# AN ECONOMIC EVALUATION OF SOUTH AFRICA'S PEACH AND NECTARINE RESEARCH

By

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# DECLARATION

I, Chiedza Zvirurami Tsvakirai, the undersigned, declare that the work contained in this study is my own work and has not previously in its entirety or in part been submitted at any University for a degree. Where use has been made of the work of others, it was duly acknowledged in the text.

**Signature:** ………………………

**Date**: …………………………….

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# AN ECONOMIC EVALUATION OF SOUTH AFRICA'S PEACH AND NECTARINE RESEARCH

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## ABSTRACT

The Agricultural Research Council Institute for Deciduous Fruit Technology (ARC–Infruitec) has played a significant role in the growth and development of the peach and nectarine industry in South Africa. This institute's peach and nectarine research programme has developed 96 cultivars since 1937 that have been extensively used in the local industry. The programme accounted for two thirds of the stone fruit cultivars bred at ARC–Infruitec between 1996 and 2012. Based on the number of cultivars released between 1990 and 1996, the research programme was ranked 7$^{th}$ in the world. The Institute's various research outputs have led to farmers reaping higher yields and the expansion of the industry's production area, which used to be restricted to the Western Cape Province. The research outputs have also enabled industry stakeholders to explore new lucrative marketing windows and increase the production capacity in the canning sector.

Despite these contributions, there still remains an inadequate understanding of the benefits of research for the industry stakeholders who are expected to provide the financial resources that are required for the delivery of this research service. In addition, the rate of decay of research investment benefits is also unknown thus, investors fail to appreciate the full effect of their research investment in the peaches and nectarine industry. Therefore, this study serves to supplement the aggregate level rate of return studies that have been done in the past. It is envisaged that the accurate attribution of research benefits at this level will bring a better appreciation of the rate of return on the industry stakeholder's investment in research and will end the continued decreasing trend of research investment in the Institute, a trend that is threatening research and research benefit generation.

The study has approached this task by reporting on the degree of use of the technologies that the Agricultural Research Council has released into the industry through its peach and nectarine research programme, and also by performing a rate of return calculation. The relationship between the stakeholders' research investment and the industry output has been modelled using a supply response function. This econometric model uses a 41–year time series that stretches from 1971 to 2012. The results of the regression analysis show that the magnitude of production increase associated with a ten percent increase in research investment, ranges from 3.1 percent to 12.5 percent. A Marginal Internal Rate of Return of the programme of 55.9 percent is estimated. The analysis also shows that the returns of investment in peach and nectarine research reach their maximum benefit level in the 13$^{th}$ year after investment and thereafter continue being positive and of increasing significance for an undefined period of time. The calculated peach and nectarine research programme's rate of return is relatively high and shows that the investment is valuable. This figure lies within the range of other rate of return calculations which have been done for similar South African research programmes. It is advisable for industry stakeholders to increase their research investment in order to ensure future profits in the industry.

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# LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ARC | Agricultural Research Council |
| CFB | Canning Fruit Board |
| CFPA | Canning Fruit Producers' Association |
| DACST | Department of Arts, Culture, Science and Technology |
| DAEM | Department of Agricultural Economics and Marketing |
| DATS | Department of Agricultural Technical Services |
| DFB | Deciduous Fruit Board |
| DFTS | Dried Fruit Technical Service |
| DST | Department of Science and Technology |
| DoA | Department of Agricultural |
| FFTRI | Fruit and Food Technology Research Institute |
| FFTRI | Fruit and Fruit Technology Research Institute |
| NACI | National Advisory Council on Innovation |
| PPECB | Perishable Products Export Control Board |
| PWG | Peer Work Group |
| SAAPPA | South African Apple and Pear Producers' Association |
| SAFVCA | South African Fruit and Vegetable Canners' Association |
| SAPO | South African Plant Improvement Organisation |
| SASPA | South African Stone Fruit Producers' Association |
| TAC | Technical Advisory Committees |
| URS | Unifruco Research Services |
| WPRS | Western Province Research Station |

# CHAPTER 1

# INTRODUCTION

## 1.1 BACKGROUND

The peach and nectarine industry is one of the important agricultural industries that were established in the Western Cape region. It has a history that dates back to 1655 when the Dutch East India Company's commander, Jan Van Riebeeck, started the experimental planting of perennial crops and fruit trees in the Cape Colony. Peaches and nectarines had the highest tree numbers in the Cape Colony in 1892 and peaches pioneered fresh fruit exports in the same year (Standard Bank, 1965). The emergence of the industry is attributed to the introduction of better suited production practices by the French Huguenots, the availability of high yielding and easy to grow fruit varieties and the availability of an accessible local market (Pickstone, 1917; Aucamp, 1987).

The industry seemed to have been set up for success as it had a reliable supply, accessible and growing local and export markets, and there were rapid developments in transport and cold storage infrastructure and in the institutions (Aucamp, 1987). However, this was not the case as factors such as enterprise productivity and fruit quality began to pose great limitations to the industry's growth. Industry exports were reduced to zero when a wooliness disease was discovered in 1936. At this time, industry stakeholders realised that locally developed agricultural research and development (R&D) services were needed to ensure the continuity of the industry. The following year, the Western Province Research Station (WPRS) which is now known as the Infruitec–Nietvoorbij research Institute of the Agricultural Research Council (ARC) was established. Unfortunately, the economic benefits of the peach and nectarine research carried out by this Institute have not been calculated thus far and the value that it has created remains unknown.

Since the establishment of this research institution, the industry's tree numbers increased from 4 million in 1940 to 9.2 million in 2012 (BCS, 1960; DAFF, 2014). Annual production volumes increased from 43 946 tons to 181 996 tons between 1949 and 2012, while annual export volumes increased from 825 tons to 10 834 tons during the same period (BCS, 1960; DAFF, 2014). The ARC peach and nectarine research programme played a major role in this growth as it has developed 96 peach and nectarine cultivars between 1937 and 2012. These cultivars were planted in the greater part of the industry's production area. The cultivars were well received due to their ability to meet the industry's requirements in terms of: yields per tree, growth and fruiting habits, pest and disease resistance, flesh texture, shelf life, sugar content, fruit shape and fruit colour (Smith, Bester, Human, Kotze, Pieterse, and Tobutt, 2012).

The peach and nectarine research programme accounted for two thirds of the stone fruit cultivars bred at Infruitec between 1996 and 2012 (Smith *et al.*, 2012). Based on the number of cultivars released between 1990 and 1996, the research programme was ranked 7$^{th}$ in the world (Byrne, 2005). In 2012, ARC–bred peach and nectarine cultivars contributed 100 percent of canning fruit volumes, 100 percent of the fresh nectarine exports and 55 percent of dried peach exports (Pieterse, 2013). The research programme's contribution was also noted in terms of its ability to conduct maintenance research which inspired the introduction of new production practices that led to the expansion of the peach and nectarine production area into areas that were once deemed unsuitable for production (Marais, 1977). Its applied research further led to the control of diseases such as the wooliness disease and the control of pests such as the fruit fly and the black aphid (Olivier, 1960). The overall effect of the research conducted was that it increased productivity at farm level, improved handling and fresh market fruit quality, and improved processing efficiency for canning and drying companies.

Whilst the ARC programme has made a profoundly positive contribution in advancing the peach and nectarine industry's development; the need for basic, maintenance and applied research remains far from satisfied. Peaches and nectarines have shifted from being the most grown fruits in the Western Cape Province to occupying 13 percent of the total area planted to deciduous fruit in 2012 (Tree census, 2012; Hortgro, 1989–2012). South Africa has changed from being ranked second amongst Southern Hemisphere's fresh peach and nectarine exporting countries in 1964–1970, to fourth in 2010, and the difference between South Africa's export volumes and those of the region's largest producer and exporter, Chile, has increased from a mere 200 tons as recorded in 1964–1970 to over 80 000 tons in 2010 (FFTRI, 1974, FAO statistics). These statistics indicate that there still remains a need to strengthen R&D provision in order for the industry to realise its full potential.

## 1.2 RESEARCH PROBLEM

The ARC's peach and nectarine research programme conducts research in five disciplines, which are: Soil Technology and Irrigation, Biotechnology and Pathology, Post–Harvest

Technology, Horticulture; and Plant Improvement. The Soil Technology and Irrigation discipline conducts research on optimising the use of soil and water through the use of good orchard layouts and appropriate farm equipment design, use and maintenance (Kotze, 1987). This discipline is important because it ensures the development of sustainable farming practices that safeguard the continuity of future production. The research conducted in the Biotechnology and Pathology discipline focuses on investigating the factors that cause post–harvest losses such as decay, internal disorders, pests and diseases (Olivier, 1960). This discipline is essential because it investigates ways of minimising the industry's losses. The research conducted in Post–Harvest Technology investigates all aspects relating to storage, processing and process optimisation (Annual research review, 2002: ARC–Infruitec, 1992–2002). This research is significant because it ensures the quality and efficiency of the canning and drying sectors. The Horticulture discipline focuses on evaluating and adapting production practices to South Africa's different production areas (Aucamp, 1987). This research is important because it enables farmers to acquire higher returns on their production through improved yields and fruit quality. The peach and nectarine research programme's forte is in the Plant Improvement discipline which is responsible for cultivar development. This discipline is important because it develops varieties that are well adapted to South Africa's production and market needs.

There is a need for the continuous provision of soil technology and irrigation research because new production systems and farm machinery are constantly introduced and the industry requires that these new products be adapted to South African production areas (Byrne, 2005; Pieterse *et al.*, 2012). Processing methods and refrigeration machines are also constantly being improved, hence the need for post–harvest technology research. In addition, there is a need for more horticultural research because the industry's production area is continuously shifting and production practises should be adjusted to ensure optimal production in these new production regions (Byrne, 2005).

The cultivars that were released in the past are becoming obsolete. This is due to changing consumer preference, from the round yellow fleshed types which have made up the bulk of South African production, to white fleshed, doughnut and flat fruit types (Pieterse *et al.*, 2012). The increasing evidence of the impact of global warming and climate change in South Africa's production areas has also necessitated the production of new cultivars that are adapted to warmer temperatures whilst at least maintaining the high yield levels of the cultivars they are to replace (Smith *et al.*, 2012). There is also a need to develop high–quality varieties which are either harvested early in the season or harvested late, which will enable the industry to fill the gap in existing and future global markets (Pieterse, 2013). Like all agricultural industries, the peach and nectarine industry is also continually faced with increasing production costs. Hence, the need exists to develop more cost effective pest and disease control programmes, which will further increase the efficiency of peach and nectarine enterprises.

Unfortunately, the significant demand for investment in the various fields of R&D described here, has not been reflected in the funding that has been made available for the ARC peach and nectarine research programme. The programme's funding decreased from R21.3 million in 1960 to R7.2 million in 2012 (in 2010 values) (Author's calculations). This decrease has limited the programme's ability to meet the industry's research needs. More funding is required to allow the research programme to acquire new equipment for advanced breeding methods such as molecular marking, venture into the use of GMO techniques (cisgenics), acquire genetic resources, and to increase its research capacity (Smith *et al.*, 2012). Improved funding would also assist the programme's researchers to acquire higher education qualifications, attend specialised short courses and interact with researchers from other countries at conferences. Most importantly, funding is needed to acquire and retain the expertise which often leaves the ARC to join the private sector without effectively applying the knowledge within the organisation. Increased employee retainment will also solve problems of research continuity and, skills and knowledge transmission that the institution is facing (Tobutt and Smit, 2011).

The decrease in funding has partly been due to a lack of information regarding the benefits of R&D investment in the peach and nectarine industry. To be specific: it is unknown how much value the industry is getting for every R1 that is invested in research and how long these benefits last. Although previous studies by Thirtle, Townsend, Amandi, Lusigi and Van Zyl (1998) have sought to quantify the value of R&D in South Africa, such studies were conducted at a macro–level and do not provide decision–makers with enough information on the rate of return of past investments into peach and nectarine research. This gap in knowledge has made it difficult for the ARC to demonstrate the relevance of this particular research programme. It has also fettered the organisation's efforts to justify the need for increased research funding from its stakeholders.

Against this backdrop, peach and nectarine research funders are demanding more information on the returns of the specific research activities they are promoting because the opportunity costs of their research investments are rising yearly. Added to this is the growing competition for funding from private research companies that offer the same research services as the ARC

(Tobutt and Smit, 2011). Furthermore, the demand for other forms of research that are not offered by the ARC has provided further motivation to research funders to rethink their investment allocations to its peach and nectarine research programme. The increased resource pressure facing governments, other donors and recipients, have also emphasised the need for the prior assessment of potential benefits of both research vision and individual projects to assist planning and management (Townsend, Amandi, Lusigi and Van Zyl, 1997).

Thus this study is important as it will bring an appreciation of the importance of R&D in the peach and nectarine industry. It will also equip the ARC with evidence that will provide justification for more funding to advance its work; which will in turn enable the industry to realise its full potential.

## 1.3 OBJECTIVE OF THE STUDY

The overriding objective of this study is to quantify the rate of return on expenditures of the ARC peach and nectarine research programme in an effort to provide empirical evidence of the value that has been created through past investment. To achieve this overall objective, the study shall:

- Give an overview of the history of the peach and nectarine industry and explain the trends in production and sales;
- Provide a detailed history of the peach and nectarine research programme and the technologies released to the industry through the programme;
- Determine the trend of investment in peach and nectarine research; and
- Calculate the rate of return for the peach and nectarine research programme.

## 1.4 RESEARCH HYPOTHESIS

According to Thirtle *et al*. (1998), the return to research to deciduous fruit research carried out at the ARC–Infruitec research institute was estimated at 78 percent. As the peach and nectarine research programme has produced a considerable number of cultivars in this institute, it is expected its rate of return will also be positive. In addition, these cultivars have been planted to the majority of the peach and nectarine industry, it is expected that the return will be almost as high as the institute's rate of return.

## 1.5 RESEARCH METHODS

The methods used to calculate the rate of return to agricultural research investment can be divided into *ex–ante* and *ex–post* methods. *Ex–ante* methods are based on experimental data and are done to postulate future returns while *ex–post* methods use secondary, historical data to quantify total gains as cumulated in the past (Marasas, Anandajayasekeram, Coetzee, Martella and Van Rooyen, 1998). This study shall focus on *ex-post* methods due to the fact that this study has made use of secondary data. Other ex-post methods that have been used in South Africa include: congruence, Total Factor Productivity (TFP), Error Correction Models (EMC), the economic surplus approaches and econometric models.

The study estimates the effect of research investment on the production of peaches and nectarines using an econometric method called the supply response approach. This method was applied in order to capture the effect of the programme's research on both annual production and on fruit quality improvement. It also captures the effect of opportunity cost of production in the deciduous fruit industry. The effect of the lagged research investment variables is modelled using the Almon Polynomial Distribution Lag model. The explanatory variables in these models include: research expenditure figures, a weather index, conventional input indices and deciduous fruit prices. The rate of return on investment in the ARC–Infruitec peach and nectarine research programme is estimated using a marginal internal rate of return calculation.

## 1.6 STUDY LAY–OUT

Chapter 2 gives an overview of the peach and nectarine industry. This includes its history, changes in production practices, shifts in production area, market trends, and a comparison of South Africa with other Southern Hemisphere countries. This chapter is important in giving an understanding of how the industry has developed and the factors which have affected the production and sale of peaches and nectarines. It also shows the influence of research on the industry.

Chapter 3 describes how R&D was introduced to the industry with a pertinent focus on the services delivered by the WPRS/ARC–Infruitec. The shifts of the Institute's research focus and particularly in peach and nectarine research are shown, and the technologies released and their uses in the industry are discussed. The chapter ends by briefly discussing the competitiveness of the ARC–Infruitec's peach and nectarine research programme.

Chapter 4 discusses the evolution and role played by farmer organisations in the development of the peach and nectarine industry. It particularly highlights their inputs in directing the research priorities, project development and funding allocations. Using the funding allocations and the project allocations at FFTRI/ARC–Infruitec, a long–run expenditure data set for peach and nectarine research is estimated.

Chapter 5 discusses the econometrics method of calculating the rate of return to agricultural research investment. Its strengths and weaknesses are mentioned and the rationale applied for the selection of the specific function adopted in the study is provided. The chapter ends by briefly discussing the findings that previous rate of return studies that have been carried out using the different econometric functions.

Chapter 6 presents the results of the rate of return analysis of the research investment in peach and nectarine using the supply response function. The data used in this analysis are shown and the sources of this data are stated. The relationship that exists between the interacting variables is explained and the marginal internal rate of return calculated for peach and nectarine research is presented.

Chapter 7 summarises the study and presents its conclusions, limitations and recommendation for future studies.

# CHAPTER 2

# AN OVERVIEW OF THE PEACH AND NECTARINE INDUSTRY IN SOUTH AFRICA

## 2.1 INTRODUCTION

The goal of this chapter is to create the context for this study. This is done by discussing the peach and nectarine industry's origins, the changes in production practices, shifts in production area, market trends and comparing South Africa with other Southern Hemisphere countries. The influence of R&D on the industry dynamics and trends shown in this chapter will bring an appreciation of the analysis that is central to this study.

## 2.2 ORIGINS OF THE PEACH AND NECTARINE INDUSTRY

Peach and nectarine production in South Africa dates back to 1655 when the Dutch East India Company's commander, Jan Van Riebeeck, started to experimentally plant different types of perennial crops and fruits in the Cape Colony (Pickstone, 1917). According to Micklem and Kriel (1952), the first peach and nectarine varieties and rootstock varieties were imported from St Helena in 1655 and later from Holland in 1666. Very little is known about the actual cultivars that were imported except that they were selections made of the best quality varieties available at the time (FFTRI, 1982). Unfortunately, these cultivars had high mortality rates because they were not well adapted to the production conditions of the Cape Colony (Pickstone, 1917). The few varieties that survived were used mostly as orchard fillers ("fifth trees") which were uprooted as soon as apple orchards came into full bearing (Micklem and Kriel, 1952). Due to the high mortality of these varieties, Jan van Riebeeck's successor Simon van der Stel, started to introduce cultivars of lower quality that were grown in areas with climatic conditions similar to those of the Cape Colony in the hope that these would perform better in this new production area. According to Pickstone (1917), most of the high–quality cultivars which required sophisticated production practices such as grafting ceased to be produced in the period between 1775 and 1875 and the "pit boom", i.e. fruit grown directly from seed, became the more popularly grown variety. The pit boom was easy to produce; it bore large quantities of fruit but of inferior quality.

Much of the original work done in establishing the peach and nectarine industry was done by Simon van der Stel and his son Willem Adriaan. Simon van der Stel reorganised and enlarged the original experimental garden of the Dutch East India Company and devoted considerably more attention to fruit–tree farming (Aucamp, 1987). He also imported a number of new cultivars from Europe which were first planted on the van der Stel private farms: Groot Constantia and Vergelegen, located in the Wynberg and Somerset West districts respectively.

As enthusiastic horticulturists, Simon and Willem van der Stel also encouraged farmers to venture into fruit farming and went out of their way to encourage fruit farming north of the Cape Colony (Aucamp, 1987). In addition to the work done by these horticulturists, the peach and nectarine industry grew due to the arrival of the French Huguenots who had experience in fruit production. Using the skills of the Dutch and French settlers, peach and nectarine production areas were established in Stellenbosch, Franschhoek, Groot Drakenstein, Paarl and Wellington (Aucamp, 1987). As the industry grew, a group of yellow peach varieties which later became known as the Transvaal peaches became popular (Black, 1947). Peaches and nectarines were particularly popular because they are self–pollinating trees that do not require complex orchard layouts to accommodate pollinator species, or do not require additional pollinators (bees), to facilitate successful fruiting. They also come into bearing in the third year of production unlike apples which come into bearing in the sixth year.

Although the early farmers had successfully mastered the basic horticultural skills that made peaches and nectarines among the first fruits to be farmed in the deciduous fruit industry and to be the main fruit type grown in the Cape Colony, there remained the problems of developing a local market and accessing international markets (PPECB, 2003). According to Liebenberg (2013), the biggest stumbling block for development of a local market was the absence of urban consumption centres and local markets through which the fruit could be sold. Pickstone (1917) adds that the primitive transport facilities further restricted local market development, and the lack of knowledge of the correct handling practices stifled all attempts to access the overseas market.

The discovery of diamonds in 1870 and subsequently of gold in 1884 provided the much needed economic stimulus for the development of a domestic market (Micklem and Kriel, 1952). The emerging mining industry brought an increasing demand for fruit and provided improved road and railway networks connecting the peach and nectarine production area with the mining settlements located far north of the Cape Colony (Black, 1952). It further provided new capital which became widely circulated and used in the purchase of fruit and in the establishment of fruit shops in the small towns and cities (Pickstone, 1917). Moreover, Rev. C. Legg's attempts to access the markets in England finally became successful in 1892 with the help of Mr Percy A. Molteno, a man who had gained experience in deciduous fruit shipping from Australia (Standard Bank, 1965). The first shipment comprising 14 trays of peaches opened doors for more consignments of peaches and nectarines as well as grapes, pears and apricots. By the end of the year, 5 000 cases of fresh fruit had been exported. Fresh fruit export volumes trebled the following year when 15 000 cases of fruit were exported to the United Kingdom; of these, 11 000 were grapes and 2 400 were peaches (PPECB, 2003).

The peach and nectarine industry was now set for success. It had established itself in the Cape Colony, producing high volumes that were sold at an easily accessible and rapidly growing local market. The growth in demand for fresh fruit in its newly established export market, Europe, also presented even greater opportunities for growth (Kotze, 1987). The industry performed comparatively well against the citrus fruit, viticulture and grain industries which were experiencing production setbacks due to problems caused by destructive pests and diseases (Kotze, 1987; Pickstone, 1917).

Although traditional production practices, the mining industry and export success had laid a foundation for growth, poor fruit quality and low production efficiency remained as serious obstacles to industry growth for products that had to be sold on a competitive global market (Standard Bank, 1965). As a result, the industry's growth stagnated for the decades that followed. Other deciduous fruit industries grew at a much faster pace and by 1911 the peach and nectarine industry made up only about 20 percent of the annual production volume of all deciduous fruit (BCS, 1960). Increasing competition on international markets and increasing production costs necessitated changes in production and management practices to be made in order for South Africa's products to fare competitively and to sustain production. The next section discusses the changes in production and management practices, production region and market distribution that enabled the industry stakeholders to cope with the industry dynamics and ensure the industry's survival.

## 2.3 CHANGES OF PRODUCTION AND MANAGEMENT PRACTICES

At the time of the peach and nectarine industry's establishment, production was done using traditional production practices. Propagation was done by seed and trees were planted according to a square orchard layout, which had individual trees planted with 6.1–7.3m inter row and 6.1–7.3m intra–row planting distance and a central leader training system (Wickson, 1889). There was minimal interference with the tree's natural growth and fruiting habits. As a result, orchards were characterised by tall and willowy trees and wide drive spaces. Although the popularly used Transvaal peach "variety" bore much fruit per tree, yields per acre were low because a relatively high percentage of the orchard space was devoted to open or drive areas (Black, 1952; Bruwer, 1978). New production methods had to be introduced in order to improve land use thus increasing the industry's productivity. Another reason for improving the production practices was the increasing need to produce a product of better quality that would be able to compete in global markets.

Pickstone (1917) reports that the first changes to the industry's production landscape were seen in 1892, when a well–respected fruit farmer, Mr G. H. Marchand, secured a copy of Wickson's book called "The California fruits and how to grow them". Pickstone (1917) further reports that additional changes were introduced by European agricultural consultants who specialised in horticulture, entomology and extension work. The bulk of the changes witnessed today were as a result of research and extension delivered by the Department of Agriculture and the national research institutions. These contributions will be discussed in the rest of this section.

### 2.3.1 Grafting

One of the first changes that were introduced to peach and nectarine production was the reintroduction of grafting practices which had been done away with in the 1700s. Grafting had stopped for peaches and nectarines because the practice required expert skills, specialised equipment and often left the trees susceptible to pests and diseases. This practice also resulted in the formation of a weak spot on the stem of a tree which led to an increase in the incidences of wind damage. Grafting was reintroduced to the Cape Colony by the Californian horticulture consultant, Mr H. Pickstone, in 1892 when he established the first fruit nurseries in Constantia and Groot Drakenstein (Pickstone, 1917; Standard Bank, 1965).

Grafting involves transplanting cultivars (i.e. scion cultivars) which produce fruits with desired qualities such as long shelf–life onto certain cultivars (i.e. rootstocks) which have superior growth habits, disease and insect resistance, and/or drought tolerance (Ham, 2010). The scion cultivars are grown in a controlled environment in a nursery for one to two years and thereafter transplanted so that they can continue to survive in the uncontrolled environment on the farms.

This method has been very beneficial to the industry's development as it has enabled quality cultivars that are not adapted to the South African production area to be grown successfully.

Kakamas seedling has been the most widely used rootstock since 1933 because of its resistance to pests and diseases (Reinten and Stassen, 2013). However, due to its limited performance in high pH, wet, saline, sandy and root nematode infested soils, the industry has also used other rootstocks (Stassen, 2007). These include the Floraguard rootstock which has been used because its resistance to root nematodes and, the Alta and SAPO 778 rootstocks which perform well in areas with very cold winter temperatures. Other rootstocks which have been preferred for their good performance in calcareous soils are GF 677, Cadaman and Viking (Stassen, 2007). According to Reinten and Stassen (2013), grafting has led to improvements in yield, fruit quality and consequently to improvements in the industry's profitability.

### 2.3.2 Pruning

Pruning was part of the traditional practices that were introduced by the French Huguenots. In those early days, pruning involved only the removal of weak and unproductive branches. The first modifications to this practice involved concentrating all tree–trimming activities in one season and adding heading back (dwarfing), i.e. cutting the terminal bud to stimulate lateral vegetative growth and shaping the tree canopy to maximise light interception (FFTRI, 1980). Pruning was done in winter when the trees were in a dormant state and least susceptible to sap loss, pest and fungus damage. According to the University of California (2010), this modified pruning practice was important because it ensured the establishment of strong bearing limbs and enhanced the tree's flowering and fruiting frequencies. The tree structure that resulted also promoted easier fruit harvesting.

In the 1950s pruning practices were divided between winter (May and June) and summer (August and September). All the large cuts such as heading back that were done to shape the tree's canopy and stimulate vegetative growth were done during winter pruning, and the minor cuts that removed branches damaged by wind or a heavy crop and induced reproductive growth were done in summer (FFTRI, 1980). In winter pruning, an average of nine trees were pruned per man–day and an average of 13 trees were pruned per man–day during summer pruning (Bruwer, 1978). This method is still used in the industry to date (Saint, 2014). The new pruning practice has led to effective light intercession and optimum nutrition use by bearing branches.

The benefits of adopting this type of practice have been: increased yields per tree, improved fruit colour development and reduced silver leaf and other rotting fungi infections (Saint, 2014).

### 2.3.3 Thinning

The traditional way of thinning required that farmers removed the second and third fruits that were formed on a bud (Wickson, 1889). Thinning was done only after the fruit had been firmly formed, i.e. about eight to ten weeks after flower blossom. At present this production practice has changed and involves the removal of damaged or ill–formed flowers during the first 50 days of a tree blossoming and/or the removal of immature fruit six to eight weeks after flower bloom (Costa and Vizzotto, 2000). The early fruit selection introduced by the thinning practice improvements has led to increases in the amount of nutrients per fruit; consequently the peach and nectarine industry experienced improvements in fruit colour, quality and maturity (Saint, 2014). Osborne and Robinson (2008) report that the adoption of the improved method of thinning caused optimisation of fruit size and maximisation of fruit value by promoting efficient cropping frequencies.

In the 1950s, mechanised thinning was introduced. This was a change from hand thinning that had been traditionally carried out; however, the thinning distance was maintained 10–15cm between flowers or fruits (Wickson, 1889, FFTRI, 1980). The most used machine in mechanical thinning was the Darwin machine which had a single operating arm with a number of rubber filaments that rotated and knocked blossom off the tree (Saint, 2014). Mechanised thinning reduced labour costs because it reduced the number of labourers; however, it required a more skilled workforce. The main problem with this method was that it often left branches damaged.

In the 1970s, the peach and nectarine farmers began to thin orchards using chemical thinning agents. The first thinning agent used for peach thinning (from 1969) was 3–chlorophenoxy–aproprionimide (3–CPA) (FFTRI, 1973). Today, fish oil lime sulphur, surfactants such as Tergitol–TMN–6, and also fertilisers are commonly used (Osborne and Robinson, 2008). Though chemical thinning reduces the labour requirements and foliar damage, its most serious weakness is that it only removes 50 to 75 percent of the excess fruit and tends to remove flowers that would have been very productive (Osborne and Robinson, 2008). Due to the strengths and weaknesses of the three different types of thinning methods, the industry applies all three types of thinning methods today (Saint, 2014).

### 2.3.4 Planting density and training systems

The first training system to be introduced was the closed vase system which maintained the conventional central leader training system that had an individual tree, square orchard layout. The closed vase system had 6.1m intra–row spacing and 6.1m inter–row spacing and shorter trees which were trimmed to a height of 2.5m (Fideghelli, Della Strada, Grassi and Morico 1998; Downes, 1977). This system had trees with three or four scaffold branches which were encouraged to grow as upright as possible. Growth was guided by a plastic band or wire ring that was introduced in the first year of planting and removed when tree branches were firm. Each of these branches was developed into a main branch (a leader) which had side subsidiary branches to the leader. The leader was pruned like a pyramid tree; as a result, the tree had a broad base formed by branches which were ± 80cm apart (FFTRI, 1980). The strengths of this training system were that it allowed for free air circulation, therefore reducing the occurrence of disease and pests and maximising sunlight utilisation which increased yields per tree. Its biggest weakness was that this particular training system offered very little protection against wind damage and sunburn. It also did not make efficient use of the soil area as compared to the V–shaped trellising systems that became widely used when the closed vase system lost its popularity (FFTRI, 1980).

The V–shaped training system arranged trees in 15m rows with 3.7m intra–row spacing and 4.9m inter–row spacing (FFTRI, 1980). Trees had two scaffolds which were 50–60 degrees apart and supported by “V”–shaped poles that were placed at 2–4m intervals in rows which were lined with eight horizontal wires spaced 30–20cm from each other (Fideghelli *et al.*, 1998). This framework of poles and wires maintained the shape of the tree and supported the entire weight of the tree and the crop. The V–shaped training system lost its popularity in the 1950s because it did not provide efficient light penetration. The poor light penetration caused drying out of bearing wood in the lower parts of the trees and, as a result, orchards experienced reduced production potential because production was restricted to the upper levels of the tree canopy (Aucamp, 1987). The V–shaped system also did not make efficient use of labour as workers would spend too much time scaling ladders in the 4.27m tall trees (Downes, 1977). For these reasons, and because of problems with breaking branches, most farmers resorted to using the closed vase training system with planting distances similar to those of the V–shaped system. Another reason for farmers using this training system, was the inability of the V–shaped training system to accommodate narrower planting distances.

In the mid–1970s, the palmette training system that was used in apple orchards was modified and became widely used in peach and nectarine production. The palmette training system had trees with multiple leaders angled at 45–50$^{o}$. It set the trees in a hedgerow type of structure, supported on a pole and wire frame that had 3.63m intra–row spacing and 4.85m inter–row spacing (Fideghelli *et al.*, 1998; Downes, 1977). Though the palmette training system was associated with relatively high input costs due to its intensified input requirements, it offered better utilisation of soil surface, trees came into bearing faster and it reduced the incidence of wind damage in orchards (Aucamp, 1987). The most recently developed system is the Tatura training system. This system limits trees to two main branches which are trellised on Y–shaped trellises at an angle of 60$^{o}$ and planted with 1–2m intra–row spacing and 4.5m inter–row spacing (Fideghelli *et al.*, 1998; Downes, 1977). This training system is relatively expensive due to the considerable amount of manipulation necessary to maintain the shape; however, use of this system leads to an earlier return on capital investment. This attribute has led to its popularity because shorter break–even time reduces production risks (Downes, 1977).

### 2.3.5 Irrigation and fertilisation

The artificial application of water and nutrients has always been the most critical production practice in the industry because peach and nectarine trees prefer well drained soils that have low water and nutrient retention qualities. Good irrigation practices are required because inadequate water causes drought stress which reduces fruit size and stunts tree growth, while too much water leads to tree death (Allemann and Young, 2006). Good fertilisation practices are required to replace the nutrients used in production and that are leached to lower levels in the soil. Good fertilisation and irrigation practices have been reported to enhance fruit flavour, ensure maximum tree growth, fruit size and yield (FFTRI, 1980).

In the peach and nectarine industry, flood irrigation systems such as furrows, borders and level basins were the most common type of irrigation systems that were initially used (Taylor and Gush, 2007). However, flood irrigation was only effective in areas with abundant water supplies and level land, thus drip and micro–irrigation systems were introduced to curb these problems. Drip irrigation pumps between 1.3 and 5 litres of water per hour per dripper (Saint, 2014). There is often more than one dripper per plant, so the amount of water delivered is spread over the area that the roots of the tree cover. With the micro–irrigation system, water is pumped through a network of pipes that are fitted with a series of small micro–sprinklers that can supply about 5mm of water per hectare per hour (Saint, 2014). Although these modern systems provide a very efficient and precise automatic watering system, the electricity cost incurred by pumping water increases production costs. However, these technologies have been proven to be cost effective because fertilisers are often mixed with the irrigation water and applied where the root concentration is the densest (Allemann and Young, 2006).

As an improved practice, farmers send leaf and soil samples to scientists who analyse them and prepare irrigation and fertiliser schedules accordingly. These samples are taken during the last week of January and the first week of February (FFTRI, 1980). A typical irrigation schedule would include the application of 40–50 mm of water every 10–14 days between full bloom stage and harvest stage; and application of 50 mm every 21 days up until the end of April (Allemann and Young, 2006). The most irrigation is required two weeks before the bud–break stage, and after spring fertiliser application. A typical fertilisation schedule would consist of 56g of Potassium and 10g of Nitrogen per tree in the first year of planting, and application of 30g of Potassium, 140g of Nitrogen and 195g of Phosphate per tree for an orchard that is in its third year (Allemann and Young, 2006).

### 2.3.6 Handling and harvesting

The industry has used short–term and long–term solutions to reduce postharvest losses. The short–term solutions can be described as improvements to fruit handling and the long–term solutions are described as scientific improvements to harvest practices and the use of improved cultivars (Combrink, Benic, Truter, Visagie, and Von Mollendorf, 1992). The former are described as short–term solutions because they prevent fruit from being harmed by abrasions, cuts and compression (i.e. mechanical injury) while the latter enable the fruit to withstand any harsh conditions which may cause fruit damage and decay.

The first significant change in fruit handling was the improvement of refrigeration at sea ports (1911–1918) and during transportation (1925) (PPECB, 2003). Soon after, in 1927, a mobile platform called a skid was introduced. It served the purpose of reducing the number of times that fruit changed hands as it eliminated the handling of individual fruit boxes from the point of leaving the farm until its arrival at the overseas market (PPECB, 2003). In 1989 pallets, a modern version of skids, were introduced. Pallets are more efficient because they are closed, refrigerated containers which have temperatures that are specific to the cultivar type (PPECB, 2003). The packaging and filler material was also changed to reduce the incidences of mechanical injury. In 1894, peaches and nectarines were exported in wooden vats which were padded with cork dust, wool or cotton; in 1897 woodwool became the main padding material and in 1979 cartons replaced the wooden vats (Standard Bank, 1965, PPECB, 2003). Other improvements in handling included: the use of plastic harvest bags and the introduction of air suspension in transporting vehicles (Crisosto and Valero, 2008).

According to Ritchie, Barbra and Pagani (2008), long–term solutions to postharvest problems were only introduced when a scientific research approach was adopted. The use of science brought a better understanding of how the knowledge of plant physiology could be used to avoid postharvest disorders (Combrink *et al.*, 1992). The main change that was introduced involved more accurate estimations of appropriate harvesting time. Using science, it was found that, when peaches are picked too soon they ripen abnormally. They soften slowly and irregularly and fail to reach the desired flesh textures. Late harvest results in fruit that is too soft and susceptible to decay and mechanical injury (Ritchie *et al*., 2008).

Conventional practices used colour and size (measured using sizing rings) to determine fruit maturity (Crisosto and Valero, 2008). Peaches with circumferences ranging between 19cm and 25cm with lime green background were picked while nectarines of similar size with a dull appearance were harvested (Maloney, 2006). Fruit maturity is now determined using the average fruit firmness and average Soluble Solids Content (SSC) of an orchard. These are determined using a fruit sample from the orchard and measuring it using a penetrometer and a refractometer. The orchard is harvested if at least 80 percent of its sample lies in the 6 to 12–pound firmness range on the penetrometer scale and if at least 80 percent of the sample records SSC values which lie between 0.5 and 0.8 units on the refractometer (Maloney, 2006). Both modern and conventional fruit maturity determination methods are used in harvest even today (Saint, 2014).

Other modern harvest management methods include treating peaches with growth regulators such as polyamines and gibberelic acid, and preharvest application of calcium, magnesium and titanium to increase firmness (Crisosto and Valero, 2008). In addition to girdling, i.e. cutting a strip of bark from fruiting wood to induce quick and/or uniform fruiting, farmers have changed to also spraying a chemical called ethylene to achieve even and quick ripening. According to Ritchie *et al*. (2008), the use of improved harvest management practices has further increased yield quality and increased consumer acceptability in addition to reducing postharvest losses.

### 2.3.7 Pest and disease management

Peach and nectarine orchards are affected by a number of pests and diseases which do not occur at the same time, but appear in a fairly regular sequence. Due to the spread occurrence, the industry developed low–cost control strategies that would control the spread of disease and prevent the development of pest problems during the whole production period. Three management practices were developed, and have come to be known as cultural, biological and chemical control practices.

Cultural practices describe the various practices that ensure the trees are healthy. This consists of applying good irrigation and fertilisation schedules that provide trees with adequate water and nutrition. Adequate watering is important because too much or too little water will result in a water–stressed tree that is more susceptible to attacks from diseases and pests (Bruwer, 1978). Another important component is providing good sanitation practices, which include keeping the area near the fruit tree free of debris, stumps, brush piles, weeds and leaf litter as these areas provide the perfect hiding, breeding and living environment for diseases and damaging insects (Wickson, 1889). Regularly pruning diseased wood and early thinning of infected flowers and fruit from trees also prevents new infections from occurring.

Biological control measures consist of the use of certain species of insects which prey on pests. According to the University of California (2010), natural predators such as lacewings, leatherwing beetles, ladybird beetles, ground beetles, wasps, praying mantis and pirate bugs have been used to control aphid, mite, mealybug and whitefly populations. The latest development in biological control methods has been the use of sterile pests to limit the growth of pest populations. Sterile pests are bred and released to mate with the naturally occurring potent insects thus reducing the chances of reproducing more pests. The method of sterile fly dispersion has moved from aerially using planes to ground releases on home gardens, farm backyards and in urban areas (Barnes and Venter, 2006).

Chemical control has traditionally involved the use of a fixed copper spray which is used once or twice during winter. The copper is applied after leaf drop in late autumn and in early spring at budswell or before blossoms (University of California, 2010). According to the University of California (2010), the use of copper–based chemicals controls common diseases such as bacterial canker, brown rot, coryneum blight and peach leaf curl. Recent additions to these pesticides have included adding 1 percent horticultural spray oil to the application mix. Adding this oil has aided in controlling some aphids, scale insects, and mites. The use of chemicals in disinfecting pruning equipment and sealing pruning wounds has also led to control of disease like bacterial canker and silver leaf (FFTRI, 1973).

## 2.4 CHANGES IN PEACH AND NECTARINE PRODUCTION

### 2.4.1 Trends in the number of trees planted

Figure 2.1 below shows the trend in the number of trees planted in the peach and nectarine industry from 1930 to 2012. As shown, there has been a general increase in the number of trees that have been planted from 3.6 million trees in 1930 to 9.2 million in 2012. In the timeline shown, the industry experienced the highest growth in tree numbers between 1930 and 1960 as the number of trees doubled during this period. This increase is attributed to the adoption of the Kakamas cling[1] peach cultivar. The Kakamas planting area increased from 7 400 acres (2 994.7 ha) in 1949 to 17 330 acres (7 013.2 ha) in 1955 (French, 1958). This cultivar was particularly popular because it had high yields due to its resistance to pests, diseases and droughts. According to the Canning Board's 1965 annual report, the average industry yield per tree increased from 48lb/tree (21kg/tree) in 1952 to 67lb/tree (30kg/tree) between 1955 and 1957 and then to 83lb/tree (37kg/tree) in 1964 due to the increase in the number of Kakamas trees planted and coming to bearing. The cling peach varieties are generally popular because they have non–melting flesh that enable them to be used in both fresh market sales and for processing (canning and drying) (Siphugu, 2009). The use of the adapted cling peach cultivars enabled peach tree plantings to spread to areas beyond the borders of the Western Province, i.e. to the summer rainfall area (DoA, 1936).

After this period of rapid growth in tree plantings, the number of trees was maintained at an average of 6.5 million between 1955 and 2000 and increased to 9.2 million in 2012 as shown in Figure 2.1 below. This increase in tree plantings was caused by an increase in dessert peach[2] varieties and nectarine tree numbers. These varieties were not popular in the past because their melting (soft) flesh restricted their use to just the fresh market. However, the introduction of improved production practices and cultivars allowed the industry to plant more dessert peaches

[1] Cling peaches are one of two major peach classes: clingstone and freestone (dessert). Cling peaches have non–melting flesh with stones that tend to cling to the flesh inside the peach.

[2] Dessert (freestone) peaches belong to the second class of peach varieties: peaches that have melting (soft) flesh and seeds that do not stick to the fruit's flesh.

and nectarines which were more lucrative and more suitable for fresh market sales in place of cling peaches. The new cultivars also satisfied changing global consumer tastes which had started shifting from yellow fleshed to white fleshed peaches and nectarines in the 1970s. Thus the new fruit cultivars not only replaced cling peaches in the fresh market, but further resulted in increased fresh fruit production. According to the 2001 and 2012 Hortgro deciduous fruit censuses, there was a 42.5 percent and 35.4 percent increase in dessert peach and nectarine tree numbers respectively; while cling peach tree numbers decreased by 6.8 percent.

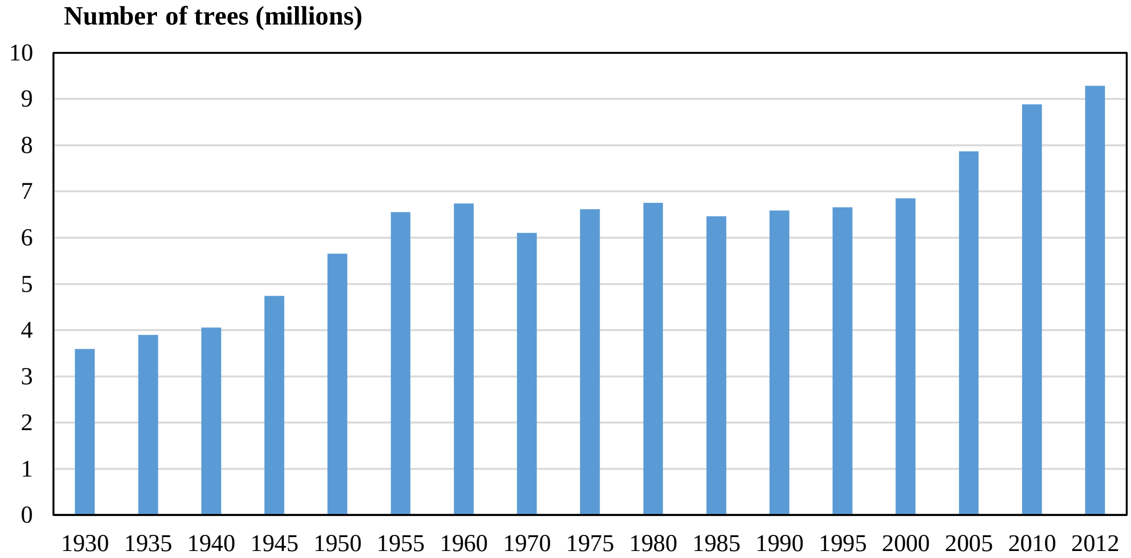


**Figure 2.1: Peach and nectarine industry tree plantings, 1930–2012.**

*Sources: BCS, (1960); DFB, (1970–1989); CFB, (1970–1989); Hortgro, (1989–2012).*

### 2.4.2 Trends in the area planted

Figure 2.2, below, shows that there has been a decrease in the area allocated to peach and nectarine production. The industry’s production area decreased from 11 078 hectares to 9 716 hectares between 1978 and 2012. This decrease in land area has been as a result of the increasing need for efficient production systems due to the increasing cost of production, increasing competition on the global market, introduction of stricter international quality standards and increasing competition for land with alternative deciduous fruit which are fetching higher prices (Siphugu, 2011; Pieterse, 2013; Mashabela and Vink, 2008).

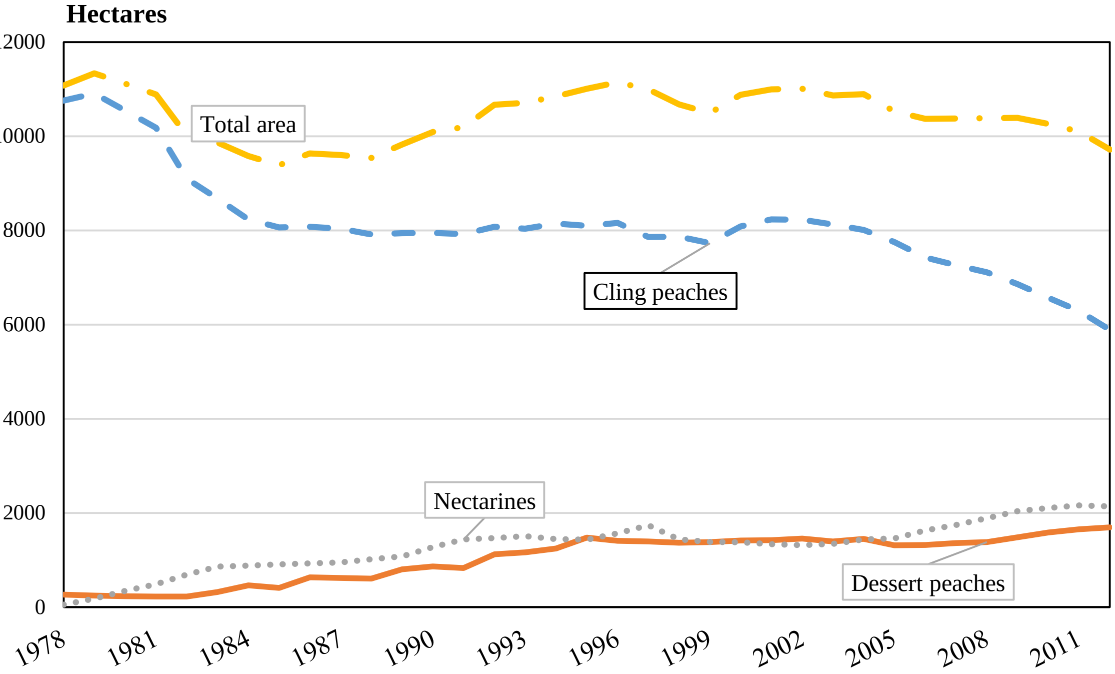


**Figure 2.2: Total area planted to peaches and nectarines, 1978–2012**

*Sources: DFB, (1978–1988); CFB, (1978–1988); Hortgro, (1989–2013)*

One of the ways in which farmers have met the challenge of increasing production costs was by adopting high density training systems such as the palmette and Tatura training systems, which were designed to maximise farm productivity. As shown in Figures 2.1 and 2.2 there was a 12.3 percent decrease in area between 1978 and 2012, while the number of trees planted increased by 41.5 percent. This implies that the industry's planting density increased from 609 trees per hectare in 1978 to 956 trees per hectare in 2012.

The second way the farmers compensated for increasing production costs was to adopt better fruit varieties and cultivars that produced higher quality fruits. This higher quality production fetched higher prices on the international fresh fruit market. The new cultivars lent themselves to the new high density production systems which promoted the development of characteristics such as colour, texture, taste, and size which, in turn, determined the price on fresh markets. As shown in Figure 2.2, the proportion of the industry production area planted to dessert peaches and nectarines increased from 10 percent of the industry's production area (320 hectares) in 1978 to 39.4 percent (3 832 hectares) in 2012. The improved production practices were especially effective in nectarine production as these had the lowest land allocation of the three fruit types because of their susceptibility to pests, diseases and weather elements (Allemann and Young, 2006). The area planted to nectarines increased from 0.5 percent in 1978 to 22 percent in 2012 (Tree censuses; Hortgro, 1989–2012). According to the Hortgro census (Tree census, 2012; Hortgro, 1989–2012), nectarine planting density was calculated at 1 301 trees per hectare, dessert peach planting density was 962 trees per hectare and cling peach planting density was 828 trees per hectare in 2012.

The third way the industry compensated for increasing production costs was through cutting out the less productive and marginal production areas (Siphugu, 2012). These were mainly located in the summer rainfall areas. According to De V. Lotter (1973), the summer rainfall area had gained popularity because it had deep soils which minimised the necessity of irrigation and its summer rains reduced the occurrence of diseases such as silver–leaf. Production in this area was high – problem was that it was not efficient (De V Lotter, 1973). Between 1930 and 2000, the industry focused on producing high production volumes and the production extended to the areas north of the winter rainfall area. However when production costs continued to rise, the production area returned to the Western Cape.

In 1950, 87 percent of all peach and nectarine trees were planted in the Western Province (Tree census: 1952: DFB, 1947–1988). The Province's share reduced to 72.9 percent between 1969 and 2001 (De V Lotter, 1973; Tree census, 2002: Hortgro, 1990–2012). In 1969 the proportions of the trees planted in other provinces were as follows: Transvaal 18 percent, Orange Free State 5.8 percent and the Northern Province 3.3 percent (De V. Lotter, 1973). In 2001, the distribution of trees planted in the different provinces was as follows: Limpopo 7.8 percent, Free State 4.5 percent, Mpumalanga 5 percent, North West 4.4 percent, Eastern Cape 3 percent, Gauteng 2 percent and KwaZulu–Natal 0.4 percent (Tree census, 2002: Hortgro, 1989–2012). By 2012, the production area had shifted back to the winter rainfall area as 88.8 percent of the peach and nectarine trees were planted in the Western Cape Province (Tree census, 2012: Hortgro, 1989–2012). The proportions of trees planted in the different provinces was as follows: Limpopo 5 percent, Free State 0.6 percent, Mpumalanga 0.8 percent, North West 3.9 percent, Eastern Cape 0.3 percent and Gauteng 0.8 percent (Tree census, 2012: Hortgro, 1990–2012). Apart from the poor production practices adopted, the summer rainfall area was also frequented by heavy rains and hail storms (De V Lotter, 1973). These factors often caused premature fruit drop therefore farmers were unable to maximise profits.

### 2.4.3 Changes in area share planted to different varieties

Figure 2.3 shows the changes in area planted to ARC–bred cling peach varieties against the area planted to imported varieties. In 1949, 72 percent of the area planted to cling peaches, was planted to ARC–bred varieties. The Kakamas cultivar was responsible for all the ARC–bred tree plantings in this year. From 1970 to 1988, the total cling peach production area was planted to ARC–bred cultivars. By this time, the cultivars Woltemade, Keimoes, Bonnigold, Professor Black, Professor Neethling, Professor Malherbe and Sandvliet had been released, which caused the dominance of ARC–bred varieties.

The area planted to ARC–bred varieties decreased between 1991 and 2003 as these cultivars became obsolete. Simply put, these cultivars were not as well adapted to the improved production practises as the new imported varieties. New ARC varieties that were adapted to these practises were still in the process of being introduced and finding their place in the market. After the adoption of cultivars such as Cascade and Autumn Crunch, as well as the increasing adaption of the improved practises to the above–mentioned cultivars, the ARC–bred cultivars regained their dominance in the industry. In 2012, Kakamas was planted to 20 percent of the cling peach production area.

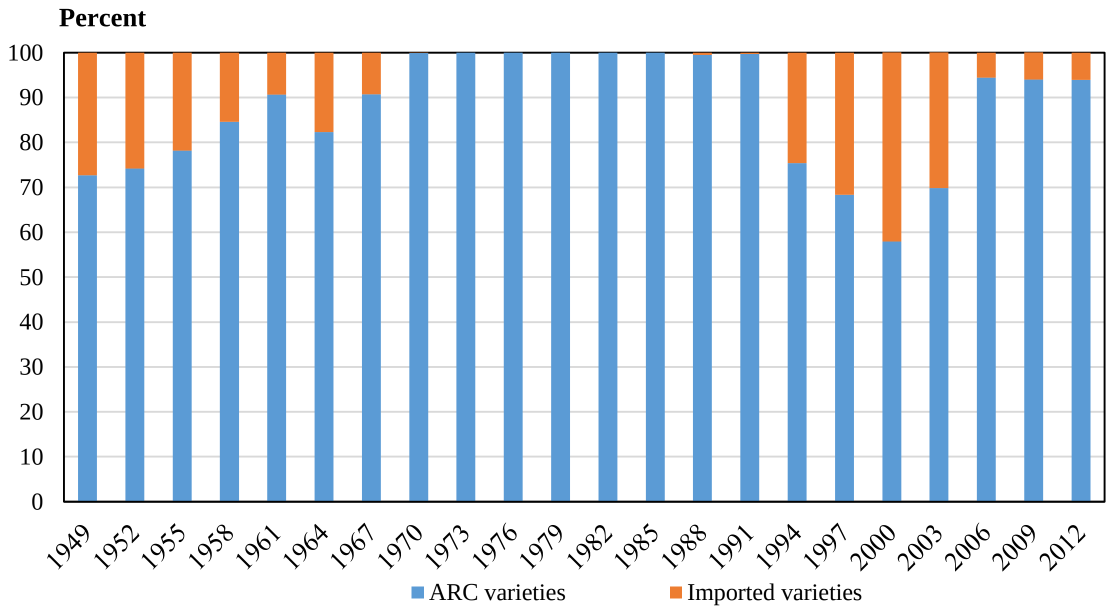


**Figure 2.3: Share of area planted to different cling peach varieties, 1949–2012**

*Sources: CFB (1949–1988); Hortgro (1989–2012)*

Figure 2.4 below shows the changes in the percentage of area planted to ARC–bred dessert peach and nectarine varieties against the area planted to imported varieties. In 1955, 30 percent of the area planted to dessert peaches and nectarines was planted to ARC varieties. At this time the two most popular ARC cultivars were Early Dawn and Van Riebeeck. The ARC had their highest area share between 1967 and 1982 when Culemborg gained popularity. After that, imported cultivars such as San Pedro and Fairtime became popular because they satisfied the tastes and preferences of the consumers better. Improvement in production practises also enabled the successful production of these cultivars. The release of Transvalia marginally increased the area share of the ARC varieties after 2000, however its percentage area has stagnated at 40 percent since 2009.

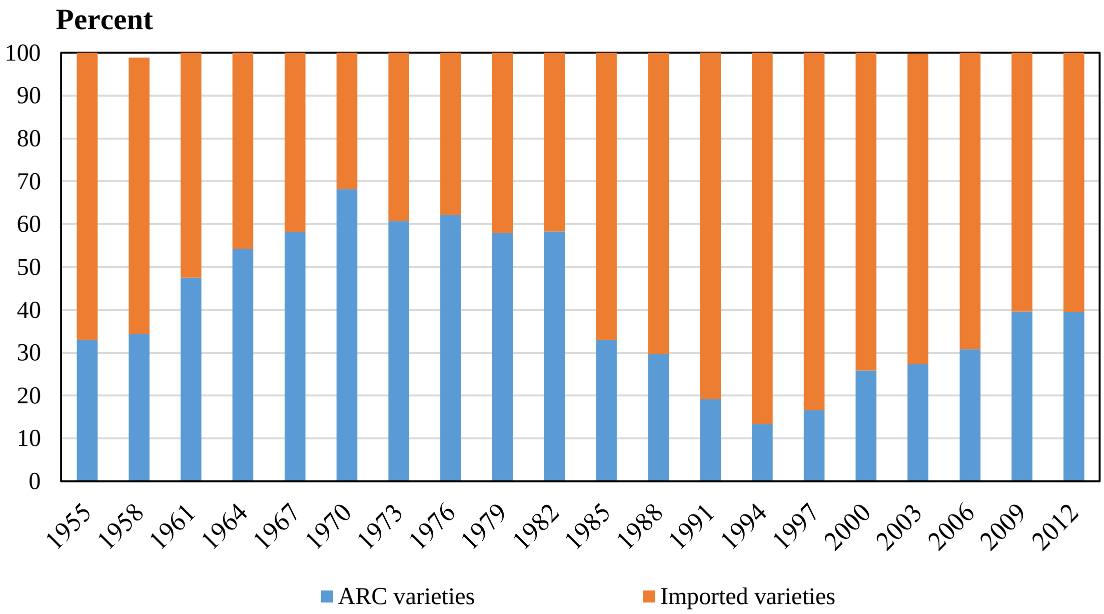


**Figure 2.4: Share of area planted to different nectarine and dessert peach varieties, 1955–2012.**

*Sources: DFB (1955–1988); Hortgro (1989–2012).*

### 2.4.4 Changes in prime peach and nectarine production areas

The main determinant of the success of peach and nectarine farming is the provision of adequate chilling units for a given cultivar (Taylor and Gush, 2007). Chilling units are the minimum number of hours with temperatures below 7 °C in a production season that should be satisfied before a tree can leave a stage of rest and no–growth called the dormancy stage (Allemann and Young, 2006). Dormancy occurs in winter and flowering starts after the break of dormancy. Failure to meet the chilling requirements causes a condition called delayed foliation. The trends in production area distribution from 1952 show how the cultivar choice and the use of dormancy–breaking chemicals enabled the industry to extend into areas with more suitable soils but lower chilling units.

In 1952, all peach and nectarine production was in regions which provided high chilling units[3]. The main production districts were Elgin (1 074.5 chilling units) and Franschhoek (939 chilling units) which were planted to 23.6 percent and 19.4 percent of all the industry's trees respectively (Tree census, 1952: DFB, 1947–1988). With time, the production expanded to include medium chilling unit zones[4]. According to the 1964 Deciduous Fruit Board census (Tree census, 1964: DFB, 1950–1988), Elgin and Franschhoek production districts remained the leading production districts in 1964, with 21.2 percent of peaches and nectarines planted in the Franschhoek district and 17.5 percent in the Elgin production district.

However, by 1972 only 6.1 percent of the total peach and nectarine production area was located in the Elgin production district and the two leading districts in peach and nectarine production were now Franschhoek district, which was planted to 26.5 percent of the industry's trees, and Piketberg district (466.5 chilling units) which was planted to 18 percent of the industry's trees (Tree census, 1972: DFB, 1950–1988). By the end of the 1970s, the Piketberg production district became the main peach production district as its share of the industry's tree numbers was equivalent to 23.6 percent of the total tree numbers while Franschhoek district's tree plantings were equal to 16.1 percent of the total (Tree census, 1978: DFB, 1950–1988).

There was no significant change in the production district distribution in the 1990s. After 2000, the Little Karoo production district which provided 359–530 chilling units became the fastest growing production district as it grew from accounting for 5.5 percent of the peach and nectarine production area in 2000 to accounting for 40 percent of the total production area in 2012 (Tree census, 2000; Hortgro, 1989–2012). The change in production area classified in terms of production region is shown in Figure 2.5 below.

As shown in Figure 2.5, the Groenland production region was the main production region in the 1950s because Elgin, the dominant production district at that time, was located in this region. Figure 2.5 shows that production shifted to the Franschhoek region which had become the main production region by 1970. In the 1980s the Piketberg region became the dominant production region and by the late 1990s the Little Karoo region was the dominating regions. Notably, the Ceres and Wolseley/Tulbagh productions region have grown in significance since 1950 while the Franschhoek production region has reduced in size.

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[3] Areas with high chilling units provide over 800 full hours of temperatures which are below 7 °C per production season.

[4] Areas with medium chilling units provide between 400 and 800 full hours of temperatures which are below 7°C per production season.

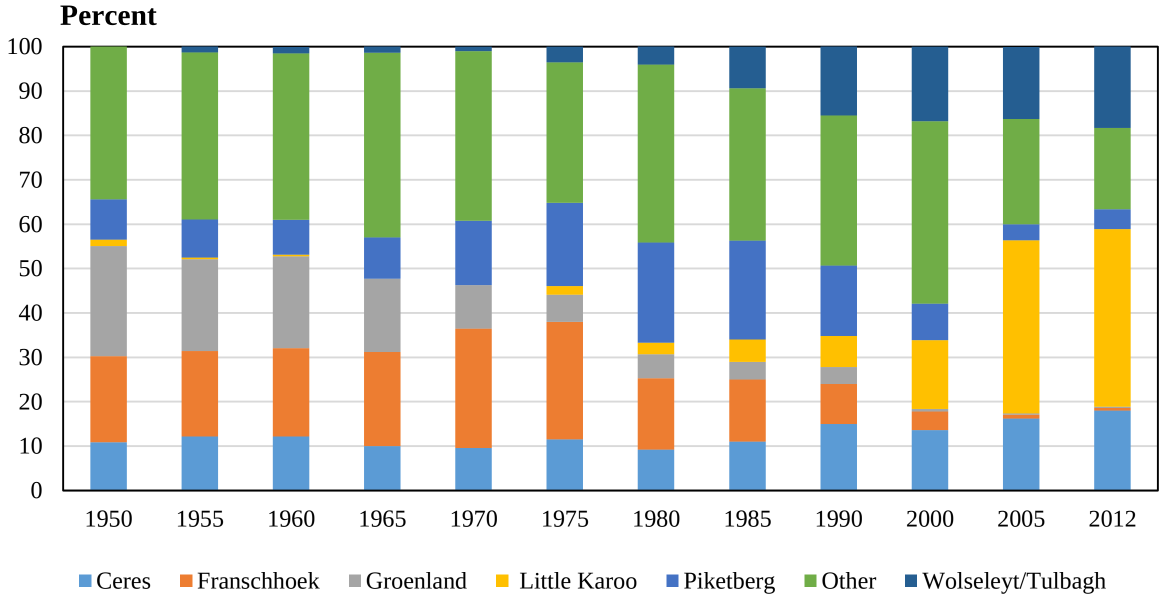


**Figure 2.5:** **Trend in regional distribution of peach production, 1950–2012**

*Sources:* *DFB, (1950–1988); Hortgro, (1989–2012)*

**Notes:* *Other comprises of Bergriver, Orange river, Hex valley, Langkloof, Northern Province, Stellenbosch and Villersdorp/Vyeboom.*

### 2.4.5 Trends in annual production volumes

Figure 2.6 below shows the trend in annual production between 1949 and 2012. As shown, there has been a general increase in the annual production from 43 946 tons produced in 1949 to 181 996 tons produced in 2012. Annual production volumes increased to 105 167 tons in 1953 and decreased because of flooding in cling peach production areas (Memorandum: DFB, 1954). The smooth growth trend that followed after 1960 was a result of increased availability of credit, improvements in extension services and improvements in research and technology transfer provided by the agricultural boards (Bruwer, 1973). The increasing production volumes experienced between 1950 and 1970 are also attributed to the introduction of improved production practices and improved cultivars (FFTRI, 1980). Production increases were sustained by increasing global demand for fruit which was due to the consumers' shift to more healthy food choices, higher global wage levels and higher consumption per capita at global level (Bruwer, 1973). Therefore, the higher remuneration for fruit production encouraged the planting of more trees; thus the extension of the production area. The decrease in production volumes in 1977 resulted from hail storms in the summer rainfall production area (Memorandum: DFB, 1978).

The increases in production peaks between 1979 and 1983 and also between 1996 and 1998 are attributed to the orchard composition. During these years the general orchard composition was made up of larger proportion number trees in their optimum production stages as compared to the number of trees in the non–bearing or less productive stages. Production figures returned to the industry average when the some orchards reached their unproductive stages and trees were replaced. The increases in production volumes in the 1990s are also attributed to increased farmer access to better production inputs which were a result of the removal of trade sanctions in the 1980s and 1990s. After 2000, annual production volumes decreased because a significant part of the industry's production was now planted to lower yielding dessert peach and nectarines trees. The shift in focus to these fruit varieties had a significant effect because the dessert peach and nectarine cultivars are specifically bred to produce high–quality fruit as opposed to high yield. The high density planting systems that were adopted even in the cling peach orchards also favoured the development of quality fruit at the expense of quantity.

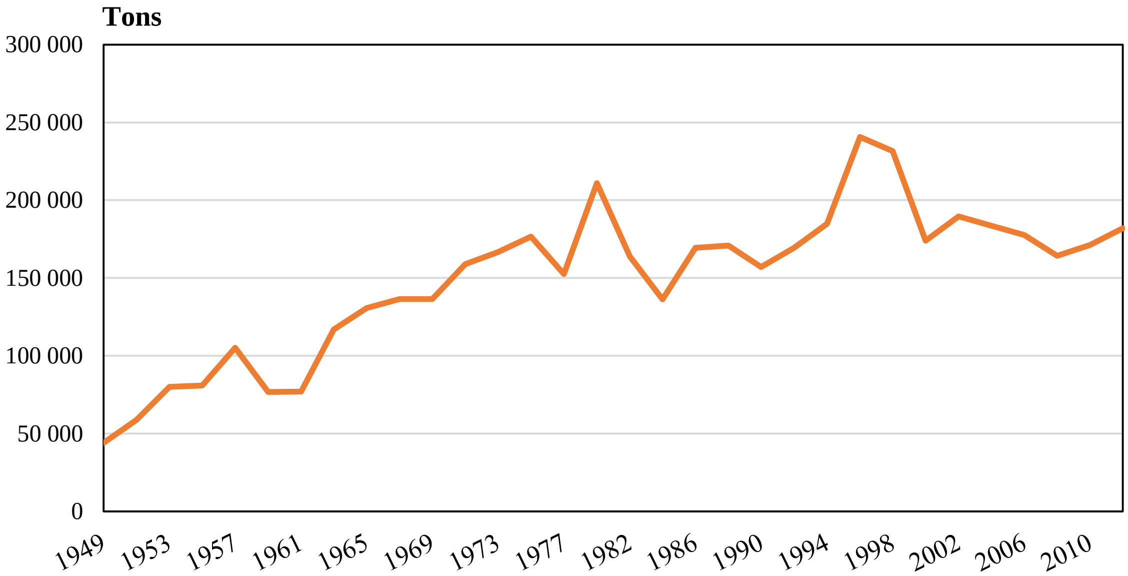


**Figure 2.6: Production trends of peach and nectarine production, 1950–2012**

*Source: DAEM, (1970, 1980), DAFF (2014)*

### 2.4.6 Competitiveness of South Africa's production

The USA is the global leader in peach and nectarine production. Its average production between 1934 and 1938 was 1.7 million tons while the production of its nearest competitor, Italy, was 239 000 tons (French, 1958). Amongst the Southern Hemisphere producers, Argentina, which produced 60 000 tons, was the largest producer and it was followed by Australia which produced 42 000 tons. South Africa, which produced an average of 11 000 tons, was ranked fourth amongst the Southern hemisphere countries after Chile which produced 15 000 tons. New Zealand's average production was 5 000 tons and it was ranked fifth (French, 1958).

South Africa's ranking improved in the 1960s as the peaches and nectarine plantings increased. South Africa was ranked third in Southern Hemisphere as its average production between 1961 and 1970 was 89 000 tons (FFTRI, 1974). Argentina and Australia maintained first and second position, as they produced an average of 194 000 tons and 100 000 tons respectively. Chile's and New Zealand's ranking dropped to fifth and sixth place as Brazil was ranked fourth. Brazil's average production was calculated at 84 000 tons while Chile's production average was 41 000 tons and New Zealand's average production was 22 000 tons (FFTRI, 1974).

The rankings of Southern Hemisphere producers greatly changed after 1980. Chile was ranked as the highest peach and nectarine producer in the Southern Hemisphere as its production average between 2001 and 2010 was 335 000 tons. South Africa was ranked fourth after Argentina and Brazil, which produce an average of 275 000 tons and 215 000 tons respectively (FAO statistics). Australia's average production was 115 000 tons between 2001 and 2010 and was ranked fifth in the Southern Hemisphere while New Zealand's average production was below 10 000 and was ranked sixth (FAO statistics). Chile has achieved this increase in production by adopting a market driven research system and implementing a state driven technology transfer programme, which enabled small–scale farmers to produce fruit more efficiently. Though global production still remains concentrated in the EU community, the largest growth in production has been from China which has the lowest production costs (Ntombela and Moobi, 2013).

### 2.4.7 Production costs

Due to the introduction of improved production practices, South Africa's production costs have increased over the years. The overhead (labour, water, interest on loans and depreciation etc.) costs measured per hectare have shown an increase from R19 363 recorded in 1978 to R22 758 in 2007 and to R30 338 in 2012 (according to 2010 values) (FFTRI, 1979; DFPT, 2008; Tree census, 2012; Hortgro, 1989–2012). The variable costs have also shown increasing trends according to the respective stages of the orchards' maturity. Production costs are highest in orchards that are in their bearing stage (4–25 years old), moderately high in the year of orchard establishment, and lowest in orchards that are not yet bearing fruit (2–3 years old).

The biggest cost driver in the year of an orchard's establishment is the costs of plant material (seedlings). Before 1892, plant material took up a very small part of the production costs because seeds were used for propagation. The main costs incurred during these years were for irrigation and land preparation (Wickson, 1889). By 1978, the cost of plant material per hectare was R11 926.22 and it increased to R17 365.73 in 2007 and to R20 470.76 in 2012 in 2010 values (FFTRI, 1979; DFPT, 2008; Tree census, 2012: Hortgro, 1990–2012). The cost of plant material as a proportion of the orchard establishment cost increased from 12.1 percent to 20.5 percent between 1978 and 2012. The overall cost of establishing an orchard was R99 299.62/ha in 1978 and it decreased to R84 915.32/ha in 2007 and again increased to R102 858.67/ha in 2012 in 2010 values.

The cost of maintaining an orchard that has not reached the bearing stage has been driven by the fertiliser costs. The cost of fertiliser increased from R1 980/ha in 2007 to R3 116/ha in 2012 in 2010 values. The proportion of fertiliser costs in the maintenance costs increased from 6.8 percent in 2007 to 8.6 percent in 2012 (DFPT, 2008; Tree census, 2012; Hortgro, 1989–2012). The next highest costs after fertiliser in this stage of production were for labour, electricity, herbicides and fuel. The overall cost of maintaining a non–bearing orchard increased from R20 159/ha in 1978 to R29 114/ha in 2008 to R36 415/ha in 2012 in 2010 prices (FFTRI, 1979, DFPT, 2008; Tree census, 2012; Hortgro, 1989–2012).

Packing material is the largest cost item on a peach or nectarine enterprise budget (NAMC, 2008). However, recent trends have shown that the cost of rental transport, labour and fertiliser is beginning to take larger shares of the cost of production for bearing orchards (Ross, 2007). The cost of packing material decreased from R59 132 to R55 410 between 2007 and 2012 in 2010 values (DFPT, 2008; Hortgro, 2012: Hortgro, 1989–2012). The share of packing material cost in production costs has decreased from 41.6 percent to 35.1 percent of bearing orchard production costs between 2007 and 2012. Overall, the total production cost for a bearing orchard per hectare increased from R142 010 to R158 034 between 2007 and 2012 in 2010 prices (FFTRI, 1979, DFPT, 2008; Tree census, 2012: Hortgro, 1989–2012).

## 2.5 TRENDS IN PEACH AND NECTARINE MARKETS

### 2.5.1 Trends in peach and nectarine distribution on local markets

Since the establishment of the peach and nectarine industry, most of the fruit has been distributed to the domestic market, i.e. to the local fresh fruit market, as well as canning and dried fruit agents/companies. Of the three, the canning sector has been the largest distribution channel because the cultivars farmed were more suitable for canning than the other two markets (Ntombela and Moobi, 2013). Fruit sales to the canning sector presented a more organised and remunerative distribution channel, since the canneries were established close to the production region. Therefore large volumes could be sold without the extra cost of marketing or transporting the fruit (Douglas and Mullins, 1957). In 1949, 34 740 tons of peaches were sold to the canning sector as shown in Figure 2.7 below. This was equivalent to over 50 percent of the industry's total production. Due to the increasing popularity of adapted cling peach cultivars and the volumes of canning peaches, there was a threefold increase in the fruit volumes between 1953 and 1977. The years that followed were hard years for South Africa as the country was faced with trade sanctions and low prices from the international community. With a great proportion of the canning markets lost, fruit was diverted to drying or sold on the local fresh fruit market. Since the lifting of trade sanctions, 75 percent of the industry's produce has been sold to the canneries (DAEM, 1980; DAFF, 2014).

As shown in Figure 2.7, 6 040 tons of peaches and nectarines were sold on the local fresh fruit market in 1949. This was equivalent to 14 percent of the fruit produced that year. In 1993, 36 609 tons (24 percent of total production) of fruit was sold on the local market. The increase in the local fresh fruit market sales is attributed to the production area expansion to include the summer rainfall area and a change in local consumer taste towards peaches (De V Lotter, 1973). Including the summer rainfall area was significant because it is close to the large local markets, i.e. Johannesburg, Durban and Pietermaritzburg (Memorandum: DFB, 1973). The proximity of the new production areas reduced the losses that had been incurred during rail transportation of fruit to local markets (Memorandum: DFB, 1972). The fruit was also easily sold through informal markets by hawkers or from fruit stalls (De V. Lotter, 1973).

The drying sector has been the smallest sub–sector since 1911 (BCS, 1960). Drying was the farmers' last option for fruit disposal because the dried fruit agents offered low prices. In 1949 a ton of fruit was sold at R28.57 in the drying sector, while the canning sector's price was

R34.11 (DAEM, 1970). The dried fruit sector also had a competitive disadvantage because it was relatively labour intensive as compared to the fresh fruit sector. However, it provided a good alternative market for cling peaches. As shown in Figure 2.7, the volumes of fruit used for drying increased from 995 tons in 1949 to 18 133 tons in 1981. This increase is also attributed to the release of the ARC–bred Du Plessis cultivar which grew well in the summer rainfall area. New drying tunnels that were built in the Middelburg and Lydenburg production areas also encouraged the growth in this sector (Memorandum: DFB, 1978). However, the sector's growth was limited because of unsuitable production practices used on this cultivar. In addition, Du Plessis, did not gain popularity in the winter rainfall area due to problems in handling which were caused by clashes of its harvest time with Sultana grapes which took first preference in the use of the drying equipment (De V. Lotter, 1973).

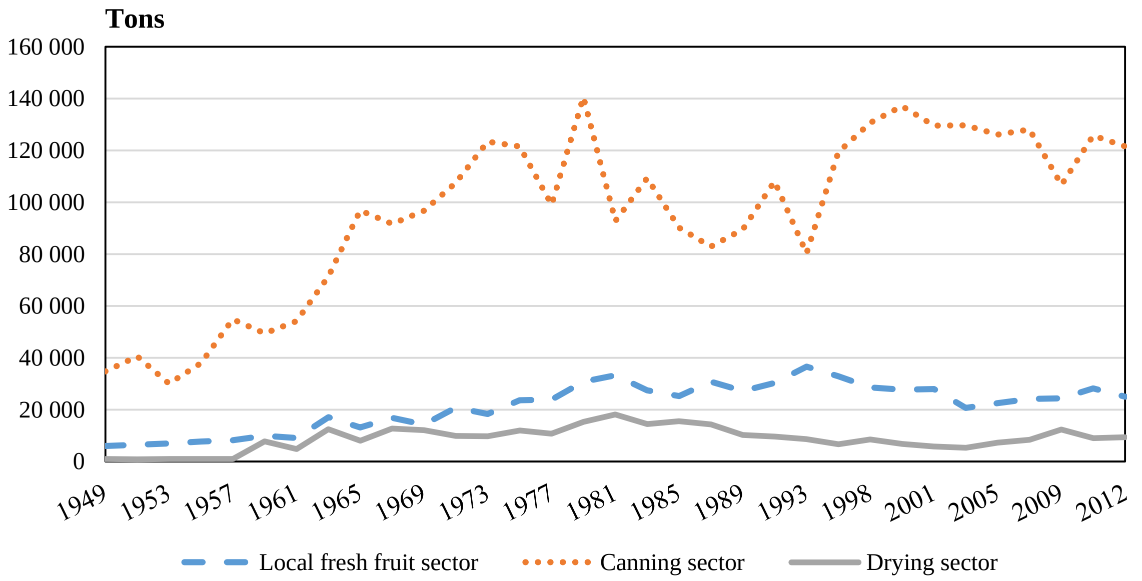


**Figure 2.7: Peach and nectarine sales by market type, 1949–2012**

*Source: DAEM, (1970, 1980), DAFF, (2014)*

### 2.5.2 Competitiveness of the canning sector

According to Cook, Corey, Lynch and Simone (2007), South Africa dominated as the top producer of canned peaches in the Southern Hemisphere from the 1940s through to the early 1990s. In 1952/53, South Africa canned 30 028 tons of peaches while Australia canned 1 350 tons and Argentina canned 1 000 tons (DAEM, 1970; French, 1958). At the end of the decade, South Africa processed 54 824 tons of peaches while Australia and Argentina processed 8 700 tons and 14 400 tons respectively (DAEM, 1970; French, 1958). The largest producer of canned peaches was the USA which processed 493 000 tons and 519 000 in 1952/53 and 1958/59 respectively (French, 1958). The USA secured its position as the best producer because it had highly efficient production systems which produced yields which varied between 9 and 11 tons an acre while South African yields were below 3 tons per acre (French, 1958). Another weakness of South Africa's cling peach production was that it relied on one variety for most of its production at this time (FFTRI, 1974). Argentina's weaknesses were in pest and disease control and canned product quality. It also had a heavy duty that was charged on the sugar cane it imported (French, 1958). This was a big disadvantage because sugar is an important input used in producing canned fruit.

In 1983, South Africa was still the biggest southern Hemisphere canned peach producer as it processed 114 000 metric tons of peaches (FAO statistics). Of the Southern Hemisphere producers, Argentina showed the highest growth as its canning volumes increased to 81 000 metric tons in 1983. New Zealand's canning volumes grew to 20 747 metric tons while Chile produced 14 000 metric tons (FAO statistics). South Africa's canning sector was strongly competitive internationally with respect to costs and it was absolutely superior with respect to product quality (Ross, 2007; Glending, 1975; Cook *et al.*, 2007). Its competitive advantage was gained through a combination of inexpensive labour, a good climate for production, low raw product costs, improvements in efficiency, and a favourable exchange rate with its export markets (Lynch and Moulton, 1995; Ross, 2007). Production costs were comparatively low because all the raw materials used by the canning sector are grown or produced in South Africa (Glending, 1975). South Africa was also part of the Commonwealth, so the sector's products passed onto its largest market, the United Kingdom, tariff free under the Commonwealth Preferential Tariff (Glending, 1975). During this time, South Africa had a General Export Incentive Scheme from its government which reduced the sector's freight costs by 17 percent as it allowed lower taxation rates on the canning companies (Lynch and Moulton, 1995). In addition to this, the government also subsidised the farmers in the years when peach prices were low due to exchange rate fluctuations or other similar reasons (Memorandum: DFB, 1983).

In 1994/95 South Africa was still the highest Southern hemisphere producer of canned peaches (Lynch and Moulton, 1995). It produced 3 772 tons of canned peach cases and was followed by Argentina which produced 2 964 tons. Chile was ranked third as it produced 1 911 tons and Australia was ranked fourth as it produced 1 617 tons (Lynch and Moulton, 1995). The quality premium of South Africa's product was the source of a long–run competitive advantage (Ross, 2007; Cook *et al.*, 2007). Chile managed to increase its production because it has excellent climate for production, low costs of production and moderate productivity rates (Lynch and Moulton, 1995). Mashabela and Vink (2008) added that Chile has also been successful in developing a high-value product that is in line with global demand. This success was realised because of series of reforms which moved Chile's deciduous fruit industry away from the initial import substitution industrialisation model (Mashabela and Vink, 2008). Australia's strength was that its canning agents bought fruit at relatively low prices unlike Argentina which experienced high production costs.

South Africa lost its dominance in Southern Hemisphere canned peach production in the late 1990s. Ross (2007) attributes this, in part, to the trade barriers that were yet to be removed in the late 1990s. To encourage the removal of these barriers, the government stopped providing the General Export Incentive Scheme in 1997 (Lynch and Moulton, 1995). This was done in order for the country to comply with international trade regulations which promoted fair trade. Removal of this and other forms of government assistance increased the in the cost of production for the sector by about 10 percent. In 2006, South Africa processed 84 534 tons of peaches and was ranked third in the Southern Hemisphere region after Argentina and Chile which processed 106 800 and 98 400 metric tons respectively. Australia canned 26 846 tons and was ranked fourth among Southern Hemisphere canned peach producers. According to Ross (2007), there has been a decline in the sector's export profitability which was caused by an increase in the profit capture of value chain by retailers. South Africa is also disadvantaged by the high transportation costs it faces during export (Lynch and Moulton, 1995). These transportation costs are significant because the sector exports 90 percent of the canned products unlike Chile which has most of its products consumed within its borders (Cook *et al.*, 2007). Siphugu (2012) reports that South Africa struggles with inflation rates that are considerably higher than its trading partners and with increasing input (labour, electricity, sugar and cans) costs. Mashabela and Vink (2008) suggest that the sector's competiveness can be improved by increasing the direct investments in R&D within the deciduous fruit value adding activities in the industry's supply chain.

### 2.5.3 Trends in fresh peach and nectarine exports

After the breakthrough in exports 1892, peaches and nectarines contributed very low volumes of fresh exports when compared to the volumes used in processing and local fresh fruit markets. The low export volumes were due to the unavailability of cultivars that had superior shelf–life qualities. Export was done by sea, so fruit had to be kept fresh for an additional 2–3 weeks during the sea voyage (Memorandum: DFB, 1988; Pieterse, 2013). It was also difficult to establish a market because the fruit arrived in variable condition and also because the few cultivars that were available at that time had a widespread harvest period. An additional factor was the high transaction cost that was involved in exporting fruit as export costs took up 65 percent of the production costs of a typical deciduous fruit exporter (Memorandum: DFB, 1981). Most fresh fruit cultivars were not competitive enough to fetch the high prices that could cover the additional exporting costs, therefore only the best fruit was exported and most fresh fruit was sold on the local market.

In 1949 the peach and nectarine industry exported 825 tons of fruit as shown in Figure 2.8 below. Exports grew to 1 272 tons recorded in 1969 but started to decrease because the country was placed under trade sanctions. At its lowest, the industry exported 326 tons of fruit in 1987/88. The years after 1990 saw an exponential increase in the fresh fruit export. This increase was due to the relaxation of the trade sanctions and improvements in handling as air transport of fruit was introduced (Memorandum: DFB, 1992). Growth was further encouraged by the introduction of new cultivars that were in line with changing consumer preferences; which had bigger, sweeter tasting and white flesh fruit (Memorandum: DFB, 1988). The new cultivars also had better keeping qualities.

The decrease in exports after 1999 resulted from a decreases in price. The price of fresh peach and nectarine exports decreased from R19 514 per ton (1999) to R11 542 per ton (2005) in 2010 values (DAFF, 2014). After 2007, the export volumes increased to 10 834 tons recorded 2012 as shown in Figure 2.8. Siphugu (2012) claims that the increases in exports have generally been as a result of improvements in handling, value–chain coordination, improved transportation networks, infrastructural developments, favourable exchange rates as well as institutional changes which created a more enabling trading environment. The percentage of the industry's fruit that was exported increased from 1.9 percent to 6 percent between 1949 and 2012 (DAEM, 1970; DAFF, 2014).

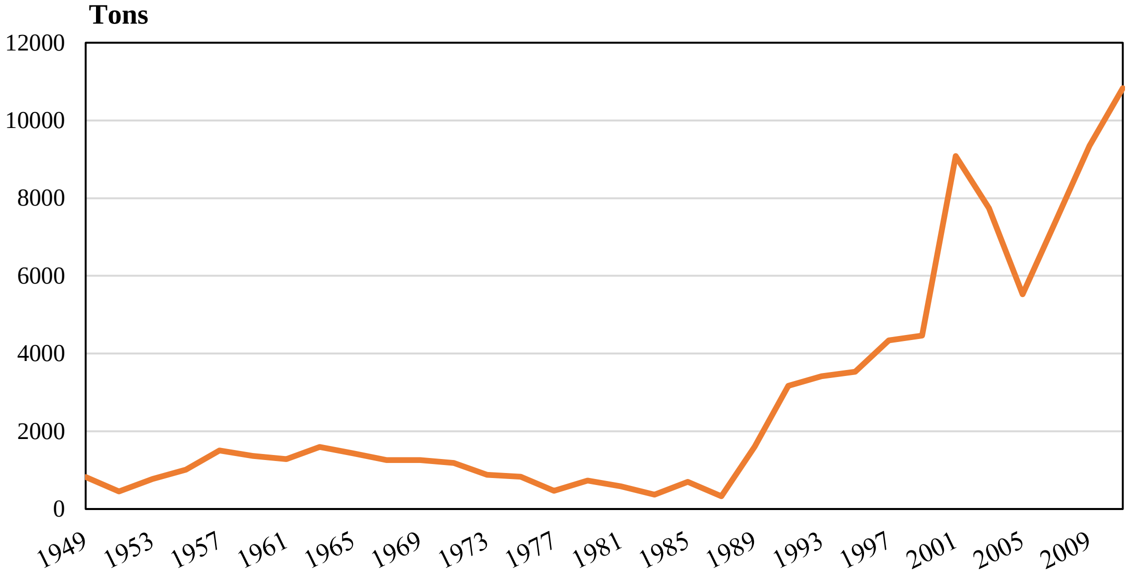


**Figure 2.8: Exports of fresh peaches and nectarines, 1949–2012**

*Source: DAEM, (1970, 1980), DAFF, (2014)*

### 2.5.4 Competitiveness of South Africa's fresh fruit exports

Although South Africa's export volumes are low in comparison to its total production volumes, the fresh export sector has been quite competitive when compared to other Southern Hemisphere exporting countries. Based on the average annual volumes exported between 1961 and 1970, South Africa (with exports averaging 1 500 tons) was ranked second among the Southern Hemisphere exporting countries and was ranked eighth in the world (FFTRI, 1974). The difference between South Africa's average export volume and the largest exporting country, Chile, was just 200 tons (FFTRI, 1974). Argentina, whose average annual export volume was calculated at 200 tons, was ranked third in the Southern Hemisphere (FFTRI, 1974).

By 2010, Chile's exports were almost ten times larger than South Africa's. During that year Chile exported 93 800 tons while South Africa exported 9 631 tons (FAO statistics). South Africa's was ranked third after Argentina which exported 10 017 tons. Australia, which exported 5 526 tons was ranked fourth while New Zealand, which exported 84 000 tons, ranked fifth (FAO statistics). The remarkable growth experienced by Chile was achieved through improving its macro–economic policies and acquiring free trade agreements with the European Union. Though not producing as high volumes, New Zealand and Australia fare quite competitively in terms of freight rates as these greatly lower the cost of doing business (Memorandum: DFB, 1990).

One of the biggest causes for South Africa downward performance were the export sanctions imposed on the country in the 1980s with crippled the industry's progress. The playing field was levelled after the removal the economic sanctions and reduction of state support. South Africa continues to use its competitive advantage of producing earlier ripening cultivars which fetch high off–season prices (Memorandum: DFB, 1990). Using this advantage, South Africa has managed to obtain premiums that range between 50 percent and 100 percent above Chilean cultivars (Memorandum: DFB, 1994). The introduction of airfreight in 1980 has allowed the local exporters further use this advantage as air transport enabled them to widen the geographical distribution of their exports (Memorandum: DFB, 1990). This strategy is significant because the introduction of Chile's fruit on the markets reduces prices to uneconomical levels – especially in the second and third week of December.

### 2.5.5 Gross value of production

Figure 2.9 shows the trend in the gross value of the peach and nectarine industry in South Africa. As shown, the industry's value of production increased from R1.3 million in 1980 to R0.9 billion in 2012 in 2010 values. The growth in the industry's value is attributed to a number of factors which include (though not exhaustively): improvements in the co-ordination of all stakeholders in the supply chain, institutional management more efficient port operations, better innovation and infrastructural efficiency improvements such as sufficient cold storage facilities, improvements in farm productivity due to technical change, better fuel efficiency and increases in labour productivity due to mechanisation. As shown, the bulk of this growth was experienced after 1988. A period which coincided with introduction of television advertisement so the industry stakeholders could better communicate the value of their product and consumers were more prepared to pay a premium for the value the product. There was also the introduction modern fruit handling technology which enabled the preservation of fruit quality from the farm to the end market. These changes resulted in an increase in price paid per ton. Although fruit sold on international markets fetches prices that are, on average, ten times higher than fruit sold on local market, the highest growth in price has been on the local market.

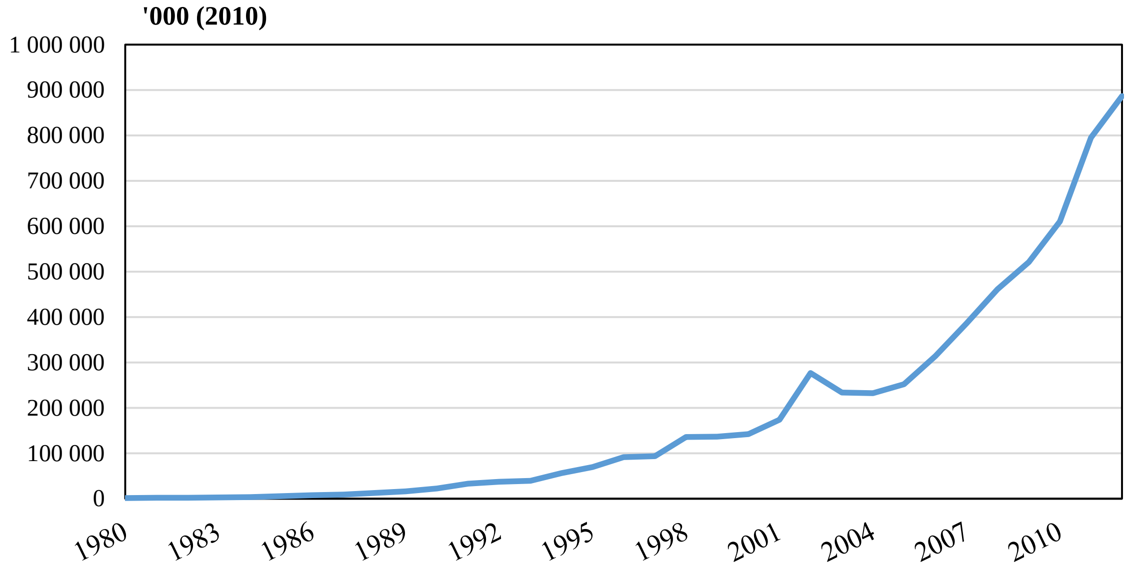


**Figure 2. 9: Gross value of the peach and nectarine industry production, 1980–2012**

*Source: DAFF, (2014)*

## 2.6 SUMMARY

The purpose of this chapter was to give a comprehensive overview of the peach and nectarine industry. As detailed in the chapter, the peach and nectarine industry has changed from the time of its establishment due to the introduction of new production methods. Changes have mainly been driven by the need to produce quality products which perform competitively on the global market and the need to increase production efficiency. The changes in the industry's production area, productivity and market trends were strongly influenced by R&D outputs such as better cultivars and R&D inspired production practices. Despite South Africa's efforts to adjust to stiffening market demands, the industry is struggling to remain competitive in the global market. The next chapter discusses the details of the work that the ARC–Infruitec institute has done in R&D and points to the gaps that are yet to be filled in order to further improve the industry's performance in the market.

# CHAPTER 3

# AN OVERVIEW OF THE AGRICULTURAL RESEARCH COUNCIL'S PEACH AND NECTARINE RESEARCH

## 3.1 INTRODUCTION

As discussed in Chapter 2, changes brought by the application of R&D in production practices have played a profound role in driving the success of the peach and nectarine industry. The specific focus of this chapter is on how R&D was introduced to the peach and nectarine industry and to the deciduous fruit industry as a whole. The aim of this chapter is to discuss the type of research that has been extended to peach and nectarine stakeholders through the ARC's peach and nectarine research programme. As this research was carried out by a research institute that has a wide scope of research, aspects of the research station's research capacity, organisational structure and research priorities are also discussed as these have had an effect on project allocation and the quality of the research done for peaches and nectarines. In particular, the chapter documents the key researchers and goes on to document the technologies that have been developed by the Institute until 2012. Furthermore, the chapter describes changes in research priority/focus and concludes by comparing how the research program fared internationally and evaluates the competitiveness of the technologies.

## 3.2 INTRODUCTION OF AGRICULTURAL R&D

In the 18$^{th}$ century, success in peach and nectarine production was achieved with very little application of science. The early Dutch settlers were out of touch with Europe and the technical science of horticulture, resulting in scientific fruit production practices not taking root in the early Cape Colony, except when it came to vines (Pickstone, 1917). After the book, The California fruits and how to grow them (Wickson, 1889) was made available in 1892, as mentioned in Chapter 2, farmers started to adopt modern production practices which were inspired by science. The government only began to support the farmers' efforts after the first successful exports in 1892 as this was the first evidence that deciduous fruit farming could become a very lucrative industry. Through the use of public funds, two industry representatives were sent to California to learn of the new production and marketing methods. The first person to go on such an educational trip was a member of the Cape Legislative Assembly; Mr A. J.

Louw, who travelled in 1892. The second was Mr P. J. Cillie, a well–known farmer from Wellington, who travelled in the same year (Aucamp, 1987). Cillie's trip was more successful as he quickly gained knowledge on the cultivation and marketing of fresh fruit because he had basic knowledge in fruit farming. Upon return, Cillie delivered lectures and wrote publications that described the new methods of drying fruit and the correct packing methods for fresh fruit he had learnt in the USA (Standard Bank, 1965).

The government realised that the knowledge of the average South African farmers were limited and below that of their international counterparts which, needless to say, affected yields and the performance of South Africa produce in global markets (Kotze, 1987). Realising this, the Cape government appointed a select committee in 1892 to evaluate the deciduous fruit industry and design strategies that would enable farmers to acquire the knowledge they needed to improve output and stimulate the growth of the industry (Standard Bank, 1965). The committee recommended that experts on specific subject matters be contracted to investigate priority issues in the industry. The first consultant that was contracted was a Californian horticulturalist and commercial stone fruit farmer, Henry Pickstone (Pickstone, 1917). Upon arrival, Pickstone immediately established the first deciduous fruit nursery using a £100 advance paid by Cecil John Rhodes, the Cape Prime Minister at that time (Standard Bank, 1965). Pickstone was followed by Henry Meyer who was appointed to conduct a fruit tree census, identify the various cultivars as far as possible and collect information on the position and prospects of fruit cultivation in general (Aucamp, 1987). The aim of these two research projects was twofold: first they sought to identify good fruit cultivars and offer help for their successful propagation while, second, they sought to encourage fruit growers to plant more deciduous trees and produce fruit of a higher standard.

In 1895, the Department of Agriculture contracted Professor R. Wallace from the University of Edinburgh to investigate issues surrounding the cultivation and marketing of fruit. In his research, Wallace identified the lack of a locally based research and advice provider as well as the lack of coordination in the fragmented industry as the two biggest hindrances to the industry's growth (Standard Bank, 1965). In 1896, an entomologist, Dr C. P. Lounsbury, and a mycologist, Dr C. W. Mally, were contracted from the USA  (Aucamp, 1987). Their research produced, among other outputs, the guidelines for controlling existing and preventing the importation of new pests and diseases (Standard Bank, 1965). As the deciduous fruit industry continued to grow, so did its needs, and it was soon discovered that they were beginning to outpace the rate of delivery of technical services (Olivier, 1960). As advised by Mr L. Morgan, the last contracted pomologist (horticulturalist), a permanent advisory pomology council was established in 1902 called the Horticultural Council (Standard Bank, 1965).

After the establishment of the Union of South Africa in 1910, public sector involvement in the sector increased when the Board of Horticulture was established to act as a liaison between the farmers and the Department of Agriculture, and to carry out cultivation and marketing research (Aucamp, 1987). This board was made up of two representatives from each of all the fruit industries and farmers in those industries. However, due to capacity limitations, the Horticultural Board mainly carried out activities that can be described as fruit inspection (Carter, 1999). In 1914, all agricultural extension services were transferred to agricultural colleges. The Stellenbosch–Elsenburg College of Agriculture of the University of Stellenbosch which shall henceforth be referred to as “the University”, became entrusted with the responsibility of delivering research services to deciduous fruit farmers (Standard Bank, 1965). The University was instructed to increase the scope of agricultural technical services to include soil selection, soil preservation and cultivar selection (Memorandum: DFB, 1952). The idea was met with resistance because the University staff had their hands full. Low state allocation of research funds also made it difficult for the university researchers to produce tangible and worthwhile research (Carter, 1999).

According to Carter (1999), the first formal research was conducted in 1925. This research investigated the effects of pre–cooling and refrigerated transportation on deciduous fruit quality. During the same year, the Low Temperature Research Laboratory was established and later the Dehydration and Cold Storage Laboratory was also established. These research stations investigated and gave advice on cold–storage matters while the University handled plant protection and production issues. By 1935, the growing needs of the still expanding industry began to out–pace the development rate of the technical research facilities (Olivier, 1960). Meanwhile, for the peach and nectarine industry, there was dire need for research investigations amidst the emergence of a “mysterious” disease, which was later identified as the wooliness disease, that had reduced exports to zero in 1936 (DoA, 1936). With fears that the peach and nectarine ordeal would surface in other deciduous fruits, it was decided that a research station that would focus on deciduous fruit be established in 1937. The research station was called the Western Province Research Station (WPRS) and the scope of its investigations was increased after its research agenda was revised.

## 3.3 ESTABLISHMENT OF A RESEARCH INSTITUTE

The WPRS had its modest beginning in a few rooms of the University (Olivier, 1960). It had three permanent employees — Dr du Toit, Dr Reynecke and Dr Reinecke — who worked closely with an external consultant, Dr Hatton, the director of the East Malling Research Station in the USA (Kotze, 1987). An experimental farm, Bien Donne, was established for field experiments on two farms which were purchased from the Rhodes Company (Olivier, 1960). This research station was now in charge of most of the experimental work that was done on crops such as perennial horticultural crops, nuts and fruits (Black, 1947). Its researchers also worked closely with the University's researchers who were not incorporated in the research station. The University conducted some biochemistry and horticultural research, while the WPRS concentrated on cultivar selection, agrometeorology, soil selection; and horticultural and entomology advisory services (Aucamp, 1987; Kotze, 1987).

Peaches and nectarines were set as one of the top five priority fruits to be researched at the establishment of the WPRS (Steyn, 1955). At first, the station had a pre–bureaucratic organisational structure where there was no standardisation of tasks and all the researchers performed any type of research that was commissioned by the industry. In 1939, the research station began to also conduct research on strawberries and ornamental shrubs and flowers (Olivier, 1960). This increase in scope came with an increase in the number of researchers and technicians. By 1942, the permanent research staff increased to 20 graduate scientific personnel and a bureaucratic structure was adopted in which Dr du Toit was the director of the research station (Olivier, 1960). The number of researchers was further increased in 1947 when the Cold Storage Laboratory (formed by the amalgamation of the Dehydration and Cold Storage Laboratory and the Low Temperature Research Laboratory) was absorbed into the WPRS (Kotze, 1987). This merger increased the station's research scope to include cold storage research. Although the bureaucratic organisational structure resulted in a greater degree of standardisation of tasks, the station did not fully adopt discipline specialisation, owing to financial and human resource limitations. It remained common for a researcher to be involved in research projects in different disciplines such as breeding, soil science and pathology in the same or in successive years.

True discipline specialisation was achieved in the 1950s when a functional organisational structure was adopted. In this structure, the employees were grouped according to their areas of speciality and each unit performed a specialised function which was defined by agricultural research disciplines such as Horticulture or Plant Improvement. The unit leaders reported to the research station director, Dr Reuben Nel, who was responsible for coordinating the efforts of each of the units and meshing them together into a cohesive whole. This increase in specialisation was made possible by large infrastructural investments that were made by the state through the Deciduous Fruit Board. The research station was moved from the University to a bigger and more permanent building complex, the Reuben Nel Building on the present day ARC–Infruitec Institute campus, and a number of research farms were purchased (Kotze, 1987). Olivier (1960) reports that the Institute's buildings and equipment were ranked among the best in the world at this period in time. The number of researchers increased and the research focus was expanded to include research on other plants such as vegetables and rooibos tea (Kotze, 1987). Plants that formed part of the research scope were: peaches, nectarines, apricots, plums, prunes, pears, apples, wine grapes, table grapes, dried grapes, nuts, kiwi–fruits, pineapples, strawberries, cherries, olives, berries, figs, dates, buchu, red tea, rooibos tea, Lachenalia flowers and Proteceae flowers (Black, 1952, Annual research review, 1982: FFTRI, 1970–1989). Deciduous fruits and vines were the main focus of the research Institute and the station's name was changed to The Fruit and Food Technology Research Institute (FFTRI) along with an expansion in its mandate to serve as a national research institute.

### 3.3.1 Research capacity of the FFTRI Institute

Since 1960, the Institute has had an average of 56 researchers. As shown in Figure 3.1, it had its lowest number of researchers in 1980, (42 researchers). This number decreased from 52 researchers (in 1970) and this was as a result of the restructuring in South African research institutes. According to Kotze (1987), research on ornamental plants and vegetables was transferred to Roodeplaat Research Institute, while the research on pome and stone fruits was separated and assigned to the Fruit and Fruit Technology Research Institute (FFTRI) and grape research was moved to the Viticultural and Oenological Research Institute. In order to more effectively conduct research for the summer rainfall region, some research on deciduous fruit, especially breeding, was also transferred to the Roodeplaat Research Institute (Annual research review, 1982: FFTRI, 1970–1989). The restructuring also included the transfer of some experimental farms from the new FFTRI Institute's administration (Kotze, 1987).

Hereafter, the FFTRI gradually increased the number of research personnel. This took time because of the scarcity of agricultural research skills in the country and the challenges related to the lack of attractiveness of agricultural research careers in South Africa at the time

(Memorandum: DFB, 1983). The number of researchers per deciduous fruit increased as the Institute had a narrower research scope after 1980. Between 1992 and 1994 the Institute experienced a loss of a few but critical researchers because the formation of the Agricultural Research Council (ARC) in 1992 came with changes in leadership and organisational structure to a complex matrix structure[5] which caused problems with coordination within the organisation and with stakeholders, which left researchers frustrated. Liebenberg and Kirsten (2006) state reductions in the core, state funding as the major factor resulting in the stagnant number of researchers in this period. FFTRI later became known as the Infruitec Research Institute of the ARC in 1992. ARC–Infruitec's researcher numbers increased from 50 to 65 after 1993. During this period, it also merged with the grape Institute to form the Infruitec–Nietvoorbij Institute of the ARC.

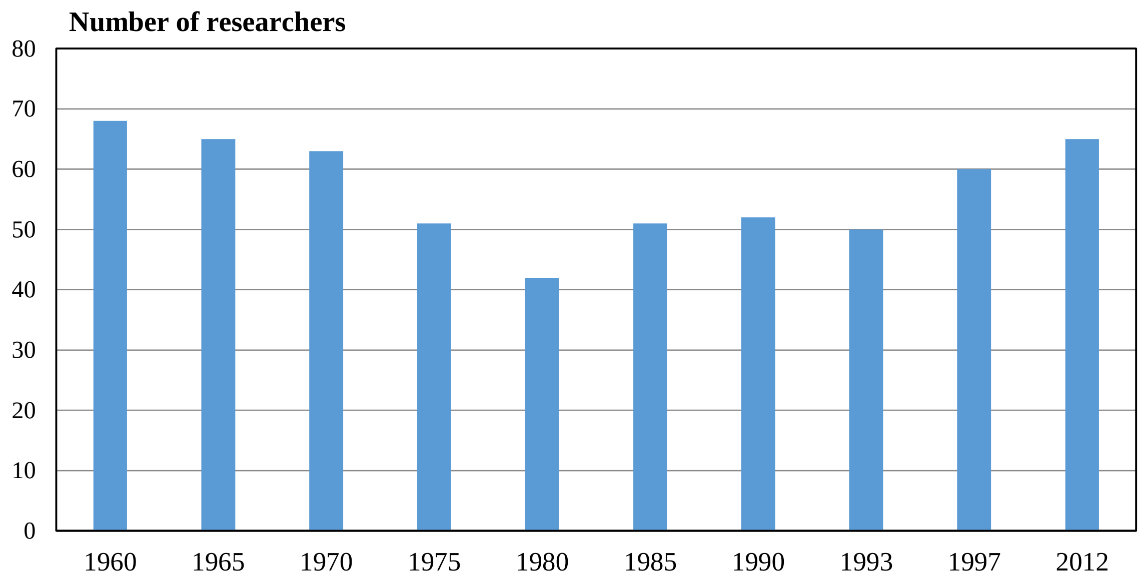


**Figure 3.1: Number of researchers at FFTRI/ARC–Infruitec, 1960–2012**

*Sources: DATS, (1960–1993); ARC–Infruitec (1997); ARC–Infruitec, (2012)*

Figure 3.2 below shows changes in the researcher turnover or the number of years researchers worked at the Institute calculated from 1960. It shows that, there has been a general increase in the average number of years a researcher works at the Institute. From 1978, the average researcher in the FFTRI/Infruitec Institute accumulated at least five years of working experience before leaving the Institute. At most, a researcher spent nine years in the Institute before seeking employment elsewhere. These figures imply that researchers would conduct one

[5] A matrix organisation structure is one which aligns employees according to more than one criterion e.g. product and function as a result have multiple reporting lines

or two projects since a project took, on average, four to five years to complete. This was a loss for the Institute because the researchers would leave without effectively applying their gained knowledge in the Institute. Therefore, due to the Institute's inability to retain its employees, it finds itself in the position of constantly training employees. The employee turnover was especially counter–productive in the years before 1985 when projects took longer than the average life span. As a result, research continuity was a great problem at this time.

By inspection, Figure 3.2 shows that there a relationship between employee turnover and change in organisational structure. The decrease in the average employee experience around 1980 coincided with the restructuring in South African research institutes. The decrease in the average employee experience between 1992 and 1994 coincides with the adoption of the matrix organisational structure. It is not clear why the average experience decreased between 1986 and 1988, but researcher trends from the National List of Professional Research Workers of South Africa (DATS, 1960–1993) shows that a large number of experienced researchers (between 17–20 years' experience) were being replaced by researchers with 2 to 4 years' experience that had higher educational qualifications during this time. According to the Infruitec–Nietvoorbij Times (2006), the Institute actually performed much better than other research institutions in terms of employee retainment as the lowest staff turnover as recorded in 1991/92. The trend for the Institute's researchers' average experience could not be calculated for the years after 2001 because the data for the staff records for the years between 2000 and 2012 were not available.

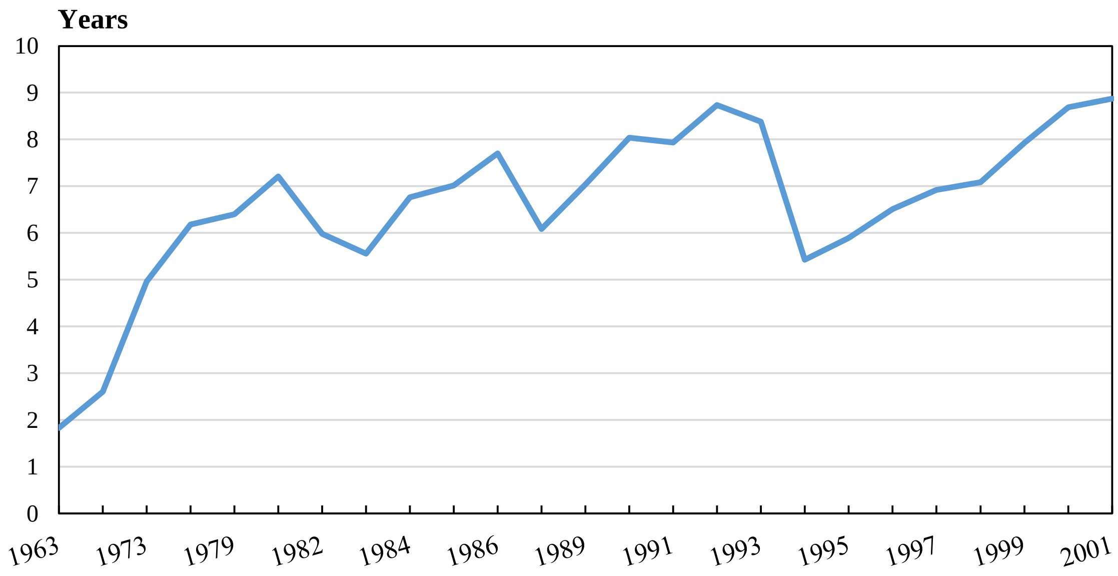


**Figure 3.2: Average experience for FFTRI/ARC–Infruitec researchers, 1960–2012**

*Sources: Author's compilations from DATS, (1960–1993); ARC–Infruitec (1992–2002)*

Figure 3.3 below shows that the research capacity measured in terms of the highest educational attainment. It shows that the FFTRI's research capacity has gradually increased since 1960 as the number of researchers that have a BSc or equivalent degree qualifications has decreased as compared to those that have PhD and MSc or equivalent qualifications. This increase in research capacity has been a result of the ARC taking various measures of capacity building by providing funding for MSc and PhD degrees (Annual research review, 1992: ARC–Infruitec, 1992–2002). The Institute also shifted to educating its researchers at local universities as opposed to educating them abroad which was three times as expensive as educating them locally (Memorandum: DFB, 1983).

The increasing trend in research capacity also reflects the general increase in the number of people with MSc or equivalent degree qualifications in the country which has been as a result of the increased opportunities for tertiary education funding. In 1991 the FFTRI had the highest percentage of researchers with MSc and PhD or equivalent degrees of any research institute in the country (ARC–Infruitec–Nietvoorbij, 2006). Despite the increase in these opportunities there still remains a shortage of individuals with PhD or equivalent educational qualification. This is reflected by the stagnant trends in the number of researchers with PhDs. The shortage of certain competencies has led to some researchers performing duties in more than one research discipline even in the matrix organisational structure. For example, Dr Mollendorff, the head of the Breeding and Evaluation division in 1994 had to take over the duties of Dr O. Bergh who had been the head of the Horticulture division, because the Institute was unable to find a replacement for Dr Bergh after his retirement in 1995.

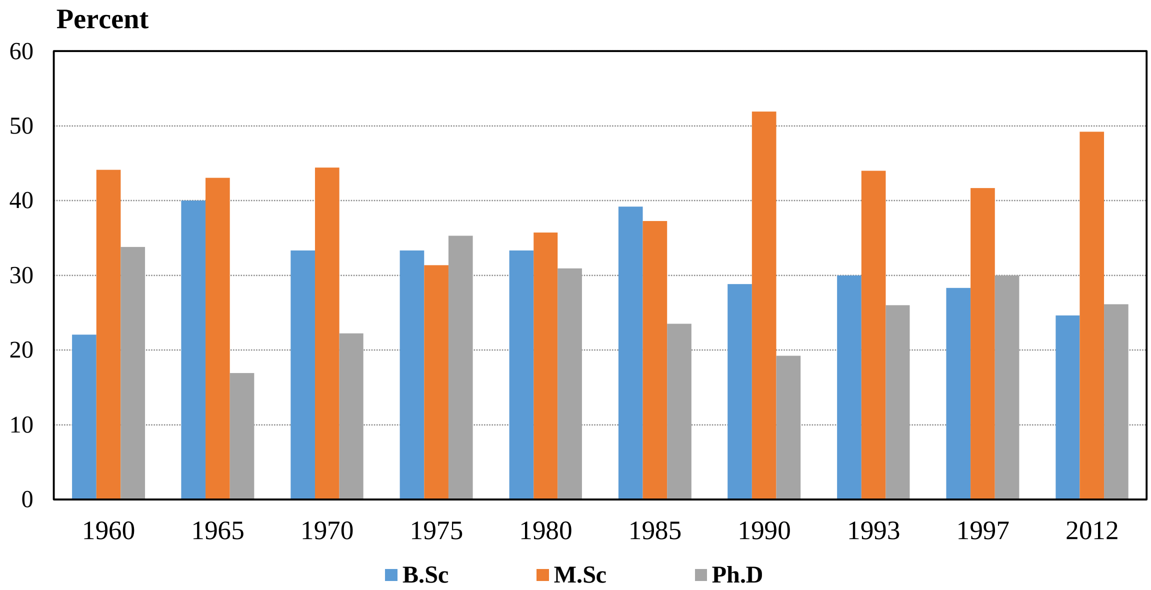


**Figure 3.3: Share of FFTRI/ARC–Infruitec research staff by educational attainment, 1960–2012**

*Sources: DATS (1960–1993); ARC–Infruitec (1997); ARC–Infruitec (2012)*

The ARC has also put remunerative incentives in place to encourage educational investment for researchers.

### 3.3.2 Research focus/priority of FFTRI Institute

The research done in FFTRI/ARC–Infruitec units can be classified into five research disciplines, namely: Plant Improvement, Horticulture, Biochemistry and Pathology, Postharvest Technology, and Soil Science and Irrigation disciplines.

- The Plant Improvement discipline builds on work done in the Cultivar Selection unit and in the Breeding and Evaluation division. Work done in this discipline includes all research that was conducted to develop new cultivars.
- The Horticulture discipline focuses on research that was done by the Crop Science, Pomology and Biotechnology divisions. These divisions were responsible for investigating dormancy breaking compounds, delayed foliation, packaging materials, rootstock breeding, evaluation and propagation and production practices.
- Biochemistry and Pathology focuses on work conducted in the Physiology, Biochemistry and Nutrition divisions. The aim of these divisions was to carry out basic and applied research in the field of biochemistry and plant physiology with the view of ensuring

optimum production and quality. It also includes research on pest and disease identification and control.

- Postharvest Technology discipline combines the work that was done in the Cold Storage as well as the Food and Processing Technology divisions. The research carried out in this discipline includes all aspects relating to storage, processing and process optimisation of horticultural crops.
- The Soil Technology and Irrigation discipline builds on the research that was conducted in the Soil Science, Water Requirement and Radio–isotopes divisions. This research is done to optimise the use of natural resources.

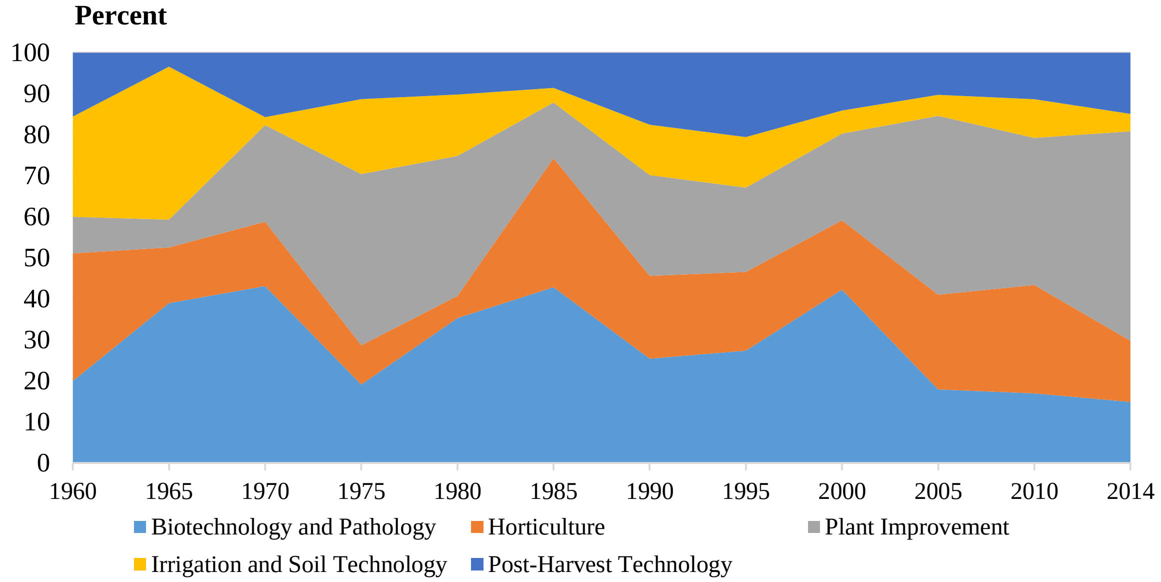


**Figure 3.4: Distribution of projects within FFTRI/ARC–Infruitec, 1960–2014.**

*Source: FFTRI (1960–1969); FFTRI (1970–1989); ARC–Infruitec (1992–2002); ARC–Infruitec (1999–2014).*

The change in research focus and or priority among these five disciplines with respect to the total number of research projects allocated to each discipline for the FFTRI/ ARC–Infruitec research Institute is shown in Figure 3.4[6]. Most of the deciduous fruit research that has been done by the FFTRI/ARC–Infruitec institute between 1960 and 2014 has been in the Biotechnology and Pathology and Plant Improvement disciplines. In 1960 most projects were conducted in the Horticulture and Irrigation and Soil Technology disciplines as the number of projects conducted in these two disciplines as a share of the total number of projects was

[6] Project allocation was used to estimate distribution of research effort because the financial investment figures were not available. Human capital could not be used either because the researchers shuffled between the research disciplines. Time logs for the amount of time spent on different tasks were only introduced 2012.

55 percent, but by 2010 these two disciplines had just over 30 percent project allocation. The only discipline to have experienced an increase in project allocation during this 54–year time period is the Plant Improvement discipline. This is primarily due to the increase in popularity of this discipline's outputs (i.e. cultivars).

## 3.4 PEACH AND NECTARINE RESEARCH

Table 3.1 below shows the number of projects that were pursued to investigate matters that affect deciduous fruit, and the number of projects that were done to investigate matters that affect peaches and nectarines. As shown, the number of projects allocated to deciduous fruits increased from 44 to 110 between 1960 and 1990. Thereafter, project numbers decreased such that in 2014 only 51 were recorded. The number of peach and nectarine projects has increased from 9 to 15 between 1960 and 2014. The proportion of peach and nectarine projects as a percentage of the deciduous fruit projects has increased from 20 percent to 29 percent during this period.

**Table 3.1: Number of deciduous fruit projects done at FFTRI/ARC–Infruitec**

| Year | 1960 | 1965 | 1970 | 1975 | 1980 | 1985 | 1990 | 1995 | 2000 | 2006 | 2014 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of deciduous fruit projects | 44 | 60 | 61 | 76 | 96 | 106 | 110 | 84 | 55 | 47 | 51 |
| Number of projects allocated to peaches and nectarines | 9 | 14 | 10 | 11 | 18 | 17 | 23 | 16 | 13 | 13 | 15 |

*Source:* *FFTRI (1960–1969); FFTRI (1970–1989); ARC–Infruitec (1992–2002); ARC–Infruitec (1999–2014)*
*Notes:* *Statistics exclude wine, table and dried grape projects*

Figure 3.5 below shows the change in distribution of projects within the peach and nectarine research programme. Peach and nectarine research focus shifted from the Biotechnology and Pathology discipline in 1960 to Horticultural investigations in 1985 and then to Plant Improvement in 1999. The increase in breeding projects resulted from an increase in funding of breeding which, in turn, resulted from the high success rate of cultivars released. The successes of the Plant Improvement discipline as well as some of the research that has been done in the other disciplines are discussed in the sections that follow.

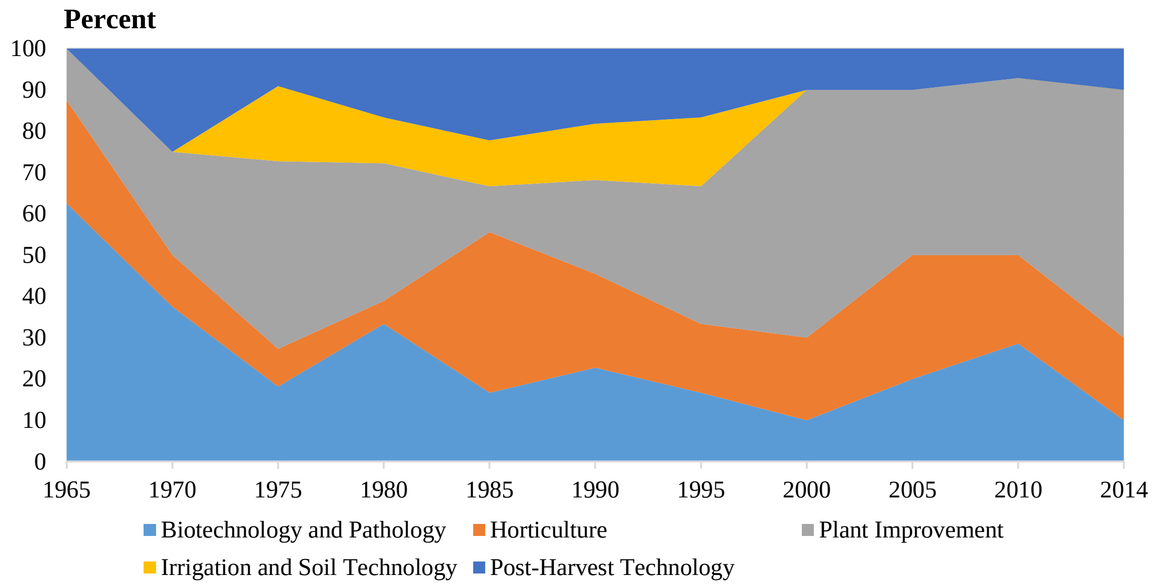


**Figure 3.5: Distribution of projects within the peach and nectarine research programme, 1960–2014**

*Source: FFTRI (1960–1969); FFTRI (1970–1989); ARC–Infruitec (1992–2002); ARC–Infruitec (1999–2014)*

### 3.4.1 Plant Improvement

Plant Improvement research was one of the most important disciplines that were undertaken by the WPRS. In 1939, a peach breeding project was started along with two other projects: table grapes and strawberries breeding (Steyn, 1955). The peach breeding project was led by A. F. De Wet and it was started in order to solve the "variety problem" by coming up with new cultivars that would replace poorly adapted and low quality imported peach cultivars (Wenzel et *al.*, 1975). The early researchers used the most conventional method of breeding based on cultivar selection, which comprised conducting field surveys and testing the fruits for the desirable characteristics. This method produced what the US termed "Gift from God varieties", as unique characteristics of the new cultivars resulted from mutations (Black, 1952; Steyn, 1955). Cultivar selection was a painstaking exercise that required much perseverance and patience.

The first breeding project was built on the work conducted in 1932 by H. Reinecke, who discovered and registered two cling peach cultivars, Maluti and Kakamas, and the dessert peach Early Dawn cultivar (ASHS, 1997, Wenzel *et al.*, 1975). These discoveries were made from seedlings and vegetative material collections made from the Transvaal yellow peach progenies (Steyn, 1955). These cultivars performed significantly better than the imported cultivars such as Goosen and were received well by the farmers. It was soon realised that, with the tremendous increase in production, problems would arise in handling as millions of trees were harvested in a short space of time. Consequently, it became imperative that new cultivars be found that would spread the harvest period. The introduction of new cultivars was also important in the fresh fruit market because Early Dawn was susceptible to delayed foliation, it had poor keeping qualities and it caused a production peak during the season, which depressed prices on overseas markets (Hurter, 1978; FFTRI, 1982). As the industry's processing and fresh fruit sectors had unique cultivar requirements, two different breeding projects were started; each focused on the unique breeding requirements of one of the two sub–sectors.

Three more cling peach cultivars (Keimoes, Du Plessis, Walgant) and four dessert peach cultivars (Culemborg, Van Riebeeck, Rhodes/Swellengrebel, Tokane) were discovered from the Transvaal peach tree sample collected by Reinecke. The new cling peach cultivars did very little to solve the problems in the canning sector (Steyn, 1955). As shown in Table 3.2 below, the harvest periods of the new cultivars were in the same week as Kakamas. However, they provided a solution to the problem with texture defects present in the imported cultivars (FFTRI, 1982). The imported cultivars were too soft and could not be handled by the canning companies' pitting machines and some would also clog the machines (Annual research review, 1960: 1966: FFTRI 1960–1969). Due to the unsuitable textures, peach halves were often discarded and canneries faced high losses.

P. A. L Steyn, a new FFTRI peach breeder, took a different approach by using controlled cross–pollinations to develop new cultivars. This method was introduced in 1942 and involved three steps. First, the cultivar Kakamas was self–pollinated then cross–pollinated with Early Dawn. The resultant hybrids/offspring ($F^1$ generation) were then self–pollinated and/or back–crossed to Kakamas (Wenzel *et al.*, 1975). The USA–bred cultivar, Goosen, was also used in some cross pollinations. The cling peach cultivars resulting from this new cross–pollination method were named Oom Sarel, Professor Black, Professor Malherbe and Professor Neethling, and released in 1961 (ASHS, 1997). These cultivars managed to solve the handling problem as they extended the canning season from being concentrated in just February to cover the period between December and February (Hurter, 1978). As shown in Table 3.2 below, the harvest period now stretched from week 51 to week 6 in the new calendar year.

**Table 3.2: Cling peach cultivars released, 1932–1961**

| Cultivar | Year released | Breeder | Harvest (mean ripening time) |
|---|---|---|---|
| Kakamas | 1932 | H. Reinecke | Week 6 (February 19) |
| Maluti | 1933 | A. F. De Wet | Week 5 |
| Woltemade | 1948 | A. F. De Wet | Week 6 |
| Tokane | 1952 | A. F. De Wet | Week 6 |
| Keimoes | 1952 | A. F. De Wet | Week 4 |
| Du Plessis | 1952 | A. F. De Wet | Week 3 |
| Walgant | 1959 | P. A. L. Steyn | Week 5 (February 5) |
| Oom Sarel | 1961 | P. A. L. Steyn | Week 51 (December 20) |
| Professor Black | 1961 | P. A. L. Steyn | Week 2 (January14) |
| Professor Malherbe | 1961 | P. A. L. Steyn | Week 52 (December 26) |
| Professor Neethling | 1961 | P. A. L. Steyn | Week 2 (January 17) |

*Source: FFTRI 1973; Wenzel et al., 1975*

The new dessert peach cultivars developed using the new breeding method led to the extension of the harvest period from three weeks (week 48 to week 50) with Early Dawn, Inkoos and Marina to six weeks (Hurter, 1978). These new cultivars had a significant impact on extending the production area as they had low chilling requirements, which meant that they could be grown in warmer areas. Breeding also increased the variety of fruit characteristics as shown in Table 3.3 below. Fruits with blushes and varied shapes were developed.

**Table 3.3: Dessert peach cultivars released 1920s–1974**

| Cultivar | Year released | Breeder | Harvest time | Chilling requirements | Characteristics |
|---|---|---|---|---|---|
| Inkoos | 1920s | H. O. Arton | Week 49 –50 | Medium | Red skin colour |
| Marina | 1933 | Mr Swart | Week 49 –50 | High | Red skin colour |
| Early Dawn | 1937 | H. Reinecke | Week 48 –49 | High | Red skin colour |
| Boland | 1944 | H. Reinecke | Week 52 –1 | Low | Cream white with red, |
| Culemborg | 1952 | P. A. L. Steyn | Week 48 –49 | Low | White flesh, green–white with red blush |
| Van Riebeeck | 1952 | P. A. L. Steyn | Week 51 –52 | Low | Red colour |
| Rhodes /Swellengrebel | 1952 | P. A. L. Steyn | Week 51 –52 | Low | Round shape, white flesh, dark fully red skin |
| Safari | 1974 | P. A. L. Steyn | Week 48 –49 | Low | Round–oblong shape, yellow flesh with red stone cavity |

*Source: FFTRI, (1973); Hortgro, (undated)*

During the early application of the new cross–pollination method, crosses were done by isolating whole trees (Hurter, 1978). The resultant seeds were cultured for three months on suitable media and planted in pots and raised in greenhouses during winter (Wenzel *et al.*, 1975). Subsequently, they were planted in a nursery or directly in an orchard with 3x5 metre spacing. Records of the seedlings' flesh colour, stone (seed) condition and ripening were kept and promising selections were propagated; 2–10 trees were propagated at the Bien Donne experimental farm (Steyn, 1955). All dessert peaches were screened for their keeping qualities and cling peach cultivars were screened for canning and drying qualities. Kakamas and Goosen were used as the benchmarks for canning cultivars while the USA cultivars Muir and Elberta were the bench–markers for drying cultivars, and USA bred Babcock and Early Dawn were used for dessert peaches (Wenzel *et al.*, 1975).

The method of cross pollination and recurrent mass selection changed from open air pollination to hand pollination in the 1950s. The new method followed three steps. The first was called emasculation and pollination, where the breeder would cut the flowers of the cultivars before blossom and manually transfer the male gametes to the female reproductive parts in the laboratory (FFTRI, 1980). The second stage was called stratification where the seeds were refrigerated to break dormancy and start germination (Smith, 2009). The breeder would use an in–vitro culture technique called embryo rescue to increase the success of germination (Pieterse, 2013). In this technique, the embryo would be cut out of the seed and cultured in suitable media.

This was done because some cultivars would have the embryos mature and die before the seed started germination (Smith *et al.*, 2012). Stage 3 involved the planting of the young seedlings into greenhouses and nurseries and then on the experimental farm (Smith, 2009). This method made the breeding process more efficient as it made better use of land on the experimental farm and reduced the time taken for results to be acquired. Embryo rescue reduced mortality of embryos. In 1960, a nectarine breeding project was started using this method (Wenzel *et al.*, 1975). This project was amalgamated with peaches projects, along with all other nectarine projects, because these two fruits are genetically identical, the only difference occurring in the allele that causes fuzzleness (hairiness), fruit aroma and sweetness.

Due to the fact that there was more certainty of the likely characteristics of the product in the hand pollination breeding method, the scientists could now breed cultivars that could better satisfy industry–specific needs. The breeding objectives were streamlined to the development of cultivars which cropped reliably (produced high yields consistently) and had medium–low chilling requirements, required minimal use of pesticides, had an upright growth habit with sturdy branches, and were early ripening (harvested in week 43) or late ripening (harvest week 10) (Pieterse, 2013). Characteristics such as full yellow flesh colour and high sugar content are relevant in drying sector cultivars (Pieterse *et al.*, 2006). Small fruit with no red colouration on stone pit and non–melting texture are required for canning sector cultivars. Fresh market breeding aimed to produce cultivars with full red flesh colour, 80 percent skin blushed and sub–acid levels (Smith, 2009).

After restructuring of the national research institutions in 1980, a peach and nectarine breeding project was started at the Roodeplaat Research Institute. This breeding project was led by Mr P. E. Evans while the FFTRI research was led by Dr N Hurter and Mr W. G. Wenzel (Hurter, 1978). The next change in the cultivar development involved clustering all the breeding processes that were conducted up to this stage into one breeding phase (Phase 1). This phase produced 3 000 seedlings. A second phase was introduced where six trees of each promising Phase 1 selections were tested for their climatic adaptability in the winter rainfall area as well as the summer rainfall area. These trees were grafted on rootstocks in sites identified in different production regions (Pieterse, 2013). Storage and/or processing properties which were tested in Phase 1 were further tested in Phase 2. Phase 3 entailed the semi–commercial planting of the most promising selections (maximum of 5 000 trees) (Culdevco, 2012). Experimental fruit samples were also exported to generate market feedback. Before 2006, this Phase 3 was done by the ARC researchers but after 2005 a private company named Culdevco took over the marketing of the cultivars and it also collects the royalties earned on the cultivars used (Smith, 2009). Part of this marketing involves field days, workshops and fruit exhibitions held on a regular basis for exporters, supermarkets, overseas importers/marketing agents and producers during the harvesting season (Smith *et al.*, 2012).

Recently, the Institute introduced a new breeding method called molecular marking. As the name suggests, this method uses molecular DNA markers to identify the characteristics of a cultivar before it bears fruits. This method has greatly reduced the time taken to develop a new cultivar as the breeder does not have to wait until year three when the tree produces fruit to see the characteristics of the new cultivar (Annual research review, 1994: ARC–Infruitec, 1992–2002). This method has mainly been used where there are a strong market demand for certain characteristics as it involves cumbersome procedures. In 2014, the breeding at Infruitec was led by C. Smith while I. Meintjies led the breeding at Roodeplaat.

Table 3.4 shows the release of cultivars from 1965 to 1996. During this period, 44 cultivars were released. Seven of these were nectarines, eight were dessert peaches and twenty–nine were cling peaches. Nectarine breeding was mainly targeted at the export market. However, the first concerns were on cultivation aspects because nectarines are very susceptible to poor production conditions. Donnarine was released in 1976 due to its ability to withstand “unsuitable production conditions”. Margret’s Pride was released in 1991 as it had a favourable harvest period and a long shelf–life. For the canning cultivars, De Wet was released because it stores well; however, it had an oval shape and sharp point which made it prone to mechanical injury. Therefore Oribi, which had a round shape, was released in 1993 to replace it. Impora, Monate and Talana cultivars were released because they had better cropping frequencies, handling and shelf–life than Malherbe, Neethling and Keimoes (Annual research review, 1990: FFTRI, 1992–2002). For the dessert peach cultivars, Hantam, Wavern and Bokkeveld were released because they could be used for both fresh market sales and for drying. They also had low chilling requirements and large fruit sizes (Annual research review, 1986: FFTRI, 1970–1989).

**Table 3.4: Peach and nectarine cultivars bred, 1965–2012**

| Year | Peach Cultivars | | Nectarine cultivars |
|---|---|---|---|
| | Cling peaches | Freestone/Dessert peaches | |
| 1965 | Earlibelle, Golden Amber, Sunray | | |
| 1972 | Ingwe | | |
| 1973 | Albatross | | |
| 1974 | | Safari | |
| 1975 | Don Elite | | |
| 1976 | | | Donnarine |
| 1979 | De Wet | | |
| 1983 | Rolees | | |
| 1984 | Imperani | Bokkeveld, Hantam | |
| 1985 | | Waveren | |
| 1986 | Impora, Monate, Talana | | |
| 1987 | Desert Pearl, Don Elite, Transvalia | Sonette | |
| 1989 | Goumyn, Cinderella | | |
| 1991 | Keisie, Cascade, Bonnigold, Sandvliet, | Summer Giant, Sunsweet | Flavorine, Margaret'sPride |
| 1993 | Oribi | | |
| 1994 | Carona, Classic, Klara, Western Cling | | |
| 1995 | Summersun | Excellence | Crimson Giant, Summearly |
| 1996 | Snowhite | | Unico, Nectar |
| 1997 | Western sun | | Alphine |
| 1998 | | Elandia | |
| 1999 | | Witzenberg | |
| 2004 | Supreme, Fantasy | Summer Gold | |
| 2005 | | | Sunburst, Royal Gem, Horizon |
| 2006 | | | Crimson Blaze, Bella Rosa, Bella Donna, Bella Nova |
| 2007 | Cederberg, Cascade | | Ruby Sweet |
| 2008 | Autumn Crunch | | Summer Prince |
| 2009 | Earligold, Scarlet, Summer Gold, Summertime | Sundry | Early Glo, Colorburst™ (ARC NE–8) |
| 2010 | Fiesta Gold, Golden Pride, Temptation | Red Velvet | Bella Nova |
| 2011 | Afrisun, Desert Sun | Earliblush, Honey blush | Primrose, Donna Rosa, Tango, Ruby Rose, Bella Donna |

*Source: FFTRI, 1973; Hortgro, (undated)*

Forty cultivars were released between 1996 and 2012. Eighteen of these were nectarines, seven were dessert peaches and fifteen were cling peaches. Overall, the cling peach cultivars bred after 1996 extended the canning period from week 50 to week 11 (Pieterse *et al.*, 2013). Supreme was released because it filled the gap between Neethling (mid–January) and Kakamas (mid–February) (ARC–Infruitec, 2006). Summer Gold which is harvested in week 50 was released because it extended the early part of peach canning season. Sundry extended the drying season from week three to week four to five. For the dessert peach cultivars, the ARC–bred cultivars extended the fresh fruit harvest period from week forty–four to week twelve (Mollendorff, undated; Smith *et al.*, 2012). Scarlet and Summertime cultivars were released because they have high sugar content while Earligold was released to fill the local market gap during week forty–nine to fifty (Pieterse, 2013). Between 1997 and 2012, the nectarine breeding project has also successfully registered three trademarks: Colourburst™, ARC–NE–1 and ARC–NE–2. Colourburst™ has been noted for its striking bright yellow colour and its excellent drying qualities (Smith *et al.*, 2012). The latter two fill the week 4 harvest gap and have exceptional appearance and eating qualities (Mollendorff, undated).

### 3.4.2 Biochemistry and Pathology

As mentioned, the discovery of the wooliness disease in 1936 sent a panic in the deciduous fruit industry which led to the establishment of the WPRS. Upon its discovery, very little was known about this disease except that its arrival coincided with innovations introduced in the transport system. This convinced farmers that the new ventilation system had caused the surfacing of the disease symptoms and they demanded compensation for their losses from exporting agents (DoA, 1936). The WPRS researchers spent a long time trying to identify the disease, identifying the factors that caused it and then searching for its remedies. Investigations started within the Engineering unit and gradually shifted to pathological investigations through an interchange of various multi–disciplinary approaches. The breakthrough in effectively controlling this disease was realised in 1950s after of adapting the solution into a user–friendly form which farmers could use with ease. It was through this research that it was discovered that wooliness was caused by the physiological breakdown of the fruit when it was picked prematurely and/or placed under inadequate refrigeration. So the remedy for the disease involved recommendations on optimum refrigeration temperatures that were specific to each cultivar and recommending the use a penetrometer in determining picking maturity. The scientists also adapted the shape of the penetrometer to better suit its use in South Africa.

In 1960 pathological investigations focused on the use of thio–urea against delayed foliation. This was an area of importance because one of the most popular cultivars, Early Dawn, was prone to delayed foliation. The winter rainfall area had also experienced warm winters (which triggered delayed foliation) in the years preceding the study. The research involved the application of thio–urea on Early Dawn and USA bred Elberta (Annual research review, 1962: FFTRI, 1960–1969). The results of the study showed that the spray had a positive effect with respect to breaking dormancy. Following these results, the use of thio–urea in breaking dormancy became widely used in South Africa. Further research was conducted on the suitable time for spraying and the appropriate chemical concentration. In 1964, a research study that showed that delayed foliation could be avoided by the effective use of growth inhibitors. As a result artificial growth inhibitors such as indoleacetic acid oxidase were added to the list of remedies used to break dormancy (Annual research review, 1965: FFTRI, 1960–1969).

In 1974, a study conducted by P. J. C. Stassen investigated the seasonal uptake of nutrients and the seasonal patterns for accumulation, storage, mobilisation and the use of carbohydrate and nitrogen nutrients by Kakamas (Annual research review, 1975: FFTRI, 1970–1989). This research showed that adequate applications of nitrogen induced early bud–break and flowering. The study also found that good autumn nitrogen treatment was necessary for initial spring growth and summer nitrogen applications were essential for stimulating growth and delaying the formation of a terminal bud. In 1984, M. du Preez carried out a study on nitrogen scheduling through irrigation systems which revealed the importance of differential nitrogen fertilisation in the different phases of an orchard (Annual research review, 1985: FFTRI, 1970–1989). It also emphasized the importance of nitrogen in an orchard that is in its third year and highlighted the significance of complimentary production practices such as pruning and thinning that ensure optimum nitrogen use.

In 1987, Mr L. J. Mollendorf conducted a study on the interaction between weather and the wooliness disease (Annual research review, 1988: FFTRI, 1970–1989). This research showed that orchard temperatures experienced one month prior to harvest had an influence on the development of wooliness in peaches. The nectarines used in the research were particularly susceptible to the disease when there were low day/night temperature ratios. In 1990, Mollendorf conducted a study on the effect of different storage periods on Flavortop and Independence nectarine cultivars. The research showed that wooliness developed in the two cultivars 3–4 weeks after storage when the storage temperature was set at –0.5°C (Annual research review, 1992: ARC–Infruitec, 1992–2002).

Applied biochemistry became particularly important after 1992 because chemical control of diseases such as bacterial canker and bacterial spot which proved to be successful elsewhere in the world failed completely in South Africa (Annual research review, 1993: ARC–Infruitec, 1992–2002). The use of the recommended management practices brought mixed successes and the over–use of bactericides had hazardous effects on the environment. In 1992, biochemistry principles began to be applied in other research disciplines as well. Thus there was an increase in the use of molecular genetics in breeding and fruit ripening.

Since 1990, research in this discipline has managed to contribute to industry's success by controlling pest population through the introduction of mating disruption and pheromone dispenser techniques. Researchers also breed sterile fruit flies and use treated fibre nets to reduce chemical emissions (Annual research review, 1996: ARC–Infruitec, 1992–2002). The research institute also served the industry by offering diagnostic services, agrochemical evaluations for registration of chemicals, spray programme recommendations, sanitation evaluations of pack houses and cold storage facilities as well as on–farm consultancies.

### 3.4.3 Horticulture

According to De Wet and Micklem (1937), the Stellenbosch–Elsenburg set a good foundation or the horticultural research. Examples of its cherished breakthroughs are the release of Kakamas rootstock in 1933 and the successes in adapting the soft–wood propagation processes and successes in developing true–to–type rootstocks (Nel, 1947). The establishment of the WPRS enabled for a larger scale of work to be do this discipline.

In 1959, the WPRS conducted a project on how plastics and poles used for shaping tree structure affected vegetative propagation (Annual research review, 1960: FFTRI, 1960–1969). This research revealed that the equipment prohibited water penetration and lateral movement of water. In the same year, research was done on blossom and chemical thinning on Kakamas, Tokane, Culemborg and Rhodes cultivars. This research used GNOP ("Gebutow") and NPA ("peach Thin 322") as chemical thinners. The project was discontinued because these cultivars did not respond to the treatment. The research was redone in 1967 but with dinitro–ortho–secondary butyl (ONOBP) used for thinning (Annual research review, 1968: FFTRI, 1960–1968). The research revealed that chemical thinning reduced thinning expenses by half and that it was most effectively done at full bloom.

Between 1969 and 1974, a study was conducted by D. K Strydom showing how grafting Kakamas seedlings yielded better fruit quality than trees grown from seeds (Annual research review, 1975: FFTRI, 1970–1989). Another research project by H. J. van Zyl from 1971 to 1975 showed how a home–made grafting wax consisting of Colas and starch served as a wound dressing material which performed as well as a commercial product but cost a fifth of the price of the cheapest commercial wound dressing material. In 1977, O. Berg conducted a research study on pruning and trellising (Annual Research Review, 1978: FFTRI, 1970–1979). The research showed that V–shaped trellising produced higher yields than the open vase trellising. This research led to an increase in adoption of the V–shaped training system. In addition, summer pruning was found to cause a significant increase in yield as compared to winter pruning but the combination of the two methods produced the highest yields. This research led to more farmers adding summer pruning to their pruning schedules.

In 1985, T. Haulik compared planting distances in four different trellising systems (Annual research review, 1985: FFTRI, 1970–1989). The results of the study showed that closer planting decreased the average size of the fruit but increased fruiting frequencies and yield. It was concluded that comparison in terms of remuneration between the trellising systems could only be done according to characteristics of a production region. The results of this research, led to the planting distances of training systems' being customised according to the production area. In 1993, a peach x almond root stock called GF 677 was released. This rootstock's strength was that it could be grown in calcareous soils unlike Kakamas which performed poorly in high pH soils (Annual Research Review, 1993: ARC–Infruitec, 1992–2002). In 1994, the rootstock, SAPO 778 was released. This rootstock was less susceptible to wet conditions than the Kakamas rootstock and was suitable for medium to high density plantings (Annual research review, 1994: ARC–Infruitec, 1992–2002).

Since 2000, horticultural research has now shifted to promoting sustainable agricultural practices. This shift in research focus has been driven by the industry's drive to preserve natural resources and promote harmony between agriculture and the environment. Management tools investigated included rootstock research, development of training systems, and methods of fruit and tree manipulations (Annual research review, 2002: ARC–Infruitec, 1992–2002). The goal of improving yield, fruit size, colour and internal quality remain at the fore of research priorities. The research done in this discipline also motivated for the establishment of over 60 automatic weather stations set up in Western Cape since 1937. The ARC has also established a gene bank which has all true–to–type ARC–bred cultivars and rootstocks (Smith *et al.*, 2012)

### 3.4.4 Postharvest Technology

The Fruit Processing unit's research was the sole focus at the Institute between 1940 and 1945 as much of the research in other disciplines had been stopped due to the massive cut in funding that was a result of the World War II (Kotze, 1987). The Fruit Processing unit was primarily tasked to investigate new canning technology to dispose of the high volumes of fruit diverted from the export markets as a result of the war (Kotze, 1987).

In the 1960s, researchers focused on finding ways of improving the efficiency of equipment which reduced postharvest losses. Research concentrated on improving storage and spraying machinery (Annual research review, 1962: FFTRI, 1960–1969). Research on the storage machinery investigated ways of improving the extent refrigerated machinery could be operated automatically. At the time, commercial cold rooms required continued supervision which raised labour costs for farmers (Annual research review, 1960: FFTRI, 1960–1969). The main concern with the spraying machinery was of customising the machinery for different farm conditions. In 1963, a research study was done investigating different ways of reducing postharvest losses of canning peaches. This research was important because the organisms under investigation (i.e. *Rhizopus nigricans* and *Monilinia fructicola*) were the principal causes of postharvest decay of canning peaches. The research found that these two pathogens were controlled using Allian (dichloran) and Kaptan (captan) (both at 1.5 lb per 100 gallons) and even more effectively when fruit was wrapped with paper saturated with the two fungicides.

Between 1972 and 1974, J. J. P. Hayward conducted research on the best methods of drying peaches using sulphur dioxide. This project compared four drying methods and it was found that the method of preparing dried fruit that was most effective in preserving moisture and taste in peaches was one that used syrup. In this method, the peach halves were boiled for ten minutes in a 40$^{o}$B syrup at 180$^{o}$F and thereafter left in the warm syrup for three hours (Annual research review, 1974: FFTRI, 1970–1989). The study recommended the use of the blanching and dehydrating method which uses sulphur dioxide for drying. This method was recommended for the South African drying companies because it had lower cost implications due to the absence of syrup use. Between 1972 and 1975, research on the performance of the peach dehydrator design was done. Theron recommended that the drying tunnels have air delivery set at 500m$^3$/h and handling set at 4.8 tons of peaches every 24 hours (Annual research review, 1976: FFTRI, 1970–1989).

In 1977 T. R. Visagie and B. K. Nortjé carried out two studies which investigated the picking maturity of peaches (Annual Research Review, 1978: FFTRI, 1970–1989). Visagie's study revealed that the use of picking pressure as opposed to fruit colour was a more reliable criterion for determining maturity of cling peaches. Nortjé's study showed that the sugar content of the fruit was another reliable criterion but could only be used to supplement picking pressure. These research results led to the joint use of the penetrometer and refractometer in the harvest season. In 1989, J. F. Fourie and Visagie conducted two studies which investigated postharvest decay in the summer rainfall region. These were relevant studies because the production volumes of this region had almost been halved by postharvest losses caused by the *Monolinia laxa* and *Rhizopus stolonifer* pathogens (Annual research review, 1989: FFTRI, 1970–1989). The results of these studies showed that reducing the lag between harvest and refrigeration reduced the occurrence of these pathogens.

After the year 2000 the discipline has mainly concentrated on research relating to process optimisation. The research was important because it contributed to ensuring optimal producer income, food security, value–adding and extension of shelf life.

### 3.4.5 Soil Technology and Irrigation

In the 1960s, Soil Technology and Irrigation research was focused on improving the performance of machinery used to measure soil moisture. Studies done on the neutron meter showed that the calibration curve of this instrument was affected by the compaction of the soil and the soil's fixed–hydrogen concentrations (Annual research review, 1960: FFTRI, 1960–1969). Further research recommended different ways to correct these errors (Annual research review, 1964: FFTRI, 1960–1969). The research focus thereafter shifted to using radio–active isotopes to measure the efficiency of different irrigation systems. One research study done between 1969 and 1973 focused on calibrating a new monitor that was used to measure nutrient absorption using radio–active isotopes. A study conducted by W. Truter between 1970 and 1974 also used the same radio–isotope technology to investigate the simultaneous absorption of soil elements such as calcium, nitrogen and potassium that are essential for plant growth (Annual research review, 1975: FFTRI, 1970–1989).

In 1980, the research focus shifted to customising the soil–quality measurements for different production regions. The first research in this area was done by Mr H. Tormann and sort to develop irrigation schedules for winter rainfall region farmers (Annual research review, 1982: FFTRI, 1970–1989). Tormann's study revealed that differential irrigation led to increases in tree growth, fruit production and fruit size. In the 1990s the researchers focused on synchronising irrigation scheduling with fertiliser scheduling. This was a relevant research area because drip irrigation and micro–fertilisation had been widely adopted in the country; therefore, there was need to make sure this new technology did not erode the benefits of the fertilization practice. Other research was done on orchard floor management. This research showed that cover crops were essential for reducing water loss to the atmosphere, and led to the modification in the conventional pest control method which had once left orchard floors bare.

After 2000, research focused on the species that are most suitably used as cover crops (Annual research review, 2002: ARC–Infruitec, 1992–2002). The research has also been at aimed further adapting soil technology to meet farmers' needs. A greater proportion of the work now done involves technology transfer. The services provided under technology transfer include: planning of farmyard lay–out, designing irrigation systems, advice on tractor and implement use and maintenance, testing of pumps and mouldboard ploughs (Annual research review, 2002: ARC–Infruitec, 1992–2002).

## 3.5 COMPETITIVENESS OF THE ARC PEACH AND NECTARINE RESEARCH

The peach and nectarine research programme fares well compared to other programmes that are carried out at Infruitec. It has the highest success rate in breeding as it accounts for about a third of all the deciduous fruit cultivars patented by the ARC–Infruitec–Nietvoorbij institute in 2012 (Culdevco, 2012). It accounted for two thirds of the stone fruit cultivars bred at Infruitec between 1996 and 2012 (Smith *et al.*, 2012). Based on the number of cultivars released between 1990 and 1996, the research programme was ranked seventh in the world (Byrne, 2005).

The programme's research priorities are in line with global trends. Fideghelli *et al.* (1998) report that research priority for research in the top peach breeding countries (the USA, Argentina, Brazil, France and Italy) are ranked as follows (in descending order of priority): Breeding, Horticulture, Pest and disease control, Postharvest and fruit quality and lastly, Irrigation. The similarity in research priorities is because most countries face the same problems of low fruit quality, high production costs and international competition with regards to quality and quantity

(Fideghelli *et al.*, 1998). The ARC research programme is among the leading programmes that produce low chill and early ripening cultivars (Ntombela and Moobi, 2013). Similar to other research programmes in the world, the research programme has shifted to relying on more private funding and using peach x almond rootstocks (Byrne, 2005).

In the local market, the ARC varieties have had their biggest success in the canning sector. As shown below in Figure 3.6, the ARC–bred cultivars have delivered most of the fruit used for canning. The ARC–bred cultivar intake increased from 86 percent of the total fruit volumes used for canning in 1964 to 99 percent in 1988. According to Hurter (1978), ARC cultivars contributed as much as 90 percent in the canning industry for the period not represented in Figure 3.6. The ARC share was completely composed of the Kakamas cultivar from 1940 to the late 1950s (French, 1958). The cultivars used during the period between 1964 and 1988 were Kakamas, Professor Malherbe, Professor Neethling, Professor Black, Keimoes, Walgant and Woltemade. The main imported cultivar used for canning was the USA bred Goosen cultivar. Ever since 1990, the canning sector has been solely dependent on ARC–bred varieties.

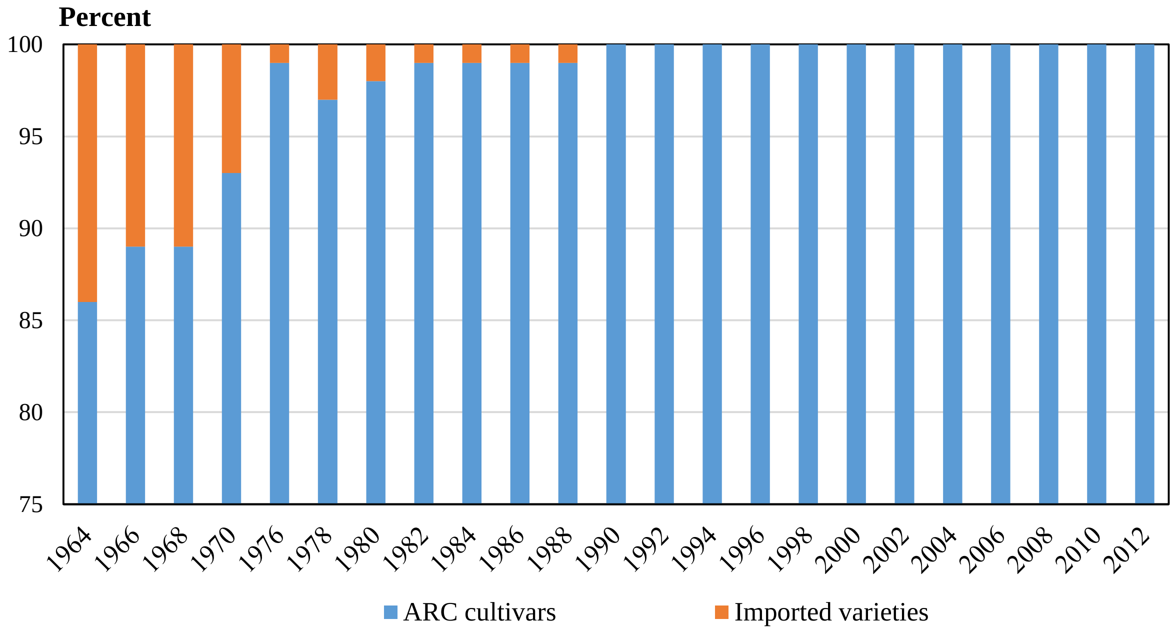


**Figure 3.6: Percentage of ARC–bred varieties of the total used annually in the canning sector, 1964–2014**

*Source: CFB (1964–1988); CFPA (1989–2012)*

Figure 3.7 below shows the percentage of total export cartons which were filled with ARC–bred dessert peach and nectarine cultivars. It shows that the contribution of ARC–bred varieties in annual export volumes increased from 22 percent in 1946 to 40.5 percent in 2012. The ARC–bred cultivars had the highest number of carton allocation in 2000 when 67.8 percent of the fresh market export cartons contained ARC varieties. Pieterse *et al.* (2012) report that 100 percent of the nectarines exported in 2012 were produced from ARC–bred cultivars.

The percentage of ARC–bred cultivars in the annual export volumes was low (between 20 and 25 percent) from 1946 to 1958 because only one cultivar (Early Dawn) was used for export. After the release of Rhodes, Van Riebeeck and Goldmine, the use of ARC's cultivars in fresh fruit export increased. The peak in ARC–bred cultivars experienced 1985 was a result of the increase in demand for the Culemborg cultivar. The share of ARC cultivar use decreased after 1990 because Culemborg, which had been used for the past 40 years, was now obsolete, and the carton allocation again increased after Transvalia was released. The decreasing trend after 2009 were due to the introduction of new imported cultivars that better satisfy the changes in consumer tastes which has changed from yellow round fruits to white–fleshed doughnut and/or flat shapes. The ARC produces white–fleshed fruits but has yet to prove success in the novel fruit shapes (Pieterse, 2013).

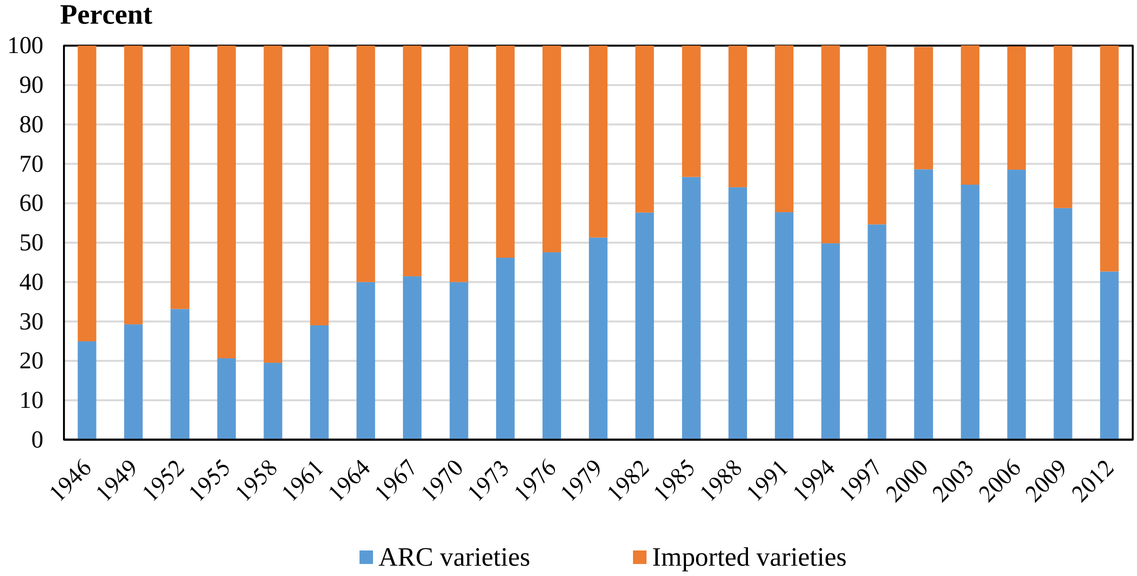


**Figure 3.7: Percentage of ARC–bred varieties in the fresh export sector, 1946–2012**

*Source: DFB, (1947–1988); Hortgro, (1989–2012)*

In the drying sector, ARC cultivars have managed to win the majority market intake over the US–bred Elberta cultivar. The ARC cultivars contributed 55 percent of the dried fruit exports in 2012 (Pieterse *et al.*, 2012). The number of fruit cultivars bred by the ARC especially suitable for drying has increased from one to nine between 1960 and 2012.

## 3.6 SUMMARY

The aim of this chapter was to provide an overview of the research that has been done for nectarines and peaches. The chapter achieved this objective by discussing the work conducted at FFTRI/ARC–Infruitec. The preceding argument shows that Institute's peach and nectarine research programme has had incredible successes in the past, which has seen it scoring very well in international rankings. In 1996, the research programme was ranked seventh in the world. Its influence has increased as evidenced in the canning sector which is dependent on the cultivars produced through the programme, as well as the growth in the percentage of ARC–bred cultivars in exports which have doubled since 1946. The programme's research priority has drifted towards the Plant Improvement discipline, while the research conducted in the Horticulture, Biochemistry and Pathology, Postharvest Technology and Soil Science and Irrigation disciplines have enabled the cultivars developed in this discipline and other imported cultivars to perform optimally. The infrastructural investment that was done in the 1950s and the increase in research personnel numbers have encouraged the success of the research programme. However, changes in the institution's organisational structure and funding allocations have limited the achievements of the programme as they have led to the loss of some critical expertise. The next chapter takes a close look at the changes in the funding organisations, models and patterns that have occurred over the years.

# CHAPTER 4

# FUNDING OF PEACH AND NECTARINE RESEARCH IN SOUTH AFRICA

## 4.1 INTRODUCTION

Farmer associations have played a profound role in the development of the peach and nectarine industry. They provided a central body that coordinated the handling, packing and, export of fruit, as well as ensuring that funding was available for all the required support services such as marketing, research and administration. This chapter details the evolution of these institutions and their role in improving the efficiency of the industry. It particularly focuses on the role of these organisations in funding research and directing research priorities. A peach and nectarine research expenditure series is also estimated based on the research expenditure figures of the various organisations and ARC–Infruitec's project allocations discussed in Chapter 3.

## 4.2 INSTITUTIONAL EVOLUTION

### 4.2.1 Early cooperative movement

The first institutional body to represent peach and nectarine farmers as well as other deciduous fruit farmers was formed in 1894 in the Wellington production district (Pickstone, 1917). This volunteer organisation was called the Fruit Growers' Association and was headed by Mr J. F. Pentz and Mr P. J. Cillie. Soon after the formation of this cooperative, similar farmer organisations began to form in other production districts. In 1895, a Fruit Conference composed of delegates from these different associations began to be held annually. This network of farmer organisations began to share production and market information; and liaise with similar and more successful cooperatives in California (Standard Bank, 1965). According to Pickstone (1917), the principal achievement of the first fresh fruit associations was in standardising fruit packaging. This was an important step for the deciduous fruit industry because it formed the basis for pricing and made fruit transportation easier (Black, 1952).

Collective action was particularly useful to farmers supplying fruit for canning and drying. These farmers often received low prices despite the improving quality of their fruit (Pickstone, 1917). The processing companies preferred to import Californian fruits because of their high demand on the local market and because there was an established organised system of credit available which made their procurement easy. In 1902 a cooperative dried fruit company and also a cooperative canning fruit company was formed by the farmers (Pickstone, 1917). Using their combined efforts, these companies managed to produce a uniform product, in bulk quantities which had the same quality of the Californian product. With the publicity rendered by Sir P. Stewart–Bam, these local companies managed to penetrate and dominate the local market by 1917.

Discussions on forming a larger cooperative started in April 1894 during a conference which was chaired by Mr John. X. Merriman, the Minister of Agriculture at the time. The bargaining power made available by collective action enabled the farmers to provide sufficient justification for the establishment of cold storage facilities, acquire refrigerated trucks for local transport to Johannesburg, import new varieties and acquire an entomologist (Aucamp, 1987). In 1899, the small fresh fruit associations then merged to form the Western Province Fruit Exporters' Association (Olivier 1960). This cooperative managed to negotiate for increased cold storage space in export companies such as Union Steam Co. and Donald and Co. The success of this negotiation was primarily due to the influence of the Cape Prime Minister, Cecil John Rhodes, who was an active member of the farmers' association (Pickstone, 1917). The influence of other government officials such as Mr Messers, Mr Mallison, Mr Persse as well as Mr Pickstone who had become a powerful individual while working for Mr Rhodes, also led to the establishment of refrigeration facilities at the Cape docks between 1902 and 1918 (Black, 1952). An export agent who specialised in deciduous fruits was also appointed using state funds (Aucamp, 1987).

Unfortunately, the rapid increase in production volumes quickly outpaced the rate of development of technical facilities at the ports and the methods of regulating exports could not cope with increasing export volumes. The number of export cartons filled with deciduous fruit increased from 7 706 to 201 871 between 1894 and 1910 (Aucamp, 1987). Furthermore, the industry faced grave problems in shipping delays which greatly reduced the quality of the perishable product (Black, 1952). At this time the need for collaborative work between the various fruit cooperatives became clear. In 1922, the deciduous, citrus and pineapple cooperatives came together to form the Fruit Growers' Cooperation Exchange of South Africa. Its board had eight citrus industry representatives, five deciduous industry representatives and two pineapple industry representatives (Standard Bank, 1965). The combined effort achieved by this union further increased the fruit farmers' ability to promote infrastructural development in their favour.

Increased government representation in this larger farmer organisation led to the establishment of an independent state organisation called the Perishable Products Export Control Board (PPECB) in 1925. This organisation took over all perishable products exports. To be more specific, the PPECB's mandate was to ensure equitable cold storage space allocations in the ports, enforce quality regulations on perishable export products and to ensure proper refrigeration and storage methods during exports (Black, 1952). In 1926, a larger precooling depot was established at East Pier in Cape Town. This depot had modern equipment which increased exporting efficiency.

The Fruit Growers' Cooperation Exchange was short–lived because it did not provide effective sales organisation for exports, and thus the growers themselves began to distribute their produce to agents overseas (Norman, 2009). It became apparent that improved overseas marketing arrangements which addressed the unique needs of the different industries were necessary for a stable export market (Olivier 1960). As a result, citrus fruit farmers formed their own Citrus Fruit Exchange, while deciduous fruit farmers formed the Deciduous Fruit Exchange. The latter also served the interests of pineapple farmers (Black, 1952). The Fruit Growers' Cooperation Exchange, which was now known as the Central Exchange, continued to exist merely as a shipping agency which provided services to the two new farmer associations.

Different from the preceding associations, the two new farmer organisations appointed overseas marketing representatives who were responsible for exploring new market opportunities and fostering relationships with existing buyers. The first overseas representative for the Deciduous Fruit Exchange was Mr Dykes who was appointed in 1931 (PPECB, 2003). Though the Deciduous Fruit Exchange delivered pioneering work in the interests of the fruit industry, its work was limited by the fact that the entire scheme was voluntary. Hence the scheme was exploited by the opportunistic behaviour of farmers. Western Province farmers with their conservative background were still on average too individualistic in their outlook (Black, 1952). Therefore, farmers only worked collaboratively during their low production seasons and pulled out of cooperatives in good years (Norman, 2009). As a result the cooperatives did not make much money.

In addition to the loyalty and enforcement problems, the Deciduous Fruit Exchange contended with problems of a more technical nature. Exports continued to increase each year and many of the newcomers had neither the background nor the experience to appreciate all the trade implications. Many mistakes were made in important matters such as choosing the stage of ripeness for packing, accuracy of grading and packaging technique (Black, 1952). Some farmers also did not have the necessary knowledge on how to market their products (Aucamp, 1987). There was a need for the establishment of a central body that could coordinate the handling, packing, distribution of fruit, as well as ensure that adequate funding was available for all the necessary support services such as marketing, research and administration (Standard Bank, 1965). A report by an international commission of enquiry in 1934 recommended the establishment of agricultural boards for the various commodities, with statutory powers to effectively coordinate exports and marketing as well as the provision of all the necessary support services (Du Toit, 1975). This recommendation was also made to address the problem of the low efficiency and low productivity of the agricultural sectors – especially to improve the prices obtained for deciduous fruit as these were the lowest priced of all exported goods (Carter, 1999). Following this recommendation, a new Marketing Act was promulgated in 1937 and various commodity boards were established soon after.

### 4.2.2 Controlled marketing in the Control Board System

The Deciduous Fruit Board came into being, on 4 October 1939, with the publishing of the Deciduous Fruit Regulatory Scheme (Proclamation No. 230 of 1939) (Norman, 2009). Under this Scheme the Deciduous Fruit Board, referred to as "the Board" from here on, was vested with the power to be the sole buyer and seller of deciduous fruit, to create prohibitive measures in production and marketing areas and to undertake the export of all fresh deciduous fruit (Vink, 1999). A Peach Scheme, a subsidiary of the Deciduous Fruit Scheme, regulated peach and nectarine production and sales. The Board's control of peaches and nectarines excluded local markets south of De Doorns and in the vicinity of Port Elizabeth (Norman, 2009). The Board worked in collaboration with the Canning Fruit Board and Dried Fruit Board which served as supervisory boards tasked to ensure quality of fruit distributed for processing (Du Toit, 1975).

The Board used a single marketing channel and exports were done under a collaborative trademark called "The Cape" (Standard Bank, 1965). This marketing system strictly controlled production volumes, exports volumes and fruit distribution destinations (Norman, 2009). This strict control of flow of fruit enabled the Board to minimise short–term price fluctuations. The single market channel also stabilised and increased revenues by eliminating duplication in the marketing chain (Carter, 1999). During the export ban that was enforced between 1940 and 1945, the Board provided credit in the form of production loans, loans for packing material, processing loans, and facilities to make bulk containers available to farmers (Olivier 1960).

During its existence, the Board also significantly contributed to ensuring high–quality technology and the provision of research services support. Efficient provision of research services led to improvements in the quality of yields and in production efficiency.

In 1987, the Board appointed the Universal Fruit Trade Co–operative (Unifruco) to be in charge of marketing, information dissemination as well as the allocation of research funds to the FFTRI and the University of Stellenbosch respectively (Memorandum: DFB, 1996). Unifruco also provided research services through an arm called the Unifruco Research Service (URS). The URS had the best infrastructure and equipment of the three research entities (Memorandum: DFB, 1996). Unifruco broke away from the Board in 1996 and established itself as a private company providing research services. Hortec was formed in the same year and took over the duties of Unifruco on the Board, but handling and marketing duties remained under Unifruco.

### 4.2.3 Market deregulation and liberalisation

The Board was disbanded in 1996 because of serious bureaucratic inefficiencies that weakened the integrity of the institution. The Board often promoted the agenda of the government rather than that of the farmers it was supposed to serve (Vink, 1999). Farmers that produced high–quality fruit were often left disgruntled by the Board's pricing policy which did not take into account differences in fruit quality (Kirsten, Edwards and Vink, 2007). Farmers also had grievances with the Board's unsatisfactory means of regulating the flow of money and surplus fruit (Norman, 2009). Another weakness was that the Board relied on restricted market access for participants in order to maintain high average return for each producer. This restriction was the main cause of its demise because the system inhibited economic growth which was contrary to the economic goals of the country (Vink, 1999).

The promulgation of the Marketing of Agricultural Products Act (Act 47 of 1996) on 1 January 1997 led to the termination of the Deciduous Fruit Scheme (Norman, 2009). The Deciduous Fruit Producers Trust (DFPT), which was formed in the same year, took over the coordinative role that the Board performed. DFPT was established with three industry representative bodies: the South African Apple and Pear Producers' Association (SAAPPA), the South African Table Grape Producers Association (SATGPA) and the South African Stone Fruit Producers' Association (SASPA) (Smith *et al.*, 2012). The roles of the Canning Fruit Board and Dried Fruit Board are now performed by the Canning Fruit Producers' Association (CFPA) and the Dried Fruit Technical Service (DFTS). Hortec continued to manage the allocation of research funds, but in 2002 it broke away from the farmer associations and became a private company that offered research in postharvest and marketing services. Hortgro$^{\text{Science}}$ took over Hortec's role in the DFPT. In 2012, the Hortgro$^{\text{Science}}$ name was changed to Fruitgro$^{\text{Science}}$ (Fruitgro$^{\text{Science}}$, 2013). Since industry deregulation and trade liberalisation in 1996, a private company called Capespan has exported most of the country's fresh deciduous fruit. This company was formed by a merger that took place between the deciduous fruit exporter, Unifruco and citrus fruit exporter, Outspan.

From the discussion above, it is evident that the role of farmer organisations has shifted from participating in export handling to focusing on ensuring the provision of support services such as research and market information. The next section gives clarity on how these institutions allocated research funds and how they influenced the research priorities. It also describes how the ARC peach and nectarine programme started to use its Plant Breeders Rights to acquire royalties which added to the programme's funding.

## 4.3 RESEARCH FUNDING AND DEVELOPING RESEARCH PRIORITIES

### 4.3.1 State research project development and funding policy

Similar to the rest of the world and in line with economic theory, the government is the largest and oldest investor in agricultural R&D in South Africa (Liebenberg and Kirsten, 2006). In the 20$^{\text{th}}$ century, research funds were provided as a lump sum, but in 1950 the Deciduous Fruit Board introduced a systematic way of developing research projects and distributing adequate levels of funds among the increasing number of research institutions. The monies (funds) distributed by the Board were collected through user–based levies which were enforced by statutory laws (Liebenberg, Pardey and Kahn, 2010). The funds collected by the Dried Fruit Board and the Canning Fruit Board were submitted to the Board as well. Details of these levies are given in section 4.4 below. In some years, the levies would not generate revenue to allow for sufficient research funding levels in which case the state would subsidise the research levy in order to ensure the continuation of agricultural research. An example of such years was during the World War II.

From 1950, the release of funds collected by the Board required a chain of steps which were referred to as the research project development pathway. This pathway used a bottom–up approach which involved: (1) the users of research outputs: the farmer organisations, fruit processing and export cooperatives, (2) the suppliers of the research funds: the state which was represented by the Department of Agriculture staff, (3) the Board's Consumer Advisory Committees who supplied the rationale for investing in specific research projects and (4) the researchers from research institutions who conducted the research.

The pathway started with the farmers, exporter co–operations and/or farmers' organisations suggesting research projects based on the problems evident in the industry such as problems in fruit production, handling or storage. These would be articulated into a research project by a researcher or researchers from the research institution. In a few cases, industry level problems would be identified by researchers during their field surveys and observations would then be articulated into a project. The project would then be suggested to the Board's Projects Advisory Committee who would then discuss the project's feasibility and make recommendations to the Board's Planning Advisory Committee (Memorandum: DFB, 1967).

After the project had been assessed for its relevance in the industry by the Planning Advisory Committee it would be transferred to the Director/Chief of the Research institution who would approve the project after checking its alignment to the institution's mandate and resource base. After approval from the Director/Chief of the Research Institution, the project would be submitted to the Department of Agriculture. After approval from the Minister of Agriculture, the project would be registered, indexed and funds would be released for the research institution to start conducting scientific investigations under the project (Memorandum: DFB, 1967). The state performed the role of monitoring the progress in the research projects. Evaluations were done annually using progress report submissions. Further supervision was done by assessing the research institution's bulletins and scientific publications. Discontinuation of a project would only occur after the Department's approval (Memorandum: DFB, 1967).

The fate of each project concept was determined by the Planning Advisory Committee and Project Advisory Committee. These two advisory committees were entrusted with the role of directing agricultural research because they consisted of a collection of the most knowledgeable individuals in the deciduous fruit industry. During the 1950s and 1960s, the committees were primarily made up of senior staff members of the research institutions and senior staff from the Department of Agriculture. Later, Control Board members, farmers' organisations and exporter cooperatives filled certain key positions in these committees.

According to Townsend and Van Zyl (1998), the funding model described above was efficient because it ensured that the research was done in line with the industry's needs. It further insured that good quality research was conducted by emphasising that research projects were allocated according to an institution's resource endowment and also on basis of the centres of expertise within the different research organisations. Hence, the University of Stellenbosch would be allocated projects on basic research while the URS was allocated projects investigating postharvest and quality management research, and project allocations to the FFTRI Institute comprised basic research, pre–harvest research as well as research in selected postharvest areas (DFB, 1996). The University was also utilised as a cost effective institute because spill–overs occurred between the teaching, research and community development aspects in which the University researchers were involved (Memorandum: DFB, 1996).

After the abolishment of the Control Boards and to date, the administration of state funding has become the responsibility of the Department of Science and Technology (DST) (Liebenberg and Kirsten, 2006). Public research institutions receive state funding as a lump sum which is referred to as The Research Parliamentary Grant, which is a sum of fund allocations from central–government level, the science budget allocations from the Department of Science and Technology (DST) and various other national government departments (Liebenberg *et al.*, 2010). Loosely put, this lump sum is responsible for covering fixed expenses such as infrastructural maintenance and salaries of the permanent employees (Liebenberg and Kirsten, 2006).

The new state funding model employs an up–down approach in financial administration and project development as funds allocated to agricultural research are now determined during priority setting exercises which involves the Department of Science and Technology (DST) and the National Advisory Council on Innovation (NACI) (Liebenberg and Kirsten, 2006). These exercises involve the analysis of the public research entities' three–year medium–term expenditure plans. Research project progress is monitored using a 25–indicator balance scorecard system. Two other sources of state funding that are also utilised are the Innovation Fund and the National Research Foundation (NRF). These two sources of funding are only used in the event that a public research institution undertakes a long–term extensive innovation project or in the event that it undertakes a capacity building exercise (Liebenberg *et al.*, 2010). Due to the increasing pressure on state funds, all funding allocation for these two funds is done on a competitive basis.

### 4.3.2 Farmer association research project development and funding policy

The farmer associations continued to use the bottom–up approach that was used by the Board to determine fund allocations and to prioritise research projects. According to Liebenberg and Kirsten (2006), the results of the farmer association priority setting exercises often influenced the research priorities set by the state. Similar to the preceding era, the funds used for agricultural research are acquired from levies that were collected from the farmers. Fruitgro$^{\text{Science}}$ also uses the same tools to track the progress in each project. The number of advisory committees has increased over the years as they are now divided according to fruit type (e.g. stone fruit), production region (e.g. Little Karoo) and discipline (e.g. crop production). The advisory committees meet two to five times a year depending on the demands of their areas of focus (Farrell, 2013). Figure 4.1 below shows a graphical representation of the new pathway that a project takes until its commencement.

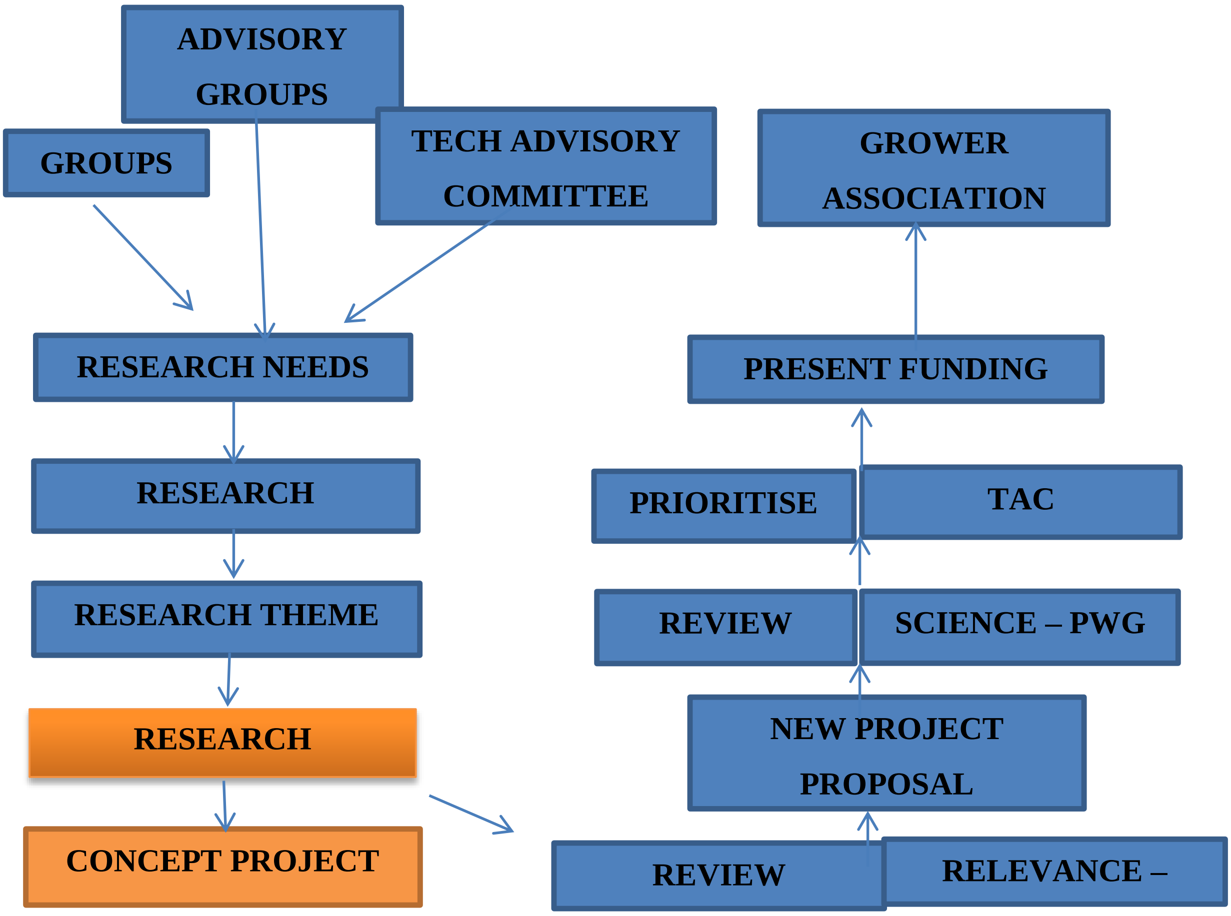


**Figure 4.1: The FruitgroScience project development path.**

*Source: Farrell, (2013).*

According to Farrell (2013), the project development path proceeds as follows:

- The advisory committee for a given production area identifies and calibrates the regional research priorities at least once every three years. Research prioritisation is done according to the importance of the production area and a research strategy is drawn up. (This is an improvement from the system used by Hortec where the size of production area did not have any influence on the prioritisation of research.) A separate meeting is then held with the Deciduous Fruit Development Chamber, the Fruitgro$^{\text{Science}}$ arm that deals with the research needs of emerging growers.

- Inputs from the grower meeting, the advisory and focus groups, Technical Advisory Committees (TACs), and information about other ad hoc research needs are fed into the research strategy and the research requirements are broken down into various research themes and presented to the relevant advisory group, which then articulates the research need into a research question.

- These research questions are then presented to researchers for their consideration.

- Researchers from different research institutions then draft concept research proposals that are presented to Fruitgro$^{\text{Science}}$ for consideration.

- Next, these proposals are reviewed by the relevant TAC and the projects that meet the set criteria are then taken to the next step where the relevant researcher will be asked to draft a full project proposal.

- These new project proposals are then fully reviewed by one or more Peer Work Groups (PWGs)

- The project proposals approved by the PWGs are developed and then presented to the appropriate TAC where they are ranked according to priority

- The final list of high priority research projects is then presented to the Fruitgro$^{\text{Science}}$ Board, which then makes a funding recommendation to grower associations.

- The final decision relating to what is to be funded is made by the grower associations.

This new funding model implies that the research organisations are required to compete for the research funds through what can be described as a bidding exercise. Over ten other research organisations, such as ExperiCo (Pty) Ltd and Stargrow (Pty) Ltd, compete with the ARC–Infruitec for funding from farmer organisations. Financial resource allocation remains influenced by institutions' resource endowments as this a major determinant of an institute's ability to meet research requirements. There have been changes in the centres of expertise as researchers migrate between research organisations and through normal attrition. This is especially evident in market and value chain related research capacities. New entrants into the research field have managed to build competitive advantages in these areas and as a result they compete against existing research institutions which do not offer this type of research services. The ARC–Infruitec's competiveness has decreased because most of its infrastructure is now outdated and because some of its good researchers continue to move to the private sector due to higher salaries offered in the private sector.

The competition introduced by the increasing number of research organisations has had a positive influence on the quality of the research products as it has spurred an increase in innovative research output which has led to market growth on both the demand and supply side (Carter, 1999). Nevertheless, the biding process has been criticised by Liebenberg and Kirsten (2006) as one that has not promoted collaborative work across the competing research organisations. This new bidding method has also been criticised by Townsend *et al.* (1997) as a method that has high transaction costs. It also promotes erratic funding patterns which deter the continuous benefit streams that can be acquired from continuous long–term investment. Fruitgro$^{\text{Science}}$ has worked around forfeiting these research benefits by assigning undefined life spans to long–term research projects which require lengthy periods of investment before returns from investment can be realised. Examples of these projects are breeding projects which are conducted in the Plant Improvement discipline. So instead of bidding for funding each year, these projects have an assured funding allocation each year, but the size of the allocation depends on the project's progress in the preceding year.

### 4.3.3 Policy governing royalties

The third way in which research organisations have acquired funding has been through the commercialisation of research results. This has been aided by the strengthening of Plant Breeders Rights laws. Infruitec started to exercise its intellectual property rights in 1992 when it was absorbed into the ARC. Although commercialisation of the Infruitec's research products started in 1992, substantial progress in this area was only realised in 2006 when the Institute formed a joint venture with a private company, Culdevco (Mollendorff, undated). Culdevco is responsible for marketing the Infruitec's cultivars and rootstocks to local and international farmers and retailers; and for collecting the royalties by the use of three types of levies (Mollendorff, undated).

The first levy is charged upon purchase of a deciduous fruit tree which was produced from an ARC–bred cultivar at a nursery (Smith, 2009). This levy is also collected from purchases of

ARC–bred rootstocks. The second levy is charged per hectare cultivated to ARC–bred deciduous fruit cultivar trees. The third levy is charged for every carton of fruit produced from ARC–bred cultivars (Smith, 2009). The royalty charged varies from cultivar to cultivar depending on the value attached to the characteristics each cultivar possesses. In 2012, the royalty collected for the Earlygold peach cultivar was R700/1000trees while that of Cascade was R600/1000trees (Culdevco, 2012). The royalty collected for the Sun Kiss peach cultivar was R0.80/carton while Unico's peach cultivar royalty was R1/carton (Culdevco, 2012).

Fifty–five percent of the total royalty earnings are then apportioned to the ARC–Infruitec research institute as remuneration for its breeding while the remainder covers the marketing and administration costs of Culdevco (Mollendorff, undated). Infruitec's financial reports show that Culdevco has recently started investing some of its proceeds into some of the ARC–Infruitec Institute's research projects (Financial records: ARC–Infruitec, 2000–2014). Its funding has been directed at the peach and nectarine research programme.

## 4.4 ALLOCATION OF RESEARCH FUNDS

This section discusses the contribution of the various funding providers in the peach and nectarine research programme.

### 4.4.1 Allocations from the control boards

The control boards played a central role in providing infrastructure and equipment that was required for FFTRI's research. Examples of infrastructural investments funded by the control boards are: £16 000 (equivalent to R288 000) provided for the establishment of the Assembly Building in 1950, £1 200 (equivalent to R21 600) provided for the purchase of a greenhouse in 1955, £16 278 (equivalent to R293 004) provided for the building of an experimental cannery in 1958, £4 000 (equivalent to R72 000) provided for the establishment of the radio–active isotope laboratory in 1982 and R130 000 for building cold stage facilities in 1982 (Memorandum: DFB, various years).

From the time the control board system was introduced until 1950, the Deciduous Fruit Board allocated a fixed research grant of £25 000 (equivalent to R450 000) annually for FFTRI research projects (Memorandum: DFB, 1950). Fund allocation among the different fruits and the different research disciplines was done by the Institute's director according to the needs of the different projects. The funds for the peach and nectarine research projects were acquired from a Peach Levy paid for fruit that was canned, dried, exported and sold on the local market. The Peach Levy was made up two types of levies. The first was a fixed levy which catered for all the support services the Board offered. The rate at which this levy assessed was increased when the Board deemed necessary. For research in particular, this levy covered the administrative costs and the long–term research projects. Between 1976 and 1988 the general levy was fixed at R4 per ton.

As shown in Table 4.1 below, the research levy fluctuated between 50c/ton and 80c/ton between 1976 and 1988. The Peach Levy fund increased from R12 020.39 in 1965 to R4.5 million in 1988 (Memorandum: DFB, various years).

**Table 4.1: Allocation of the general levy charged per ton from 1976 to 1988**

| **Year** | **1976** | **1978** | **1980** | **1982** | **1984** | **1986** | **1988** |
|---|---|---|---|---|---|---|---|
| Administration | R2.10 | R2.10 | R2.10 | R2.30 | R2.30 | R2.30 | R2.70 |
| Research | R0.50 | R0.60 | R0.60 | R0.50 | R0.70 | R0.80 | R0.50 |
| Advertising | R0.60 | R0.60 | R0.50 | R0.50 | R0.40 | R0.30 | R0.10 |
| General purposes | R0.40 | R0.40 | R0.50 | R0.50 | R0.50 | R0.60 | R0.70 |
| Price stabilisation | R0.40 | R0.30 | R0.30 | – | R0.10 | – | – |
| Total | R4.00 | R4.00 | R4.00 | R4.00 | R4.00 | R4.00 | R4.00 |

*Source: Memorandum: CFB, 1988.*

**Notes: Monetary values in nominal terms*

The second type of levy was called a special levy. It was used for short–term research projects which investigated urgent issues which arose during the year and were not included in the long–term research projects. It also covered the expenses incurred on bursaries, educational tours, fruits and packing material used in experiments, and the salaries of temporary or special skills employees. Due to the fluctuations in the need for these goods and services, the amount paid in special research levy changed more often than that of the general levy. In 1976 the special levy was 4c/carton and it increased to 7c/carton in 1980 then to 11c/carton in 1988 and to 17c/carton in 1996 (Memoranda: DFB, various years). Table 4.2 below shows allocations of the special levy among the research service providers, i.e., FFTRI, the University and URS.

**Table 4.2: Allocation of the special peach levy from 1982 to 1996**

| Year | University of Stellenbosch | FFTRI/ARC–Infruitec | URS |
|---|---|---|---|
| 1982 | R 23 803 (31.7%) | R 51 202 (68.3%) | – |
| 1987 | R 791 779 (63.9%) | R 448 166 (36.1%) | – |
| 1991 | R 130 319 (14%) | R 342 500 (36.7%) | R 460 995 (49.3%) |
| 1993 | R 20 411 (2.3%) | R 536 849 (58.8%) | R 355 480 (38.9%) |
| 1996 | R 52 457 (5.2%) | R 539 705 (53.4%) | R 418 148 (41.4%) |

*Source: Memoranda: DFB, (1982–1996)*

*Notes: Monetary values in 2010 prices*

As shown in Table 4.2, FFTRI had larger allocations from the special levy than the University. The large University allocation recorded for 1987 was because the Board provided salary of the University lecturer, Dr Uys (Memorandum: DFB, 1988). As shown by the large funding allocated to URS from 1991 to 1996, this new research entity was very competitive in attracting funding because it had the best research equipment.

The Special Peach Levy was pooled in a “Special Fruit Levy” with other special levies which were collected from other deciduous fruits. Figure 4.2 below shows how the funds allocated to the peach and nectarine research reported above compared to the total special fruit levy allocation to the FFTRI/Infruitec institute between 1982 and 1996. As shown, the peach and nectarine research allocation in comparison to the Institute’s total special fruit fund increased from 6 percent to 74 percent between 1982 and 1993. The reason for the sudden decrease experienced in 1996 was an increases in the allocations to other research programmes particularly the apple research programme which increased fourfold from R0.4 million to R1.65 million (in 2010 values) between 1993 and 1996 (Memoranda: DFB, various years).

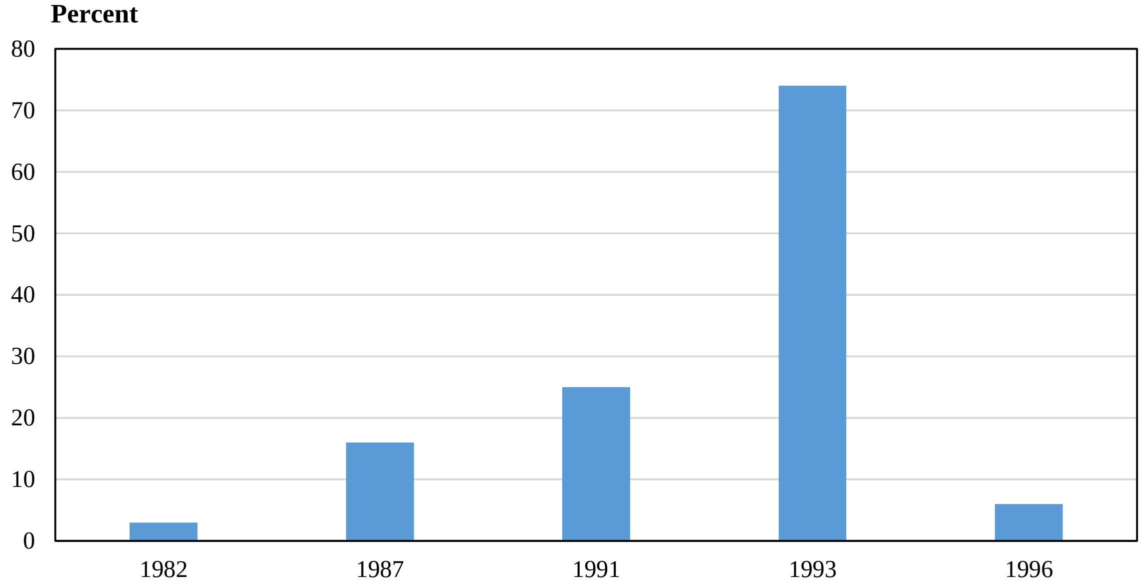


**Figure 4. 2: The percentage of FFTRI's special fruit levy allocated to peach and nectarine research.**

*Source: Memoranda, DFB (1982–1996)*

### 4.4.2 Allocations from the private sector

Figure 4.3 below shows the trend in private sector's investment in the peach and nectarine research programme and also for the ARC–Infruitec institute as a whole. As shown in Figure 4.3, private sector funding for Infruitec has shown a decreasing trend while it's funding for the peach and nectarine research programme has shown an increasing trend. The private sector's funding for Infruitec decreased from R6.3 million in 1999/00 to R5.13 million in 2014/15 in 2010 values, thus recording an 18.6 percent decrease. Private funding for the peach and nectarine research programme increased from R788 587.91 in 1999/00 to R1.12 million in 2014/15 in 2010 values (Financial records: ARC–Infruitec, 2000–2014), thus recording a 42.3 percent increase between 1999 and 2014. This increase in funding is consistent with the increase in the number of projects that are conducted in the peach and nectarine research programme as illustrated in Table 3.1 (Chapter 3). This trend shows that the programme has performed well in comparison to the other research programmes conducted at the Institute. As research fund allocation is done on a competitive basis; the trend implies that the programme has continually met the needs of the industry and an increase in quality of the research results.

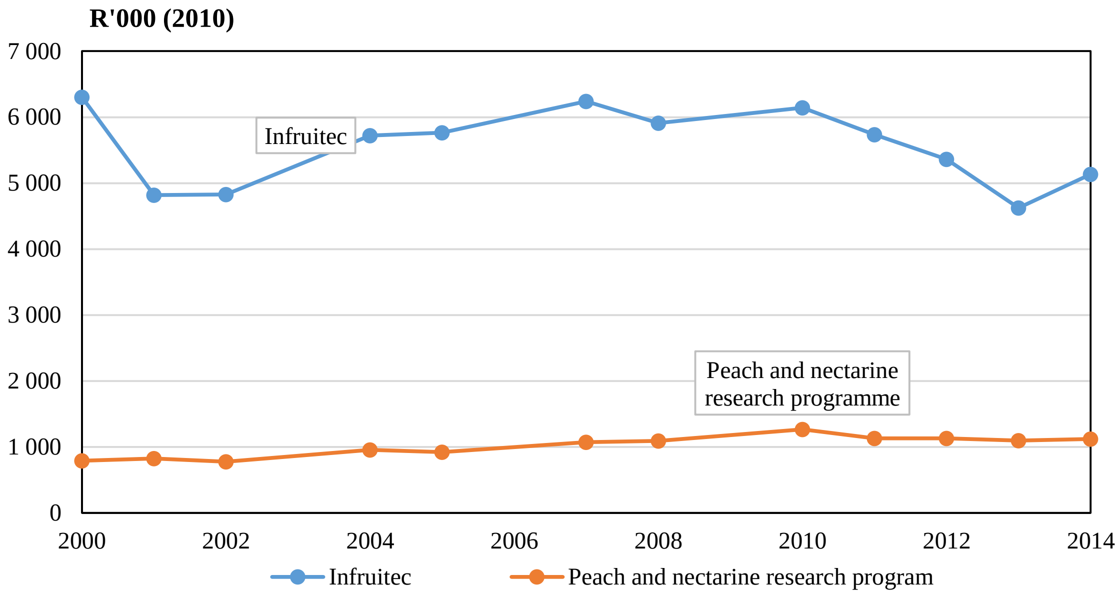


**Figure 4.3: Private sector investment at research programme level and Institute level, 2000–2014.**

*Source: ARC–Infruitec, (2000–2014)*

Figure 4.4 below shows how the private sector's funding has been divided among its three industry representative organisations. The proportion of Culdevco funding as compared to these three organisations is included for the years that Culdevco provided research funding. Most of the peach and nectarine research funding was provided by the SASPA which contributed an average of 56.3 percent of the total DFTS funding. The average investment contributions of CFPA and DFTS between 2001 and 2014 have been calculated to equal 32.7 percent and 9.7 percent respectively. The contributions are considerably large as the CFPA and DFTS contributions at institute level are on average 15 percent and 5 percent respectively (Financial records: ARC–Infruitec, 2000–2014). The higher involvement of CFPA and DFTS at research programme level as opposed to Institute level is due to the high proportion of research that is specific to the processing sector that is done as part of the peach and nectarine research programme. This is because most (80 percent) of the industry's fruit is used in processing. Figure 4.4 also shows that Culdevco's investment contribution is the smallest of the four funding organisations. However, Culdevco's decision to invest in peaches and nectarines is an indication of the company's confidence in the programme as it has not funded research projects in other deciduous fruit programmes.

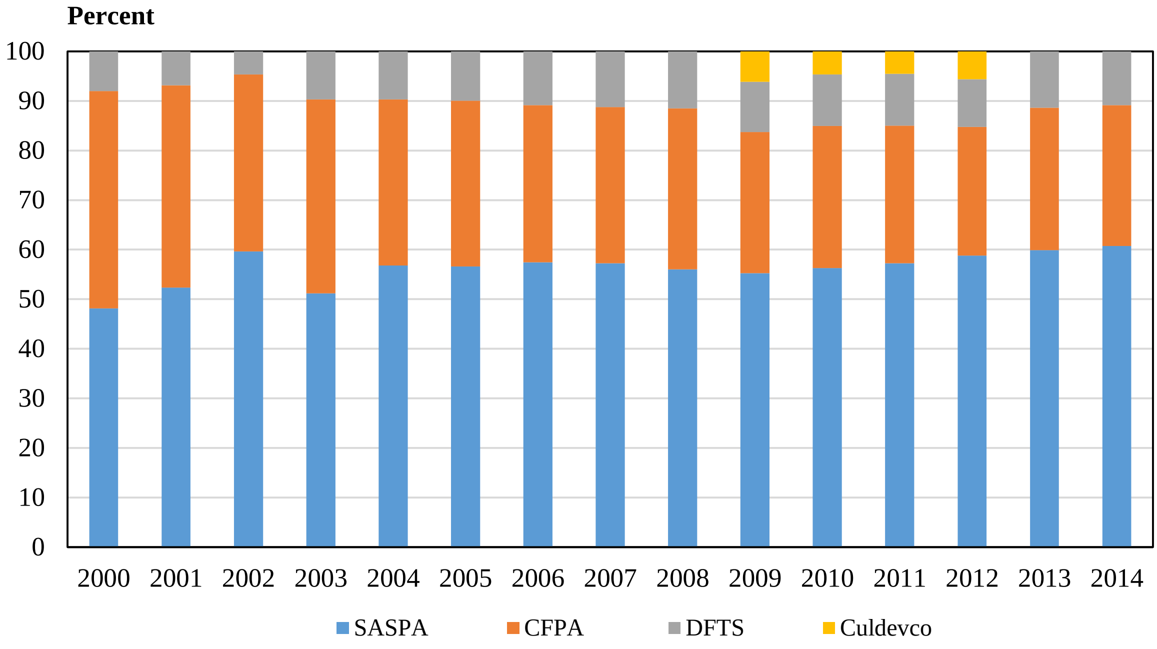


**Figure 4.4: Share of ARC–Infruitec Institute's research investment per private sector investor, 2000–2014.**

*Source: ARC–Infruitec, (2000–2014)*

Figure 4.5 below shows how the private sector's funds have been distributed at research discipline level. As shown, the private sector has focused on funding four of five research disciplines. Particular emphasis has been put on breeding research in the Plant Improvement discipline. As a principle, the private sector funds 55 percent of total expenditure for new projects, 35 percent of Plant Improvement project expenditures and 45 percent of the expenditures in other disciplines (Financial records: ARC–Infruitec, 2000–2014). As shown in Figure 4.5, investment in the Plant Improvement discipline increased from R501 282.30 in 2000/01 to R840 563.22 in 2014/15 in 2010 values; indicating a 68 percent increase in private sector funding. This increasing trend is attributed to the ARC's competitive advantage in breeding over its competitors and the funding policy used by the private sector. The funding levels for the other three disciplines were recorded at below R100 000 each in 2000/01 (inflation adjusted to 2010 prices). Private investment in the Postharvest discipline and the Processing Technology discipline has shown the least change between 2000/01 and 2014/15. The Horticulture discipline has experienced a 24.5 percent increase in private investment and the Biotechnology and Pathology discipline has experienced a 51.6 percent decrease in private investment during the same period.

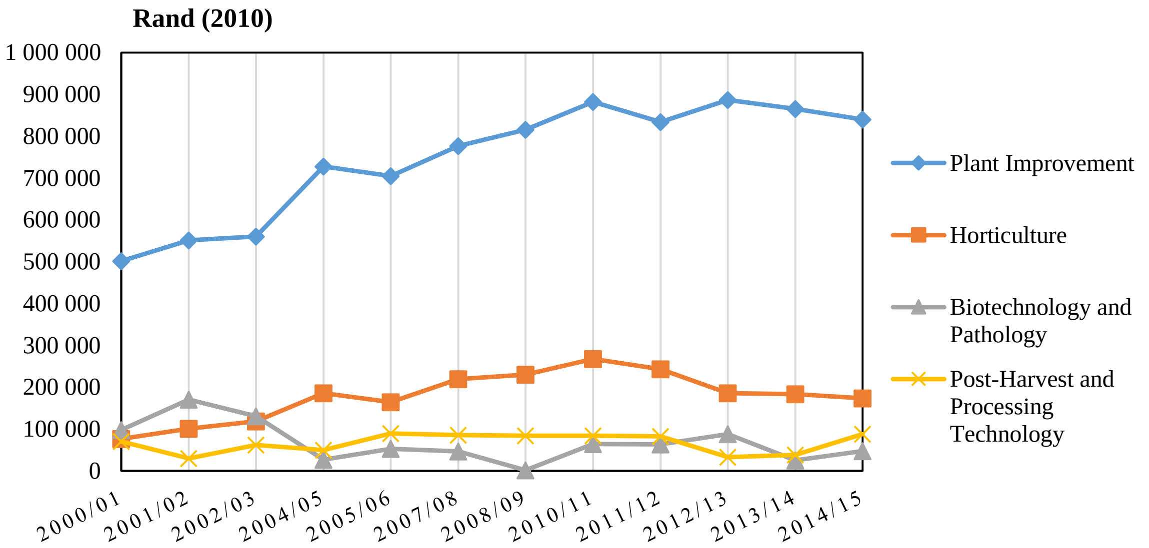


**Figure 4.5: Private sector funding allocation per research discipline, 2000–2014.**

*Source: ARC–Infruitec–Nietvoorbij, (2000–2014)*

### 4.4.3 Allocations from royalties

Figure 4.6 below shows the royalties that were collected on trees bought and planted, and from production. As shown, when Culdevco started in 2006, the company collected R673 308.61 from tree royalties (adjusted to 2010 values). The highest royalties were collected from the peach cultivars Charisma (R43 798.80) and Bonnigold (R32 489.55) (adjusted to 2010 values) (Culdevco, 2012). The first production royalties were collected in 2009 and amounted to R3 251.30. The royalties were collected from four cultivars which were: Autumn Crunch, Cresta, Cascade and Ruby Sweet. The highest production royalties were collected from Ruby Sweet, representing 90 percent of all the peach and nectarine production royalties. The increasing trend in tree royalties stopped in 2009 because the PBRs of over half of the licensed cultivars expired in 2010. The royalties collected on trees increased after 2011 because of the increased adoption of the newly licensed cultivars.

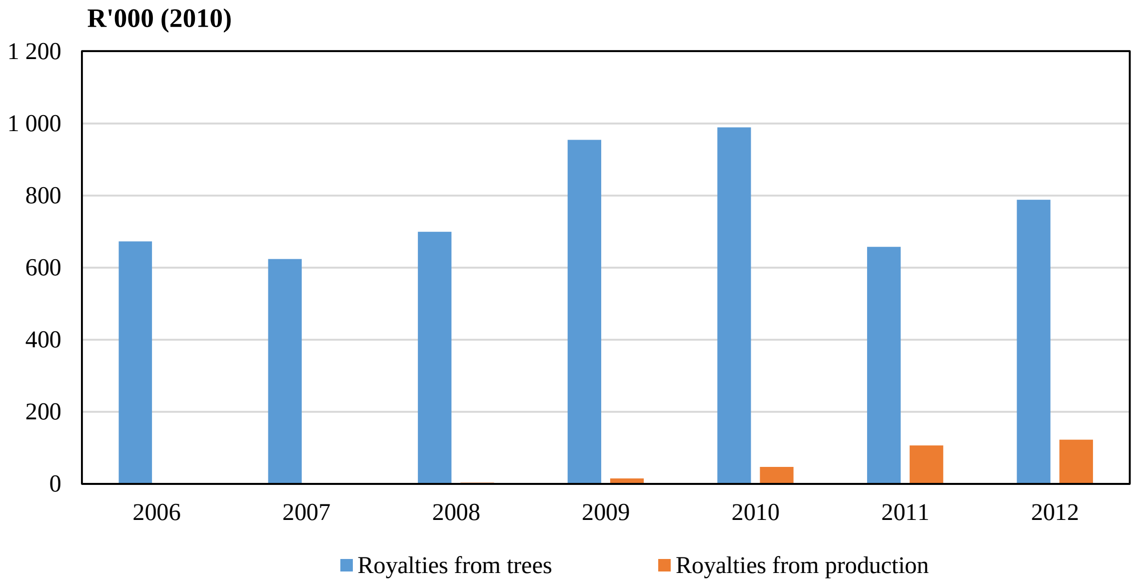


**Figure 4.6: Royalties allocated to the ARC–Infruitec, 2006–2012.**

*Source: Culdevco, (2006–2012).*

## 4.5 ESTIMATING PEACH AND NECTARINE RESEARCH EXPENDITURE

The longest financial data series on peach and nectarine research was acquired from the breeding project income statements which was available for the years between 1994 and 2012. This series included expenditure on researchers' remunerations, overheads and maintenance costs. The data acquired from these statements gave an indication of how the expenditure trend in the peach and nectarine research programme because Plant Improvement research has been the prime research discipline in the programme making up between 64 and 77 percent of the private funding and 100 percent of the income from royalties.

Funding for this breeding research shown in Figure 4.7 is divided into the Parliamentary Grant which was supplied by the state, and external income which is a sum of the funding from the farmer organisations and income allocations from intellectual property, technology transfer efforts and interest earned on short–term investments (Annual Research Review, 2002: ARC–Infruitec, 1992–2002). As shown, total breeding expenditure was R4.6 million in 1994/95 in 2010 values. During this year the Parliamentary Grant made up 75 percent of the total breeding funding. The lowest expenditure was recorded in 1995/96 due to a large reduction of Parliamentary Grant allocation from R3.5 million to R1.6 million in 2010 values. Since 1995, the private sector and the Institute have intensified their efforts in ensuring adequate funding. The state funding has made up an average of 50 percent of the total funding. As this is less than the 65 percent funding that is expected, this figure shows the research programme's success in acquiring external income.

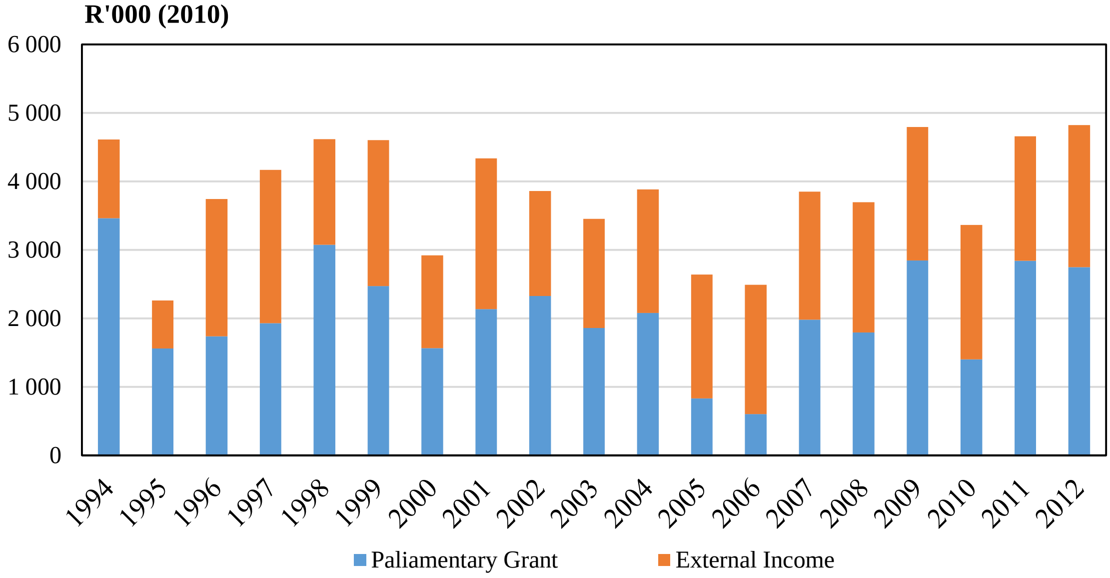


**Figure 4.7: Expenditure on peach and nectarine Plant Improvement discipline, 1994–2012.**

*Source: ARC–Infruitec, (1994–2012).*

The breeding expenditure series was used to estimate the total research expenditure for peach and nectarine research using the average proportion of breeding allocations given by the private sector. Estimation of the peach and nectarine research expenditure series also made use of the percentage of projects allocated to the peach and nectarine research programme as a fraction of the total number of research programme carried out at the Institute. This method was used because an aggregate research expenditure series for Infruitec was available. The resultant research expenditure series followed similar trends to those shown by Deciduous Fruit Board allocations between 1982 and 1996 in Figure 4.2 and the trends after 1994 in Figure 4.6 above; trends which were deemed adequate representations of the expenditure levels for the research programme.

Figure 4.8 below shows the disaggregated peach and nectarine research expenditure series. The expenditure trend suggests that the peach and nectarine research programme has experienced decreased funding as its expenditure decreased from R21.3 million in 1960 to R7.2 million in 2012, in 2010 values.

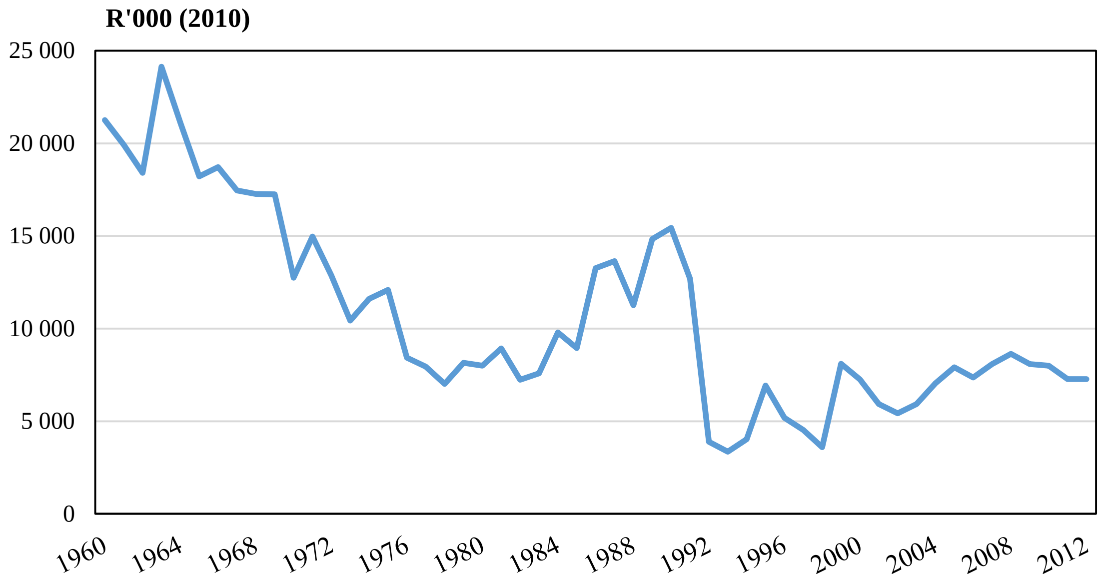


**Figure 4. 8: Expenditure on peach and nectarine research, 1960–2012.**

*Source: Author's calculations*

## 4.6 SUMMARY

The role of collective action in the development of the deciduous fruit industry cannot be understated. Farmer associations were instrumental in the development of a well–coordinated handling system, in the introduction of innovative ways of handling, packing, transporting and processing. They were also important in lobbying against low fruit prices, and in the transfer of information and technology, lobbying for government support and most importantly in funding and shaping R&D projects. This chapter has shown the profound work that these organisations have done in the areas stated above and has shown the amount of funds that have been availed for the peach and nectarine research programme. The estimated long–run funding series shows that there has been a reduction in research investment in the programme from R21.3million in 1960 to R7.2 million in 2012 in 2010 values. The next chapter discusses the different ways in which the rate of return of this funding can be calculated.

# CHAPTER 5

# METHODS OF EVALUATING THE ECONOMIC RETURNS TO AGRICULTURAL RESEARCH INVESTMENT

## 5.1 INTRODUCTION

Agricultural research and development is considered an investment that yields a stream of future benefits (Alston *et al*, 1998). This definition allows for the calculation of costs, benefits and ultimately the rate of return of this investment. Through various manipulations, the impact of the outputs of research can be calculated along economic lines and attributions can be allocated to the contributors. The methods used in these analyses draw from neoclassical theory of production that postulate that economic agents subject to certain technological constraints, aim to maximise their utility (Carter, 1999). Rate of return calculations then assume that agricultural R&D lifts or adjusts this limit to some extent and thus enables the economic agents to derive more utility with the same set of inputs. In this chapter, different types of rate of return methodologies are discussed and their strengths and weaknesses are alluded to. The aim of this discussion is to provide the rationale for selecting the analytical tool used in this study.

## 5.2 APPROACHES TO RATE OF RETURN CALCULATIONS

The first contributions to literature on the rate of return on agricultural research investment were made by Griliches (1958) and focused on gross annual benefits. Methodological rigor has since improved and various efforts have been extended to include methods that calculate average and marginal returns to investment. These methods are divided into *ex–ante* and *ex–post* methods. *Ex–ante* methods are based on experimental data and are done to postulate future returns while *ex–post* methods use secondary, historical data to quantify total gains as cumulated in the past (Marasas, Anandajayasekeram, Coetzee, Martella, Pieterse and Van Rooyen, 1998). Due to the fact that this study has made use of secondary data, this chapter will focus on *ex-post* methods.

The ex-post benefits of research investment have been estimated using a number of methods which include: congruence, Total Factor Productivity (TFP), Error Correction Models (EMC), economic surplus approaches and econometric models. This chapter will particularly focus on the econometric model because this technic allows for the separation of the effects of research, extension and complementary services. This is an important aspect for this study as it distinctly seeks to measure the impact of research carried out at a particular research institute separate from the effect of other research providers and the effect of extension and other complementary services.

Econometric models are the analytic tool of choice because TFP models are more suitably used when dealing with aggregate data and in analysis done at national level (Anandajayasekeram *et al*., 1996). Though ECM could be suitably used for disaggregated studies (Thirtle *et al*., 1998), this analytical tool is difficult to work with as data is handled in a sophisticated manner. The advantage that economic surplus approaches have is that they are flexible and they incorporate other several effects such as spill-over effects, elasticity changes, policy implications and environmental consequences (Marasas, 1999). However, these approaches are often not accurate because a level of value judgement used when using the tools. The source of research funds is ignored and the tools are prone to measurement errors. Similarly, congruence technic is not as rigorous as econometric methods. Thirtle *et al*. (1998) note that they are commonly used as a crude first step in examining the allocation of resources to research.

## 5.3 THE ECONOMETRIC APPROACH

An econometric approach is an analytical method which directly relates past research investments to measures of agricultural output, profit or costs in a mathematical equation. It uses estimates derived from information provided by the different variables to calculate the proportional contribution of agricultural research investments (Marasas, 1999). In this approach, there is accuracy of what is actually being calculated as it allows for calculation of the returns attributable to the marginal financial unit (Alston *et al.*, 1995). The disadvantage of this method is that there are often aggregation problems that are inherent in data or that are generated by the data analyst, which make it difficult to calculate productivity attributions (Anandajayasekeram *et al.*, 1996).

Figure 5.1 below shows the three functions that make up the econometric approach. These include: the production function, the profit function and the supply response function. These methods are disused in the following sections.

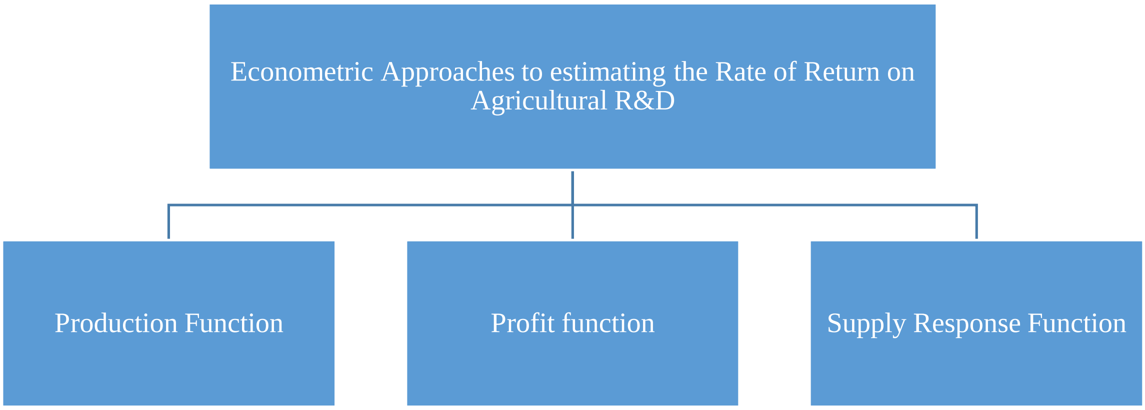


**Figure 5. 1: Econometric Approaches to estimating the Rate of Return on Agricultural R&D**

### 5.3.1 The production function

The production function estimates agricultural research as an input that is critical for agricultural production. In South Africa, this function has been used to calculate the rate of return to wine grape research by Thirtle *et al.* (1998). The function is used in measuring the returns resulting from the technical change caused by research, which in turn affect production. These changes have a considerable time lag and require time series data on conventional input prices, research expenditure and weather. Since time series data for agricultural inputs are collinear, the number of input groups must be restricted. The input groups are also restricted because parameter estimates of a full, fitted production function would not be robust enough to account for all the changes in output (Alston *et al.*, 1998). Inclusion of all conventional inputs would also use up too many degrees of freedom (Townsend and Van Zyl, 1998).

The model uses the well–known Cobb–Douglas production function shown in equation 5.1.

$$Y_1 = \beta_0 \, X_{i1}^{\ \beta 1} X_{i2}^{\ \beta 2} \tag{5.1}$$

This equation can be expressed in logarithmic terms as shown below in equation 5.2.

$$Y_1 = \beta_0 + \beta_1 \, lnX_{i1} + \beta_2 \, lnX_{i2} \tag{5.2}$$

Where: $Y$ is output and the $X_{ij}s$ are inputs (Gujarati and Porter, 2009). These inputs include conventional input cost, research expenditure and weather. The $\beta$'s are the elasticities of dependent variable ($Y$) with respect to the independent variables.

Due to the lagged effects associated with research expenditure, the Almon Polynomial Distribution Lag (PDL) functional form is used to capture lagged effects associated with research expenditure while avoiding collinearity problems (Townsend *et al.*, 1997). The advantage of this functional form is that it simplifies the calculation of research lags and saves on the degrees of freedom (Townsend and Van Zyl, 1998). It also estimates the magnitude and distribution of research returns (Kaliba, Fox and Norman, 2007). A production function which uses the PDL functional form is represented as follows:

$$lnYIELD_{\,t} = \beta_{\,0} + ln\beta_{\,1}X_{\,i} + ln\beta_{\,2}WEATHER + \sum_{i=1}^{n}\beta_{\,t}lnR\&D_{\,t-i} + u_{\,t} \qquad (5.3)$$

Where: *Yield* is tonnage of produce measured relative to a conventional input, *R&D* is research expenditure, $X_i$ is the price of a conventional input(s) and weather is the weather index, $\beta$ is the elasticity of research investment at various lag lengths where $n$ is the maximum lag of research investment that affects yield and $u_t$ is the residual which accounts for variables not included in the model.

According to Hall *et al*. (2010), the production function has its strength in its flexibility as a large number of inputs can be incorporated in the model. It also combines the cost-reducing and product-creating aspects of R&D as well as allowing for imperfect competition, scale economies, and mark-up pricing. One disadvantage the production function has is that R&D elasticities are a combination of output elasticities and price elasticities, and cannot be identified separately (Hall *et al*., 2010). This is an important factor as this study would like to determine whether the increase in industry's value is as a result of the research effect of production volumes or on the quality

### 5.3.2 The supply response function

The supply response function is an alternative to the production function, in which output is a function of own price, the price of substitutes and compliments, conventional input prices, research investment or expenditure and weather (Thirtle *et al.*, 1998). This function has been used to calculate the rate of return to South African deciduous fruit research by Thirtle *et al.* (1998). The supply response function incorporates the price in the model and some details of dynamics of responses to the price changes. Including price variables enables the capturing of such aspects as the effects of opportunity cost of producing the specified agricultural crop and research effects on changes in quality which are reflected in prices (Hall, Mairesse and Mohnen, 2010).

Similar to the production function, the Almon Polynomial Distribution Lag and a restricted number of input groups are used to avoid collinearity problems. Selection of variables requires considerable judgement based on local knowledge (Thirtle *et al.*, 1998).

The supply response function is denoted as shown in equation 5.4 below:

$$Q_j = f\,(P_j, P_r, X_i, R\&D, W) \tag{5.4}$$

Where: $Q_j$ is the quantity of output of the good $j$ supplied, $P_j$ is the price received for output $j$, $P_r$ is the price of related or competing outputs, the $X_i$s are prices of conventional inputs, $R\&D$ is research investment and $W$ is a rainfall index, which represents the weather.

Equation 5.4 implicitly assumes that the suppliers will have reached an equilibrium position in response to known current prices. Since the farmer will tend to be in a state of disequilibrium, adjusting to changing prices and other condition, partial adjustment is assumed (Thirtle *et al.*, (1998) as shown below.

$$Q_t - Q_{t-1} = (Q_t^* - Q_{t-1}) \tag{5.5}$$

Where the actual change in the level of output in period $t$, $Q_t - Q_{t-1,}$ will depend on the gap between the target value, $Q_t^*$, and the value of the last period, $Q_{t-1.}$ Thus introducing logarithms and allowing for price expectations and slow response to price changes for the tree crops, leads to a Nerlove (1958) type model in which lagged prices appear as independent variables. This model is represented as follows:

$$lnQ_{\ j} = \beta_0 + ln\beta_1 X_{\ i(t-i)} + ln\beta_2 P_{\ j(t-i)} + \ ln\beta_3 P_{\ r(t-i)} + ln\beta_4 W_{\ t} + \textstyle\sum_{i=1}^{n} \beta_5 lnR\&D_{\ t-i} \ + \ u_t \tag{5.6}$$

Where: $Q_j$ is the quantity of output of the good $j$ supplied, $P_j$ is the price of output $j$, $P_{r(t-i)}$ is the lagged price of related or competing outputs, the $X_i$s are lagged prices of conventional inputs, R&D is research investment, $W$ is a rainfall index, which represents the weather and $u_t$ is the residual which accounts for variables not included in the model. The $\beta$'s are the elasticities of dependent variable ($lnQ_j$) with respect to the lagged independent variables and $n$ is the maximum lag of research investment that affects yield.

The advantage of using the supply response function is that it reports on both the short–term and long–term elasticities of a commodity (Kaliba *et al.*, 2007). According to Kapuya (2011), the disadvantage of this model is that it may yield biased and inefficient estimates if there is auto-correlation of error terms and if a stochastic lagged dependent variable is used. Kapuya

(2011) adds that this problem can easily be dealt away with by after Error Correction mechanisms which allow for a time invariant error term that is stationary.

### 5.3.3 The profit function

The profit function which often referred to as the dual approach involves estimating a cost function and then deriving Marshallian factor-demand equations and output-supply functions. In South Africa, this function has been used to calculate the rate of return to Horticulture agricultural sub–sector by Thirtle *et al*. (1998). The cost function assumes that farmers are economic agents that seek to maximise their profit from production (Hall *et al*., 2010).

The cost function is represented as follows:

$$C^v = C^v (w_t, Y_t, C_{t-1}, \Delta C_t, A_t) \tag{5.7}$$

Where $C^v$ is the variable cost (the sum of the sum of the costs of the variable inputs only), $w_t$ is the *n*-dimensional vector of variable input prices, $C_{t-1}$ is the m-dimensional vector of input quantities, $Y_t$ is the level of output, $A_t$ is a shift variable reflecting technical change cause by research investment, and $\Delta C_t = C_t - C_{t-1}$ is the m-dimensional vector of net investment in the inputs, entering because of adjusted costs. The R&D stock of knowledge (K) is a component of the vector *C*.

Similar to the production and supply response functions, the demand function explicitly models the product and the R&D investment. According to Alston *et al*. (1998), output-supply equations are obtained by setting the cost function with respect to output (i.e., marginal cost) equal to price and then inverting to solve for output. This inverted function is given by:

$$P_t = d(Y_t, K_{t-1}, z_t) \tag{5.8}$$

Where $p_t$ is the output price, $K_{t-1}$ is the R&D stock and $z_t$ is a vector of exogenous variables affecting demand.

The producer's input and output choices over his planning horizon (assumed to be infinity for simplicity) are determined by maximising the expected present value of the net inflow of funds:

$$\max \Sigma^{\infty} E_t \alpha^{t,s} \left[ D(Y_s, K_s\text{-}1, z_s) Y_s \text{-} C^v(w_s, Y_s, C_{s-1}, \Delta C_s, A_t) - q_s(C_s - (I_m\text{-}\sigma) C_{s-1}) \right] \tag{5.9}$$

Where $E_t$ is the conditional expectation operator, *V* is the *n*-dimensional vector of variable inputs, $\alpha^{t,s}$ is the discount factor, *q* is the row vector for input prices, $I_m$ is the *m*-dimensional identity matrix, and $\sigma$ is the m-dimensional diagonal matrix of depreciation rates of the production inputs.

According to Hall *et al*. (2010), one advantage of using the profit function is that it can incorporate financial choices, pricing decisions or multiple outputs. The use of factor prices, rather than their quantities, as explanatory variables may avoid problems of simultaneity that arise when input choices are jointly endogenous with output (Alston *et al*., 1998). A great deal of structure is imposed on the estimation, allowing the estimation of a number of economic effects within a unified framework and increasing the efficiency of the estimation. The disadvantage of the model is that it greatly relies on the model specification. All benefits of using the model may be forfeited if the specification is flawed or unsuitable functional form is used.

### 5.3.4 Rate of return calculation

The most commonly used method of calculating the rate of return uses the elasticities acquired from the econometric models. These are used to calculate the corresponding marginal product values. As done by Thirtle and Bottomley (1989), each lagged coefficient, $\beta_i$ is the output elasticity of research investment (*R&D*) for that year:

$$\beta_i = \frac{\partial \ln OUTPUT_t}{\partial \ln R\&D_{t-i}} = \frac{\partial OUTPUT_t}{\partial R\&D_{t-i}} \cdot \frac{R\&D_{t-i}}{OUTPUT_t} \tag{5.6}$$

Thus, the marginal physical product of *R&D* is the elasticity multiplied by the average physical product:

$$MPP_{t-i} = \frac{\partial OUTPUT_t}{\partial R\&D_t} = \beta_i \frac{OUTPUT_t}{R\&D_{t-i}} \tag{5.7}$$

Replacing $Yield/R\&D_{t-i}$ by its geometric mean, and changing from continuous to discrete approximations, gives:

$$\frac{\Delta OUTPUT_t}{\Delta R\&D_{t-i}} = \beta_i \frac{\overline{YIELD}}{\overline{R\&D}_{t-i}} \tag{5.8}$$

Then multiplying by the increase in the value of the output and divided by the change in quantity converts from output quantity to output value. Thus the value marginal product of research investment in period $t–i$ can then be written as:

$$VMP_{t-i} = \frac{\Delta VALUE_t}{\Delta R\&D_{t-i}} = \beta_i \frac{\overline{OUTPUT}}{\overline{R\&D}_{t-i}} \cdot \frac{\Delta VALUE_t}{\Delta OUTPUT_t} \tag{5.9}$$

Where: $OUTPUT/R\&D_{t-i}$ is an average and $\Delta VALUE_t/\Delta OUTPUT_t$ is calculated as the average of the last five years minus the average for the first five years, for both variables. Thus these are constants, but $\beta_i$ varies over the lag period, giving a series of marginal returns resulting from a unit change in research expenditure. The value of output, $\Delta VALUE_t/\Delta OUTPUT_t$ is the geometric mean calculated using the value of output relative to chosen base year. Similarly, $YIELD/R\&D_{t-j}$ is a constant–price geometric average. The marginal internal rate of return (MIRR) is calculated from:

$$\sum_{i=1}^{n} \frac{VMP_{t-i}}{(1+r)^{i}} - 1 = 0 \tag{5.10}$$

Where: $n$ is obtained by solving for $r$ to get the MIRR.

## 5.4 APPLICATION OF ECONOMETRIC METHODS IN SOUTH AFRICA

### 5.4.1 Past studies

The application of econometric methods in South Africa's rate of return studies is shown in Table 5.1 below. As shown, the rate of return for South Africa research investment calculated with this method ranges between 5 percent and 100 percent. Rate of return figures calculated at sub–sector level have shown the highest variability as these figures have ranged from 5 percent to 100 percent while those calculated at research programme level have shown the lowest variability as they range from 17 percent to 60 percent. The rate of return calculated at enterprise level is shown to range between 21 percent and 78 percent.

**Table 5.1: Rate of return studies conducted in South Africa**

| Approach | Commodity | Rate of Return | Reference |
|---|---|---|---|
| Supply response | Sweet potato enterprise (1952–1994) | 21 percent | Thirtle *et al.* 1998 |
| Supply response | Deciduous fruit enterprise (1965–1994) | 78 percent | Thirtle *et al.* 1998 |
| Production function | Animal production enterprise (19847–1982) | >36 percent | Thirtle *et al.* 1998 |
| Production function | Maize research programme | 28–39 percent | Townsend *et al.* 1997 |
| Production function | Sugar research programme (1925–2001) | 17 percent | Nieuwoudt and Nieuwoudt 2004 |
| Production function | Viticulture research | 40–60 percent | Townsend and Van Zyl 1998 |
| Profit function | Horticulture agricultural sub–sector (1947–1992) | 100 percent | Thirtle *et al.* 1998 |
| Profit function | Livestock agricultural sub–sector (1947–1992) | 5 percent | Thirtle *et al.* 1998 |

*Source: Liebenberg and Kirsten (2006)*

### 5.4.2 Model selection

This study has adopted the supply response function because of its simplicity, flexibility and accuracy of measurement. Most importantly, the model includes price variables which capture the influence of research on quality and the effect of the opportunity cost of producing peaches and nectarines. These are important aspects as peach and nectarine research has been reported have an effect on fruit quality as shown in Chapter 3 and as discussed in Chapter 2 the area planted to the peach and nectarine industry has been decreasing due to the high opportunity cost of production. This is in addition to R&D's effect on output change that would be normally captured in the production function.

## 5.5 SUMMARY

The methods of rate of return to R&D investment developed can be divided into *ex post* and *ex ante* approaches. This chapter focused on the econometric approach which falls under *ex post* approaches. This approach was more relevant because the econometric approach makes use of time series data that has been discussed in the previous chapters. The strength of the econometric approach is that it is accurate but its weakness is that it is prone to aggregation problems. Of the three econometric functions discussed, this study adopts the supply response function because it captures all the effects of the research carried out in the ARC–Infruitec peach and nectarine research programme. It further captures the effects of cost of production which have played a critical role in dictating the size of the production for the industry in question. The data used in this analysis and the results are described in the next chapter.

# CHAPTER 6

# THE RATE OF RETURN OF THE INVESTMENT IN THE PEACH AND NECTARINE RESEARCH PROGRAMME

## 6.1 INTRODUCTION

The rate of return analysis has gained increasing popularity since 1990 in South Africa due to the increasing need for accountability and increasing competition for research funding in the country (Thirtle *et al.*, 1998). As this study envisages to calculate the returns to peach and nectarine research, this chapter provides the data series that was used in the analysis, shows and discusses the results attained thereafter. Lastly, the rate of return for peach and nectarine research is also compared with the results of past studies.

## 6.2 THE DATA DESCRIPTION

### 6.2.1 Data sources

The study made use of a time series data spanning the 42 years from 1971 to 2012 as shown in Table 6.1. These were the years that sufficient data was consistently available. R&D data were defined as the research costs. This comprised of labour, maintenance, overhead and operational costs. The data for research expenditure in peach and nectarines research was estimated from the Western Province's allocation to deciduous fruit research in the FFTRI/ARC–Infruitec research institute for the years before 1992. Data for the years after 1991 were acquired from Infruitec's annual reports and financial reports. The amount that was allocated to peach and nectarines was estimated using the percentage of the total projects that was allocated to peaches and nectarines. This method was adopted because the financial reports did not separate the expenditure between the various fruits. Research investments were reported according to the organisational structural units which were structured according to research discipline rather than according to fruit type. Still, data disaggregated to research discipline level was only available from 1994 to 2012 from the records of the ARC.

The data on agricultural output and all the deciduous fruit prices were acquired from the Abstracts of Agricultural Statistics which published by the Depart of Agriculture, Forestry and

Fisheries. The study makes uses of average fruit prices from this source. These prices and the R&D investment were adjusted for inflation using a 2010 GDP deflator.

The weather index was calculated using data collected from South Africa's Weather Bureau. Calculation of this index was done using rainfall and temperature data from peach and nectarine production areas. Deciduous fruit conventional input cost indexes were used as proxies for the cost of peaches and nectarines convention inputs. Conventional inputs considered were fertiliser and packing material because these were found to be the highest production cost drivers in Chapter 2's discussions. These input indexes which were acquired from the Department of Agriculture's input cost monitor data. Here the assumption was made that the average input price of the deciduous fruit industry would serve as an adequate proxy for the price for peach and nectarine inputs.

### 6.2.2 Data series

The data used in the regression is shown in Table 6.1 below. As shown in Table 6.1, the annual production output has increased from 158 892 tons to 191 294 ton while R&D investment has decreased between 1971 and 2012. The price of deciduous fruit, adjusted to 2010 values, has decreased in this same period. At the beginning of the series, grape and apricot prices were higher than peach and nectarine prices but towards the end of the series. The increasing Packing Material index indicates that there has been an increase in the cost of production over the years.

The investment in the R&D has fluctuated between R 14 972 and R3 352 (adjusted to 2010 values). As discussed in Chapters 3 and 4, the fluctuations were due to changes in the administration of research funding. The biggest change in this time series' trend is shown after 1991, when there was withdrawal of government funding from research due to the formation of the ARC, an organisation that was expected to acquire funds from the private sector, royalties and the government. The regression analysis could not be split into a period before an economic shock (formation of the ARC) and period after the shock because of the limited data as Ordinary Least Square (OLS) regressors used in the Eviews software require at least 30 observation points for reliable regression to be computed.

**Table 6.1: Data series used in analysis**

| Year | Output (t) | R&D | P and N | Grapes | Apricots | Pears | PM | W |
|---|---|---|---|---|---|---|---|---|
| | Ton | Rand | Rand | Rand | Rand | Rand | Index | Index |
| 1971 | 158 892 | 14 972 | 9 128 | 8 430 | 11 930 | 5 921 | 11 | 102.0 |
| 1972 | 153 318 | 12 868 | 10 588 | 8 762 | 11 402 | 5 346 | 11.9 | 93.2 |
| 1973 | 166 655 | 10 432 | 11 033 | 9 951 | 11 638 | 6 190 | 12.4 | 95.6 |
| 1974 | 164 500 | 11 598 | 9 532 | 8 954 | 11 553 | 6 611 | 13.4 | 106.4 |
| 1975 | 176 561 | 12 092 | 11 715 | 9 093 | 12 353 | 6 111 | 16.5 | 111.3 |
| 1976 | 175 237 | 8 432 | 8 994 | 10 208 | 12 611 | 5 688 | 17.9 | 110.9 |
| 1977 | 152 560 | 7 946 | 9 475 | 10 232 | 10 338 | 5 382 | 19.5 | 107.1 |
| 1978 | 164 428 | 7 018 | 11 427 | 11 093 | 10 544 | 6 552 | 21.7 | 96.1 |
| 1979 | 158 892 | 8 150 | 11 972 | 10 104 | 10 669 | 5 888 | 24.3 | 96.6 |
| 1980 | 165 871 | 7 992 | 10 235 | 8 588 | 8 844 | 5 533 | 27.8 | 95.2 |
| 1981 | 169 566 | 8 936 | 8 912 | 7 828 | 8 013 | 4 657 | 32.3 | 106.9 |
| 1982 | 163 854 | 7 242 | 8 058 | 7 992 | 8 729 | 5 139 | 35.8 | 93.2 |
| 1983 | 168 545 | 7 588 | 6 490 | 6 860 | 7 432 | 3 508 | 38.4 | 89.5 |
| 1984 | 136 324 | 9 788 | 9 149 | 26 408 | 7 393 | 4 322 | 41 | 92.2 |
| 1985 | 147 132 | 8 940 | 8 728 | 6 781 | 10 539 | 4 976 | 43.5 | 102.4 |
| 1986 | 169 356 | 13 256 | 9 551 | 8 644 | 9 918 | 5 707 | 56.3 | 97.9 |
| 1987 | 154 962 | 13 638 | 7 659 | 8 061 | 6 983 | 4 479 | 64.9 | 79.6 |
| 1988 | 170 747 | 11 256 | 9 990 | 7 840 | 8 126 | 3 984 | 77.1 | 105.5 |
| 1989 | 145 332 | 14 836 | 8 909 | 7 252 | 8 079 | 4 587 | 86.9 | 90.2 |
| 1990 | 157 100 | 15 442 | 8 949 | 7 112 | 8 041 | 4 406 | 100 | 99.5 |
| 1991 | 169 792 | 12 692 | 8 912 | 6 808 | 7 600 | 4 096 | 105.7 | 105.4 |
| 1992 | 169 314 | 3 882 | 7 985 | 6 853 | 6 175 | 4 410 | 111.1 | 95.2 |
| 1993 | 151 530 | 3 352 | 6 753 | 7 136 | 7 099 | 2 664 | 122.6 | 103.8 |
| 1994 | 184 737 | 4 026 | 5 811 | 6 507 | 4 663 | 3 301 | 134 | 107.6 |
| 1995 | 157 100 | 6 922 | 6 701 | 6 411 | 6 019 | 3 626 | 151.7 | 103.3 |
| 1996 | 182 801 | 5 176 | 6 178 | 6 381 | 7 425 | 4 048 | 197.1 | 107.6 |
| 1997 | 240 566 | 4 520 | 6 198 | 6 257 | 5 998 | 2 707 | 206.9 | 107.1 |
| 1998 | 214 040 | 3 602 | 6 971 | 7 097 | 5 814 | 3 162 | 191.1 | 98.4 |
| 1999 | 231 549 | 8 092 | 6 146 | 7 135 | 6 214 | 2 814 | 193.1 | 94.5 |
| 2000 | 173 868 | 7 252 | 6 999 | 5 839 | 7 804 | 2 730 | 197.1 | 88.7 |
| 2001 | 189 647 | 5 918 | 5 637 | 6 527 | 7 371 | 2 627 | 221.7 | 87.2 |
| 2002 | 249 290 | 5 428 | 5 654 | 4 773 | 4 486 | 2 616 | 224.6 | 95.6 |
| 2003 | 178 203 | 5 930 | 6 663 | 5 405 | 5 810 | 2 798 | 228.6 | 91.7 |
| 2004 | 183 610 | 7 042 | 6 889 | 5 240 | 5 018 | 3 059 | 234.5 | 85.5 |
| 2005 | 175 430 | 7 912 | 6 128 | 5 342 | 5 376 | 2 829 | 238.4 | 87.3 |
| 2006 | 177 571 | 7 362 | 5 906 | 4 575 | 5 024 | 2 784 | 242.4 | 92.1 |
| 2007 | 182 785 | 8 088 | 6 088 | 5 045 | 3 950 | 3 013 | 250.3 | 98.6 |
| 2008 | 164 286 | 8 638 | 6 498 | 5 498 | 4 890 | 3 353 | 260.1 | 102.0 |
| 2009 | 167 352 | 8 080 | 6 572 | 6 163 | 3 489 | 3 561 | 271.9 | 97.7 |
| 2010 | 175 430 | 7 990 | 6 602 | 5 752 | 5 191 | 3 253 | 315.3 | 90.8 |
| 2011 | 171 104 | 7 278 | 6 468 | 5 932 | 5 367 | 3 313 | 340.9 | 91.5 |
| 2012 | 191 294 | 7 264 | 8 585 | 7 151 | 6 461 | 3 845 | 366.5 | 90.7 |

Source: *Author's compilations.*

*Notes: *P and N represent average peach and nectarine prices, while PM and W are packing material and weather indices. Grape price exclude wine grapes.*

*Fruit prices are recorded per ton*

## 6.3 REGRESSION ANALYSIS

### 6.3.1 Constructing the regression model

The regression model was constructed using the data presented above. As the variables had a unit root, they were differenced once to make then stationary. In the model, peach and nectarine output was the dependent variable and the deciduous fruit prices, the packing material index and the weather index were the significant independent or explanatory variables. The explanatory variables (except for the weather index) were lagged individually to determine the time delay effect of these variables on peach and nectarine production. The lag with the most significant effect on the dependent variable was selected using the t statistic criteria. The variables which showed the weakest statistical relationship were progressively dropped individually until the variables with the highest levels of statistically significant relationships with the peach and nectarine fruit production remained. The combination of lagged explanatory variables showing the highest significant levels was selected using the F statistic criteria. The prices of packaging material, pears, apricots, table and dried grapes showed a significant relationship with the peach and nectarine production. The supply of peaches and nectarines was modelled as follows:

$$lnQ_t = \beta_0 + ln\beta_1 X_{j(t-i)} + ln\beta_2 P_{j(t-i)} + ln\beta_3 P_{r(t-i)} + ln\beta_4 W_t + \sum_{i=1}^{n} \beta_5 lnR\&D_{t-i} + u_t \qquad (6.1)$$

Where: $Q_t$ represents the total tonnage of peach and nectarine produced in the industry, $X_{i(t-i)}$ represented lagged price of packing material; $P_{j(t-i)}$ represents the lagged average price of the different deciduous fruits; $W$ represents the weather index, $R\&D_{(t-i)}$ represents the investment in the Infruitec peach and nectarine research programme and $u_o$ which represents all other uncontrolled factors.

### 6.3.2 The lag structure and length

The constructed model showed that "weather" had an immediate (short–run) effect on the quantity of peach and nectarine produced. That is, a change in weather had an effect in the same year of production. The prices of grapes, packaging material, pears and apricots were found to have lagged (long–run) effects which were significant after 17, 16, 13 and 4 years respectively. This means the quantity of peaches and nectarines produced were going to be affected grape prices, packaging material costs, pear prices and apricot prices after 17, 16, 13 and 4 years respectively. The long lag lengths are in line with economic theory as perennial crop farmers are reluctant to switch to the production of different fruits due to the high costs associated with switching, long break–even lags associated with fruit farming, and the risk–averse nature of farmers. Response to price incentives in the grape industry had the longest lag because switching to producing table and dried grapes requires a different set of skills and infrastructure. Some observable differences between the two enterprises are the use of different trellising systems and different maintenance requirements.

The model shows that it would be easier for a peach and nectarine farmer to switch to the production of stone fruits (apricots) than pome fruits (pears). These findings are justified by the fact that all stone fruits are affected by the same pests and diseases; and stone fruits use the same production and maintenance practices (Ntombela and Moobi, 2013). Therefore switching to a different stone fruit would imply that they would utilise the same production inputs and knowledge in production unlike with pome fruits. Farmers can easily respond to price incentives in the apricot industry, as shown by the short lag, because the peach and nectarine industry's main production area (The Little Karoo) is located in an area that is known to produce the best apricots in the whole world (Taylor and Gush, 2007). Thus the premium acquired from producing apricots serves as an incentive for farmers to switch to apricot production. In addition, Hortgro (2012) shows that apricot production costs for orchards that are in their bearing stage are 31.6 percent lower than those of peach and nectarine orchards in the same production stage. These lower costs are additionally significant because an orchard spends 75% of its time in the bearing stage. It also implies that the break even time for apricot farmers is shorter. The advantage of a short break even period is that it reduces the production risk.

The unresponsiveness of peach and nectarine production output volumes to their own prices is attributed to the fact that the fruit processing market, which consumes about 80 percent of the annual production, uses specific cultivars grown under specific production conditions. South Africa has a limited production area that can provide these production conditions. Thus it would be impossible for the industry to respond to a price movement since production levels are dictated by the availability of resources i.e. cultivars and land. In the same way, the fresh export market fruit volumes cannot increase in response to price increases due to the fact that South Africa peaches and nectarines were sold in a short pre–season window of opportunity before Chile's fruit floods the market. Thus, the ability to increase export volumes is actually determined by the industry's ability to increase supply during that short window of opportunity rather than price. These harvests are produced by a small collection of early season harvest cultivars. On the other hand, positive price movements on the local market would not cause a change in peach and nectarine production because the demand in the local fresh fruit market is not high enough as the industry exports about 85 percent of its annual production (Siphugu, 2009). These facts in addition to the long–term nature of perennial farming make the industry as a whole unresponsive to market or price incentives.

Investments in R&D were estimated to have both short–run and long–run effects on peach and nectarine production quantities. The lag distribution was estimated by a PDL functional form which restricted the shape of R&D distribution to a bell–shaped, second order degree polynomial. This restriction was made in line with economic theory. As reported by Hall *et al.* (2010), R&D investment is thought to have a continuous stream of benefits which peak at some point in time and decrease thereafter and do not necessarily end up being negligible. As the model conformed to literature and expectations, there was no need to apply "far end", "near end" or "both end" constraints. That is, there was no need to assume that the immediate and final effect of R&D of effect was zero.

The results for the acquired from the regression the model are shown and discussed in the following section.

### 6.3.3 Relationships between variables

The prices of grapes and apricots were negatively related to the dependent variable. This means that table and dried grapes, and apricots are fruits which compete with peaches and nectarines on the markets and in production. From economic theory, packing material is expected to be negatively related to peach and nectarine output because higher production costs discourage increase in production volumes. The constructed model was in line with theory as packing material index was negatively related to the dependent variable. "Weather" is positively related to production output. It had a small coefficient because, as shown in Chapter 3, the industry uses ARC–bred cultivars which are well adapted to changing environmental conditions. The coefficient for the "constant" term is negatively related to the dependent variable. This implies that in the absence of market incentives and R&D investment the production is most likely to decrease.

## 6.4 RESULTS AND DISCUSSION

### 6.4.1 Cobb Douglas functional form

A regression was first run using the Cobb Douglas functional form. Eviews 8 software was used in this analysis. The model with the best fit was selected according to the t–test criterion, F–test criterion, Akaike Information Criterion (AIC) and adjusted R squared criterion is shown in Table 6.2 below.

**Table 6. 2: Supply response regression results for Cobb Douglas functional form**

| Variable | Coefficients | Standard error | t–statistic | p–values |
|---|---|---|---|---|
| Constant | –7.404350 | 0.591624 | 12.51530 | 0.0011 |
| Weather Index | 0.077471 | 0.005243 | 14.77508 | 0.0007 |
| Packaging material$_{(t-16)}$ | –0.023262 | 0.604575 | 13.27091 | 0.0009 |
| Price of apricots$_{(t-4)}$ | –0.117724 | 0.167440 | 0.703080 | 0.5327 |
| Price of table and dried grapes$_{(t-17)}$ | –0.321340 | 0.149563 | 2.148533 | 0.1209 |
| Price of pears$_{(t-13)}$ | 0.074542 | 0.275006 | 11.17992 | 0.0015 |
| R&D | 1.120717 | 0.075172 | 14.90861 | 0.0007 |
| R&D$_{t-1}$ | 0.718056 | 0.101414 | 7.080436 | 0.0058 |
| R&D$_{t-2}$ | –0.717579 | 0.117806 | 6.091189 | 0.0089 |
| R&D$_{t-3}$ | 1.281724 | 0.230452 | 5.561780 | 0.0115 |
| R&D$_{t-4}$ | –0.714988 | 0.105298 | 6.790133 | 0.0065 |
| R&D$_{t-5}$ | 0.516839 | 0.075981 | 6.802239 | 0.0065 |
| R&D$_{t-6}$ | 0.089665 | 0.075458 | 1.188280 | 0.3202 |
| R&D$_{t-7}$ | 0.892686 | 0.097504 | 9.155341 | 0.0028 |
| R&D$_{t-8}$ | –1.419562 | 0.166183 | 8.542147 | 0.0034 |
| R&D$_{t-9}$ | –0.130175 | 0.090521 | 1.438065 | 0.2460 |
| R&D$_{t-10}$ | 0.655299 | 0.084820 | 7.725754 | 0.0045 |
| R&D$_{t-11}$ | 0.532602 | 0.108601 | 4.904222 | 0.0162 |
| R&D$_{t-12}$ | 0.396677 | 0.126708 | 3.130632 | 0.0520 |
| R&D$_{t-13}$ | 0.532922 | 0.532922 | 0.085190 | 0.0082 |
| Adjusted R–squared | 0.992292 | | | |
| F–statistic | 149.0378 | | | |
| F–statistic p–value | 0.000782 | | | |
| Akaike information criterion (AIC) | –3.067376 | | | |
| Durbin-Watson statistic | 1.993945 | | | |

*Source: Eviews output*

As shown in Table 6.2 above the model had an adjusted R squared value for the shows that 99 percent of the variation in production of peach and nectarine is explained by the explanatory variables. The model's F–statistic p–value (0.000782) shows that the joint interaction of the explanatory variable has a significant effect on peach and nectarine production. The Durbin-Watson statistic of 1.99 shows there is no serial correlation present in the model.

***Interpretation of coefficients***

The model suggests that, in the long run, every ten percent increase in the price of grapes causes the peach and nectarine industry's output to decrease by three percent, *ceteris paribus*. As shown in Table 6.2, every ten percent increase in the price of packing material, the industry's output decreases by 0.2 percent, *ceteris paribus*. Holding all things constant, a ten percent increase in the price of apricots leads to a one percent decrease in the peach and nectarine industry's output. Every ten percent increase in the price of pears causes the peach and nectarine industry's output to increase by 0.7 percent, *ceteris paribus*. As the coefficients of the price variables are less than 1, this implies that the supply peach and nectarine production is price inelastic. This means the industry's production does not significantly respond to market incentives. However, the sign on pear prices is different from expectations as the coefficients of the deciduous fruits are interpreted as the opportunity cost of production and are expected to have negative signs.

The model adequately explains the relationships which exist between the explanatory variables and the independent variable. However, it marred by the collinearity in R&D lagged terms that is signified by the changing signs of R&D coefficients, the unexpected sign on the coefficient for pear market price and constant appearance of insignificant relationships (shown by the p values) between R&D and the dependent variable in every other year of the R&D lagged distribution. This is indicated by the p–values that are higher than 0.15. In order to rid the model of collinearity, restrictions are introduced using the PDL model as positive coefficients of the R&D terms are required in the rate of return calculation.

***Testing the reliability of the Cobb Douglas functional form***

The model adequately explains the relationships which exist between the explanatory variables and the independent variable. However, the reliability of this model is questionable due to the high (0.99) adjusted R squared result. It is suspected that the inefficiencies in the model could have been as a result of multicollinearity in the explanatory variables. This may be the case in this model because there is often some levels of congruency in the price movements in these prices as the goods are related.

Table 6.3 below shows the results for tests run to investigate collinearity on SAS software.

**Table 6. 3: Multicollinearity analysis**

| | Yield | Weather index | R&D Investment | Peach and Nectarine prices | Grape prices | Apricot prices | Pear prices | Packaging Material index |
|---|---|---|---|---|---|---|---|---|
| **Yield** | **1** | | | | | | | |
| **Weather index** | **0.035** (0.826) | **1** | | | | | | |
| **R&D investment** | **-0.461** (0.002) | **-0.0183** (0.910) | **1** | | | | | |
| **Peach and Nectarine prices** | **-0.472** (0.002) | **0.239** (0.127) | **0.540** (0.000) | **1** | | | | |
| **Grape prices** | **-0.395** (0.010) | **0.050** (0.756) | **0.221** (0.160) | **0.492** (0.000) | **1** | | | |
| **Apricot prices** | **-0.401** (0.008) | **0.335** (0.030) | **0.494** (0.010) | **0.823** (0.000) | **0.394** (0.010) | **1** | | |
| **Pear prices** | **-0.488** (0.001) | **0.308** (0.048) | **0.529** (0.000) | **0.886** (0.000) | **0.437** (0.004) | **0.868** (0.000) | **1** | |
| **Packaging Material index** | **0.471** (0.002) | **-0.324** (0.036) | **-0.446** (0.003) | **-0.736** (0.000) | **-0.500** (0.001) | **-0.813** (0.000) | **-0.790** (0.000) | **1** |

*Source:* *SAS output*

**Note:* *Parenthesis contains p-value of multicollinearity coefficient*

Table 6.3 shows that there was multicollinearity in the model. The most significant collinearity was between the packing material index and the deciduous fruit prices. This was the case because the index was one calculated for deciduous fruits as a whole. The deciduous fruit prices were congruent as expected. Interestingly, there was a long-run relationship between R&D investment and, peach and nectarine prices. This shows that there is a relationship between market remuneration and the level of investment. Given they are important variables in model, it was not be possible to drop any of them, as a way of solving for the multicollinearity problem.

In addition, it was impossible to create aggregate index of the variables as they represent different input variables in the model (i.e production cost, cost of the good in question and price of competitor good). In any case, the resultant index from this aggregation would be difficult to interpret.

The model with the Cobb Douglas function form was also marred by the collinearity in R&D lagged terms that is signified by the changing signs of R&D coefficients and constant appearance of insignificant relationships (shown by the p values) between R&D and the dependent variable in every other year of the R&D lagged distribution. This is indicated by the p–values that are higher than 0.15. In order to rid the model of collinearity, restrictions are introduced using the PDL model as positive coefficients of the R&D terms are required in the rate of return calculation.

### 6.4.2 Polynomial distribution Lag functional form

A regression was first run using the PDL functional form. Eviews 8 software was used in this analysis. The model with the best fit was selected according to the t–test criterion, F–test criterion, Akaike Information Criterion (AIC) and adjusted R squared criterion is shown in Table 6.3 below.

Table 6. 4: Supply response regression results for PDL functional form

| Variable | Coefficients | Standard error | t–statistic |
|---|---|---|---|
| Constant | –4.958356 | 1.225062 | –4.047432 |
| Weather Index | 0.061426 | 0.011245 | 5.462659 |
| Packaging material$_{(t-16)}$ | –0.57976 | 1.036323 | 10.20895 |
| Price of apricots$_{(t-4)}$ | –0.062676 | 0.271420 | 3.915241 |
| Price of table and dried grapes$_{(t-17)}$ | –0.380973 | 0.163389 | 8.452033 |
| R&D | 0.31400 | 0.16974 | 1.84993 |
| R&D$_{t-1}$ | 0.44739 | 0.23668 | 1.89030 |
| R&D$_{t-2}$ | 0.57056 | 0.30859 | 1.84891 |
| R&D$_{t-3}$ | 0.68351 | 0.37756 | 1.81031 |
| R&D$_{t-4}$ | 0.78623 | 0.44098 | 1.78291 |
| R&D$_{t-5}$ | 0.87874 | 0.49781 | 1.76522 |
| R&D$_{t-6}$ | 0.96103 | 0.54755 | 1.75513 |
| R&D$_{t-7}$ | 1.03309 | 0.58997 | 1.75110 |
| R&D$_{t-8}$ | 1.09494 | 0.62492 | 1.75212 |
| R&D$_{t-9}$ | 1.14656 | 0.65233 | 1.75763 |
| R&D$_{t-10}$ | 1.18796 | 0.67217 | 1.76737 |
| R&D$_{t-11}$ | 1.21915 | 0.68441 | 1.78131 |
| R&D$_{t-12}$ | 1.24011 | 0.68907 | 1.79967 |
| R&D$_{t-13}$ | 1.25085 | 0.68618 | 1.82291 |
| R&D$_{t-14}$ | 1.25137 | 0.67579 | 1.85171 |
| R&D$_{t-15}$ | 1.24167 | 0.65797 | 1.88712 |
| R&D$_{t-16}$ | 1.22175 | 0.63285 | 1.93057 |
| R&D$_{t-17}$ | 1.19161 | 0.60059 | 1.98407 |
| R&D$_{t-18}$ | 1.15125 | 0.56148 | 2.05039 |
| R&D$_{t-19}$ | 1.10067 | 0.51595 | 2.13330 |
| R&D$_{t-20}$ | 1.03987 | 0.46473 | 2.23757 |
| R&D$_{t-21}$ | 0.96885 | 0.40912 | 2.36814 |
| Adjusted R–squared | 0.925570 | | |
| F–statistic | 30.53400 | | |
| F–statistic p–value | 0.000002 | | |
| Akaike Information Criterion (AIC) | –0.100243 | | |
| Durbin–Watson statistic | 2.136780 | | |

*Source: Eviews output*

As shown in Table 6.4, the adjusted R squared value shows that 93 percent of the variation in production of peach and nectarine is explained by the explanatory variables included in the model. According to Gujarati and Porter (2009), adjusted R squared values closer to 100 percent are more desirable than values closer to 0. A value of this magnitude does not come as a surprise as Carter (1999) who used the supply response model to calculate the rate of return for deciduous fruits had adjusted R squared vales ranging from 85 percent to 95 percent. Townsend and Van Zyl (1998) had values above 74 percent while Nieuwoudt and Nieuwoudt (2004) had an adjusted R squared of 87 percent. The model's F–statistic p–value was 0.000002. Such a low p–value shows that the joint interaction of the explanatory variable has a significant effect on peach and nectarine production. This result is reliable as shows that the joint effect of the explanatory variables significant at a 99 percent level of confidence. The AIC value of –0.1 is sufficiently low to confirm that the model an adequately high goodness–of–fit with respect to the number of parameters included in it. The Durbin–Watson statistic value of 2.13 is sufficient close to 2; thus it can be concluded that the model is free of serial correlation.

***Interpretation of coefficients***

The model suggests that, in the long run, every ten percent increase in the price of grapes causes the peach and nectarine industry's output to decrease by three percent, *ceteris paribus*. As shown in Table 6.2, every ten percent increase in the price of packing material, the industry's output decreases by six percent, *ceteris paribus*. Holding all things constant, a ten percent increase in the price of apricots leads to a 0.6 percent decrease in the peach and nectarine industry's output. As the coefficients of the price variables are less than 1, this implies that the supply peach and nectarine production is price inelastic. This means the industry's production does not significantly respond to market incentives. As shown by the magnitude of the packaging material's coefficient, the cost of production has a bigger influence on the industry's output than deciduous fruit price.

***R&D lag distribution***

The coefficients of the research investment terms for the regression model shown in Figure 6.1 below.

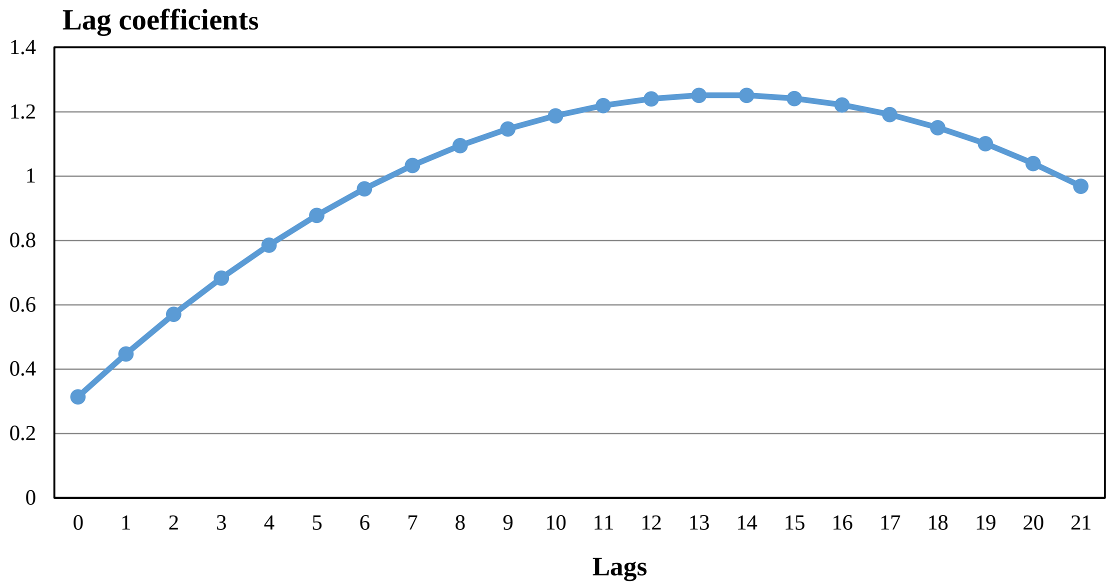


**Figure 6. 1: Distribution of R&D effects on peach and nectarine production.**

*Source:* *Eviews output*

Figure 6.1 shows that the coefficients for the research investment terms range from 0.31 to 1.25. As shown, the returns to research are initiated immediately, i.e. in the initial year of investment. These returns increase gradually and reach a peak and then start to decrease. This initial impact of research is due to the agronomic and maintenance research that influences the quality of the existing crops (Townsend and Van Zyl, 1998). An example of such a project, discussed in Chapter 3 is the breeding of sterile fruit flies which reduces the pest's populations and reduces postharvest losses. This and other projects carried out in the Biochemistry and Pathology discipline form part of the integrated pest–management programme. This programme is problem–oriented and adaptive in nature, thus have positive effects of investment materialise in the same year in the form of reduced postharvest losses (Townsend and Van Zyl, 1998). The use of pest traps which are baited with extracted pheromones is another example of projects in the integrated pest–management programme. Thirtle *et al.* (1998) attribute the quick effect of some of Infruitec's research to the targeted extension programme which is conducted in the Biochemistry and Pathology discipline.

The research lag distribution shows an increasing effect of research investment because other research disciplines with longer research lags begin to yield dividends. Examples of this type of research is conducted in the Postharvest technology discipline and Plant Improvement discipline which take time to be completed. Time also elapse when the developed technologies are transferred and adopted. As there is an overlap between the realisations of short to long term research, the peak represents the combined effect of the different types of research. The slow rate of decrease in the magnitude of coefficients after the peak in year 13 represents the wearing of effects of short term and medium term effects research. This peak is in line with literature and the effect of research investment is expected to remain positive as Hall *et al.* (2010) report to have a relatively slow rate of decay.

Figure 6.1 shows that the combined effect of the different types of research reaches a maximum after thirteen years. This result is in line with Anandajayasekeram *et al.* (1996) who claim that this peak is between twelve and twenty years. As the coefficients of the research investment terms are greater than one from year seven to year twenty, this means peach and nectarine production is inelastic from year zero to year six. This implies that the investment in research starts to cause a significant increase in the quantity of peach and nectarines produced in the industry seven years after investment. In year twenty-one research investment continues to have a positive influence however the production is inelastic (unresponsive). This result emphasises the need of continuous investment in research as the benefits of research tend to decay with time. The study's results show that the lagged research investment terms become more significant with time therefore it is expected that the large coefficients of research investment could remain high (though below one). This could not be determined in this study owing to the data limitations.

***Diagnostic tests***

To further ensure the consistency and reliability of the model used in the analysis, four diagnostic tests were conducted. These tested the model for normality of the error terms, autocorrelation in the error terms, autoregressive conditional heteroscedasticity of the error terms and heteroscedasticity. The results of these tests were favourable as they showed that the model was free of autocorrelation, heteroscedasticity and autoregressive conditional heteroscedasticity problems. These tests were run because the supply response function is known to produce to yield biased and inefficient estimates if the model is plagued with auto-correlation of the error terms and if it also has a stochastic lagged dependant variable (Kapuya, 2011). As the estimated peach and nectarine supply response model in this study does not use a stochastic dependent variable and is free of auto-correlation; the results acquired from this study can be used with confidence as they appear to be reliable and robust. The results from the diagnostic tests are summarised in Table 6.5 below.

**Table 6. 5: Results from diagnostic tests**

| Test | Null hypothesis ($H_0$) | Test Statistic and degrees of freedom | P–Value | Conclusion |
|---|---|---|---|---|
| **Jarque–Bera** | Normality | **JB (2)** = 10.74 | 0.005 | Residuals are normally distributed |
| **Breusch–Godfrey LM** | No second order correlation in the residuals | **$nR^2(2)$** = 0.87 | 0.81 | No second order correlation in the residuals |
| **ARCH LM** | No 1st order autoregressive conditional heteroscedasticity | **$nR^2(1)$** = 0.02 | 0.91 | No 1st order autoregressive conditional heteroscedasticity |
| **White** | No heteroscedasticity | **$nR^2$** = 2.75 | 0.98 | No heteroscedasticity |

*Source:* *Eviews output*

## 6.5 RATE OF RETURN ANALYSIS

The regression analysis has shown that an increase in peach and nectarine research investment is associated with an increase in production of peaches and nectarines. The supply response model used has shown that the magnitude of this increase, associated with a ten percent increase in research investment, ranges from 3.1 percent to 12.5 percent. The marginal internal rate of return (MIRR) of peach and nectarine research programme was calculated to be 55.9 percent. This rate of return is relatively high; however, it lies within the expectations as it falls within the range of rate of return figures calculated at research programme level reported by Liebenberg and Kirsten (2006). Also according to expectation, it is lower than the rate of return calculated at institutional level which was reported to be 78 percent by Thirtle *et al.* (1998). This rate of return is justified by the fact that the peach and nectarine industry has experienced exponential growth in its annual value of production while there was a decrease in land area and stagnating production volumes between 1971 and 2012 (Tree census, 2012: Hortgro, 1989–2012).

According to Kaliba *et al.* (2007), when a high rate of return of this magnitude is associated with inelastic supply responsiveness, it is an indication of potential underinvestment in R&D.

So the rate of return acquired in this study justifies an increase in investment in the ARC peach and nectarine research programme.

## 6.6 SUMMARY

The study used the supply response function to estimate the rate of return to peach and nectarine research investment. Using various econometric criteria, the best model that explained the relationships existing between the production, market price, weather and research investment variables was determined using a PDL model which had a 21–year lag distribution. The lag distribution of research effect was in line with the literature and expectation as Thirtle *et al*. (1998) explain that maintenance research is expected to have immediate effect while the impact of breeding and other basic research are expected to start show 12 years after investment. Using this model, it was found that there is no lead for Infruitec’s peach and nectarine research. The industry was found to be well adapted to potential changes that could be as a result of drier or hotter climatic conditions. The return to R&D investment increases until year 13 after which it decreases. The model shows that the cost of production has a bigger influence on the industry’s output than deciduous fruit price. The industry’s production’s unresponsiveness of peach and nectarine price was also explained by the strong influence of cultivar availability, timing of harvests and sales, and limitations in the production area. The rate of return calculation revealed that every R100 invested in the ARC peach and nectarine research programme yields a R56 increase in value in the industry. This figure compares well with other rate of return calculations done for South Africa. As it is associated with an industry that has an inelastic supply, it is possible that there is underinvestment in the ARC research programme. This suggests that there should an increase in investment in Infruitec’s peach and nectarine research programme.

# CHAPTER 7

# SUMMARY, CONCLUSION, LIMITATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

## 7.1 SUMMARY

The peach and nectarine industry is one of the important industries that were established in the Cape Colony in the 17th century. The industry was instrumental in pioneering fresh fruit exports in 1892, and peaches and nectarines constituted the largest number of trees in the Cape Colony in the same year. The emergence of the industry is in part attributed to the use of good production practices which were introduced by the French Huguenots and also to the availability of high yielding and easy to grow fruit varieties. The prospects of the industry seemed bright as it had a reliable supply. There was a growing demand on the local market and accessing this local market was becoming easier due to the establishment of road and rail networks, stimulated by the emerging mining industry. The growth in demand for fresh fruit in its newly established export market, Europe, also presented even greater opportunities for growth. However, these opportunities could not be fully exploited as factors such as productivity and fruit quality began to impose great limitations that brought the industry to stagnation. It was at that time that the industry stakeholders realised that science was needed to improve the performance of the industry if they wanted its products to survive in the global markets.

The first changes that were introduced were as a result of farmers' efforts to bring about improvements — by purchasing books that contained information on scientifically inspired production practices in the USA, and by importing better quality cultivars. Unfortunately, these cultivars did not perform satisfactorily as they were not adapted to local conditions. Farmer organisations were subsequently formed and information was shared at these organisations' annual conferences. However, real progress was only made in 1936 after a "mysterious" disease had reduced the industry's exports to zero. This disease caused panic throughout the industry as its hopes for growth, which had just been revived by the discovery of the Kakamas cultivar, were stifled. It is at this time that the government responded to the advice given by international consultants and established the Western Province Research Station (WPRS) to carry out horticultural research and offer advisory services for perennial horticultural crop, nut and fruit production. The research scope, organisational structure and capacity of this research institution changed continually over time, causing both a positive effect on the quality of research delivered and negative effect on the number of researchers retained in the institution. The research conducted for peaches and nectarines was classified into five research disciplines, which are the Plant Improvement, Horticulture, Postharvest Technology, Soil and Irrigation, and Biochemistry and Pathology disciplines.

The success of this research initiative is largely due to the establishment of strong farmer institutions that successfully lobbied for research funding from the state and later controlled fund allocations. The farmer organisations further contributed to the development of the industry as they enabled farmers to lobby for state investment in infrastructure development.

Through collective action the farmers also successfully lobbied against low prices with canning agents and negotiated for shipping space. In 1937, the farmer institutions were absorbed into the state institutions in the Control Board System, which spurred the growth of the entire deciduous industry. These state institutions served collectively as a central body that coordinated the handling, packing and export of fruit. They also ensured that funding was available for all the essential support services such as marketing, research, credit and administration. The Control Board System functioned by restricting new industry entries. This was done to protect the average prices made possible by its single channel marketing system. Due to the implied restriction on economic growth brought about by the system, the Control Board System was disbanded and the industry has operated in an open market since 1997.

Changes in the industry have led to a shift in the role of farmer organisations in the industry to the provision of research and market intelligence, while a private organisation called Capespan focuses on fruit handling destined for export. Fruit destined for processing is handled by the processing companies. The number of research service providers has increased and thus the farmer organisations have revised the research funding model to ensure that industry funds are directed to projects that meet the needs of the stakeholders. The peach and nectarine research programme initiated by the WPRS, which is now called ARC–Infruitec Institute, fares quite competitively as it has produced the highest number of cultivars in the Institute. Within the peach and nectarine industry, it bred all the cultivars used in canning in 2012 and all the cultivars used in nectarine fresh exports in 2012. It was ranked seventh in world based on the cultivars released between 1990 and 1996. Despite these achievements, its research funding has decreased, in inflation adjusted terms, from R21.3 million in 1960 to R7.2 million (in 2012 using 2010 values). Some funding has been diverted to private research companies because they have better research capacity, better furnished and equipped laboratories — and they offer market research, which is not the case at Infruitec.

The rate of return (ROR) to Infruitec's peach and nectarine research was calculated using the supply response function, a method that has been used before by researchers to calculate the ROR for deciduous fruit. This analytical method was chosen because it captures the effect of research on yield and on quality as well as the effect of the opportunity cost of production. The model was found to adequately explain the interaction between peach and nectarine production, research investment, deciduous fruit prices, weather and production costs. The deciduous fruit prices that were used were for peaches and nectarines, apricots; and dried and table grapes. The regression analysis used a Polynomial Distribution Lag model to deal with the collinearity between the lagged terms of research investment. Weather had a short–term effect on production while production costs and market prices and long–term effects. Production costs had a bigger influence on production levels than market price of deciduous fruits. These results were supported by the fact the perennial farming has high exit barriers that are encapsulated and indicated in the long break–even time and the high cost of switching to producing an alternative fruit. The results also showed that peach and nectarine supply is price inelastic due to the large influence of: the availability of suitable cultivars, harvest timing and land availability.

The benefits to R&D investment were found to have a positive effect that continued for an undefined period of time. These findings were in line with economic theory. Research investment was found to have an effect from the first year of investment due to the targeted projects that are carried out in adaptive research. An example of such a project was one that produces sterile fruit fly to control the pest population and reduce postharvest losses. The rate of return for the programme was found to be 55.9 percent. This is within the range of the previous South African ROR results.

## 7.2 CONCLUSIONS

Agricultural R&D has been instrumental in stimulating the growth of the peach and nectarine industry. The marginal rate of return for Infruitec's peach and nectarine research programme which was estimated at 55.9 percent shows that the investment in this programme was worthwhile and justifies an increase in investment. This implies that the peach and nectarine industry's value increase by 56c for every R1 invested in the ARC peach and nectarine research programme. Lack of a lead the R&D effects, as well as the long lag effect, show that the research programme adequately responds to industry's problems, and the effects of research continue to have a positive effect several years after investment. The lesson that can be learnt from this study is that investment today has an effect on future production. As shown, today's peach and nectarine production is still benefiting from the research investments made 21 years ago. Therefore today's investment in research can secure the future of the industry. The unresponsiveness of the industry's production to market incentives (prices) reinforces the idea that growth of the industry can be only achieved innovation. Thus the Infruitec's peach and nectarine research programme will continue to be relevant in the future. As continuity of this programme is vital for the industry future, it would rewarding for the industry if the funding in this programme is increased.

## 7.3 LIMITATIONS AND RECOMMENDATION FOR FUTURE RESEARCH

The biggest limitation for this investigation was the lack of adequate detailed data on research investment in the peach and nectarine research programme. Data on expenditure was available at research institute level; however, only fragments of the disaggregated expenditure series were available. These could be used only as indicators of the levels of funding for the years they represented as their use in extrapolation led to over–estimating the research investment. As a result, the estimation of the peach and nectarine research expenditure series was based on the percentage of Infruitec's projects carried out on peaches and nectarines. It is recommended that in future the Institute should systematically capture information on research expenditure electronically and disaggregate it according to the fruits or projects involved, before the financial source documents are discarded. With more data the institute can be able to split the regression between the time the ARC was form and the period before and reliable regressions can be done comparing how the change in administration and organisational structure has affected the performance of the Institute. These alternative method of approaching the research problem could be tackled using a different analytical tool such as the Vector Autoregression models (VAR) which are forgiving when it come to the length of the data series. The VAR model would be especially useful in measuring the effect of the introduction of the ARC as this analytical tool measures impulse responses. Alternatively the research funding could be split in into its different sources and the rate of return could be calculated according. This would make a better case when motivating for an increase in funding to the different funders.

Accurate long–run data series will ensure the success of further and in–depth analyses that could be done on the socio–economic benefits or spill–over impact of research. Such studies can then also find a way of capturing the impact of political and institutional changes that affect peach and nectarine research — information that could not be represented in the model used in this study. This study has also made available information on the research capacity, i.e. trends in the level of experience and the educational qualifications of Infruitec researchers, which can be used to as indicators of the ability of the Institute to deliver quality research. As data on the specific area planted to the different ARC peach cultivars has been made available in this study, it could also be possible to calculate the rate of return on the progenitor cultivars (Kakamas and Early Dawn) of the ARC breeding programme. Data on the export destinations and export per cultivar has been collected and could be used in future studies. Alternatively, a study that could do a comparison of the peach and nectarine industry with other deciduous fruit industries can be done. It also would be interesting to see how the research programme now fares globally since the last time this type of study was done, 1996 statistics were used. The research programme has released over 40 cultivars since then and its world ranking has most probably improved.

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