plant pathology in the department, which was headed by Gustav Holz (host-pathogen interactions) at the time.

I was elected as president for the term 2000-2003 at the SASPP congress in 1999. One of the big contributions we made during this period was that Paul Fourie managed to set up a new "flashy" website for the society. We also worked on a new logo and letterheads (still used to this day). My experience with overseas societies, most notably the Mycological Society of America, led me to conclude that the SASPP needed more awards to recognise the contributions made by its members at various levels. This decision saw the introduction of numerous awards (e.g. Plant Pathology Publicity Award, Applied Plant Pathology Award, and the JE Vanderplank Award, as well as the Vanderplank and Doidge lectures). I fondly remember how several persons questioned if we would ever find worthy members to give lectures linked to these illustrious names!

A personal success for me was to publish the book of Peter Sidney Knox-Davies (*Diseases of plants, their development and control*), and place it on the web, and to also finally complete the *Phytopathogenic fungi of South Africa*, which we could make available as book, and freely as an online version (with acknowledgement to Dave Farr at the USDA, Beltsville) to our members. This book was essentially an update of the Gorter (1977, 1981, 1982, 1993) booklets, or records of plant pathogenic fungi from South Africa. Some of the obscure records from Doidge (1950) were omitted. An interesting anecdote is the fact that I received a small amount of money from the Food and Agriculture Organisation of the United Nations (via Tony Putter) to enable me to print the book. What no-one knew was the fact that I actually did this at the university library, making hundreds of photocopies, and then having them bound as we did for university theses. Conrad Schoch, a talented PhD student at the time (now head mycologist at NCBI), designed the cover, and my technician, Alana den Breeÿen, did most of the typing of the text itself. Alice Baxter and Alan Phillips, my co-authors, corrected most of the typos, while several senior members of the SASPP checked their own literature for potential missing records.

As a student, one was always acutely aware that Peter Knox-Davies spent many days in his office editing papers for the journal *Phytophylactica*. Unfortunately, due to the costs involved, the journal ceased to exist, and eventually became *African Plant Protection*, and is no longer the official journal of the society. Knox spent so many days working on this journal, and now, it is simply a forgotten part of the history of the SASPP. Many members of the SASPP used to publish in *Phytophylactica*, but the timing, funding and technology was simply not right for the journal, leading to its unfortunate early demise.

The year 2005 marked the 100th Anniversary of the National Collection of Fungi (NCF), now part of the Biosystematics Division of the Plant Protection Research Institute, Agricultural Research Council of South Africa. In effect, this was also the 100th anniversary of mycology in southern Africa. The advent of this remarkable milestone in mycology was known to some, but to most it came as a surprise when it was featured in January 2005 at the joint meeting of the SASPP, the African Mycological Association (AMA), and the Pan-African Medical Mycological Society (PAMMS). A special volume of *Studies in Mycology* (*100 Years of Fungal Biodiversity in southern Africa*) was dedicated to the anniversary of mycology in South Africa, containing a set of 20 papers. In addition to these papers, the monumental publication of Ethel Mary Doidge (1950), *The South African Fungi and Lichens to the end of 1945* was also digitized by Karina Crous and placed online (www.wi.knaw.nl/publications/mycoheritage/doidge/index.html).

Unfortunately, this *magnum opus* has not yet been updated, which remains a major challenge to those working with fungi in southern Africa. It is my sincere hope that given the relevance of plant pathology in southern Africa, and the great challenges that await in securing sufficient food supply for Africans in the coming years, the SASPP will prosper, and take up the challenge to combat plant disease, striving to improve quality of life for future generations.

4.8 TERESA COUTINHO

I began a BSc degree, majoring in botany and zoology at the University of Natal, with the intention of becoming a schoolteacher. I fell into plant pathology accidentally. I was a few credits short and, at registration for second year, Doug Hawsworth, my chemistry professor, advised me to take plant pathology. I very nearly dropped the subject after the first lecture, as we were expected to do a presentation during the course (this was my worst nightmare - I detested public speaking). After a "talking-to" by my mother, I continued with the course and cannot remember the presentation (probably wiped it from my memory).

I fell in love with plant pathology when Frits Rijkenberg lectured mycology. He was an inspirational lecturer and passionate about fungi. Our first field trip to the Cedara forests was magical and I was hooked. I ended up majoring in plant pathology and botany. My honours project was on characterising a new disease of maize in South Africa, bacterial streak. I continued on this topic for my MSc dissertation under the supervision of Mike Wallis, who, prior to his career in industrial microbiology, had completed both his MSc and PhD theses on bacterial diseases of plants. I lost my mother to cancer during the course of my MSc, and he was incredibly supportive.

I decided to change topics and began to do research on coffee rust under the supervision of Frits Rijkenberg for a PhD. The first eight months were a nightmare, and I was making little progress. Nobody told me that one had to remove the seed coat off coffee beans before they would grow… Frits offered to send me to the International Microscopy Conference in Germany "if I got results". Well, that worked, and it was an incredible experience - my very first overseas trip. I think back on those PhD years with very fond memories.

Frits Rijkenberg also gave me the opportunity to attend SASPP congresses - my first one at Wits in 1984, UOFS in 1985 and Kruger National Park in 1988. I remember the social events well; the actual presentations are a bit hazy. Except for one, when Cecilia Roux challenged Wally Marasas as to whether it was *Graminaceae* or *Poaceae*. Driving to the congress at Kruger was also a memorable event. We (the postgrads in Frits' research group) decided to drive there in Stuart McLaren's kombi, which we later discovered had no brakes. It broke down near Barberton and we were forced to spend the night there. The next morning, we arrived late for the opening of the congress and received that very memorable and formidable "look" from Frits.

After a couple of years at the Foundation for Research Development (FRD) (now the National Research Foundation (NRF)), I joined Mike Wingfield's group as a postdoctoral fellow, later taking up a lecturing position at University of the Free State. I remained as part of the Tree Protection Co-operative Programme for over 24 years. My role in the programme changed over the years, especially once the group moved to the University of Pretoria. I managed the diagnostic clinic for about 14 years and then became more involved in the administrative side of what had become a very large programme. Being part of this group was an incredible experience. I learnt so much about research, people, mentorship, and collaborations. I was also given the opportunity to train students, the majority of which I fondly remember. I also had the opportunity of working with Wally Marasas - one of the highlights of my career.

In the early 2000s, the then council of SASPP raised concern about the lack of research focused on plant pathogenic bacteria in South Africa. I took up the challenge and returned to my first love, phytobacteriology. My research focused on those bacterial pathogens infecting *Eucalyptus*. This was the most important change I made in my career, and it was the best move I ever made. Although bacterial pathogens of plantations trees are of minor importance, I still was able to carve a niche for myself in this field. In 2017, I left the Tree Protection Co-operative Programme and moved to the Centre for Microbial Ecology and Genomics at UP. My research focus changed again from trees to vegetable crops.

After my first SASPP congress in 1984, I only missed a couple. The one I wish I had attended was the notorious 'tent congress' in Cintsa. If I look back on the many congresses, three of which I was involved in organising, the one I enjoyed most was at Hogsback in 1985. I remember walking over a cattle grid with John da Graça when one of my fellow students, Cheryl Crookes, commented that he had better be careful he didn't slip through the grid (John is on the thin side). Quick as a flash he commented that "my nose would catch me". The atmosphere at that congress was just different to the rest… maybe more relaxed. I also remember the field trips linked to congresses (we should do more). The one I remember most is with Jim Deacon and Fusarium wilt of banana. We were also fortunate to network with the invited plenary and keynote speakers, and when I look at the list, I'm impressed to see that they were the leaders in their field at that time and how lucky we were to get them to South Africa.

I was elected president of SASPP in 2011. I consider myself to have been extremely fortunate to be part of an incredible team comprised of Jolanda Roux, Schalk van Heerden and Wilmarie Kriel. We had such good intensions, one of which was to increase the involvement of plant pathologists from other African countries. Unfortunately, we had limited success. We did, however, liaise with the British Society for Plant Pathology (BSPP), and established the Grace Waterhouse Fellowship. We put together a biannual newsletter, at the time not understanding its importance (refer to section 30.11). We also decided to extend the congress by an afternoon - ending with the gala dinner. I found the four years as SASPP president to be rewarding and came to realise the importance of the society, not only for the discipline but also for the country.

4.9 BRENDA WINGFIELD

My first association with the SASPP were posters which were presented in 1990 and 1991; I did not attend these meetings. My first presentation at an SASPP meeting was being invited to give a keynote address (Future prospects for the molecular characterisation of plant pathogenic fungi) at the Cintsa meeting in 1992. My PhD research was on *Saccharomyces cerevisiae,* and I started working with plant pathogens as a side-line interest with Mike Wingfield in 1989. We had started to discuss the value of RNA sequences in taxonomy during my PhD and I spent two months in Peoria, Illinois to learn how to sequence ribosomal RNA. The rest, one might say, is history. Looking back, the keynote address was prophetic. I had no doubt that DNA or RNA sequence data were going to answer many of the more important questions for plant pathologists. But I would have never predicted how fast the technology would develop.

SASPP meetings have become my favourite meetings to attend, and I have tried to attend as many as possible. Attendees of the meetings have become close colleagues and friends; our collaborations and relationships have been strengthened as a result of engagements at the SASPP meetings. When I have not been able to attend SASPP meetings, I have sent posters and students and colleagues have presented work at these meetings. In the early years there was a lot of resistance to the idea of using molecular biology techniques in plant pathology, many thought that the techniques were too expensive and would never become widely accepted.

The BIOY2K meeting was in many respects a watershed meeting for the understanding of the importance of DNA sequences in plant pathogen taxonomy. This was a joint meeting of the South African Society of Microbiology, South African Society of Biochemistry and Molecular Biology and the Southern African Society for Plant Pathology, and was held in Grahamstown. By this time, we were routinely using DNA sequences and phylogeny in our presentations. Of course, the sequences were done using X-ray film and we really had very little data in comparison to the phylogenies we have in 2020. We had also started to consider population genetics in our studies, and RAPDs and SSRs featured in our presentations. We also had some early MAT gene sequences.

SASPP meetings are linked in my mind with some of my personal milestones. My abstracts of presentations at SASPP meeting track the progression of my career. First the RNA sequencing, followed by the development of PCR technologies, then the development of microsatellite markers, followed by increasing access to DNA sequences, single gene phylogenies have been followed by multi gene phylogenies and now most recently by phylogenomics. My first genome presentation was at a SASPP meeting.

The Southern Africa Society for Plant Pathology has been a very important society in my career and that of the students who I have supervised. The society has provided a vehicle where I and my students could engage with other researchers with similar interests. The discussions after the sessions were always great, the parties even better. I guess this is what these days is referred to as 'networking'. As an early career academic, I saw this as fun and learned a lot along the way, from both senior academics who always had time for discussion to younger researchers who were quick to ask important and difficult questions.

4.10 MARK LAING

I started going to SASPP conferences in 1983, as a postgraduate student. The first was at the Wilderness Hotel close to Knysna, and it was a memorable event for me. I made lifelong friends at that one meeting. And I try to get to every SASPP conference, wherever it is in South Africa; there are so many SASPP friends made over many years.

The society has faced several interesting challenges in the time I've been associated with it. There was a tussle over how often we should meet - every year or every two years? That went on for at least 15 years. The issue was that most of us go to too many conferences and don't have time or the money to go a SASPP conference every year. Secondly, the needs have changed: in a previous era (especially with the academic boycott) there were not many conferences to go to, and there was no email, so the annual conference was a crucial forum for networking, socialising and keeping up to speed with developments around the country. We now meet every two years, and it is a much better balance with our needs as plant pathologists.

In the 1980s the SASPP was very inbred and inward-looking, because of apartheid and a hostile global environment of academic and scientific boycotts. That changed in the 1990s, to engaging with the wider world and, in particular, Africa. We learnt to see ourselves as southern African and part of the global scientific community, rather than just a South African plant pathology society. That changed many things, and raised a language issue.

In the 1980s and before, Afrikaans dominated much of the SASPP conference, and especially society matters and meetings. However, in the late 1980s, younger scientists in the SASPP started pushing for an international perspective, given that English had already become the global language of science and conferences. They proposed that SASPP events needed to be in English, so that our students could practise presenting in English before going to international conferences; and also to ensure that international scientists could participate fully in our conferences. There were huge tensions over the language issue and switching from largely Afrikaans meetings to entirely English. An "old guard" fought to retain the *status quo* until sometime in the early 1990s, when the switch was made. It was a brutal debate, with slanging matches, personal attacks and some unpleasantness. But it reflected the massive changes that our entire society underwent in the 1990s, as South Africa reintegrated into the global community, post-apartheid.

I have found the SASPP to be one of the most sociable of the many professional societies I have encountered or have been a member of. I go to a lot of similar conferences, and have found that some of the professional societies, both local and international, are uptight and serious, with prestige and status being an important issue. It is almost like a human version of a lek, where male birds come to display to attract female birds. The contrast is the SASPP, which is active in creating an egalitarian and proletarian ethic. For example, in one of its rituals, the Mildenhall Stakes, the members drink a beer from their forehead without touching the bottle with their hands. It's a feat of balance, gymnastics and focus. It's also a great leveller, because everyone does it, has fun and engages with each other. The SASPP is relaxed and less concerned about status, so students can interact with academics easily, and interactions and real friendships can develop between peers.

For me, one of the most valuable benefits of SASPP membership has been networking with fellow scientists from around South Africa, and from overseas, at the biennial conferences. South African is a big country and it's not easy to engage people from other universities regularly, to really connect with them. It's important for me and my students to talk to students and staff from other departments, as well as to see what research other people are doing, and to realise the value of what we are doing in our own laboratories. It's also good for students to get an idea of how their own department compares with others in South Africa, what is strong and what is weak. As scientists, we need to recalibrate our thinking regularly, and a regular conference like SASPP allows one to do so on a consistent basis. The SASPP conferences are also good for learning about new skills and techniques. Sometimes it's something incidental. For example, I first found out about Zoom as a teleconferencing tool at an SASPP conference two years ago, from Lindsey du Toit. Now the world knows about Zoom.

On a professional level, the society is central for keeping plant pathologists in touch and giving us a reason to meet every two years. It's crucial for keeping us up to speed with the research and teaching being done across the country, which is important for the dynamic energy of the profession of Plant Pathology. Some of the other societies are in trouble. People do not go to their conferences, and it is a strong indication of where their professions are in terms of the energy, money and research activity in their fields. SASPP has a strong, energetic vibe that reflects the energy and drive of many of the members. Also remarkable is how many world-class scientists there are in a relatively small society, people who have made a real contribution to the field, locally and internationally.

This is the society's key role: to keep us in touch with each other, the science we are in, the new directions that are developing and the new fields that arise constantly. We get a significant number of professional people at our congresses - industry players, academics and government scientists. It is an important nexus of those three sectors. Other professional conferences tend to be more generic and focused on one sector of agriculture. Perhaps it is the energy and innovation arising at the interfaces of multidisciplinary research that underpins the dynamic of the SASPP and makes it such an interesting and attractive society to belong to. Ultimately, it is the balance of dynamic science and real fellowship with valued peers that brings us back year after year to SASPP.

SECTION III

Concluding Remarks

History, according to Aristotle, is what human beings have done and suffered. The history of plant pathology is thus centred around the people that practised this discipline - who they were and what they achieved (and suffered while achieving) their goals. We hope we have captured this element in this book.

South African plant pathology formally began in 1875, when a couple of papers were published in rather unusual journals, the *Mining News* as one example. New diseases appeared and were described. The challenge then became how to manage them and mitigate the losses they caused. One of our greatest achievements was the eradication of citrus canker in the 1920s and 1930s.

Although diseases were described from native vegetation in our early history, agricultural crops were the primary focus. *Phytophthora cinnamomi'*s incursion into the Cape floristic region, beginning in the 1980s and continuing today, has highlighted the importance of native versus introduced pathogens in the country. The appearance of myrtle rust was frightening, and doom and gloom was predicted, based on the Australian experience. In the past, the diagnosis of this disease would have been based on the mere appearance of pustules on infected plant tissue. However, with the use of molecular tools, populations of the pathogen were studied, and a unique genotype was identified in South Africa. Fortunately, it was not the pandemic strain as was known in South America and Australia. This highlights the importance of the application of modern technology to our discipline.

Delving in the archives of the SASPP to glean material for this book was interesting. Meticulous records were kept during our early history. Once computer technology became available records were kept initially on 'floppies' (soft data disks) and later on other forms of disks. No written records were kept, and we lost valuable information, for example, the names of the recipients of the various awards. Another mistake that we have clearly made is changing the website every time a new council was elected. Again, all information hosted on the previous website was lost. The newsletter "The South African plant pathologist" was a valuable document, but its publication was eventually terminated due to high printing costs. With inexpensive electronic publishing now an option, this is no longer a challenge. We really need an online newsletter, and this is a challenge that we must meet in the near future.

Compiling this book has acutely illustrated the importance of maintaining and preserving the records of the SASPP. In the past, the archive has moved with the elected Council, which meant that boxes of records have needed to be moved, and in some cases, they have been poorly managed and preserved. In assembling this book, we have, for example, battled to locate the abstract books for our annual/biennial meetings. They have had to be sourced from members who happen to have kept them. And some have not been found. Likewise, we do not have complete sets of other important documents such as those pertaining to the regional meetings, and minutes of all our general meetings. A strong collection of photographic images from meetings would also be a wonderful record of our history going forward. For this reason, we would argue strongly for a formal position on the council for a historian, who would maintain and care for the archive. This could possibly be the same person having responsibility for the suggested electronic newsletter and the archive would then not need to move inordinately regularly.

This book is far from perfect, with lapses in some historical facts and the style being in parts variable. This is largely due to our need to glean material from willing members and to rely on their account of various diseases and events. But the ultimate intention has not been to achieve perfection, but rather to capture as much as possible of the history of plant pathology in South Africa. Many of the accounts or stories told will be of interest to present and future plant pathologists. And most importantly, it will form the foundation on which we can build and maintain a comprehensive historical record of a discipline that will deeply impact on the future well-being, not only of southern Africans, but the human race globally.

SECTION IV

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SECTION V

Montage of photographs

In this section, we have chosen photographs that were available to us and that depict a selection of South African plant pathologists at work and at play.

This was a challenging undertaking, as we had to rely on photographs sent to us, and it is clear that the collection is far from comprehensive.

SOUTHERN AFRICAN SOCIETY FOR PLANT PATHOLOGY

Logo of the SAVP-SASPP from 1981-1983

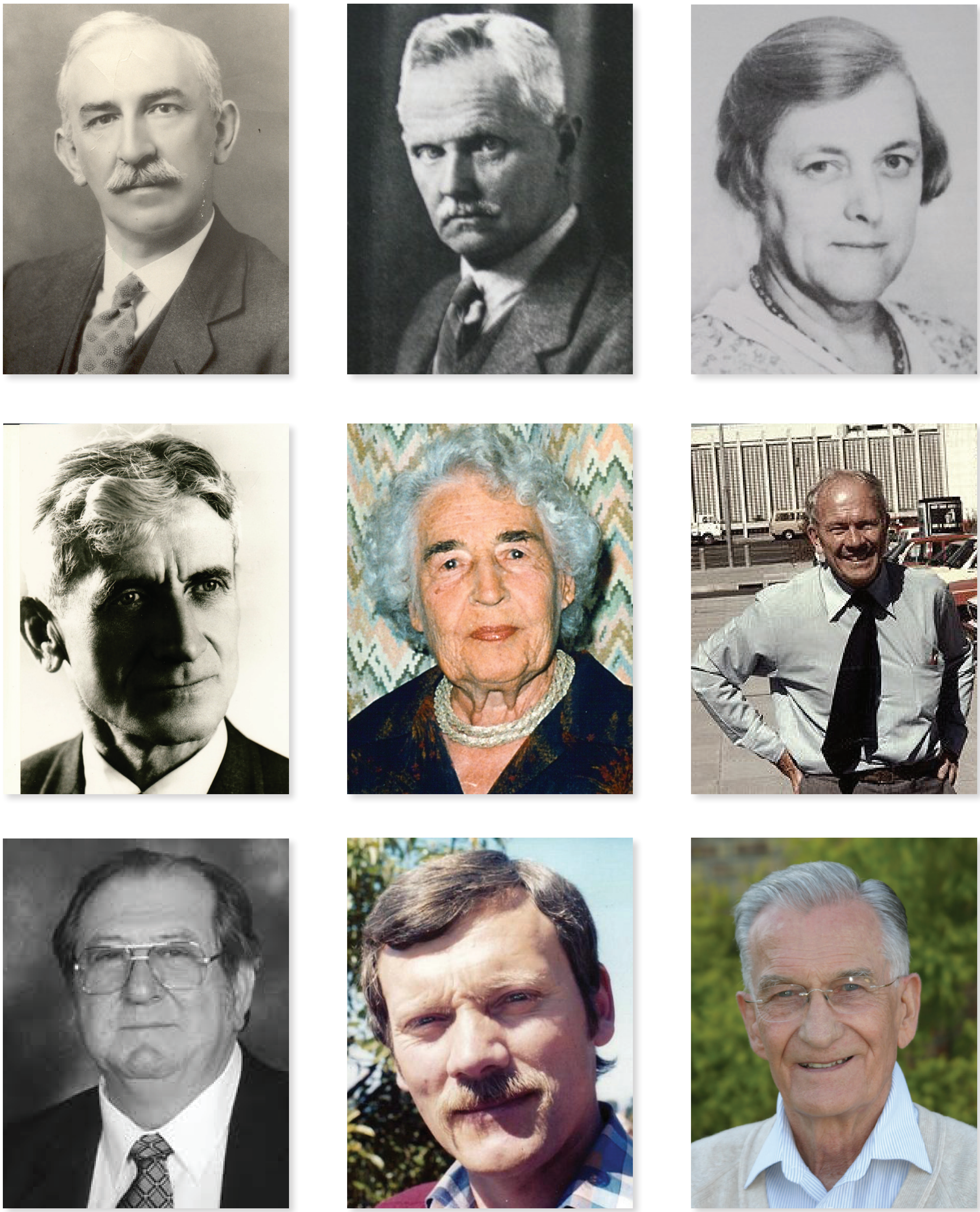
Current logo of the SASPP

RECIPIENTS OF THE CHRISTIAAN HENDRIK PERSOON MEDAL

(L to R): Pedro Crous, Mike Wingfield and Wally Marasas

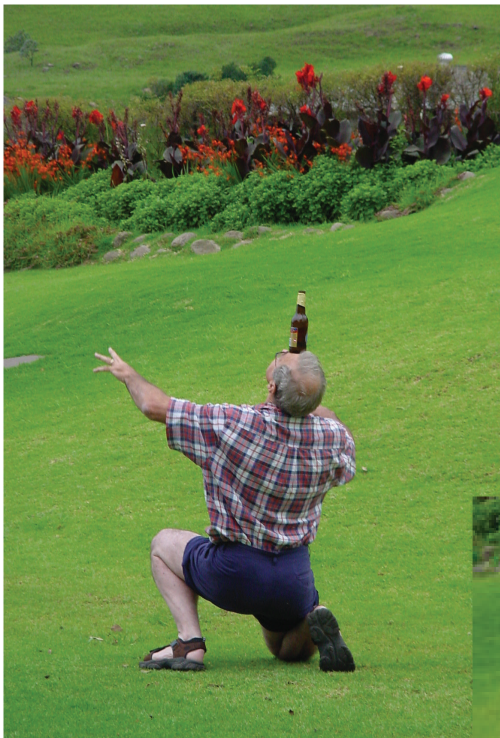
(L to R): Mike Wingfield, Pedro Crous, Zakkie Pretorius and Brenda Wingfield

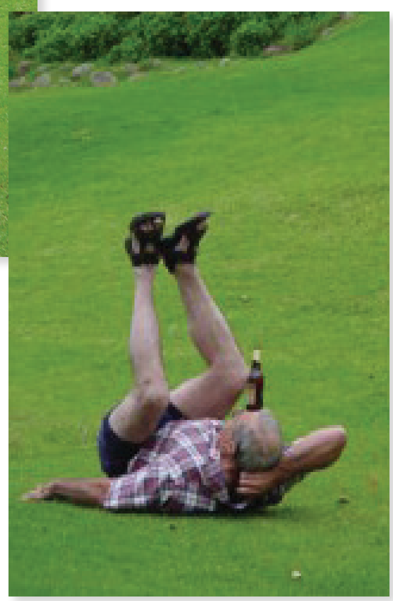
PLANT PATHOLOGISTS THAT MADE A SIGNIFICANT CONTRIBUTION TO THE DISCIPLINE

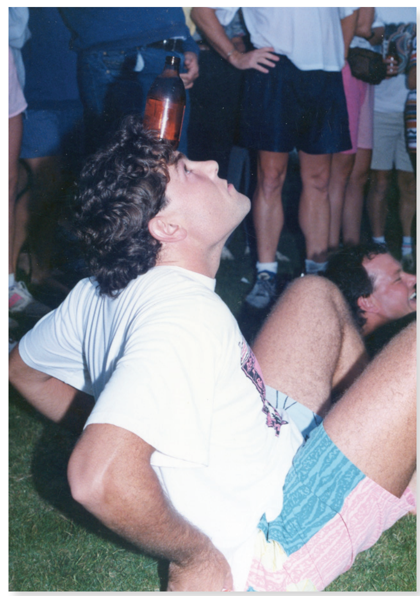


Top (L to R): Paul van der Bijl (1888-1939), Iltyd Pole-Evans (1879-1968) and Ethel Doidge (1887-1965)
Middle (L to R): James Vanderplank (1908-1997), Susarah Truter (1910-2007) and Peter Knox-Davies (1929-1999)
Bottom (L to R): Walter Marasas (1941-2012), Joszef Darvas (1945-2011) and Johannes Kotzé (1927-2019)

PLANT PATHOLOGISTS PERFORMING THE MILDENHALL STAKES







PLANT PATHOLOGISTS AT SASPP CONFERENCES


for Plant Pathology