Measuring the effectiveness of research and development on avocado, *Persea americana* Mill, in South Africa

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Abstract

The measurement of research and development (R&D) presents unique challenges. No method had yet been identified to best measure South African avocado R&D effectiveness. The research question was which criteria were best in measuring R&D effectiveness and what was the level of satisfaction with these criteria. The situational analysis showed that the R&D function provides competitive advantage to the avocado industry. The literature review concluded that a combination of quantitative and qualitative metrics was superior in measuring R&D and the study addressed a gap in the literature. The research methodology explained the experimental design and analysis of the survey questionnaire. A difference existed in importance and satisfaction levels of R&D criteria. The data could be generalised to the population and showed avocado R&D was moderately effective. A combined total of 16 R&D criteria were recommended for use as a measurement tool to assess avocado R&D effectiveness in South Africa.

Original work declaration

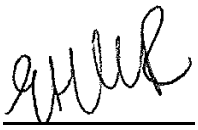
I certify that the research report; Measuring the effectiveness of research and development on avocado, *Persea americana* Mill, in South Africa, is my own original work that has not been submitted for any degree purposes previously. All references used are accurately reported.

_____ 03-03-2011

Dr. Johan de Graaf Date

Language declaration

I certify that the research report; Measuring the effectiveness of research and development on avocado, *Persea americana* Mill, in South Africa, was reviewed for language proficiency before submission for examination purposes.



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1 Chapter 1: Orientation

1.1 Introduction

Research and development (R&D) is a critical instrument for implementing strategy. To sustain their competitive position or gain a new competitive advantage in changing business environments, organisations need to make crucial investments in R&D activities. Traditionally, R&D activities were often considered as an isolated function that is nearly impossible to systematically manage, measure and control (Schainblatt, 1982; Ojanen and Vuola, 2005). This left executives with no mechanism to either judge or participate in what is potentially the organisation's best competitive weapon – its technology! (Tipping, Zeffren, & Fusfeld, 1995). Increased competition, new organisational structures, co-operational forms, justification of investments, and control models have forced managers to rethink the factors and mechanisms related to R&D and its control, and to track suitable R&D performance measures (Lee, Son & Lee, 1996; Ojanen and Vuola, 2005). Measuring R&D also provides the added benefit of recognising spatial and temporal trends and conducting benchmarking studies.

Research on the subject of research effectiveness dates back to the 1950s (Hauser, 1996), but it was only after the world recession in the 1970s, when free spending on R&D was placed under the spotlight, that paper and book outputs increased sharply. Organisational-level techniques to measure R&D effectiveness can be classified into two broad groupings, namely quantitative or qualitative measurements (Werner and Souder, 1997a). Quantitative metrics such as number of patents or bibliometric citations are quick, easy to use, and inexpensive. However, these measures often suffer from poor validity. Qualitative metrics rely on judgments that reflect perceptions, usually of expert groupings. The use of quantitative metrics is usually more appropriate at an advanced stage of applied R&D and product development, whereas qualitative measures are most appropriate when doing basic research with high levels of uncertainty (Werner and Souder, 1997a). Although some techniques may be better suited to specific types of R&D, the use of integrated measures is most often recommended to capture the full range of R&D processes and enhance the advantages of both types of measure to assess tangible, intangible, financial and non-financial components (Tipping *et al*. 1995; Werner and Souder, 1997a; Garcia and Mulero, 2005).

1.2 Purpose of the research

The aim of the study was to determine the most appropriate criteria to measure research and development effectiveness and to measure the level of satisfaction with these criteria as perceived by research sponsors and researchers in the avocado industry of South Africa. The study intended to test theory, but also provided the opportunity to generate theory. The questionnaire-based study was adapted from Lee *et al*. (1996) and included different research input, throughput, output, outcome and strategy metrics.

A focus on industry-level strategy and R&D, compared to an individual company focus, is rather rare and unorthodox. However, role players in the avocado industry are providing a commodity-type product and are highly co-dependent in terms of product quality, product safety, market access and market maintenance. This contrasts with industries where products are highly differentiated and where firms are faced with more unique situations. Common goals in the avocado industry have led to the establishment of influential fruit industry bodies, such as the South African Avocado Growers' Association (SAAGA), to drive united strategic initiatives to the benefit of all growers and agribusinesses. Research and development has a very important role to play in these shared objectives and is conducted at an industry level. This simplifies the analysis and allows the unit of measurement to be the industry level.

1.3 Problems and hypotheses

The research problem statement, research questions and sub-questions, as well as hypotheses and propositions, were developed according to the guidelines provided in Watkins (2008).

1.3.1 Background to the research problem

The R&D function can be considered a system consisting of inputs, throughputs, outputs and outcomes. Yet, most attempts at measuring R&D effectiveness have concentrated on outputs and outcomes (goal orientation) (Szakonyi, 1994; Lee *et al*. 1996; Toerien, 1997; Thirtle, Townsend, Amadi, Lusigi & Van Zyl, 1998). Studies have shown that R&D metrics often used in the USA have particular emphasis on quantitative financial output-per-unit input-ratios (e.g. return on investment, patents per dollar spent, etc.). In contrast; German managers appear to distrust R&D metrics,

especially output metrics, although they more commonly employ quantitative input metrics such as annual expense per R&D employee (Werner and Souder, 1997b). Studies and practice of R&D that use multiple measures for evaluating effectiveness comprising the entire R&D system are relatively rare (Lee *et al*. 1996). Other contingency factors should also be considered when measuring R&D effectiveness, including R&D strategy, the organisational situation and perceptions of management and researchers (Tipping *et al*. 1995; Werner and Souder, 1997b; Falkingham and Reeves, 2001; Cho and Lee, 2005).

1.3.2 Main problem statement

No method has yet been identified to best measure the effectiveness of avocado industry R&D in South Africa, resulting in sub-optimal management of the R&D function.

1.3.3 Research question

Which criteria within the entire R&D system are considered by industry role players to be the best in measuring the effectiveness of avocado R&D in South Africa and how satisfied are industry role players with current performance in these criteria?

1.3.4 Investigative (sub-) questions

A. How important do avocado R&D sponsors and researchers in South Africa perceive different criteria to be in the domain of R&D inputs, throughputs, outputs, outcomes and strategy?
B. How satisfied are avocado R&D sponsors and researchers in South Africa with different criteria in the domain of R&D inputs, throughputs, outputs, outcomes and strategy?
C. How do perceptions of sponsors and researchers compare with calculations of quantitative objective R&D criteria?

1.3.5 Hypotheses

To ensure alignment and consistency, hypotheses and propositions were developed directly from the investigative questions. Hypotheses were generated for sub-questions A and B, because these questions were intended to be tested with quantitative data. In contrast, a proposition was constructed for sub-question C, because it entailed simple calculations followed by logical inductive reasoning to compare the results with the perceptions of the survey respondents.

Hypotheses A–D tested the within-subject effects (repeated-measures effects) of 29 R&D criteria for the two dependent variables, importance and satisfaction. Hypotheses E–H tested the effect of the independent variable, the categories (two levels, sponsor and researcher), on the importance and satisfaction ratings. Hypotheses I–L tested the interactive effect of the category and the 29 R&D criteria on the dependent variables, importance and satisfaction. Lastly, hypotheses M and N tested whether a relationship existed between importance and satisfaction for any of the R&D criteria.

a. Ho: There is no difference in the level of importance between R&D criteria (29 levels) to measure the effectiveness of avocado industry R&D in South Africa.
b. Ha: There is a difference in the level of importance between R&D criteria (29 levels) to measure the effectiveness of avocado industry R&D in South Africa.
c. Ho: There is no difference in the level of satisfaction with R&D criteria (29 levels) in the South African avocado industry.
d. Ha: There is a difference in the level of satisfaction with R&D criteria (29 levels) in the South African avocado industry.
e. Ho: There is no difference between categories (two levels, sponsor and researcher) in the level of importance of R&D criteria (29 levels) to measure the effectiveness of avocado industry R&D in South Africa.
f. Ha: There is a difference between categories (two levels, sponsor and researcher) in the level of importance of R&D criteria (29 levels) to measure the effectiveness of avocado industry R&D in South Africa.
g. Ho: There is no difference between categories (two levels, sponsor and researcher) in the level of satisfaction with R&D criteria (29 levels) in the South African avocado industry.
h. Ha: There is a difference between categories (two levels, sponsor and researcher) in the level of satisfaction with R&D criteria (29 levels) in the South African avocado industry.
i. Ho: There is no interactive effect between categories (two levels, sponsor and researcher) and R&D criteria (29 levels) in the level of importance to measure avocado industry R&D effectiveness in South Africa.

j. Ha: There is an interactive effect between categories (two levels, sponsor and researcher) and R&D criteria (29 levels) in the level of importance to measure avocado industry R&D effectiveness in South Africa.
k. Ho: There is no interactive effect between categories (two levels, sponsor and researcher) and R&D criteria (29 levels) in the level of satisfaction of the South African avocado industry.
l. Ha: There is an interactive effect between categories (two levels, sponsor and researcher) and R&D criteria (29 levels) in the level of satisfaction of the South African avocado industry.
m. Ho: There is no relationship between the importance and satisfaction of R&D criteria (29 levels) in the South African avocado industry.
n. Ha: There is a relationship between the importance and satisfaction of R&D criteria (29 levels) in the South African avocado industry.

1.3.6 Propositions

The proposition of sub-question C was that the actual trends calculated for the input and output metrics of the avocado industry generally aligned with the perceptions of the questionnaire respondents.

a. Proposition: There is general agreement between the perceptions of the questionnaire respondents with calculated annual trends in real R&D funding, research intensity (R&D funding/industry revenue), R&D personnel and the number of SAAGA research reports in the avocado industry of South Africa over ten years (2000–2009).

1.4 Definitions

Special attention was paid to defining and explaining key concepts contained in and related to the research problem statement and research questions. Some additional concepts and terms that permeated the literature and this study were also defined. They are listed alphabetically:

a. *Administrative or other support staff*: Skilled and unskilled craftsmen, secretarial and clerical staff participating in R&D projects or directly associated with such projects (OECD, 2002).
b. *Benchmarking*: A formalised quality process that is used to continuously measure products, services, processes, and practices against competitors

or “best practice” companies, determining how the best-in-class companies achieve those performance levels and applying that knowledge to your own operations to achieve a competitive advantage (Ransley, 1994).

c. *Business strategy*: The formulation of long-range plans (the ‘game-plan’) to achieve the business objectives of the organisation. Business objectives are specific results to be achieved in pursuing the organisation's basic mission and include growing the business, attracting and pleasing customers, competing successfully, conducting operations, positioning the organisation in its chosen market, and achieving target levels of business performance (David, 2003; Thompson, Strickland & Gamble, 2007).
d. *Construct*: An idea or theory containing various conceptual elements (Oxford Dictionary, 2010).
e. *European Union*: An economic and political association of certain European countries as a unit with internal free trade and common external tariffs. The European Union was created on 1 November 1993, with the coming into force of the Maastricht Treaty. It encompasses the old European Community together with two intergovernmental ‘pillars’ for dealing with foreign affairs and with immigration and justice. The terms European Economic Community (EEC) and European Community (EC) continue to be used loosely to refer to what is now the European Union. The European Union consists of 27 member states (including the United Kingdom), 16 of which use the common currency unit, the euro (excluding the United Kingdom) (Oxford Dictionary, 2010).
f. *Importance:* Of great significance or value (Oxford Dictionary, 2010).
g. *Measuring*: To evaluate or estimate the nature, quality, ability, extent, or significance of something – in this case R&D effectiveness (also see R&D effectiveness measurement) (contextualised from Miller, 2010).
h. *Metrics*: The tools or variables used to measure R&D effectiveness within the R&D system (Hauser and Zettelmeyer, 1997). In this study the word criterion (plural, criteria) is used for broader concepts of the R&D system, while the word metric (metrics) is reserved for a specific measurement tool classified as quantitative objective, quantitative subjective or qualitative (Werner and Souder, 1997a).
i. *R&D department or institution*: Classified as a system within the organisation or industry (Lee *et al*. 1996; Brown and Gobeli, 1992; Brown

and Svenson, 1998; Coccia, 2001). A system is defined as ‘a set of components, both tangible and intangible, that interact in the pursuit of common goals’ (Forrester, 1977). Avocado R&D activities involve the consumption of different inputs, following a scientific process, and from these inputs and processes a series of outputs are obtained that are essential for the continued financial and commercial growth of avocado growers and agribusinesses (Garcia and Mulero, 2005). A distinction is made between an output and an outcome, where the former is a direct result of the research (e.g. published paper or patent) and the latter is an indirect result (e.g. increase in profits) (Brown and Gobeli, 1992).

j. *R&D effectiveness measurement*: Measuring the factors (including but not limited to inputs, throughputs, outputs, outcomes) that affect the degree of success in achieving the objectives and results of R&D activities pursued by the avocado industry in South Africa (contextualised from Garcia and Mulero, 2005).

k. *Research and development* is commonly regarded as one interrelated discipline, and in this study it will not be disaggregated into separate components. It is defined as ‘creative work undertaken on a systematic basis in order to increase the stock of knowledge, including the knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications’ (OECD, 1994). In the context of the present study, the definition can be extended by adding ‘for the avocado industry in South Africa’.

l. *Researcher:* Professionals engaged in the conception or creation of new knowledge, products, processes, methods, systems and also in the management of the projects concerned. Students are not considered researchers, unless they are engaged in R&D at a PhD or equivalent level (OECD, 2002).

m. *Rootstock*: A plant (consisting of a root or piece of root) on to which another variety is grafted (Oxford Dictionary, 2010).

n. *Satisfaction:* Fulfilment of one's wishes, expectations, or needs (Oxford Dictionary, 2010).

o. *Scion*: A young shoot or twig of a plant, especially one cut for grafting (Oxford Dictionary, 2010). In this study it specifically refers to the variety grafted to an avocado rootstock.

p. *Technicians:* Persons whose main tasks require technical knowledge and experience in one or more fields of engineering, physical and life sciences or social sciences and humanities. They participate in R&D by performing scientific and technical tasks involving the application of concepts and operational methods, normally under the supervision of researchers (OECD, 2002).
q. *Top-work:* Describes the procedure used to graft scions of another variety on the main branches of an avocado tree, usually to obtain a more desirable fruit (own definition).

1.5 Acronyms

a. *AMAPWG*: Avocado Marketing and Promotions Working Group.
b. *ARC-ITSC*: Agricultural Research Council, Institute for Tropical and Subtropical Crops.
c. *CEO*: Chief Executive Officer.
d. *CTO:* Chief Technology Officer.
e. *DAFF:* Department of Agriculture, Forestry and Fisheries.
f. *EU:* European Union.
g. GATT: The general agreement on tariffs and trade.
h. *HMH*: Hans Merensky Holdings (Pty) Ltd.
i. *OECD*: Organisation for Economic Co-operation and Development.
j. *R&D*: Research and development.
k. *SAAGA*: South African Avocado Growers' Association.
l. *SPS*: Agreement on Sanitary and Phytosanitary Measures.
m. *SUBTROP*: South African Subtropical Growers' Association.
n. *TBT*: Technical Barriers to Trade Agreement.
o. *TUT*: Tshwane University of Technology.
p. *UK*: United Kingdom.
q. *UKZN*: University of KwaZulu-Natal.
r. *UP*: University of Pretoria.
s. WTO: World Trade Organisation.
t. *WTS*: Westfalia Technological Services.

1.6 Delimitations

The study was limited to the avocado industry of South Africa. Sponsors of research only included individuals serving on the board and research committee of the SAAGA. Researchers were limited to personnel with at least an MSc or equivalent qualification who were active in technical avocado research and had conducted research for SAAGA since 2000. This included PhD students, but excluded MSc and other students. The researchers and students in the survey belonged to different institutions, representing the Agricultural Research Council's Institute for Tropical and Subtropical Crops (ARC-ITSC), private consultancies, University of KwaZulu-Natal (UKZN) and Westfalia Technological Services (WTS).

1.7 Limitations

The limitations identified at the onset of the research were that the study is very specific, focused and narrowly defined. The descriptive nature of the study did not allow for causal inferences to be made and the survey was a cross-sectional snapshot at a particular moment in time and did not allow extrapolation far into the future. The study relied on self-report data that may skew results, although this may have been minimised by the option of anonymity being provided to respondents. A more comprehensive discussion of the limitations of the research after completion of the study is presented in Chapter 6, section 6.3.

1.8 Importance/benefits of the study

The study was important to provide a mechanism to judge the effectiveness of avocado R&D in South Africa. It provided an opportunity to improve management of R&D by identifying the level of satisfaction associated with R&D criteria that were most important to measure R&D effectiveness. It established a means for competitive benchmarking within the industry over time as well as between other South African and international fruit industries using parameters judged to be most relevant to the South African situation.

1.9 Contribution of the study to the body of knowledge

Research over more than 50 years has investigated the measurement of research and development. Most published studies have been undertaken in advanced Western nations (USA, UK, and Western Europe) or the Far East, with few studies from Africa or South Africa. The focus of most papers was industrial R&D in sectors such as pharmaceuticals, chemicals and engineering, although some papers also focused on agriculture.

The study aimed to fill the gap in the literature to measure the effectiveness of agricultural R&D in Africa at a micro level. Specifically, the focus is on South Africa, the agricultural sector, the subtropical fruit sub-sector and the avocado industry. To the best knowledge of the author, it will provide the first validation of R&D criteria throughout the R&D system for measuring R&D effectiveness in South Africa.

1.10 Outline of the research report

The research report followed a chapter layout. Chapter 1 was aimed at orientating the reader and introducing the research topic. In this chapter the rationale of the study, research problems and hypotheses, definitions, acronyms, delimitations, limitations, importance and contribution of the study to the existing body of knowledge and assumptions were discussed.

Chapter 2 presented the strategic framework of the study, providing a situation analysis of the macro, micro and competitive environment of the avocado industry and discussing the existing strategies in place for South Africa. Critical strengths, weaknesses, opportunities and threats were identified and the research problem broadly contextualised in the strategic framework of the industry.

Chapter 3 provided a critical review of literature, concentrating on key topics identified in the research problem statement and research questions. It started with a relatively broad view and gradually became more narrowly focused, identifying the gaps in the literature and sketching the specific contextual framework of the study.

Chapter 4 discussed the research methodology in detail. It explained the experimental design, sample selection, development of the measurement instrument, data analysis and other elements relevant to the material and methods of the study.

Chapter 5 focused on the research results, presenting the statistical findings and other results obtained from the research. The trends, patterns, differences and

limitations of quantitative results were noted and a thick description provided of qualitative results. Graphs and tables were used to present the data.

Chapter 6 discussed and explained the results, putting the findings into context, providing the implications of the research results, recommending a model to measure R&D effectiveness in South Africa and suggesting future research. This was achieved by interpreting the results, comparing the results of the study to previous research and indicating the relevant gaps in the literature that should still be addressed.

The final section listed the references and provided the appendices. A concept article prepared in the format of the *Southern African Business Review* journal was provided separately.

1.11 Assumptions

It was assumed that respondents selected to complete the questionnaire were willing to participate in the study and provide their honest, unbiased answers to the questions. It was assumed that participants fully understood all the research questions contained in the questionnaire.

The author of the study is the research manager of a private research organisation (Westfalia Technological Services). It was assumed that source effects did not influence the response by the participants. The nature of the study required that three respondents from the target population view the questionnaire before completing it. It was assumed that their responses were not be affected by this. Pre-testing and in-depth discussions were focused on comparable individuals outside the target population to prevent interactions and exchanges with the researcher that may influence study responses (Cooper and Schindler, 2003). The construct validity of the selected variables in the questionnaire was assumed to be high, because these were selected from the most commonly reported criteria reported in the literature as indicators of R&D success, and a very similar questionnaire was used in two other academic studies to specifically measure R&D effectiveness under different conditions (Lee *et al*. 1996; Garcia and Mulero, 2005). The questionnaire was assumed to be a reliable instrument, because a very similar version of the questionnaire was shown to be reliable when administered in Korea (Lee *et al*. 1996).

A pragmatic view was adopted towards the Likert scale data, where equal intervals were assumed so that these qualified as interval level data, which in turn

allowed the use of parametric statistics. A level of significance (alpha) of less than 0.05 was used (Diamantopoulos and Schlegelmilch, 2006).

2 Chapter 2: Strategic framework of the study

Abstract

The world demand for avocados is growing strongly and production of avocados increased significantly over the last half century. The aim of this chapter is to provide a broad context for the proposed research by conducting a situation analysis of the South African avocado industry in the global environment. Mexico accounts for more than 30% of world avocado production, while the USA is the largest and fastest growing import market. Europe is the other main market, and together the EU and USA account for more than 90% of imports. The US market is protected by very strict sanitary and phytosanitary regulations, preventing South Africa from supplying this market. The South African avocado industry is strongly export-oriented and produces 3% of world avocados, mainly for export to the EU and UK. The main varieties grown are Hass and Fuerte, and the season extends from March to September. In the external environment, the globalisation of markets and technological advances provide some of the greatest opportunities, while land claims and labour challenges are important threats. Peru is a major competitor for the South African industry. An increasing risk of existing world industry members expanding their production capacity and market reach is apparent. The South African avocado industry is internationally competitive, although a negative trend in competitiveness is being noted. In the internal environment, human resources and R&D resources and capabilities are important strengths, while stagnant plantings, a virtually exclusive Eurocentric marketing and distribution focus, and exclusion from the largest and fastest growing markets are key weaknesses. Industry key success factors (KSFs) include innovation ability, production capacity and market and distribution access. The R&D function is the cornerstone of competitive advantage and KSFs in the industry and it is critical to fully leverage the function as a prime resource and capability of the South African avocado industry. This requires optimisation of R&D management, which in turn requires the validation of suitable criteria for the measurement of R&D effectiveness.

2.1 Introduction

This chapter analyses the strategic environment of avocado producers in South Africa and focuses on a situation analysis of the avocado industry in South Africa. As mentioned briefly in Chapter 1, focus on an industry, compared to the situation analysis of a company, is rather rare and unorthodox. However, role players in the avocado industry, similar to many other fresh fruit industries, are providing a commodity-type product and are highly co-dependent in terms of product quality, product safety, market access and market maintenance. This has led to the establishment of influential industry bodies, like SAAGA, to drive united strategic initiatives to the benefit of all growers and agribusinesses in the avocado industry. This simplifies the analysis and allows the unit of measurement to be the industry level.

2.1.1 World avocado production and marketing

World production of avocados had increased more than four-fold over the last four decades. Latin America and the Caribbean are the largest producing regions, but growth in Asia has accelerated in recent years, particularly in Indonesia and China. Over the last decade, world utilisation has increased by over 30%, due mainly to expansion in major emerging markets, particularly Brazil, Colombia, China and Chile, as well as in many developed markets, such as the USA, European Union (EU, including UK) and Australia. Per capita consumption, however, is highest in Latin America and most avocados are consumed in Mexico. Market drivers have been principally human consumption of fresh and processed products, the result of consumers' enhanced awareness of the fruit's nutritional properties, together with its utilisation in the cosmetic industry as a consequence of the growing demand for natural-based product components (FAO, 2009b).

The latest estimates show world-wide production of avocados is approximately 3.5 million metric tonnes per annum. Mexico is the largest producer, accounting for approximately 32% of world avocado production. It is followed by Chile (7%), Indonesia (6%), Dominican Republic (5%), Colombia (5%), Brazil (5%), Peru (3%), Spain (3%), USA (3%) and South Africa (3%). Exports amount to approximately 900 000 metric tonnes per year, dominated by Mexico (34%), Chile (32%), the Netherlands (6%), Spain (5%), Peru (4%), South Africa (4%), France (3%), Dominican Republic (2%) and New Zealand (1%). Import and re-export activities by

non-producers like the Netherlands and France artificially inflate these export figures so that actual avocado volumes imported are approximately 750 000 metric tonnes per year. Main importers are the USA (47%), France (15%), the Netherlands (8%), UK (6%), Japan (4%), Spain (3%), Canada (3%), Germany (3%), Colombia (2%) and El Salvador (1%) (FAOSTAT, 2010). Generally these figures are representative, but only estimate actual values due to the alternate bearing nature of avocado trees.

Approximately 90% of imports are concentrated in the United States and Europe. The consumption of avocados in the EU showed 4% annual compounded growth from 1995 to 2006. Analysts believe that the market could show stronger growth if supply was more consistent and not hampered by the on-off season phenomenon (Naamani, 2007). Traditionally, the most important suppliers to the EU (including UK) market are South Africa, Mexico, Israel, Kenya, Spain, and Chile, although volumes from Peru have increased significantly in the recent past (AMAPWG, 2009). The EU market is characterised by consisting of many countries, different languages and preferences (some countries prefer different varieties) and annual per capita avocado consumption varies greatly between countries, averaging at 500g (Naamani, 2007).

In comparison, the US consumption of avocado showed 9% annual compound growth from 1995 to 2006 (Naamani, 2007), and per capita consumption in 2007 was approximately 1 500g (ERS, 2008). The USA is a net importer of avocados from Mexico, Chile and the Dominican Republic, but is also supplied by domestic production, particularly from the states of California and to a lesser extent Florida. Supply to the USA from 1995 to 2006 has been fairly consistent, which is mooted to have facilitated the stronger growth compared to the EU (Naamani, 2007). However, additional factors are likely to be involved, including avocado fruit being better known and native to the Americas, income growth trends, population composition and population growth rates, marketing intensities, and consumer preferences (Carman and Rodriguez, 2004; FAO, 2009b). In contrast to the EU market, the US market is protected by very strict sanitary and phytosanitary regulations, preventing many countries, including South Africa, from supplying to this market (FAO, 2009b).

Both the US and EU avocado markets show a considerable degree of product differentiation and market segmentation. Markets are mainly segmented according to varieties. Hass avocados are known as black-skins, being green but turning purple or black when ripe. In contrast, green-skins like Fuerte, Ettinger and Pinkerton remain green when ripe. Hass avocados dominate international trade, while green varieties

are mostly consumed domestically in producing countries. Certain green-skins are preferred in European countries, although the preference is also changing towards Hass. Organic avocados attract a price premium above the traditionally produced avocado, and constitute a separate market (FAO, 2009b).

Avocado industries around the world have developed in two different ways: either most of the production was initially focused on the local market, as in Mexico, Brazil and Peru, or the whole industry was initially built for export, as in Israel, South Africa, Spain and Chile. In the former case, the industry's foundation is local consumption while exports started and developed at a later stage. In countries where the export market aims to be the core business, the domestic markets (or processing) were meant to deal with surpluses and/or lower quality fruit. Over time, the Israeli, South African and Chilean domestic market demand has grown and now avocados are imported to maintain adequate domestic supply for 12 months of the year. Until recently Spain had a modest domestic market that has almost doubled since avocado imports commenced (Naamani, 2007).

A common sentiment is that the world market for avocados is under-supplied with a great opportunity for growth (Naamani, 2007; FAO, 2009b).

2.1.2 South African perspective

Avocado production in South Africa is concentrated mainly in the warm subtropical areas of the Limpopo and Mpumalanga provinces in the north-east of the country between latitudes 22^{o}S and 25^{o}S. The main avocado varieties grown are Hass and Fuerte, and the season extends from mid-March to September. Climatic variability between growing regions allows the major cultivars to be available over an extended period during the season (Donkin, 2007). Generally, Fuerte is picked from March to June and Hass from April to September.

The avocado industry in South Africa has grown steadily from the first orchard planted in the 1920s, to ±2 000 ha in 1970 and ±12 000 ha in 2003. The industry is strongly export-oriented and exports of approximately 40 000 tons per annum account for about 50% of production. The United Kingdom and Western Europe absorb more than 90% of the exported crop with the remainder feeding Eastern Europe and the Middle East. Due to the Eurocentric export focus of the industry; Hass, which is preferred by these markets, have been planted more frequently than Fuerte in recent years, and in many cases Fuerte orchards have been re-planted with Hass (Anonymous, 2010; Donkin, 2007). The domestic market and avocado

processing (especially avocado puree and oil) is increasingly important in absorbing volume growth and adding value to large volumes of avocado production (Vorster, 2004).

The formation of an industry association was initiated in the mid 1960s, when avocado farmers realised that they would have to work together if they wanted to obtain the greatest possible benefits from their investments. On November 27, 1967, the first meeting of avocado growers was held at Westfalia Estates near Tzaneen, which led to the formation of an Avocado Growers Export Coordinating Committee. The name changed in 1969 to the Transvaal Avocado Growers' Association and on August 9, 1971, it became known as SAAGA (Anonymous, 2010). In 2006, SAAGA was incorporated under the umbrella organisation of the South African Subtropical Fruit Growers' Association (SUBTROP) along with the mango, litchi and macadamia growers' associations to unify administration, finance, extension, promotion and market provision. The board and levy systems remained unchanged.

The aim of this chapter is to provide background information on the South African avocado industry (SAAGA) strategy, and research and development in the industry. A situation analysis is conducted comprising of a macro, competitive and micro environment analysis. A resource-based view (Grant, 2008) is used to explore the resources and capabilities of the industry to identify its salient strengths and weaknesses. A SWOT (strengths, weaknesses, opportunities and threats) breakdown and list of industry key success factors is provided to summarise the situation analysis. The chapter then contextualises the research problem in light of the situation analysis before it provides a conclusion on the situation of the avocado industry in South Africa.

2.1.3 Vision, mission and objectives of SAAGA

SAAGA's vision is to improve the South African avocado industry to world-class status as suppliers of avocados in the export and domestic market. SAAGA aims to achieve this vision through the medium of voluntary cooperation, facilitation of communication between stakeholders, and provision of information pertinent to this industry.

The mission of the organisation is to act in the avocado grower's interest to improve the economic viability of producing, packing, and marketing avocados. SAAGA has eight main objectives: (i) Collect, collate and distribute information concerning the production and marketing of avocados; (ii) Carry out research and

development (R&D), have R&D carried out and coordinate such R&D concerning the production and marketing of avocados; (iii) Make recommendations for the necessary quality requirements and the application thereof in conjunction with the relevant state bodies, and other authorities; (iv) Make recommendations concerning the post harvest handling and distribution of avocados; (v) Encourage the coordination of export and local marketing of avocados and to assist in the distribution of marketing information to role-players; (vi) Increase the demand for avocados locally and overseas by advertising, promoting and other such means as the Association shall deem fit; (vii) Give technical support to avocado growers; and (viii) Provide a forum where matters of mutual interest to all concerned with the avocado industry can be fruitfully discussed, and initiate any action required on a united front (Anonymous, 2010; Vorster, 2004).

The South African avocado industry regards interaction between avocado-producing countries serving the EU market as a very high priority to bring greater stability to the market. The International Avocado Marketing and Promotions Working Group (AMAPWG) is a forum assisting in the sharing of information between Israel, Spain, South Africa, Kenya, Peru, Mexico, Chile, Australia and New Zealand. Although still a free market environment, the sharing of information such as crop estimates and weekly shipments allows the role players involved to better manage sales programmes (Vorster, 2004).

2.1.4 South African research and development

SAAGA-funded R&D was initiated in 1973 at a time when the industry had significant production problems. A root-rotting disease caused by *Phytophthora cinnamomi* (Pc) Rands was rampant and without any control measures. This pathogen results in tree decline and a reduction in fruit yield and plant vigour. A pre-harvest black spot disease (caused by *Pseudocercospora purpurea* Cke) and post-harvest diseases caused by a complex of pathogens were also responsible for significant fruit losses. Nurseries sold up to 100% Phytophthora infected trees and no trees on clonal rootstocks were available. Packaging and transport systems were poor and unreliable (Darvas and Kotze, 1987; Toerien, 1997).

Research and development has been mostly credited with solving or significantly reducing the impact of these constraints by developing treatments against Pc and other diseases including black spot, breeding Pc-tolerant clonal rootstocks, and improving packing and temperature management systems (Darvas

and Kotze, 1987; Toerien, 1997). More recently the focus of avocado industry R&D remains concentrated on technical issues and investigates improved post harvest practices and more environmentally friendly pest and disease remedies. A special and specific focus is on developing phytosanitary treatments to access restricted export markets like the USA, Mexico, Japan and others. The research portfolio is broadly divided into a number of areas relating to the point of loss or opportunity (Bower, 2010) as summarised in Table 2.1.

Table 2.1 R&D portfolio of the South African Avocado Growers' Association for 2009/10

Factors relating to profitability	Present research	Institution	Potential new research areas
1. Enhancement of on-farm profitability			
a) Increased and more stable yield	Phytophthora control using Si based products	UKZN	Other alternative for Phytophthora control
	Mulching materials	WTS	Alternate bearing/yield management and nutrition
	Cultivar development	Various institutions for own benefit	
b) Higher pack-out	Cercospora spot – alternative products	WTS	Additional research on stinkbug control
	Effect of Hemiptera bug complex on external damage	Consultant	New spray technologies
	Stinkbug research (survey, product registrations)	SUBTROP, committee	
	Grey speckle & freeze damage of fruit	ARC-ITSC	
c) Decreased production costs/unit yield	See all above		See all above plus precision agriculture technologies
2. Decreased packaging and logistics costs	Low temperature shipping to delay and synchronise ripening (potential to remove Controlled Atmosphere and 1-MCP product)	UKZN, WTS	Pallet design
3. Enhanced quality and consistency of quality in the market	Low temperature shipping, ripening physiology, risk analysis and mitigation (prediction of ripening and quality)	UKZN, WTS	New innovative post-harvest disease control
	Effect of cold chain breaks	ARC-ITSC	Packaging, logistics management, cooling technologies
4. New markets and products to enhance	Low temperature sterilisation projects	UKZN, WTS	New avocado products, with possible joint ventures
	Host status of *Ceratitis*		

net returns	*capitata, C. rosa, C. cosyra* in SA		
5. Threats to industry profitability			
a). Fruit flies	Risk analysis *Bactrocera invadens*	WTS SUBTROP	Expand *B*. *invadens* work where necessary
b). False Codling Moth (FCM) (*Thaumatotibia leucotreta*)	Pre-harvest control of FCM with mating disruption and granulo virus	WTS	Gamma-irradiation for FCM, fruit fly control (potential new UKZN) FCM survival at 1^0C Register Isomate for FCM control
c). Industry census for market development		SUBTROP	Conduct tree census
d). Maximum Residue Levels		SUBTROP	Monitor and evaluate effects per market

Source: South African Avocado Growers' Association, 2010 (unpublished)

SAAGA-funded R&D is mainly conducted by WTS (private), the University of KwaZulu-Natal (semi-government), and the parastatal ARC-ITSC. Of these, most of the SAAGA-contracted research is done by WTS, a division of Westfalia SA (subsidiary of Westfalia Ltd), a vertically integrated agricultural company specialising in avocado and mango production, processing and marketing. Being the main R&D institute for the avocado industry, more background will be provided on WTS and Westfalia.

Westfalia Ltd is the single largest avocado producer in Africa. The vision of Westfalia is to be an iconic, global, vertically integrated, sub-tropical fruit and related products supplier, supported by values of responsibility, making a difference, genuine service, trustworthy quality, integrity and reliability. The mission statement of Westfalia includes celebrating a heritage of diversity, to foster and nurture co-operation, integration and strategic inter-dependence throughout an integrated value chain, to be committed to practical, commercial innovation and investing in focused research and product development. The strategic objectives of Westfalia are to develop strategic global supply sources and reliably supply sub-tropical fruit and related fruit products all year round. Westfalia's strategy comprises (i) differentiation

for sustainable competitive advantage in terms of quality, service, brand value and innovation; (ii) vertical integration to achieve sustainability, improved market knowledge and proximity to market; and (iii) creating a global footprint to achieve sustainable complementary production and a 12-month supply base (Westfalia, 2009).

R&D at WTS is funded by industry and Westfalia SA and concentrates on gaining market access, extending the fruiting season and testing new avocado scion varieties, breeding clonal avocado rootstocks for Pc tolerance, improving post harvest handling of fruit, and investigating pest and disease control methods. The R&D conducted specifically for Westfalia SA by WTS is intended to provide a competitive advantage to Westfalia, whereas the industry-funded work is intended for communal industry competitive advantage. WTS also manages outsourced early-stage avocado R&D projects funded by Hans Merensky Holdings (Pty) Ltd (HMH), the holdings company of Westfalia Ltd. The products and services unit of WTS specialises in managing the intellectual property generated by WTS and other research institutions. A separate, relatively small division at Westfalia SA is responsible for processed avocado product development.

2.2 Situation analysis

2.2.1 Macro-environment analysis

The external environmental influences that may serve as critical determinants of threats and opportunities for the avocado industry in South Africa are classified according to source into physical, political, economic, social, technological, legal, environmental and global factors (PPESTLEG) (Coetzee, 2009) and presented in Annexure 2A.

South Africa has the basic required infrastructure for successful fresh fruit production, which is absent in some other lower-cost producing countries. However, despite recent road improvement efforts and good progress with the Gautrain project, deficiencies in service delivery (including the impact of industrial strike action), and transport and energy infrastructure, are damaging South Africa's reputation as a reliable supplier, raising production costs and limiting growth potential.

Politically, South Africa's international relations have improved since its first democratic government was elected in 1994. Political instability ratings for South

Africa have remained constant over recent years and are quite similar to other developing countries where avocados are produced. Public sentiment on the political performance of the African National Congress (ANC) in South Africa has improved over the past few years, but recently experienced a set-back with controversial public statements by the Youth League of the ANC and the murder of a right-wing leader.

Economically, the world distribution of power is shifting to developing nations like India and China. The recent global recession was deep, and the South African economy fell into recession during 2009, although it is expected by some analysts to recover in 2010. Global avocado prices showed strong and steady growth over the past few years, but volumes and prices were negatively affected by the recession. The recession also exposed South Africa's strong reliance on the UK and European markets where competition is increasing from low-cost competitors. The recent strengthening of the South African currency (Rand) versus the British Pound and Euro is also reducing export income and competitiveness.

Xenophobia (especially towards illegal immigrants), high unemployment and crime rates, racial tensions over political murders and controversial public statements by politicians, as well as inadequate public service delivery, are leading causes of the tense social climate in South Africa. Diversity management is therefore very important in South African organisations. South Africa has the highest number of people infected with HIV in the world and is experiencing a skills shortage. Increased labour unionisation in the avocado industry and a decline in labour productivity are also of concern. Socially, fruit industries should improve their cultural literacy in a world of increasing globalisation and understanding how to effectively conduct business worldwide is more and more important.

Technology is very important and has promoted the production growth and trade in agriculture worldwide. Agricultural innovation and technological advancements through R&D are a critical success factor for avocado production. These have enabled the successful commercial cultivation of avocado in South Africa and hold the key to gaining access to currently restricted markets by developing quarantine treatments for safe trade. Avocado R&D also investigates, develops and transfers sustainable and environmentally friendly production practices to growers.

National laws and their enforcement affect agriculture world-wide and impact exports and foreign direct investment. In particular, the Constitution and labour laws are important pieces of legislation regulating the working environment in South Africa. South African law allows for the protection of intellectual property rights and

environmental laws are increasingly strict to enforce sustainable agricultural practices. In other developing nations that produce avocados, enforcement of these laws is sometimes poor (Hill, 2007). In South Africa, land reform legislation and its poor execution is negatively affecting local and foreign investment in agriculture. Corruption is also high, which further increases the cost of doing business. Large agribusinesses now tend to invest internationally in avocado production areas, taking advantage of incentive schemes offered by host nations.

World-wide, awareness is increasing about environmental and health-related matters, pressuring agricultural producers to adopt more environmentally friendly practices. Climate change is also affecting agriculture, and numerous potential impacts on avocado production have been listed. Apart from soil and fruit pathogens and limited water resources, the physical environment in selected areas of South Africa is relatively well suited to avocado production and the main shortcoming of the environment in South Africa is that the climate does not allow for avocado production throughout the year.

Globalisation of markets and production is also impacting on agriculture worldwide. The Agreement on Sanitary and Phytosanitary Measures (SPS) and Technical Barriers to Trade Agreement (TBT) of the World Trade Organisation (WTO) guide governments in acting on trade in order to protect human, animal or plant life or health, without discrimination or disguised protectionism. As tariff barriers fall and more countries become signatory members of the WTO, foreign investment and export market access opportunities are increasingly presenting themselves to the avocado industries around the world. The WTO agreements rest on scientific justifications of risk and risk mitigation. SAAGA's R&D is increasingly focused on overcoming phytosanitary barriers to open new markets for the industry to grow volumes, reduce marketing risk and improve returns. Geographically, South Africa is located favourably to supply the Americas, and the Middle and Far East. Foreign investment by South African producers also enables the exploitation of low-cost producing sites, selection of optimal production areas, continuous production and supply of avocado fruit throughout the year, and the spread of currency risk.

A summary of the macro-environment trends and their impact on the avocado industry in South Africa is presented in Table 2.2. Strategic actions to offset these impacts are listed.

Table 2.2. Trends in the macro-environment and their impact on the avocado industry in South Africa

Macro-environment factor	Trend	Impact	Strategic actions
Physical infrastructure	Stable to negative	High, threat and opportunity	Invest in alternative energies (e.g. methanol plant, power generators), robust post harvest handling methods.
Political	Stable	High, opportunity	Lobby and support government in a strategic partnership approach to support fair trade (market access). Work closely with local and national government to negotiate land claims, improve education and fight crime.
Economic	Negative	High, opportunity	Diversify risk by accessing more export markets and diversifying production locations
Social	Negative	High, threat	Diversity management, recruitment, retention, development and selection programmes, HIV management and anti-retroviral distribution. Improve literacy and cultural tolerance. Social responsibility.
Technological	Positive	High, opportunity	Facilitate and drive innovation. Improve fruit quality and lower production costs. Leverage R&D to develop quarantine treatments for new export market access and more environmentally friendly cultivation practices.
Legal	Stable to negative	High, threat	Land claim settlement negotiations, black economic empowerment, affirmative action.
Environmental	Negative	High, opportunity	Diversify production sites to manage climate change and produce avocados 12 months of the year, reduce CO_2 and water footprints, improve cultivation practices, optimise energy consumption (solar geysers etc.)
Global	Positive	High, opportunity	Access restricted export markets and invest in global production sites

Source: Researcher's compilation from Annexure 2A.

2.2.2 Competitive environment analysis

Competitive framework

The five forces model (Porter, 1979) investigates competition in an industry, or in this case, competition between industries, in five areas of the market: (i) competitive pressures associated with rival sellers; (ii) substitute products; (iii) new entrants; (iv) suppliers and (v) buyer bargaining power. Complements were added as an additional force that impacts on the competitive analysis (Grant, 2008). A comprehensive analysis is provided in Annexure 2B.

Currently, the world demand for avocado is growing and this is being matched with a growth in supply. Avocado preference is mainly for the Hass variety, meaning it is largely a commodity product with little opportunity for differentiation. South Africa exports virtually all its avocados to the EU (including the UK). The main competitor is Peru, with an overlapping avocado season, high fruit quality and low production costs. Peru has significantly increased its market share in the EU (including UK) and it has a competitive advantage in terms of production costs and market access to the USA. Currently industry rivalry is moderate to weak, mostly because of strong market demand growth. Although the EU market was able to absorb the increasing Peruvian volumes, additional plantings in Peru coming into production may outpace the rate of demand growth. In the long term this may reduce prices, shrink the South African share of this market further and strengthen rivalry. Competitive weapons for South Africa are differentiation through service, quality, and brand image.

Avocado is regarded as a general substitute for butter or margarine and even meat in vegan and vegetarian diets. However, specific substitutes for avocados are limited to processed avocado products. The threat of substitutes is weak. Attractive profit opportunities are attracting new entrants to the avocado market. Barriers to entry deter large-scale new country entrants in the world arena in favour of regional (i.e. within industry) acquisition of existing production units coupled with additional plantings and new market entries. South Africa is especially susceptible to new entrants in the EU market, and apart from Peru, several other countries may enter the EU market during the South African season. The threat of new entrants is considered strong.

Input suppliers to the avocado industry, such as fuel, electricity, labour, and container shipping companies, have strong bargaining power with high switching costs and associated strong supplier power. In contrast, avocado industries are suppliers of a commodity to the (deregulated) world market and increasingly through

direct selling to large buyers. The avocado industry, with diluted supplier power, has moderate to weak supplier bargaining power. Buyer bargaining power in the avocado market tends to be high in the spot market. A high level of buying power concentration by large supermarkets also facilitates strong buyer bargaining power for direct selling. Possible avocado complements have been identified, but their non-exclusive nature reduces the opportunity for strong complement-driven demand growth for avocado.

The collective strength of the competitive forces is conducive to good profitability and a growth strategy (in the right low-cost areas) is indicated to take advantage of increasing demand. The industry is attractive.

Table 2.3. Competitive forces in the world avocado industry, with particular reference to the South African industry

Force	Competitive Pressure	Impact	Strategic actions
Inter-industry rivalry	Moderate to weak	Opportunity	Grow market share and competitive strengths
Product substitutes	Weak	Limited impact	Monitor and research
New entrants	Strong	Threat	Monitor, investigate joint ventures and acquisitions
Supplier power	Moderate to weak	Threat	Differentiate through service and quality
Buyer power	Strong	Threat	Concentrate suppliers
Complements	Weak	Opportunity	Monitor and investigate

Source: Researcher's compilation from Annexure 2B.

Porter's diamond

The national competitive advantage of an industry in a country can be investigated using Porter's diamond (Porter, 1990). It is applied to the South African avocado industry, although the export focus at conception of the industry is in contrast to the more traditional model where local production evolves into export activities. The tool investigates (i) factor endowments; (ii) strategy, structure and rivalry; (iii) demand conditions; and (iv) related and supporting industries. Much of the necessary background information on arguments, data and information is presented in the macro-environment analysis (Annexure 2A) and the Porter's five forces model (Annexure 2B). A recent paper by Esterhuizen, Van Rooyen & D'Haese (2008) also contains useful information relevant to this section. Table 2.4 provides a summary of

the factors impacting on the competitive success of the avocado industry in South Africa.

Overall, the model shows positive competitiveness for the South African avocado industry. The trend is variable in the different components of the model, but in most of the factors investigated a negative trend is identified. This is in line with the prediction by Esterhuizen *et al*. (2008) that a declining trend in business confidence in the agribusiness sector may cause a declining trend in the competitiveness status of the sector. The analysis showed that the firm strategy, structure and rivalry are the key factors that provide the South African avocado industry with global competitive advantage. Esterhuizen and co-workers reported a similar finding for the South African agribusiness industry between 2000 and 2004.

Table 2.4. South African competitive advantage in the avocado industry according to Porter's diamond

Factor	Components	Trend	Present judgment
A. Factor endowments		**-**	***Negative***
1. Labour		-	Negative
	1.1 Availability of unskilled labour		
	1.2 Poor quality of unskilled labour		
	1.3 Scarcity of skilled labour		
2. Infrastructure		-	Negative
	2.1 Sufficient at present		
	2.2 High crime rate		
	2.3 Land reform policies		
	2.4 BEE, labour policy		
	2.5 Incompetence of public sector personnel		
3. Technology		-	Positive
	3.1 High quality and available		
4. Capital		-	Negative
	4.1 Investment capital limited		
	4.2 Government macro-economic policy		
	4.3 Rand too strong at present		
5. Environment		-	Negative
	5.1 Limited water availability		
	5.2 Disease pressures		
B. Strategy, structure and rivalry		**+**	***Positive***
1. Structure		+	Positive
	1.1 High regulatory standards		
	1.2 Good environmental regulations		
	1.3 Difficult to start a new business		
2. Rivalry		+	Positive

	2.1 Increased rivalry, although only a few large players 2.2 New entrants		
3. Strategy		+	Positive
	3.1 Increased differentiated services and processes 3.2 Innovation ability		
C. Demand conditions		**+**	***Positive***
1. Local market		+	Negative
	1.1 Demand is growing, but can be improved		
2. Local buyers		+	Positive
	2.1 Knowledgeable, demanding, ethics and production concerns		
D. Related and supporting industries		**-**	**Positive**
1. Information technology		+	Positive
	1.1 Many internet providers 1.2 IT development and support		
2. Electricity		-	Negative
	2.1 One service provider (government) 2.2 Significant cost increases, few alternatives		
3. Primary input suppliers		-	Positive
	3.1 Available		

Source: Researcher's compilation from Annexure 2A, Annexure 2B and Esterhuizen *et al*. (2008).

2.2.3 Micro-environment analysis

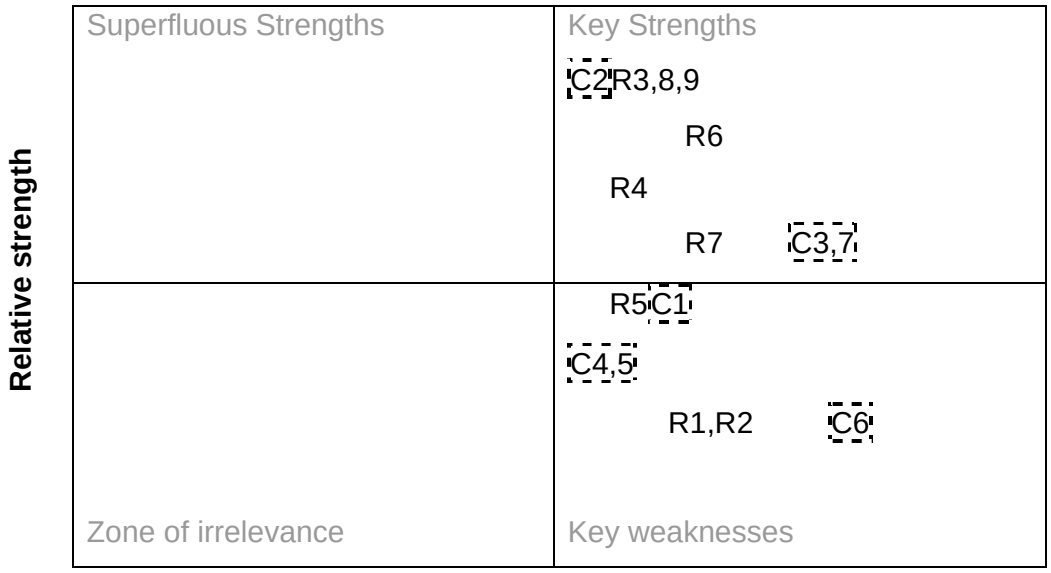
For a firm or industry to formulate a sound strategy it is imperative to match the organisation's resources and capabilities to the opportunities that arise in the external environment (Grant, 2008). However, during the 1990s, ideas concerning the role of resources and capabilities (internal environment) as the principal basis for a firm's strategy and profitability converged into the resource-based view of the firm (Barney, 1991). This indicates the importance associated with the internal environment. The resources and capabilities approach will be followed to analyse the micro-environment of the South African avocado industry. However, the exclusive resource-based view is not followed here because the external environment is not regarded as being highly unstable.

When analysing the resources or productive assets of the industry, it is important to identify the tangible resources, intangible resources and the human resources of the entity (Grant, 2008). In terms of tangible resources, the industry has

12 000 ha of productive avocado orchards (resource 1), numerous pack-houses, several processing facilities (oil, ready-to-eat and guacamole) and farming equipment (resource 2). The industry also has internationally recognised research and development institutions working on avocados (resource 3) and agribusinesses in the industry have been awarded national eco-efficiency awards (resource 4). Industry businesses are financially strong, but free cash flow is low (resource 5). In terms of intangible resources, an accredited and recognised export reputation, large vertically integrated agribusinesses, consolidated grower-driven export companies (four companies handle >75% of exports), established brand names (resource 6), international interactive working groups, a growing domestic market (resource 7), growing direct to retailer selling contracts, and plant material patents (plant breeders rights) (resource 8). Human resources are the most important asset (resource 9). The industry is blessed with experienced expert managers, marketers, growers and researchers contributing to its success. A close collaborating relationship is present between producers, R&D and marketing. Several development systems are in place, including industry-funded student bursaries, avocado agribusiness bursaries, training courses and science expo sponsorships.

The industry capabilities can be defined as the capacity to deploy resources for a desired end result (Helfat and Lieberman, 2002). A functional analysis is provided in Annexure 2C to serve as a basis for classifying and disaggregating the industry activities and identifying relevant capabilities. An appraisal of the resources and capabilities against their respective strategic importance and relative strengths is provided in Figure 2.1 (Grant, 2008). The appraisal of the resources and capabilities highlights some of the key strengths and weaknesses of the industry. It will be discussed in the following section along with the opportunities and threats identified from the preceding analysis.

Fig. 2.1 Appraisal of the resources and capabilities of the avocado industry in South Africa (figure adapted from Grant, 2008)



Key:
R=Resource
C=Capabilities

Source: Researcher's compilation from section 2.2.3 and Annexure 2C.

2.2.4 SWOT analysis

The situation analyses conducted in section 2.2.1 to 2.2.3 can be summarised as the strengths, weaknesses, opportunities and threats (SWOT) of the avocado industry in South Africa (Table 2.5). Strengths and weaknesses are mostly identified from the internal environment (micro-environment), whereas the opportunities and threats are largely recognised from the external (macro and competitive environment) environment analysis.

The most important strengths are the human resources in the industry, patents registered, the R&D institutions servicing the industry and the proven innovative ability to develop new products and processes. Furthermore, established brands, high quality avocado production ability, prudent management by agribusinesses in the industry during recessionary times, a growing domestic market and environmentally responsible practices are additional strengths. Weaknesses include a poorly developed national government relationship, ageing plant and equipment with limited investment, and stagnant production capacity. A strong distribution and

sales network is present in the EU and UK, but the largest market in the world (USA) remains closed and increased efforts are required to develop Asian markets. Marketing efforts are therefore reliant on the EU market with few alternatives, hence increasing risk. Avocado ripens in South Africa only from March until August, which limits the marketing window. Major South African role players are slow to adapt to change (e.g. the demand increases in EU/UK), while financial management activities at times may be too risk averse during bullish market developments. This results in the industry following late follower strategic approaches, which is proving to be unfavourable.

Table 2.5. The strengths, weaknesses, opportunities and threats of the role players in the avocado industry in South Africa

Strengths	Weaknesses
Human resources	National government relations
Plant patents	Ageing plant and equipment
R&D institutions and capacity	Stagnant plantings (losing market share)
Proven innovation ability	No access to the US market and market development in Asia required
Established South African brands	An exclusive Eurocentric marketing focus
Medium cost, high quality producer	Late follower strategic approach
Prudent strategic and financial management (strength mainly in recessionary times)	Strong financial controls without any risk taking are restricting growth
Growing domestic market	Avocado ripens in South Africa only from March until August, not throughout the year, thus limiting the marketing window
Environmental responsibility	
Strong distribution and sales network in EU and UK	
Opportunities	**Threats**
Increase production capacity and extend season to exploit growing world demand	New entrants
Leverage R&D abilities for innovations to	Increasing buyer power and an

improve differentiation ability and to overcome phytosanitary barriers	increased trend towards one variety in the world market
Improve national government relations	Land claims and black economic empowerment
Diversify risk by expanding market access and production locations	Deteriorating labour relations and labour force quality
Invest in alternative energies and develop more robust post harvest handling methods	Introduction of invasive quarantine pests
	Climate change, increased environmental awareness by consumers and limited fresh water supply in South Africa
	Possibility of worsening economic and/or other conditions (currency risks) reducing the market demand or export income from avocado, especially in EU

Source: Researcher's compilation from section 2.2.1 to 2.2.3.

Opportunities include increasing production capacity and minimising production risk by cultivating avocado in different micro-climates in South Africa (or abroad) to extend the production season to 12 months per year at the best quality and lowest possible cost. Leveraging of R&D abilities will improve fruit quality, develop substitutes for fresh fruit (e.g. appealing fresh cuts) to overcome phytosanitary restrictions, lower production costs, develop more environmentally friendly cultivation practices and, very importantly, develop quarantine treatments for new export market access for fresh fruit. Improvement of national government relations to identify, develop and facilitate win-win solutions for market access, land claims and socio-economic advancements is another opportunity. The importance of diversifying marketing risk by accessing the US market, and developing the Middle East, Asian and African markets is recognised. Another opportunity is investing in alternative energy sources and using R&D to develop even more robust post harvest handling methods to reduce the reliance of the industry on the national electricity grid and other infrastructure related factors.

The dominant threats are new entrants, mainly from South American countries (especially Brazil) entering the EU market and expanding their production capacities further. Increasing buyer power is also a concern and the trend of a world market being served by one variety reduces product differentiating opportunities (e.g. proprietary cultivars). Unresolved land claims, possible scrapping of the willing buyer and willing seller concept and a potential reduction in avocado quality and yield after land transfer to BEE beneficiaries, are significant concerns that limit investment and threaten future industry profitability. Deteriorating labour relations between management and farm labourers, high levels of HIV among the workforce, a skills shortage in South Africa, and a reduced number of agricultural scientists being trained are additional threats. The industry is further threatened by the introduction of invasive quarantine pests which can reduce yields and impact on present and future trade activities. Climate change, carbon and water footprints, limited supply of fresh water and periodic droughts in South Africa are cultivation concerns. Lastly, the possibility of worsening economic and/or other conditions reducing the market demand for avocado, especially in the EU, is a threat to the industry. Producers would be well advised to diversify their portfolio of crops.

2.2.5 Industry Key Success Factors

The analyses of the macro, competitive and micro-environment also provide a strong indication of the key success factors (KSFs) for the avocado industry.

Some of the KSFs identified for the industry are product quality and service, innovation ability, production capacity, market and distribution access, brand names, and access to capital. These factors are validated by their similarity to some of the generic KSFs of industries operating in a manufacturing, marketing and distribution arena at the growth stage of the industry life cycle (Thompson *et al*. 2007; Grant, 2008). Fruit quality and service are virtually the only factors that can provide differentiating ability for South Africa at present. Competitive advantage is provided by innovation abilities closely linked to R&D, whereas the scaling up of production capacity, along with market and distribution access, is important to take advantage of growing demand. Innovation improves products and processes. This includes, amongst others, the development of phytosanitary treatments and improving the tree and fruit cultivars. Phytosanitary quarantine treatments (e.g. cold treatment, systems approaches, etc.) ensuring mitigation of quarantine pest risks are mandatory to access special markets like the USA. Although the world market preference is narrow

(Hass variety), breeding, screening and selection can produce superior rootstocks and avocado scion cultivars in terms of particular characteristics (e.g. yield, disease and pest tolerance, fruiting period and shelf life) to provide competitive advantage. Scaling up of production is required to maintain (and expand) market share and involves additional plantings and improving yield from existing orchards. Market access and development abilities allow for the optimisation of profits and reduction of risks.

2.3 Measuring R&D in the context of the strategic framework

The situation analysis showed that the R&D function is the cornerstone of competitive advantage and KSFs in the avocado industry of South Africa. It is a competitive strength of the industry, assists in countering weaknesses and threats, and also allows for the exploitation of opportunities to the benefit of the industry and private firms. R&D in the avocado industry provides a means for market access through developing phytosanitary treatments; it also contributes to the extension of the fruiting season, development of new products (fruit and rootstock varieties), and the improvement of productivity and processes in an environmentally friendly way. This enables the maintenance and expansion of market access and increases barriers to entry in terms of quality, service, environmental responsibility and product safety.

R&D is therefore very important strategically and it is critical to fully leverage this function as a prime resource and capability of the industry. This requires optimisation of R&D management, which in turn requires validation of suitable criteria to use in the measurement of R&D effectiveness. The next chapter provides a critical review of literature on measuring the effectiveness of R&D to contextualise the study in more detail.

2.4 Conclusion

The situation analysis of the avocado industry revealed that the external environment presents opportunities and challenges. Arguably, the globalisation of markets and technological advances provides some of the greatest opportunities, while land claims and labour challenges are important challenges. Peru is the major international competitor to the South African industry. World avocado demand growth is enticing existing industry members to expand their production capacity and market

reach, increasing the risk of new entrants. The South African avocado industry is internationally competitive, but a negative trend in competitiveness is being noted. In the internal environment, competitive strengths and weakness came to the fore. Human resources and R&D resources and capabilities are important strengths, while stagnant plantings, a virtually exclusive Eurocentric marketing focus and exclusion from the largest and fastest growing avocado markets are key weaknesses. Key success factors include innovation ability, production capacity, and market and distribution access.

The R&D function is the cornerstone of competitive advantage and KSFs in the industry and it is critical to fully leverage the function as a prime resource and capability of the South African avocado industry. This requires optimisation of R&D management, which in turn requires validation of suitable criteria to use in the measurement of R&D effectiveness.

2.5 Annexure 2A: Macro-environment analysis (PPESTLEG)

1. Physical infrastructure

Basic infrastructure such as refrigerated road and railway transport and cooling facilities at the ports is present in South Africa, allowing the maintenance of a cold chain to maintain the quality of perishable goods. Cold chain infrastructure is very important for successful fresh fruit production, and is one of the components that prevents developing nations like India from being efficient producers and suppliers of fresh fruit. Unlike most other commodities, fruit is usually most valuable in its fresh, unprocessed form, although processing can add value to lower fruit grades.

South Africa is experiencing structural challenges, notably deficiencies in transport and energy infrastructure, which raises production costs and limits growth potential. Public service delivery in South Africa is also proving to be a severe bottleneck to growth (African Economic Outlook, 2010). A recent Transnet strike caused a significant delay in the shipping of fruit containers from South African ports. Fruit industry losses due to this action were estimated at R1 billion and it damaged the reputation of South Africa as a reliable supplier (Cohen, 2010). Furthermore, capacity constraints at the National Plant Protection Organisation of South Africa, and the Department of Agriculture, Forestry and Fisheries, are hampering efforts to access new markets and negotiate phytosanitary agreements, and protect South Africa from bio-security threats impacting on agricultural production and trade.

2. Political environment

The world political environment is experiencing a shift in the distribution of power. Since the fall of the Iron Curtain the bipolar world consisting of the USA and USSR (and their allies) has changed into a multi-polar world with the emergence of the developing world, especially countries like India and China.

Agriculture in advanced nations has been protected by tariffs and subsidies to the detriment of low-cost producers in developing nations. A focus area of the World Trade Organisation is to reduce trade barriers and promote trade in agricultural goods (Hill, 2007). Since 1994, South Africa's democratic government has strengthened its relations with Asia and other Western nations, which will further promote trade in agriculture.

Political instability ratings for South Africa have remained constant over recent years and are quite similar to other developing countries where avocados are produced (Global Peace Index, 2010). An Ipsos Markinor public opinion survey of

3 374 South Africans was conducted during November 2009 to monitor government performance by gauging public opinion on the performance levels of the president, national government and key performance areas. The results were quite positive and showed 77% of South Africans felt President Zuma was doing his job well, 70% felt the national government was doing its job well, and optimism exists despite the feeling that government has made little or no progress in reducing the crime rate, fighting corruption and creating jobs. Government is credited with improving performance in implementing affirmative action and ending political violence and for the first time since November 2007, more than half the population (56%) felt the country is headed in the right direction (Ipsos Markinor, 2010). Since the Markinor report, the leader of a right-wing group known as the Afrikaner Weerstandsbeweging (AWB) was murdered and some linked this event to a freedom song sung by the African National Congress Youth League President that translates as 'shoot the farmer' (News 24, 2010). These developments could affect political stability. Apart from political stability, agricultural land in South Africa is highly politicised, a topic that will be discussed further under legal issues.

3. Economic factors

The world distribution of power is shifting and developing nations like India and China are playing an increasingly important role in the world economic arena. The recent global recession was deep, especially for Western countries, but a massive multi-governmental response is mooted to have been mostly successful in shortening the duration of the recession that most analysts expected (Deloitte Research, 2010).

For the first time since 1992 the South African economy fell into recession with GDP contracting by 1.8% in 2009. The economic slowdown started in 2008 with the weakening of domestic demand and was exacerbated when the global crisis led to a sharp fall in exports. Prudent macro-economic policies allowed South Africa to implement strong and coordinated counter-cyclical fiscal and monetary policies. The Central Bank cut the repo rate by 500 basis points to stimulate investment. The inflation rate declined, but a sharp increase in electricity prices and wage cost pressures prevented the inflation rate from reaching the 3–6% target range. Inflation is expected to decrease during 2010, falling below 6%. Growth is expected to recover gradually to 2.4% in 2010, helped by the recovery of global demand and boosted by the FIFA World Cup, and to accelerate further in 2011 to 3.3% (African Economic Outlook, 2010). Despite these optimistic expectations by analysts, the recent strengthening of the South African currency (Rand) against the British Pound and

Euro is severely reducing export income for South Africa. This negatively affects the export-oriented avocado industry in South Africa.

Global avocado prices rose by 35% between 2005 and 2008. Since then, world-wide exports of avocados declined by about 5% in 2008, and prices between January and September 2009 dropped by 21% (FAO, 2009a). This effect was also felt in the UK and European markets where the bulk of South African avocados are exported. The price effect was especially severe in the South African mid-season of 2009, when relatively high Peruvian and South African volumes put the market price under pressure. The situation is further exacerbated by increasing input production costs including labour and electricity in South Africa.

South Africa currently does not have access to lucrative markets requiring phytosanitary treatments like the USA, Japan, Mexico, Vietnam and China, a trade-related topic that will be further discussed under the global section.

4. Social environment

The social structure is usually concerned with the level of social organisation (individualism vs. collectivism) and the degree of stratification into classes or groups. It is also related to culture along with other factors such as language, religion, political philosophy, economic philosophy and education (Hill, 2007). Different components of culture have been identified: high and low context cultures (Hall, 1990), differences based on power distance, uncertainty avoidance, individualism, masculinity and Confucianism (Hofstede, 1980), with even more parameters identified by the Globe project (House, Hanges, Javidan, Dorfman, Gupta & Associates, 2004).

Cultures are not stagnant, and some conversions of cultures across the world have even been recognised, but it remains critically important to recognise social and cultural differences and to be literate in the social environment (Hill, 2007). This is especially important since the avocado industry is interested in accessing new international markets and companies in the industry are expanding their production capacities internationally. Cultures are also often related to dietary preferences, and the main market for avocados is the USA and Mexico, with a high value but low volume opportunity identified in Japan and other Eastern markets.

In South Africa public service delivery has proven inadequate in a period of economic distress and has led to significant social discontent. Demonstrations took place throughout 2009 and if the government fails to improve basic service delivery social instability could continue (African Economic Outlook, 2010). Racial tensions are high after the recent murder of Eugene Terreblanche of the AWB (News 24,

2010). With a high unemployment rate in South Africa of over 25% (Statistics South Africa, 2010), xenophobia, especially towards illegal immigrants, is increasingly evident. A severe skills shortage and a decline in labour productivity are being experienced in the avocado industry. The latter is most likely being caused by the fact that South Africa has the highest number of people infected by HIV in the world (Avert, 2010). Social and economic tensions appear to be spilling over to the farm labour/management relationship, and a tendency of increased labour unionisation is being noted in the avocado industry. Diversity management and strong leadership are important to defuse the current social tensions.

5. Technological factors

Microprocessor and telecommunication advances, the internet and World Wide Web have improved information processing, communications and trade world-wide. These factors have assisted the growth and trade in agriculture by allowing for the technological infrastructure to export goods (air and sea freight containers), share information, link with importers and exporters, and improve coordination and service delivery.

Technology is not only important in logistics, but is also considered to be critically important in the production and marketing of avocados. Alleviation of production constraints to improve the yield and quality of fruit is important for the success of avocado growers. In the South African industry R&D over almost 40 years developed treatments to allow for economical commercial cultivation of avocados in South Africa. More recently the focus of avocado R&D in many countries has shifted towards developing phytosanitary treatments which are required to gain access to restricted markets. This will reduce the reliance of South Africa on the European market, and provide opportunities to increase profitability and grow the industry. In the South African avocado industry, technology further provides an opportunity to reduce costs, improve operational efficiencies, reduce environmental impacts and increase profitability. Industry R&D into new spray technology to reduce copper usage and modification of post-harvest fungicide solutions and their applications to reduce active ingredient usage are just some examples of how technology through R&D improves industry practices.

6. Legal factors

The Constitution, labour laws, environmental laws, property rights, protection of intellectual property and the incidence of corruption are just some of the legal aspects that affect agriculture. These play an important role in the international expansion of exports as well as production expansion. Laws and rights guide human resource management, aid the legal protection of an established brand name, and reduce risk when investing in new orchards and using proprietary plant material outside South African borders.

The Constitution, Bill of Rights, Employment Equity Act, Basic Conditions of Employment Act and the White Paper on Affirmative Action are important pieces of legislation regulating the working environment in South Africa. In South Africa, environmental laws are increasingly focused on limiting pollution, maintaining water quality and subscribing to good environmental practices. The avocado industry is responding to legislation and environmental concerns and through R&D is studying ways to reduce the use and impact of copper-based fungicides and post-harvest chemicals. In South Africa the law allows for the protection of intellectual property rights, but in some other avocado-producing countries the enforcement of these laws is sometimes poor (Hill, 2007). Land reform and corruption are posing major challenges in South Africa. South Africa's land reform programme was legalised and implemented by the new democratic government of 1994. Three components of land reform can be identified: (i) restitution (rights-based law), involving the return of land to people who were dispossessed after 1913; (ii) redistribution (not rights-based), aiming to address the highly skewed ownership of land along racial lines; and (iii) tenure reform, aiming to strengthen the rights of people whose land tenure is insecure as a result of discriminatory laws and practices in the past (Cousins, 2009).

The land reform process has been plagued by various problems since 1994. Initial targets were highly unrealistic and had to be revised regularly, a very small government budget is being allocated towards land reform, and laws and programmes aimed at protecting the tenure rights of farm workers and labour tenants have been ineffective. Post-settlement support has been poor due to weak capacity and coordination in responsible government departments. Many transferred farms are now unproductive and the majority of rural claims, representing significant portions of commercial agricultural land, remain unresolved today (Cousins, 2009). Local and foreign investment in agriculture is severely negatively affected by land claims.

The majority of avocado orchards in South Africa are under land claims, which limits investor confidence. To date, the total area of avocado orchards transferred to claimants is a mere 502 ha in the Limpopo Province, with the remaining claims unresolved. Large agribusinesses like Westfalia Ltd are now investing internationally in avocado production areas. Investment in South African avocado orchards is further handicapped in that some competing countries (e.g. Ethiopia) provide handsome incentives to secure investment in agriculture.

Corruption in South Africa is rated as being relatively high (Transparency International, 2009), which increases the cost of doing business. However, in the South African avocado industry, land claims are the major concern.

7. Environment

World-wide, awareness is increasing about environmental and health matters. Environmental legislation is increasing and forcing agricultural industries to adapt and improve their production processes. Large supermarket buyers are pressurising agricultural suppliers to monitor and reduce carbon and water footprints. Consumers are protesting the use of synthetic fertilisers and chemicals, and organic produce consumption is increasing. Climate change is also affecting agriculture, and numerous potential impacts on avocado production have been listed (Deuter, Howden & Newett, 2005).

Avocado production in South Africa is concentrated mainly in the north-east of the country in the warm sub-tropical areas of the Limpopo (Northern) and Mpumalanga provinces. Some plantings are also located in the KwaZulu-Natal province, where the conditions are cooler. The main production regions are characterised by warm, wet summers and cool dry winters. Annual rainfall in most of these areas is high (>1 000 mm per annum), but there are some orchards in semi-arid regions with rainfall of ± 400 mm per annum. Due to micro-climatic conditions between and within growing regions, most of the major cultivars are available over an extended period, which gives the industry the ability to produce avocados from the end of February to the beginning of November. The bulk of the crop is available from the end of March until beginning of September (Vorster, 2004).

In general, South African agriculture output contracted in 2009 because of adverse climatic conditions (African Economic Outlook, 2010). However, 2009 was a high volume avocado crop in South Africa. Apart from soil and fruit pathogens and limited water supplies, the physical environment in selected areas of South Africa is relatively well suited to avocado production. Diseases continue to pose a major

production constraint, but integrated management practices have been developed to allow the production of sufficient yields of high quality fruit in selected areas. The main shortcoming of the physical environment in South Africa is that the climate does not allow avocado production throughout the year.

8. Global and regional factors

The globalisation of markets and production is impacting on agriculture world-wide. The General Agreement on Tariffs and Trade (GATT) and its successor, the World Trade Organisation (WTO), are promoting the lowering of trade barriers (trade tariffs and subsidies) to improve cross-border trade and investments in agriculture (Hill, 2007).

Article 20 of the GATT is especially relevant to agricultural trade. It allows governments to act on trade in order to protect human, animal or plant life or health, provided they do not discriminate or use this as disguised protectionism. The two WTO agreements dealing with these issues are the SPS and TBT. These agreements encourage the use of international standards and guidelines, but scientific justification guides the standards and risk assessments, allowing for country-specific requirements. As tariff barriers fall and more countries become signatory members of the WTO, market access opportunities are increasingly presenting themselves to the avocado industries around the world.

SAAGA's R&D is progressively more focused on overcoming phytosanitary barriers to open new markets for the industry to grow production volumes, reduce marketing risks, improve returns and reduce currency risks. These R&D activities mainly include development of quarantine treatments and investigations into the risk potential of quarantine pests.

Foreign direct investment is another opportunity provided by the liberalisation of trade and allows for the diversification of production units throughout the world. The production of avocados in different countries allows for the exploitation of low-cost producing sites and selection of optimal production areas, provides year-round avocado production capabilities, and also further reduces currency risk.

2.6 Annexure 2B: Competitive analysis

Porter's five forces framework (Porter, 1979) was used to analyse the competitive pressures on the South African avocado industry as determined by: (i) industry rivalry, (ii) threat of substitutes, (iii) threat of new entrants, (iv) bargaining powers of suppliers, and (v) bargaining powers of buyers. In addition to Porter's five forces, complements have been added as being another force that has an impact on the competitive analysis (Grant, 2008).

(i) Industry rivalry

Avocado preference in the world market is mainly for the Hass variety, meaning it is largely a commodity product with little opportunity for differentiation, which increases rivalry. It is important for the South African avocado industry to look at avocado supply and demand growth throughout the world markets as well as the nature of current and future competition in these markets. Industry rivalry is increasing within the South African industry and also between avocado industries throughout the world. Here the focus is on the latter.

The avocado markets in the USA and EU have shown strong growth over the past decade. Import volumes should be phased over time so that demand increases keep pace with supply. Increased imports can have dramatic price-decreasing impacts during a given marketing year (Carman and Rodriguez, 2004).

Here the EU and UK markets will be focused on as this is the main market supplied by South Africa. When supply exceeds demand, competition increases. The seasonal nature of avocado production means that southern hemisphere producers are usually the main competitors during the South African season (Table 2.4). Avocado fruit can be 'stored' on the tree for reasonable periods (i.e. months), and being climacteric, the fruit only ripens after harvest. This 'storage' ability allows producing nations to avoid peaks in supply that will exceed the time-specific demand and lower market prices to the detriment of all suppliers. Suppliers also co-fund generic marketing campaigns to increase avocado consumption and demand. A co-opetition approach is therefore followed. However, should the rate of volume growth exceed demand growth, then prices would decline and competition increase.

The Peruvian avocado season overlaps closely with the South African season, and their fruit quality is high and production costs relatively low (Hofshi, 2009). Over the past ten years, the avocado production volumes in Peru almost doubled (estimated at 120 000 metric tonnes in 2008). The increase has been caused mainly

by expanding plantings from ca. 7 800 ha in 1998 to 13 600 in 2008; favouring Hass in new plantings (AMAPWG, 2009; FAOSTAT, 2010). Peru's compounded annual growth rate in volumes supplied to the EU were 34% and to the UK 42% between 2004 and 2008, surpassing South Africa with more than 45 000 tonnes pa exported to these markets in total (AMAPWG, 2009). Furthermore, after ten years of negotiation, Peru successfully accessed the US market in 2010. Peru has significantly increased its market share to the detriment of South Africa and it has a competitive advantage in terms of production costs and market access to the USA. However, a recent port strike in Peru indicates that macro-environment factors also affect their industry. Although the EU market was able to absorb the increasing Peruvian volumes, additional plantings coming into production may outpace the rate of demand growth. In the long term this may reduce prices and reduce the South African share of this market even further.

Volumes supplied by Kenya to the EU and UK have been fairly constant over the last five years and the industry is hampered by poor quality fruit (AMAPWG, 2009). A quarantine fruit fly has also recently been introduced and established in Kenya affecting avocado trade to some markets, although not the EU and the UK (Drew, Tsuruta and White, 2005). Kenya is not considered to be a major competitor at present. Avocado in Brazil is largely a neglected crop consumed locally, and it is not exported in notable quantities. The country has favourable climatic areas for production and could emerge as a major competitor. The USA produces avocados for its local market and is unable to satisfy demand. Production costs are high and it is not considered to be a major competitor. Spain supplies the EU with avocado volumes similar to South Africa. There is little overlap with South Africa regarding time of supply, because Hass avocado is usually harvested in South Africa in April, arriving in the market from May onward, when the Spanish volumes are declining. South Africa imports Spanish avocado in the off-season for the domestic market. Mexican production is mainly aimed at the domestic market and export to the USA. Mexico could be competition for South Africa in the EU and UK should the US market come under pressure. The Chilean industry has also grown significantly, from about 100 000 in 1998 to 250 000 metric tonnes per annum in 2008. The area under avocado production more than doubled between 1998 and 2008 (FAOSTAT, 2010). Chile mainly exports to the USA, especially in their early season. From October onwards it would service the EU and UK. Chile could also be competition for South Africa in the EU and UK should the USA market come under pressure.

The domestic market and processing abilities are important, even for export-oriented industries. South Africa has a growing domestic market achieved through market development programmes and ready-to-eat offerings (especially direct to retailer sales). This currently absorbs about 25% of the volume produced. The informal trade (direct from the farm to hawkers) is also important, absorbing about 15% of production. Lower grade fruit are processed to produce guacamole and culinary oils, which consist of approximately 15% of the volume produced. These are respectable figures that assist in spreading the risk from exports. Export activities are lucrative, but increase currency, logistics and other risks.

The focus of this section has been on exports and the spot market, but imports, distribution and retail sales are increasingly organised on the basis of standing order contracts. Access to these standing order markets is based on a licence to produce and a licence to deliver (Joosten, 2007). These licences are formalised in international procedures which are usually designed by large-scale retailers. The multinational buyers focus on food safety, quality standards, sanitary and phytosanitary standards, and corporate sustainable responsibility. The required standards for the product, production and supply are often included in the contracts between retailers and producers or distributors and are accompanied by detailed requirements with respect to labelling, packaging, pricing, and production and delivery schedules. To be able to perform successfully as a supplier, two golden rules must be adhered to: ensure consistency in quality and supply, and provide recorded and demonstrated traceability of products and production. In this respect the South African industry is competitive, although Peru is making strong inroads in this regard.

Table 2.6. Avocado-producing countries and their export seasons (Vorster, 2007)

	Month on Market											
	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
S A	●	●	●	●	●	●	●					
Peru		●	●	●	●	●						
Kenya	●	●	●	●	●	●	●					
Brazil	●	●	●	●	●							
U S A	●	●	●	●	●						●	●
Chile						●	●	●	●			
Mexico						●	●	●	●			
New Zealand							●	●	●			
Israel	●						●	●	●	●	●	●
Spain	●	●	●				●	●	●	●	●	●
Morocco	●	●	●				●	●	●	●	●	●

(ii) Threat of substitutes

The avocado fruit is listed as a tropical fruit along with crops like bananas, carambole, durian, guava, lime, litchis, longan, mango, papaya, passion fruit, pineapple and rambutan. In some respects it is a tropical fruit, but its oily content and nutty flavour are more reminiscent of an olive. Avocado has also been recommended as a substitute for butter or margarine and even meat in vegan and vegetarian diets.

No reported fruit substitutes for avocado could be located in the literature, likely because of the relatively unique characteristics of the fruit. This reduces the competitive pressures from substitutes. However, processed avocado in the form of culinary oils competes with olive oil, while guacamole may compete with other spreads and snack dips. Personal communication with the CEO of the South African Subtropical Fruit Growers Association, Mr Derek Donkin, revealed that industry marketing studies showed that processed avocado products like guacamole can be seen as a substitute for fresh fruit, but that there is no other fruit that consistently substitutes for fresh avocado. The threat of substitutes is thus considered weak, but South Africa's phytosanitary restrictions on fresh fruit market access to countries like the USA, Mexico and Japan may be partly alleviated by exporting processed products to substitute fresh fruit supplies to these markets. Fresh-cut avocado may provide another substitute for fresh fruit, but producing high quality, visually appealing fresh cuts with an acceptable shelf life is technically challenging.

(iii) New entrants

Avocados are experiencing strong buyer demand growth and the industry can offer attractive profits. This will attract new entrants. Economies of scale, learning curves, capital requirements, suitable and proven production areas, income delays (trees only bear fruit a few years after planting), knowledge and experience, large standing order contracts, as well as branding, reputation and loyalty are some of the barriers to entry in the avocado market. These barriers, in addition to the current economic environment, are likely to deter large-scale new country entrants in the world arena in favour of regional (i.e. within industry) acquisition of existing production units coupled with additional plantings.

The threat of new entrants is therefore mainly from countries where avocados are already being produced, which can top-work existing trees with export varieties like Hass or can switch their market of supply to the EU and UK market. South Africa is especially susceptible to new entrants in the EU market, as it has few marketing alternatives at present. Peru, a relatively new entrant, has significantly increased its market share in the EU market. More new entrants to the EU market during the South African season may include Brazil, Chile and Mexico. Saturating domestic demand for avocados is prompting the Australian industry to increase exports to New Zealand and Japan. Recently Australian shipments to the EU have also started, and apparently the quality of arrivals was good, despite the long shipping time.

The threat of new entrants is considered strong.

(iv) Bargaining powers of suppliers

The dependence of South African avocado growers on suppliers of essential services and inputs is of fundamental importance. Increasing fuel, electricity and labour costs in South Africa are of concern, especially as there is only one national electricity provider (Eskom), and labour forces are increasingly unionised with strong bargaining power. The avocado industry is highly reliant on containerised shipping for exports. Container shipping is dominated by the A.P. Moller – Maersk Group, a world-wide conglomerate. Switching costs from input suppliers are high, while limited alternative fuels are available, and solar panels, methanol plants, mechanisation of harvesting and air-freight transport is very expensive. This, along with a general world-wide trend of increasing avocado production costs, indicates that the main bargaining power lies with input suppliers.

Avocado industries are in turn suppliers to the world avocado market. Supplier bargaining power in the avocado market tends to be low in the spot market where avocados are a commodity offered by many suppliers at a going market price. However, this model is changing through improved coordination between suppliers, industry consolidation, shortening of market chains, producers with forward integrated value chains, and direct selling of large suppliers (sourcing fruit from different countries or areas) to large buyers. This improves supplier bargaining power by increasing switching costs and creating attractive win-win opportunities.

Input suppliers to the avocado industry have relatively strong bargaining power, while the avocado industry has moderate to weak supplier bargaining power.

(v) Bargaining powers of buyers

Buyer bargaining power in the avocado market tends to be high in the spot market where avocados are a commodity offered by many suppliers at a going market price. The Market Research Analyst (2008) indicates that 67% of avocado imports are concentrated in the USA, France, Netherlands and United Kingdom. Given that each country has a limited number of supermarket chains in operation, the influence and control of these chains on volumes, specifications, deliver arrangements, and prices are significant. There is a high level of concentration of buying power in the high value markets for fruits, making them typical buyers' markets instead of suppliers' markets (Joosten, 2007). Buyers' bargaining power is further strengthened by relatively low switching costs, large volume purchases being important to sellers and the identity of buyers adding prestige to the suppliers' list of customers.

Bargaining power of buyers is thus strong.

(vi) Complements

In contrast to the availability of substitutes that may reduce the value of a product, the availability of complementary products increases its value (Grant, 2008). In Africa, avocados are used to butter bread or they are eaten on sandwiches. Therefore bread could act as a complement for avocado. The European buyers, on the other hand, mostly use avocados in salads and in shrimp cocktails, implying that vegetables and even some seafoods could act as complements for avocados (Donkin, personal communication).

There are possible avocado complements, but their non-exclusive nature reduces the opportunity for strong complement-driven demand growth for avocado.

2.7 Annexure 2C: Micro-environment analysis

Functional analysis

Functional Area	Capability
Financial management	SAAGA is relatively well funded Main industry role players too risk averse *Capability 1: Financial management (too conservative)*
Research and Development	Pragmatic, applied R&D commercially oriented and internationally recognised. Includes pre and post harvest plant physiology, plant pathology, horticulture and entomology. Developed ground-breaking new innovations including phosphoric acid tree injections, superior clonal rootstocks (patented Dusa), organic fungicides (patented Biocoat) and other superior avocado cultivation processes. *Capability 2: Product and process development (core strength)*
Operations	Growers are efficient avocado producers with available resources Local diversification of planting areas to extend the season Strategic national and international partnerships Forward integration into marketing channels Innovative retail products of processed avocado International pre-packing facilities *Capability 3: Production (medium cost producer, high quality)*
Marketing	Coordinated national and international avocado marketing (volume sharing information) Close collaboration between growers, marketing and R&D Effective industry generic advertising activities Customer service with technical expertise to resolve problems No access to US market, Eurocentric focus *Capability 4: Marketing (responsive to short-term market trends, few alternatives)*
Sales and Distribution	Selling direct to retailers Good established sales and distribution network to the EU (incl. UK) Superior speed of distribution (picking to arrival) *Capability 5: Distribution (established network in the EU, not in US)*
Government	Working closely with provincial leaders with good relationship National government relations poor *Capability 6: Government relations (requires improvement)*
Strategic	Vertical integration of agribusinesses in the industry Growth strategy not pursued aggressively *Capability 7: Strategic management (financial control, slow to respond and adapt)*

Source: Researcher's compilation

3 Chapter 3: Measuring the effectiveness of research and development: a literature review

Abstract

Research and development (R&D) is critical for implementing business strategy and to sustain and gain new competitive advantages. The nature of R&D makes measuring its effectiveness a very difficult task, and although it has been studied for over six decades, it remains a rather imperfect art. The aim of this review is to provide a critical overview of measuring R&D effectiveness at the micro level for scientific and agricultural R&D disciplines and identifying the gaps in the literature as addressed by the research problem. The review defines and explains the three main research activities – basic research, applied research and experimental development – and the R&D system consisting of inputs, processes, outputs and outcomes. It continues by elaborating on R&D metrics developed over time, with quantitative and qualitative metrics considered to be most valid at the late and early stages of the R&D method, respectively. The use of integrated metrics is considered superior in measuring the entire R&D function. Situational factors, like strategy linkages, country and cultural differences, level of analysis, R&D type, R&D process and employment category (manager vs. researcher) have been shown to impact on R&D measurement. Most micro-level research on the measurement of R&D effectiveness has been conducted in the West and Far East in technology-intensive industries. The South African work focuses on macro studies of public agricultural R&D. Two studies relating to the micro-measurement of fresh fruit R&D have been conducted in South Africa, but these only focus on quantitative metrics (without testing their validity) in an incomplete R&D system. Weaknesses in the research literature serve as evidence for rather poor internal and external validity and the infrequent use of multiple metrics over the entire R&D system. The specific gap in the literature addressed by this study is the validation of R&D criteria (including strategy concepts) over the entire R&D system in the South African avocado industry.

3.1 Introduction

Research and development (R&D) is a critical instrument for implementing strategy. To sustain their competitive position or gain a new competitive advantage in changing business environments, organisations need to make crucial investments in R&D activities. Measuring the effectiveness of R&D has grabbed the attention of academics and practitioners for over six decades, but it is still considered a relatively new field and a rather imperfect art. The topic has been studied from an economic, sociological and bibliometric basis, in disciplines ranging from the humanities to physical sciences. The focus of research on R&D effectiveness has ranged from a micro level, concerned with organisational effects, to macro level studies investigating aggregate effects of R&D on society as a whole.

A comprehensive review of all these perspectives, levels and disciplines is beyond the scope of this study. The purpose of this review is to provide background information to show the significance of the research problem and the context and structure of the study (Blumberg *et al*. 2008). Therefore the aim of the review is to provide a critical overview of pertinent contributions shaping the state of the art of measuring R&D effectiveness at the micro level for scientific and agricultural R&D disciplines and identifying the gaps in the literature as addressed by the research problem.

This review follows a broad approach that gradually becomes more focused and specific as it leads towards a conclusion. It starts by explaining the problem of R&D measurement, the different activities of R&D that can be identified and the quantitative, qualitative and integrated criteria to measure R&D effectiveness. This is followed by contingency factors of measuring R&D. Next, the South African situation of measuring R&D effectiveness is presented. Finally, the conclusion identifies the gaps in the literature and how this study may contribute towards filling the gap and adding new knowledge.

3.2 The problem and rationale of measuring R&D effectiveness

The research method often involves a high degree of variability and uncertainty, and it may require a relatively long time to complete. R&D inputs and outputs can be difficult to define and measure, technology spill-overs are difficult to predict and projects may involve a large number of people working both in parallel and in

sequence. Such complexities can blur the simple output-to-input concept used for traditional measurement of other business activities and accurate measurement of R&D effectiveness is a difficult task (Brown and Gobeli, 1992; Hauser and Zettelmeyer, 1997). As a result, many firms do not even attempt to measure their R&D performance and in those organisations that do, few managers are satisfied with the system in use (Werner and Souder, 1997b).

Increased competition, new organisational structures, co-operational forms, justification of investments, and control models have forced managers to rethink the factors and mechanisms relating to R&D and its control, and to track suitable R&D performance measures (Lee *et al*. 1996; Ojanen and Vuola, 2005). Measuring of R&D also allows for the recognition of spatial and temporal trends and undertaking of benchmarking studies. Measuring R&D is therefore imperative in the modern age, but finding the most appropriate R&D performance metrics to use depends on the type of organisation, its spatial and temporal situation, measurement requirements, type of R&D performed, and data availability. Furthermore, cultural differences and available resources to allocate towards the measurement of R&D effectiveness also impact on the preferred approach towards R&D measurement (Werner and Souder, 1997b).

3.3 Research and development activities

When talking about R&D, it is definitely not a case of one size fits all. R&D comprises different activities, each with its own unique characteristics and subject specialists. Generally three activities are identified: basic research, applied research and experimental development.

According to the OECD (2002), basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying phenomena and observable facts, without any particular application or use in view. Applied research is also original investigation undertaken to acquire new knowledge, but in contrast to basic research it is directed primarily towards a specific practical aim or objective. Experimental development is systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed at producing new materials, products or devices, installing new processes, systems and services, or substantially improving those already produced or installed (OECD, 2002).

R&D activities are conducted in a framework that can be classified as a system within the organisation or industry (Lee *et al*. 1996; Brown and Gobeli, 1992; Brown and Svenson, 1998; Coccia, 2001). R&D activities involve the consumption of different inputs, following a scientific process, and obtaining a series of outputs from these inputs and processes that are essential for the continued financial and commercial growth of the organisation involved (Garcia and Mulero, 2005). A distinction is made between an output and an outcome, where the former is a direct result of the research (e.g. published paper or patent) and the latter is an indirect result (e.g. increase in profits) (Brown and Gobeli, 1992).

3.4 Research and development metrics

Measurements or metrics assist in the documentation of R&D value to justify R&D investments; they enable management to evaluate people, objectives, programmes and projects to optimise the allocation of resources, and they also affect behaviour by aligning employee and management goals with those of the organisation. The wrong metrics may be counterproductive and can lead to narrow, short-term and risk-avoiding decisions and actions (Hauser and Zettelmeyer, 1997).

This review of R&D metrics will follow the classification and summary by Werner and Souder (1997a), categorising measurements as quantitative (numerical) or qualitative (non-numerical) based on objective information or subjective judgment. The classifying variables are not independent, and the label qualitative-objective is excluded because it is regarded as a contradiction in terms.

3.4.1 Quantitative metrics

Quantitative metrics can be categorised as objective or subjective measures. Objective quantitative metrics use tangible and countable dimensions and include input metrics like number of scientists employed, total R&D expenditure and output metrics like number of refereed papers published, patents filed, and new products. Commonly ratios combining input and output metrics are used, like R&D financial return on investment or expense per patent filed. The use of patent counts and bibliometric counts of scientific publications has been reported to have merit in measuring R&D (Edwards and McCarrey, 1973; Patterson, 1983; Robb, 1991; McGrath and Romeri, 1994). However, it has been shown that some quantitative objective metrics are highly correlated in certain cases (e.g. R&D expenditure, patent

counts and new products), indicating that multiple metrics of this nature may add limited additional insight into R&D effectiveness (Hagedoorn and Cloodt, 2003). Quantitative metrics are easy and inexpensive to use, but their validity in measuring R&D effectiveness can be a problem (OECD, 2002). Other drawbacks of quantitative objective metrics are that they overlook time lags and only provide a lagging indicator of R&D measurement when focusing on outputs. Financial metrics like return on investment and discounted cash flow-type analysis can place too much emphasis on short-term profitability, and underestimate research returns when there is uncertainty about future earnings, thus hurting long-term profitability and competitive advantage (Faulkner, 1996; Mitchell and Hamilton, 2007). Quantitative objective metrics are mainly recommended for use in the late stages of the R&D effort, when outputs are more certain and definable (Collier, 1977; Werner and Souder, 1997a).

Quantitative objective metrics are most commonly used for benchmarking studies. Table 3.1 summarises some of the specific criteria used and their values in specific industries. Industry has been shown to impact greatly on the level of benchmark adopted (Bigwood, 2000). The R&D intensity (calculation details provided in Table 3.2) over a pool of 18 industries varies between 2.6 and 3.9%, but in agriculture world-wide it appears to be closer to 1%. Interestingly, the R&D intensity for public agricultural research institutes in South Africa was 2.4%, similar to that of high income countries. The cost per agricultural researcher in South Africa is above R1 million per annum at public institutions. The allocation of the R&D funding across multiple industries appears to be about 5% for basic research, 15% for applied research, 60% for development and 20% for services. New products as a percentage of sales vary between 14% and 22%, but this metric will not apply to organisations where services or processes are most important (Table 3.1).

Table 3.1 Norms of selected research and development (R&D) metrics

Metric name	Benchmark	Industry	Reference
1. R&D intensity	2.6 – 3.9%	Composite of 18 US industries from 1992-1998	Wolff, 1994; Bean, Russo & Whiteley, 1998; Bean, Einholf & Russo, 1999; Bean, Russo & Whiteley, 2000
	0.9%	US food and kindred products industry average from 1992-1998	Wolff, 1994; Bean *et al*. 2000

	1% of agricultural GDP (global average) 2.4% of agricultural GDP (high income countries)	Average R&D intensity for world-wide public agricultural R&D in 2000	Beintema and Stads, 2008
	2.4% of agricultural GDP	Average annual R&D intensity for South African public agricultural R&D between 2003-2007.	Liebenberg, Pardey and Khan, 2010
2. Expenditure per researcher	R1,05 million in 2005 (including overheads)	ARC scientists in South Africa (scientists classified according to ARC position and not according to qualification)	Liebenberg *et al*. 2010
3. Proportion of funding allocated to R&D activities	Basic research: 2-5% Applied research: 14-18% Development: 55-66% Services: 15-23%	Composite of 18 US industries from 1992-1998	Bean *et al*. 1998; Bean *et al*. 1999; Bean *et al*. 2000
	Basic research: 5% Applied research: 16% Development: 58% Services: 20% Rounding resulted in the summations equalling 99%.	US food and kindred products industry average from 1994-1998	Bean *et al*. 2000
4. New/improved products as percentage of sales	14-22%	Composite of 18 US industries from 1992-1998	Bean *et al*. 1998; Bean *et al*. 1999; Bean *et al*. 2000

Source: Researcher's compilation from references shown in Table.

Subjective quantitative metrics are based on judgments that are converted to numbers, for example staff members of different departments collect objective data and jointly estimate the expected future benefits of R&D activities. The judgments are then benchmarked against a database consisting of past estimates and accomplishments (Patterson, 1983). Judgments are converted into numbers using profiles, scaling models, checklists or scoring models. Quantitative subjective assessments have been shown to be valid leading indicators of R&D success (Souder, 1969), possibly because the individuals most closely connected to the R&D activity are in the best position to evaluate them (Werner and Souder, 1997a). These metrics therefore allow for use as lagging and leading indicators of R&D measurement. A shortcoming of these metrics is the possibility of biases, estimation errors, inaccurate perceptions and judgment based largely on reputation. Quantitative subjective metrics are generally regarded to be the most appropriate for earlier stage R&D activities (Whitley and Frost, 1971; Pappas and Remer, 1985).

3.4.2 Qualitative metrics

Qualitative metrics rely on raw judgments that are not related to numbers but are usually discrete variables like exemplary or adequate. The focus is usually shifted away from technical processes to rating human performance. Self-evaluations, supervisory ratings, peer ratings and external audits are techniques used to derive qualitative metrics to obtain a greater in-depth impression of R&D effectiveness. Qualitative ratings have been shown to be valid and reliable (Stahl and Steger, 1977), but can require extensive time and costs due to the custom nature of these assessments. Halo effects, over-estimation, under-estimation and other biases can contaminate qualitative techniques. Qualitative assessments are recommended in small teams for use at the initial stages of an R&D effort (Collier, 1977; Werner and Souder, 1997a).

A summary of quantitative and qualitative metrics that have been associated with R&D effectiveness is provided in Table 3.2. The use of a numeric scaling method or a more discrete qualitative judgement will determine the classification of the intangible parameters as quantitative subjective or qualitative.

Table 3.2 Quantitative and qualitative metrics associated with R&D effectiveness

Dimension	Name	Details	Metric	Reference
1. Strategy	1.1 Strategic alignment	a. Alignment of R&D strategy with business and corporate strategy	a. Quantitative subjective or qualitative	Chester, 1994; Ransley and Rogers, 1994; Tipping *et al*. 1995; Hauser and Zettelmeyer, 1997
2a. Input	2.1. R&D expenditure	a. Money spent on R&D	a. Quantitative objective	Lee *et al*. 1996; Hagedoorn and Cloodt, 2003; Garcia and Mulero, 2005
	2.2. R&D infrastructure	a. Available resources for R&D	a. Quantitative subjective or qualitative	Lee *et al*. 1996; Galende and Suarez, 1998, Garcia and Mulero, 2005
	2.3. R&D human resources	a. Growth rate of personnel b. Research admin staff ratio c. Skill of personnel	a/b. Quantitative objective c. Quantitative subjective or qualitative	Schmitt, 1987; Halls, 1992; Lee *et al*. 1996; Haanes and Lowendahl, 1997; Hauser and Zettelmeyer, 1997; Garcia and Mulero, 2005
2b. Input/output ratio	2.4 Relative R&D expenditure and R&D productivity	a. R&D intensity: (R&D expenses / sales revenues), as a percentage b. Cost or other input per output: (e.g. Cost/patent, personnel/publi-	a. Quantitative objective	Bachman, 1972; Patterson, 1983; Brown and Gobeli, 1992; Bean, *et al*. 1998; Bean *et al*. 1999; Kraemer, 1999; Bean *et al*. 2000

		cation) c. Profit of projects/cost of projects		
3. Throughput or process	3.1. R&D planning	a. Appropriate planning b. Appropriate selection	a/b. Quantitative subjective or qualitative	Lee *et al*. 1996; Tracey *et al*. 1999; Heidenberger, Schillinger and Stummer, 2003; Garcia and Mulero, 2005
	3.2. R&D implementation	a. Budgeting b. Staff adaptability c. Communication d. Collaboration with others to transform plans into actions	a-d. Quantitative subjective or qualitative	Lee *et al*. 1996; Young, 1997; Tracey *et al*. 1999; Leenders and Wierenga, 2002; Heidenberger *et al*. 2003; Garcia and Mulero, 2005
4. Output	4.1 Achievement of objectives	a. Reaching objectives	a. Quantitative subjective	Moser, 1985; Ransley and Rogers, 1994; Tipping *et al*. 1995; Lee *et al*. 1996; Hauser and Zettelmeyer, 1997; Garcia and Mulero, 2005
	4.2 Direct results from R&D	a. Usefulness of external or internal developed technology b. Quality of R&D c. External R&D acknowledgements (patents, papers etc.)	a/b. Quantitative subjective or qualitative c. Quantitative objective	Moser, 1985; OECD, 1991; Lee *et al*. 1996; Patel and Pavitt, 1995; Hauser and Zettelmeyer, 1997; Hirons, Simon and Simon, 1998; Ernst, 2001; Garcia and Mulero, 2005
5. Outcomes	5.1 Profit increase	a. Increase in profits due to R&D activities (including net present value, return on investment, sales from new products, cost savings from new products or processes)	a. Quantitative objective (historical) or quantitative subjective (predictive)	Boer, 1994; Tipping *et al*. 1995; Lee *et al*. 1996; Hauser and Zettelmeyer, 1997; Abdel-Kader and Dugdale, 1998; Del Monte and Papagni, 2003; Garcia and Mulero, 2005
	5.2 Management improvement	a. General improvement of management practices	a. Quantitative subjective or qualitative	Lee *et al*. 1996; Abdel-Kader and Dugdale, 1998; Garcia and Mulero, 2005

Source: Adapted from Lee *et al*. (1996) and Garcia and Mulero (2005).

3.4.3 Integrated metrics

Integrated metrics combine objective and subjective measures, and include both quantitative and qualitative criteria. Examples of integrated techniques are provided in Tipping *et al*. (1995), Lee *et al*. (1996) and Garcia and Mulero (2005). Some integrated studies are also prescriptive in nature; Ranftl (1986) for example uses quantitative and qualitative criteria to uncover industry best practices to use as benchmarks for improving performance. The technology value pyramid uses a total of

33 integrated metrics to measure the performance of value creation drivers to analyse R&D effectiveness and provide guidelines for improvement (Tipping *et al*. 1995). Another hybrid of the integrative approach is combining different metrics into a single weighted score (Brown and Svenson, 1988).

Integrated metrics are considered to be more reliable but also more complex than single metrics. They are also expensive to develop, but offer the benefits of flexibility, prescriptions for improvement and the ability to measure the entire R&D process from basic research to product development and manufacturing process R&D. They reduce bias, exploit multiple dimensions of excellence and provide built-in checks and balances, making them the most effective approach towards R&D effectiveness measurement (Werner and Souder, 1997a).

The use of integrated metrics over the entire R&D system is relatively rare, especially in the early literature before the late 1980s. Since 1990, more studies have concentrated on integrated metrics and different levels of the R&D system.

3.5 Contingency factors affecting R&D measurement

The measurement of R&D effectiveness depends on the situation (Kerssens-van Drongelen and Bilderbeek, 1999; Karlsson, Trygg and Elfström, 2004; Chiesa, Frattini, Lazzarotti and Manzini, 2009). Earlier sections elaborated on the widely reported affect of R&D type on R&D measurement, which strictly speaking may also be considered a contingency factor. However, this section investigates the more abstract factors that have been shown to influence R&D effectiveness and its measurement at the level of strategy and implementation. Only the salient factors applicable to the research problem of this study will be discussed.

The assessment of R&D in companies has mainly focused on measuring the effectiveness of implementation. However, having a close linkage between R&D and strategy is of critical importance to ensure that the right objectives are pursued (Berg, Leinonen, Leivo & Pihlajamaa, 2002). Expert panels have consistently voted that strategic alignment is one of the most important R&D metrics (Germeraad, 2003).

3.5.1 R&D and strategy

Japanese and European companies have been found to have much closer linkages between R&D and corporate strategy than the USA, and have a tendency towards centralising R&D control versus a decentralising tendency observed in the USA

(Blau, 1995; Roberts, 1995). A closer linkage between R&D and strategy was associated with increased R&D effectiveness (Roberts, 1995).

The study of Roberts (1995) did not empirically test the relationship between strategic linkage and centralisation with R&D effectiveness, but rather adopted an inductive approach in a qualitative setting. The study sampled the entire population of companies from the USA, Western Europe and Japan with an R&D expenditure of $100 million or more in 1991. The response rate was only 39% (n=95), but the response was relatively similar between regions and the sample had a representative proportion of R&D expenditure. The sample therefore appeared to be representative, but findings cannot be interpreted as cause and effect, but rather as theories to be tested deductively or at least through more studies in a triangulation approach.

In a study to measure R&D effectiveness in Spain, aspects relating to strategy, for example organisational structure, stakeholder involvement in R&D objectives and the influence of external environmental regulations on R&D, were highlighted as being important (Garcia and Mulero, 2005). In contrast, when a relatively similar questionnaire was posted to Korean R&D professionals, these aspects were not identified as being important. The comparison of the two studies did not indicate high validity, as elaborated further in section 3.6.2, but nevertheless supported differences in the perception of the role of strategy in R&D effectiveness between countries.

To the best knowledge of the author, the impact of strategy in the measurement of R&D effectiveness in South African agriculture has not been studied in the context presented here.

3.5.2 R&D implementation

To measure R&D effectiveness in terms of implementation, the testing of content validity of multiple metrics in a mainly quantitative approach (using a structured questionnaire) resulted in only a partial overlap when a relatively similar questionnaire was posted to Spanish and Korean R&D professionals. In Korea, diversification of research areas was considered important for R&D effectiveness (Lee *et al*. 1996), whereas it was not important in Spain (Garcia and Mulero, 2005). In Spain, experience of R&D personnel and performance-linked remuneration were identified as additional measures for R&D effectiveness, but not identified in Korea.

Although these results further support country (and possibly cultural) differences in the measurement of R&D effectiveness, they should be interpreted with caution. The Spanish study was a small pilot investigation and only interviewed four

purposively sampled individuals, preventing generalisation to the population. The Korean study randomly selected 60 companies from a population of 1 200 firms (Korean companies with more than 300 employees). From the 60 selected companies only 44 had R&D departments of which 28 participated in the study. The relatively small sample size, low response rate for the population size and reliance on questionnaire data from researchers and research managers, indicated that the sample was representative for Korean companies having an R&D department *and* more than 300 employees rather than for the originally defined population. The direct comparison is further handicapped by different conceptualisations of the questionnaire between the two studies.

The Korean study showed a correlation coefficient of 0.59 (significant at the 0.01 level) between researchers and research managers for 25 R&D metrics, indicating that the tendency of perceptions between managers and researchers is somewhat similar, but not completely homogenous. Perceptual differences between researchers and managers have not been researched in South Africa.

In contrast to the other studies, Werner and Souder (1997b) specifically set out to test if differences exist in measuring R&D effectiveness between countries, specifically US and German companies. The study showed a difference in the philosophy of measurement and the perception of its usefulness. US managers preferred measuring outputs per input (e.g. patents per dollar, financial rate of return) and favoured metrics with a relatively short-term focus on financial performance. In sharp contrast, German managers regarded R&D performance measurement as an act of distrust in their scientists, and their philosophy was long-term monitoring of input indicators to ensure adequate spending on R&D. The differences may be related to the fact that US companies are led by financially oriented CEOs and CTOs, whereas German companies are largely managed by engineers and technically oriented leaders. The conclusion of the study was that R&D metrics must be tailored to fit the firm, consistent with the management philosophy, traditions and culture within which the firm operates as influenced by its country of origin and socio-political environment.

The study by Werner and Souder (1997b) made use of an interview survey of top R&D spending companies in the USA (27 companies) and Germany (13 companies), interviewing multiple employees per company and in addition also interviewing five consultants specialising in R&D management. The study did not specify how the population was defined, if the samples were randomly selected or if

the interview was structured, semi-structured or unstructured. Hence, the findings can possibly not be generalised to the population. Nevertheless, the study collected rich data in a qualitative setting, and further supported the possibility that the measurement of R&D effectiveness is context specific, with no universal approach that can be applied to all companies.

Ojanen and Vuola (2005) developed a tool for R&D measurement through an iterative theory-building process using an extensive literature review and collaboration with a network of companies representing different industries. The qualitative study concluded that R&D measurement is case specific, impacted by the dimension of measurement (e.g. industry type, firm size, strategic control model used), purpose of measurement (e.g. performance management, diagnosing activities), level of analysis (e.g. national, industry, company, strategic business unit, R&D department, R&D process, project, team or individual level), R&D type (basic, applied or development) and R&D process (input, in-process, output and outcome).

Falkingham and Reeves (2001) postulated that corporate level managers and R&D practitioners can adapt different schools of thought. Their study used purposive samples when thinking about R&D management, limiting generalisation. This topic merits further investigation to determine how corporate managers and researchers differ in their perceptions to measure R&D effectiveness. Another scantly researched area is the dimensions of R&D performance analysis in collaborative and networked R&D (Ojanen and Vuola, 2005), a topic that is at hand when investigating the effectiveness of collaborative industry level R&D efforts.

3.6 Measuring R&D effectiveness in South Africa

This section critically evaluates some of the available research relating to measuring agricultural R&D in South Africa. It starts with a broad perspective, progressively narrowing to the fresh fruit sub-sector and then the avocado industry in South Africa.

3.6.1 Background

Primary agriculture accounted for about 3% of the GDP of South Africa between 2000 and 2007, down from 5.2% in 1985. In 2004, animal products made up 35.3% of this figure, field crops 41.0%, and horticulture 23.7%. The most important export crops are sugar, wine, citrus, and deciduous and subtropical fruits (Liebenberg and Kirsten, 2006; Liebenberg and Pardey, 2010).

Deregulation and liberalisation characterised the agricultural sector of South Africa in the 1980s. The election of a Government of National Unity in 1994 intensified institutional restructuring changes and expanded policies to include land reform, new legislation (including the Marketing of Agricultural Products Act and the Water Act), and trade and labour market reform. These reforms were intended to correct the injustices of past policy, to direct the agricultural sector towards less capital-intensive growth, and to enhance the sector's international competitiveness. These changes appear to have increased agricultural productivity by a decreasing level of input use or increasing output from a constant level of inputs. Trends in the suppliers of R&D funding also changed. In recent years producer organisations and international donors contributing to the funding of agricultural research have increased, and universities play a greater role as research providers (Liebenberg and Kirsten, 2006).

More detailed policy changes and their impact on public agricultural R&D in South Africa have been summarised by Liebenberg, Pardey and Khan (2010). They concluded that although long-term trends were generally favourable, short-term trends were cause for concern. The amount of real funding for public agricultural R&D has failed to grow since 1992, the intensity of investment in agricultural R&D has stagnated, and the country has lost a substantial number of well-trained and experienced agricultural scientists.

3.6.2 General

Several agricultural economic studies of public sector agricultural R&D have been undertaken in South Africa. A number of these studies have been conducted since 1995, when the ARC established a small impact-assessment unit, the Group for Development Impact Analysis. One of the unit's first initiatives was to contract a series of rate-of-return studies. The studies were usually done at relatively high levels of aggregation and mainly aimed to assist policy making (Thirtle, Sartorius von Bach & Van Zyl, 1993; Khatri, Thirtle & Van Zyl, 1996; Van Zyl, 1996; Thirtle, Townsend & Van Zyl, 1997; Townsend, Van Zyl & Thirtle, 1997; Thirtle, Townsend, Amadi, Lusigi & Van Zyl, 1998; Thirtle, Piesse & Gouse, 2005). Khatri *et al*. (1996) measured the rate of return of government expenditure on agricultural R&D using a factor productivity model at an aggregate level. The internal rate of return was high (>40%), suggesting that there is under-investment in the generation and diffusion of agricultural technology in South Africa. Returns in the social context were found to be

negligible or negative. The study concluded that government R&D investment in agriculture should focus on technology development for resource-poor small-scale farmers. A more disaggregated study by Thirtle *et al*. (1998) supported previous aggregate findings of high rates of return from government agricultural R&D at institute, crop and project levels using modified production function equations. The focus of that study was on using tangible quantitative input output ratios to measure R&D effectiveness. A summary of these findings is presented in Table 3.3 (based on Liebenberg and Kirsten, 2006).

Table 3.3 Rate-of-return studies on the impact of agricultural research at different levels of aggregation

Level	Commodity	Method	Period	Rate of return (percent)	References
National	Research and development	Two-stage decomposition	1947–91	60–65	Thirtle and Van Zyl, 1994
	Extension			28–35	
	Research and development	Profit function	1947–92	44	Arnade *et al*. 1996; Khatri *et al*. 1996
Agricultural sub-sectors	Field crops	Profit function	1947–92	30	Thirtle *et al*. 1998
		Horticulture		100	
		Livestock		5	
Enterprises	Animal health	Production function	1947–82	>36	Thirtle *et al*. 1998
	Animal production	Supply response	1947–94	11–16	
Industry	Bananas	Supply, area and yield	1953–95	50	
	Deciduous fruit	Supply response	1965–94	78	
	Groundnuts	Yield changes	1968–95	50	
	Maize	Error-correction model	1950–95	29–39	
	Sorghum	Error-correction model	1950–95	50–63	
	Sweet potatoes	Supply response	1952–94	21	
	Tobacco	Supply, price lags	1965–95	50–53	
	Wheat	Error-correction model	1950–95	26–34	
	Wine grapes	Error-correction model	1987–96	40–60	Townsend and Van Zyl, 1998
Research programmes	Dairy, beef, mutton, and pork performance, and progeny testing schemes	Economic surplus	1970–96	2–54	Mokoena, Townsend and Kirsten 1999
	Cover-crop management	Yield and residual	1987–96	44	Thirtle *et al*. 1998
	Lachenalia research and development	Economic surplus	1965–2015	7–12	Marasas *et al*. 1998
	Proteaceae research and development	Economic surplus	1974–2005	8–12	Wessels *et al*. 1998
	Russian wheat aphid integrated-control programme	Economic surplus	1980–2005	22–28	Marasas, 1999

Source: Liebenberg and Kirsten, 2006.

In line with the reasoning of Werner and Souder (1997b), these studies were prompted by the socio-political situation in South Africa. In light of increased

government focus on accountability and competition for public funding, a public research service provider like the Agricultural Research Council (ARC) had to show that its use of public money is both appropriate and effective (Thirtle *et al*. 1998). Long time periods were used in calculations that may capture most R&D activities, but reliance on a long-term lagging indicator provides poor short-term and future resolution on R&D effectiveness.

South African studies have focused on the public sector and historic economic rates of return over relatively long periods. The value in R&D in this setting has been widely recognised (Tipping, 1993). However, measuring R&D effectiveness in the private sector has different objectives to public institutions (Peterson and Perrault, 1988). There is a need to focus on shorter time frames and lower levels of aggregation, to provide measurable near-term lagging indicators as well as leading indicators which can measure R&D effectiveness (Tipping, 1993). There is also a need to include both tangible and intangible aspects of a complete R&D system, measured in terms of financial and non-financial indicators to combine both quantitative and qualitative elements in measuring R&D effectiveness (Werner and Souder, 1997a). Appropriate indicators will vary between industries and situations; generally the use of lagging indicators is less troublesome in product-oriented industries (e.g. the pharmaceutical industry) where costs and inputs can be related directly to the development and subsequent success of a product. The situation is more complicated where processes, as commonly is the case in fresh fruit production, are a key element in achieving competitive advantage (Tipping, 1993).

3.6.3 Fresh fruit and the avocado industry

Statements like "... there is no single example of a thriving agricultural industry in the world which is not strongly supported by research" (Terreblanche, 1986) and "It is a fact that countries which have invested heavily in research now have the most successful and dynamic avocado industries" (Wolstenholme, 1987) echo the importance traditionally attached to R&D in the fruit sub-sector of South African agriculture. However, few studies have investigated how best to measure R&D effectiveness in this sub-sector and none of the fruit industries in South Africa are formally measuring R&D effectiveness.

The largest South African fruit industry R&D institution, Citrus Research International (CRI), does not measure R&D effectiveness, but is investigating the prospect. CRI contends that publication records as an output metric are not a very

valid parameter because to respond rapidly to growers' needs some research is not suitable for publication. They believe that the speed with which research is accomplished and the proportion of research projects that survive to practise or are implemented are important metrics to track (Grout, personal communication). The annual report from CRI suggests that currently there is a focus on outputs, with specific sections in the annual report listing attendance of international conferences, technology transfer activities, presentations, and popular and scientific publications produced over a one-year period (Anonymous, 2008). Similarly, outputs are also pertinently listed on the web-sites of other large South African fruit industries like that of pome fruit, stone fruit (deciduous fruit industry) and table grapes (www.dfptresearch.co.za), but no formal system of measuring R&D effectiveness is being employed (Campbell, personal communication). A similar situation exists in the sub-tropical fruit industries (personal observation).

According to the available information, only two studies have been done by the South African fruit industries that can be linked to measuring the effectiveness of R&D. The first was a non-reviewed paper published in 1997 in the SAAGA yearbook. The intention of the study was not to measure R&D effectiveness, but in light of declining government subsidies for university and public agricultural research, the study aimed at showing the benefit of R&D to avocado growers, who would increasingly have to fund greater proportions of R&D. It investigated the financial R&D inputs and possible benefits in terms of the estimated cost saving and profit increasing outcomes from R&D linked to disease control, packing systems and temperature control processes (Toerien, 1997). The focus was on outcomes, which may not only measure R&D effectiveness, but also technology transfer and the implementation effectiveness of operational units. The study concluded that the contribution by researchers to the industry has not been fully recognised and thereby implied that additional metrics are required to comprehensively measure R&D effectiveness. The financial metrics used in the study were subjectively selected, without testing their validity.

A similar approach, also with an objective of illustrating the benefit of R&D to growers in order to maintain or increase funding levels, was adopted in the second study. Citrus R&D expenditures were compared to estimated financial benefits of phytosanitary market access, and research intensities were compared to citrus industries in other countries (Hardman, 2004). The study did not consider extraneous or intervening variables and did not test the validity of the parameters used. However,

it would be unfair to criticise these studies which attempted to value R&D in the fruit industries and had other aims and objectives than to specifically measure R&D effectiveness.

3.7 Research methods

The research methodology used by many of the studies investigating or related to R&D effectiveness measurement commonly used convenience or purposive samples in a case study, content analysis or survey design, employing interviews, questionnaires or focus groups to gather data. These methods have generic pro's and con's and concepts like the Hawthorne effect, risks of self-report data and experimenter expectancy will not be discussed in detail as there are dedicated texts on the matter (Lee, 1999; Leedy and Ormrod, 2005; Diamantopoulos and Schlegelmilch, 2006). The earlier research usually made use of either a qualitative or a quantitative research design. Since the 1990s, studies have more often included both methods in mixed designs. The complementary combination of both designs is strongly supported. However, it appears that in general the focus and approach has been biased towards inductive reasoning and qualitative designs.

In research on the measurement of R&D effectiveness, scientific hypothesis testing is extremely rare and the use of lab and field experiments to assess R&D effectiveness, allowing accurate cause and effect deductions to be made, was not located in the literature. This approach can, for example, allow for independent interventions (e.g. different strategies, inputs, throughputs and/or situational variables) and untreated controls to be randomly assigned to R&D units and then to monitor their impact by selecting multiple dependent variables (e.g. outputs, outcomes) to test leading indicators for R&D effectiveness. These experiments do have drawbacks by being expensive and they may fail to adequately control extraneous variables and mediating processes, but nevertheless would enrich the R&D management body of knowledge.

Unfortunately, due to limited resources, a true experimental design could not be adopted in this study. Rather, expert opinion was used to test the construct validity of elements contained in a measurement instrument as done by Lee *et al*. (1996), Lever (1997) and Garcia and Mulero (2005). The descriptive research approach adopted in this study relied on the perception of researchers and sponsors of avocado industry R&D. A mixed design biased towards quantitative methods was used, employing a

semi-structured questionnaire to survey a representative population sample. More details are provided in Chapter 4: Research Methodology.

3.8 Conclusion

Most published works on R&D measurement have been undertaken in advanced Western nations (USA, UK, and Western Europe) or the Far East, with few studies from Africa or South Africa. Many of the reviewed micro-level works on R&D effectiveness focus on industrial R&D at technology-intensive organisations in the pharmaceutical, chemical and engineering sectors, with fewer papers located on agriculture. The research reviewed at the micro level was mainly qualitative and conceptual in nature (although selected mixed designs were also found), drawing conclusions from an inductive perspective. Some studies did use triangulation techniques, but generally the internal and external validity of the research was questionable, especially their cause-and-effect propositions and the generalisability of the results. Other studies did include empirical analysis and drew samples from the population, but provided scant information on the definition of the population and/or the sampling design. In other cases the sample was purposively selected and not truly random. Qualitative studies are important and add value to the research effort, but the literature portfolio at a micro level can be enriched when qualitative works are combined with quantitative studies with higher levels of internal and external validity. The use of integrated metrics over the entire R&D system is also relatively rare, although it appears to be increasing in frequency of late. Macro-level investigations in the literature concentrated on quantitative methods like total factor productivity measures, and there is possibly a need for the use of multiple measures and also qualitative studies at this level. Contingencies have been shown to play a role in the measurement of R&D effectiveness, causing it to be context specific with no universal approach that can be applied to all companies or industries.

The gaps in the literature relevant to this study are (i) collaborative research efforts (e.g. industry level R&D) have not been thoroughly researched; (ii) further research on researcher and manager perceptions about R&D measurement is required; (iii) R&D criteria over the entire R&D system have not been validated for measuring South African R&D effectiveness; (iv) the impact of strategy in the measurement of R&D effectiveness has not been validated in South Africa; and (v)

very limited work has been done on measuring R&D effectiveness at the micro level of the agricultural fruit industries in South Africa.

The gaps in the literature cannot be completely filled by this single, narrowly focused study. However, a contribution was made and new knowledge generated using a mixed design biased towards quantitative research to study the measurement of R&D effectiveness in the avocado industry of South Africa.

4 Chapter 4: Research methodology

Abstract

Research methodology is concerned with the approach taken to carry out the research project. In this study a mixed method approach strongly biased towards a quantitative paradigm was used. The study focused on the South African avocado industry and was mainly descriptive without modifying the situation or determining cause and effect relationships. Primary data were collected using a survey questionnaire to measure the importance and satisfaction of 29 R&D criteria to measure avocado R&D effectiveness. Secondary data were collected to calculate quantitative objective avocado R&D metrics. The research instrument was an adapted semi-structured questionnaire to collect quantitative and qualitative data. The study population consisted of avocado R&D funding decision-making individuals and researchers conducting the R&D. The entire population was sampled consisting of 42 individuals. Data analysis used descriptive statistics (frequency distributions, means, standard deviations, correlations) and parametric variance analysis using appropriate *post hoc* methods to test the hypotheses. The proposition and other qualitative input received from the questionnaire were evaluated by using judgment and inductive reasoning. Internal validity of the study was enhanced by using an appropriate target population and optimisation of the questionnaire design. External validity was improved by sampling the entire target population and comparing results with previous findings. The validity and reliability of the survey questionnaire has been shown to be high in the published literature and one standardised questionnaire was used for all respondents. High ethical standards were maintained through voluntary participation, respecting participants' right to privacy and fully acknowledging previous work. The study was limited by being narrowly focused, excluding purely qualitative metrics and not allowing causal inferences and future extrapolations to be made.

4.1 Introduction

Research methodology is concerned with the approach taken to carry out the research project and dictates the research tools to be used to collect, manipulate or interpret data (Leedy and Ormrod, 2005). The aim of this chapter is to explain and justify the research paradigm used in the study, to describe and characterise the target population, the sampling method and sample, the data collection method and measurement instrument, reliability and validity, ethical issues, study limitations and the nature and form of results. The chapter concludes with a consistency matrix, ensuring that there was consistency between the problem statement, research sub-questions, the literature review, hypotheses and propositions, the data collected and the data analysis method.

4.2 Research paradigm

The research paradigm used in a study, be it qualitative, quantitative or mixed, has to align with the specific research problem. In this study, the paradigm had to (i) allow one to determine which criteria most accurately measure the effectiveness of avocado R&D in South Africa; (ii) provide an opportunity to identify other criteria that could accurately measure avocado R&D effectiveness; and (iii) allow inductive comparison of calculated R&D input and output trends with perceptions in the industry.

The first objective is satisfied by using a quantitative research method. Quantitative research, also called the traditional, experimental or positivist approach, answers questions about relationships among measured variables with the purpose of explaining, predicting and controlling phenomena, where variables are known and numeric data are analysed statistically in a deductive manner to test theory. In contrast, objectives (ii) and (iii) are aimed at generating theory and using inductive reasoning. This is the domain of qualitative research. Qualitative research, or an interpretative, constructivist or post-positivist approach, answers questions about the complex nature of phenomena, with the purpose of describing or understanding the phenomena from the participants' point of view. It commonly builds theory from an unstructured approach, unknown variables and textual data by searching for themes and categories inductively. However, quantitative and qualitative designs are not

mutually exclusive and a mixed design combines elements of both approaches (Lee, 1999; Leedy and Ormrod, 2005).

In this study a mixed method design, classified as a dominant, less dominant design is used (Lee, 1999). It entails a mainly quantitative design coupled with a smaller qualitative element. The quantitative component tested theory and relationships among R&D measurement variables. The study was mainly descriptive, involving identification of the importance and satisfaction of different criteria to measure R&D as the situation is at present, without modifying the situation or intending to determine cause-and-effect relationships. New theory was generated qualitatively through inputs by study participants. The general alignment of actual, calculated R&D metrics with perceptions of the study participants was judged qualitatively.

4.3 Data collection methods

Experimental research allows the researcher control over the variables being measured. The experimental method would allow accurate determination of variables affecting R&D effectiveness with a high level of validity. Unfortunately this approach was not practical in this case due to time and financial constraints. This research study followed the descriptive quantitative research approach. It fulfils the requirements to test the research problem and hypotheses, although it did not give the observer control over the variables being studied. Descriptive research can make use of observation studies, survey research, correlation research, and/or developmental designs (Leedy and Ormrod, 2005).

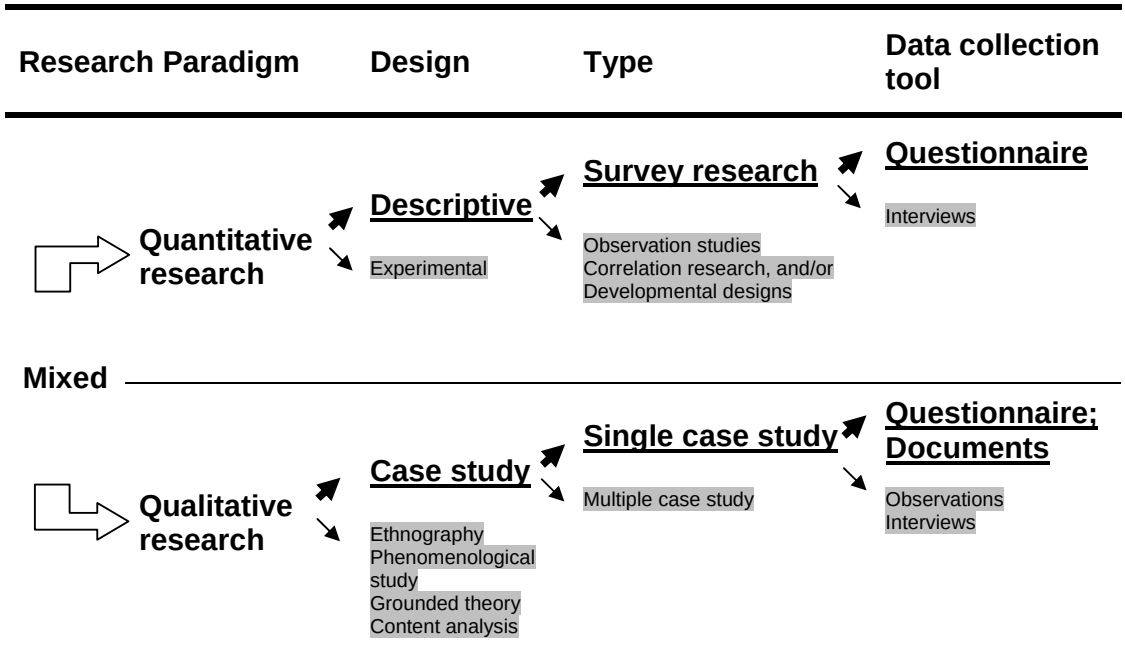
An observational study was unsuitable to the research problem because it is mainly intended to quantify a particular behaviour. Survey research was more appropriate, because it is used to acquire information about one or more groups of people and then draw inferences about the population. It was therefore suitable to quantify the perception of the population in terms of the importance and satisfaction of different R&D criteria. Correlation research gathers data from two or more characteristics of a group of people and establishes if a relationship exists between them. This was relevant for this study and useful to determine if importance and satisfaction perceptions of the population corresponded, although no cause-and-effect relationship was provided. A developmental design using a longitudinal study requires collecting data over a lengthy period of time. Unfortunately this was not

possible because of limited time and financial resources, and a cross-sectional design, surveying the population at one particular point in time, was used (Lee, 1999; Leedy and Ormrod, 2005; Diamantopoulos and Schlegelmilch, 2006).

Primary data were collected using the survey questionnaire to measure opinions on R&D criteria. Secondary data were collected by obtaining historical inflation figures, financial data and personnel trends to calculate certain R&D metrics for the avocado industry in South Africa. To compare the secondary data to the perceptions of the study participants necessitated a qualitative design. The type of qualitative designs available include ethnography (how behaviours reflect the culture of the group), phenomenological study (understanding an experience from the participants' point of view), grounded theory (deriving a theory from a process in a natural setting), content analysis (identifying characteristics from a body of material) and case study (understanding a situation in greater depth). A single case study approach was adopted as it allowed for inductive comparison of the perceptions of participants with the secondary data (Lee, 1999; Leedy and Ormrod, 2005).

A summary of the broad methodology in terms of the research paradigm and data collection methods of the study is provided in Figure 4.1.

Fig. 4.1. The research paradigm and data collection methods of the study to measure R&D effectiveness in the avocado industry of South Africa



Source: Researcher's compilation from Leedy and Ormrod, (2005).

4.3.1 Measurement instrument

The questionnaire, as modified from Lee *et al*. 1996, was designed to elicit specific information to answer sub-problem A and B. A preliminary study was conducted in May 2010 to test the design, comprehension and interpretation of the questionnaire. The instrument, close to its original format as explained by Lee *et al*. (1996), was presented to a statistics and research methodology lecturer (M. Werbeloff) at the University of Witwatersrand. Valuable comments and suggestions were obtained from her, most notably the suggestion that the semantic differential scale measurement used by Lee *et al*. (1996) be excluded in favour of a Likert scale to rate the satisfaction variable in R&D criteria. The suggestion was accepted since the semantic differential scale has been shown to provide highly correlated values and would have unnecessarily increased the length and completion time of the questionnaires (Ives *et al*. 1983). The modified questionnaire was then presented to selected board members of HMH and a former avocado researcher now employed in an administrative capacity by SUBTROP. All the test subjects were outside the target population of the study, as explained in section 4.4. Verbal feedback was obtained on the questionnaire and a follow-up semi-structured interview was held with the former researcher in June 2010 to discuss each section and question in greater depth. The results revealed that the instrument was well received, but some statements introduced ambiguity and required clarification, for example ‘The feasibility of R&D plans’. To ensure valid and reliable responses from the target population, such statements were more accurately operationalised, similar to that done by Lee *et al*. 1996, so that ‘The feasibility of R&D plans’ was rephrased to ‘The appropriateness of avocado R&D proposals submitted to SAAGA by research institutions’. In addition, a standardised presentation was given to respondents prior to them completing the questionnaire. Meetings were scheduled with a group of respondents at their research institute, at a board and research committee meeting, to go through each section of the questionnaire and explain its meaning before completion of the questionnaire. The respondents were specifically sensitised to the fact that the instrument measured their *perception* of the importance of and satisfaction with various R&D criteria, meaning there were no right or wrong answers. They were also assured that the document was completed anonymously and their participation was voluntary. Importantly, the vision, mission, strategic objectives and R&D objectives of SAAGA were provided to the audience.

The questionnaire, along with a cover letter presented in Appendix 1, was handed to respondents for immediate completion just after the presentation had been given. This ensured that a high response rate was achieved. To prevent any time-effects impacting on the cross-sectional study, the visits were all scheduled between 12 and 19 August 2010. Unfortunately, not all the members of the target population could attend the presentations on the selected dates, and in such cases they were given a short briefing via telephone and the questionnaire was e-mailed to them. The majority of these respondents indicated that they were not concerned about anonymity and sent back their completed questionnaires via e-mail, while others were hand-collected by the author or hand-delivered to a central point (the business address of the author). All the completed questionnaires were received by the author within one month of each other.

The questionnaire (Appendix 2) was classified as a semi-structured questionnaire and took about 15–20 minutes for completion. The instrument was divided into four sections. It started at Section A, where category (sponsor or researcher), years of experience in the avocado industry and employer data were obtained. The experience and employer information was not required to test the hypotheses. It was included since it provided greater background on participants and did not require much time, although the principal demographic data of interest were sponsor versus researcher. Section B contained 29 questions (repeated measures of R&D criteria) divided into five sub-categories: inputs, throughputs, outputs, outcomes and strategy. These criteria can be classified as quantitative subjective metrics. In contrast to Section B, Section C allowed participant input and required them to rate their own R&D criteria, combining a qualitative and quantitative approach. Both Section B and C made use of a five-point Likert scale to measure importance and satisfaction with each criterion. The Likert scale provided interval data, as explained in the statistics section. Section D allowed for purely qualitative inputs and comments by respondents.

4.3.2 Calculation of selected R&D metrics

To address sub-problem C, historical data were collected from SAAGA, the ARC-ITSC, University of KwaZulu-Natal, University of Pretoria, University of Stellenbosch, Tshwane University of Technology, Citrus Research International (CRI), consultants and Westfalia SA. The data focused on financial and human resources allocated to avocado R&D from 2000 to 2009. Official inflation figures were obtained from

Statistics South Africa. Lastly, data on the number of SAAGA yearbook publications from 2000 to 2009 were collected.

Annual trends and compounded annual growth rates were calculated for real R&D funding, the research intensity (R&D funding/industry revenue), R&D personnel and the number of SAAGA research reports. These criteria can be classified as quantitative objective metrics. Specific details were provided in section 4.5.

4.4 Population and sample

The study population consisted of individuals who fund and conduct avocado R&D in South Africa. Industry R&D funding was provided by SAAGA, although the research institutions themselves also obtained funding from other sources to cover overhead expenses. SAAGA represented 437 members in 2010 (SAAGA, 2010). A pilot study to investigate a suitable target population for the study, using an unstructured interview (data not shown) of 30 randomly selected growers (random probabilistic sampling), revealed that these individuals had limited overall insight into the role of R&D in executing SAAGA strategy and the R&D function in general. Furthermore, these individuals did not have direct decision-making authority that affected R&D activity or funding, and decisions were made on their behalf by the board and research committees of SAAGA. To ensure valid responses from the research instrument, it was decided that the population of R&D sponsors should be limited to the board (10 members) and research committee members of SAAGA (15 members), consisting of 22 individuals in total (three individuals were members of both the board and research committee). The population of researchers were classified as active avocado researchers (18 researchers) and research managers (three), with at least an MSc or equivalent qualification, who had conducted or managed research for SAAGA since 2000. This excludes support technicians and administrative personnel, but includes post-graduate students studying towards a PhD or equivalent degree. The members of the research category totalled 20, since one research manager was also undertaking individual research.

The overall population size was relatively small ($n=42$, $n<100$), so it was decided to sample the entire population (Leedy and Ormrod, 2005). Specific details and frequency distributions of the population are provided in the results section.

4.5 Data analysis and techniques

The details of data scales and analysis methods in the study are summarised in Table 4.1. The table is explained by starting with descriptive statistics and correlations for each sub-problem, before detailing the analysis of variance and qualitative analyses.

Table 4.1. The research sub-problems, objectives, data source, type and scale and statistical tests to analyse the data

Research sub-problem	Objectives	Data source and type	Scale	Statistics
A and B. Importance of and satisfaction with different avocado R&D criteria	Section A. Demographics - Category (sponsor or researcher)	Question-naire, Quantitative	Nominal	- Descriptive (frequency distribution)
	Section A. Demographics - Years of experience		Ratio	- Descriptive (means)
	Section A. Demographics - Employer		Nominal	- Descriptive (frequency distribution)
	Section B. Rating of 29 R&D criteria using a Likert scale - Importance Section B. Rating of 29 R&D criteria using a Likert scale - Satisfaction		Interval	- Descriptive (means, correlations) - Multivariate repeated measures analysis of variance - *Post hoc* Tukey test
	Section C. Listing of additional R&D metrics by sponsors and researchers	Question-naire, Qualitative	Nominal	- Qualitative analysis
	Section C. Importance and satisfaction ratings of additional R&D metrics using a Likert scale (if applicable)	Question-naire, quantitative	Interval	- Descriptive (means) - Multivariate repeated measures analysis of variance - *Post hoc* Tukey test
	Section D. Comments or notes (if applicable)	Question-naire,	Nominal	- Qualitative analysis

		qualitative		
C. Calculate trends in selected R&D metrics from 2000-2009	a. Avocado R&D funding, CPI figures b. Avocado research intensity (R&D funding / industry revenue) c. Avocado R&D personnel d. SAAGA research report numbers	Historical data, Quantitative	Ratio	- Descriptive (counts, averages) - Annual real geometric growth rate - Qualitative comparison with questionnaire data

Source: Researcher's compilation from Chapter 4.

Descriptive statistics were used to describe the nominal data collected for sub-problem A, B and C. Nominal data is rather limited, and can only be counted and/or a mode, or the most frequently occurring value, calculated. Apart from counting characteristics, ratio data (provided by the experience data) also allows for the calculation of a median, the value above which and below which half of the scores lay, as well as a mean. For the purpose of the study all the demographic variables were summarised using frequency distributions and percentages, except for the experience data which were presented using a mean and confidence intervals. For sub-problem A specifically, interval data was collected, provided by the Likert scale ratings of importance of and satisfaction with 29 variables, which were used to calculate means and confidence intervals. A scatter-plot of importance and satisfaction ratings for the R&D criteria was developed, and if a linear relationship appeared to be present, then a Pearson product-moment correlation was performed. To ensure the data complied with the assumptions of this parametric test, the dependent variables were tested for normality using the Kolmogorov-Smirnov (K-S) test. The null hypothesis of data distribution was that the data are not different from a normal distribution, while the alternative hypothesis was that the data are different from a normal distribution. A normal distribution was therefore indicated by $p>0.05$, when the null hypothesis is not rejected. If the dependent variables were not normally distributed (K-S $p<0.05$), then the distribution and characteristics of the data were inspected to decide if the data had to be transformed to fit the normal distribution. If the Pearson correlation was significant ($p<0.05$), then the null hypothesis (hypothesis m) was rejected and a linear correlation existed between the variables. The correlation coefficient (r) represented the linear relationship between the variables and can range from -1.00 to +1.00. A value of -1.00 represented a perfect negative

correlation while a value of +1.00 represented a perfect positive correlation (note: no causation is inferred). A value of 0.00 represented a lack of correlation. If the correlation coefficient is squared, then the coefficient of determination is obtained (r^2); presenting the proportion of common variation in the two variables (i.e. the "strength" of the relationship) (Lee, 1999; Leedy and Ormrod, 2005; Diamantopoulos and Schlegelmilch, 2006).

For sub-problem C, real and nominal avocado industry R&D funding was calculated. SAAGA's gross R&D investment was obtained from their financial records. Quantification of the specific gross financial contribution towards South African avocado R&D by WTS, the ARC-ITSC and universities could only be estimated using crude assumptions. It was assumed that at least 25% of WTS expenditures (less SAAGA income received) were related to avocado industry R&D between 2000 and 2009. Government funding for the ARC-ITSC and universities was generally awarded at an aggregate level, although under certain conditions universities received additional funding from government on a per-project basis. The funding levels by the ARC-ITSC were estimated using a Consumer Price Index adjusted cost figure of R1.05 million per researcher in 2005 (Liebenberg, Pardey and Khan, 2010). It was further assumed that each ARC-ITSC researcher serviced at least three industries in the sub-tropical fruit sub-sector at one time, so that the ARC-ITSC contribution in 2005 was approximately R350 000 per researcher conducting avocado industry R&D. Personal communication with university research programme leaders (Professors J. Bower, L. Korsten and B. Botha) provided approximate figures for contributions by universities, consisting of overhead (salary) payments, student bursaries, other supplementary funding, depreciation and project running costs less the SAAGA funding obtained. The real change in R&D funding was calculated using Consumer Price Index statistics (Table 4.2). Equivalent funding levels based on monetary values of the year 2009 were calculated according to the method described in Bender and Ward (2002).

To calculate the research intensity, the annual nominal R&D funding was divided by the corresponding industry revenue. The average annual local market price was used for the industry revenue calculations. It was assumed to be an approximate figure for the free-on-board (fob) price of export fruit, gross sales price of the local market and the direct sales to retailers and the informal market (DAFF, 2010). Volume estimates were obtained from unpublished SAAGA records. The industry revenue was a very conservative estimate, because it did not consider sales

from approximately 10–15% of the annual avocado volumes used for processing activities (e.g. guacamole and avocado oil). Virtually all avocado R&D is focused on fresh fruit so the revenue calculation ignored the sales from processed avocado.

The number of avocado researchers in the industry was obtained from unpublished SAAGA data showing the projects allocated to researchers on an annual basis from 2000 to 2009. The publication of SAAGA R&D activities was estimated by counting the number of papers in the SAAGA yearbook from 2000 to 2009 (SAAGA, 2000; 2001; 2002; 2003; 2004; 2005; 2006; 2007; 2008 and 2009).

Table 4.2 Average annual Consumer Price Index (CPI) for South Africa

Year	CPI Percentage
2000	5.4%
2001	5.8%
2002	9.1%
2003	5.8%
2004	1.4%
2005	3.4%
2006	4.6%
2007	7.2%
2008	11.5%
2009	7.1%

Source: Statistics South Africa, (2010): The Consumer Price Index for 2000 to 2009.

There were multiple variables involved in hypotheses A–L (sub-problem A and B), as independent variables could be distinguished (viz. category with two levels, sponsor and researcher, and R&D criteria with 29 levels) as well as two dependent variables (importance and satisfaction). The R&D criteria were repeated measurements of the population, and the analysis therefore followed a multivariate repeated measures analysis of variance approach. To ensure the data complied with the assumptions of this parametric test, the dependent variables were tested for normality using the Kolmogorov-Smirnov (K-S) test as described above. Using parametric statistics minimises the Type II error probability. A Type II error occurs if the null hypothesis is not rejected although it is false and hence should actually have been rejected (Diamantopoulos and Schlegelmilch, 2006). The multivariate analysis of variance will be used to test all effects, and only if it is significant ($p<0.05$) will a univariate analysis

be performed. This will be done to avoid increasing the Type I error probability. A Type I error occurs when the null hypothesis is rejected when it is actually true (Diamantopoulos and Schlegelmilch, 2006). Effects between the category factor, effects within the 29 repeated R&D criteria and interactive effects between the categories and the R&D criteria for the dependent variables of importance and satisfaction were calculated. If significant differences were found ($p<0.05$), then the relevant null hypotheses (hypotheses A–L) were rejected and a *post hoc* Tukey HSD used to indicate where the statistical differences were located.

For sub-problem C, the geometric growth rate and linear trend analysis of real avocado R&D funding, research intensity, research personnel and the number of SAAGA research papers were calculated. Statistica version 9.1 (Statsoft, 2010) was used for all the analyses. To determine if the calculated metrics corresponded with the opinions of respondents, a basic qualitative approach was followed to evaluate the proposition. This method is not very prescriptive and entails categorisation, interpretation and synthesis of the data into an overall portrait (Lee, 1999; Leedy and Ormrod, 2005). A degree of judgment and inductive reasoning was employed to conclude whether the stated proposition was supported or not. The comments and suggestions from Section D in the questionnaire were also analysed qualitatively according to the guidelines outlined above.

4.6 Reliability and validity

To determine the validity of the research project as a whole, internal and external validity had to be considered. Internal validity is the extent to which the research design allows cause-and-effect conclusions to be made. External validity is the extent to which the results can be generalised to other contexts. Apart from the internal and external validity of the research study, the research instrument used should also be valid and reliable. The validity of an instrument is the extent to which it is measuring what it is supposed to be measuring. Reliability is the consistency with which a measuring instrument yields a result when the entity being measured has not changed. Reliability is a condition for validity, but does not guarantee validity.

The detailed approach to ensure reliability and validity of the research before, during and after completion of the study is provided in Chapter 6, section 6.2.

4.7 Ethical issues

Most of the ethical issues that require consideration in a research study can be divided into four categories: protection from harm, informed consent, right to privacy, and honesty with colleagues.

The study did not expose the respondents to any physical and/or psychological harm that is appreciably higher than the risks of day-to-day living. Participation in the study was strictly voluntary and respondents were informed of the nature of the study and asked for their informed consent to participate in the study. The right to privacy was respected and the anonymity of participants guaranteed. Full acknowledgement of material and findings of other studies and their authors was provided in the list of references. Findings were reported in an honest fashion (Leedy and Ormrod, 2005).

4.8 Limitations

The *a-priori* limitations of the research are discussed in Chapter 1, section 1.7, while a more comprehensive discussion of the research limitations after completion of the study is presented in Chapter 6, section 6.3.

4.9 Nature and form of results

The data were analysed with the techniques specified in section 4.5. The descriptive data generated for all the sub-questions were mainly presented in the form of tables. Scatter-plot figures of significant correlations were provided along with the relevant statistical values (r^2 and p). Results of the variance analysis were provided in text noting relevant statistical scores (F-value, degrees of freedom and p). The findings of the *post hoc* testing were summarised in figure and table format using a scheme where means with letters in common were not significantly different. Criteria with statistically similar scores to the single highest rated criterion were recommended for inclusion in an avocado R&D effectiveness tool along with qualitative inputs by respondents. The weighted satisfaction scores (weighted by importance ratings) were used to provide an estimate of current R&D effectiveness. Differences between sponsor and researcher ratings as well as interactive differences (if applicable) between category and R&D criteria for the importance and satisfaction ratings were presented as explained above for the variance analysis. The proposition arguments

were presented in text and table format. Quotes and thick descriptions were included where applicable.

The calculations that were done for sub-problem C were presented in tables and scatter-plots. Relevant statistical variables were shown (compounded growth rate and r^2).

4.10 Consistency matrix

The consistency matrix is provided in Table 4.3. The diagram allows evaluation of the consistency throughout the study, by directly comparing the problem statement, research sub-questions, the literature review, hypothesis and propositions, the data collected and the data analysis method. The matrix showed that accurate alignment of the different elements existed in the study.

Table 4.3 Consistency matrix of the study measuring the effectiveness of avocado R&D in South Africa

Main Problem: No method is known to best measure the effectiveness of avocado industry R&D in South Africa				
Sub-questions	**Literature review section**	**Hypothesis or propositions**	**Data to be collected**	**Data analysis**
a: How important do avocado R&D sponsors and researchers in South Africa perceive different criteria to be in the domain of R&D inputs, throughputs, outputs, outcomes and strategy?	3.1-3.8	Hypotheses A, B, E, F, I, J, M, N	Primary data, quantitative analysis	Descriptive statistics (frequency distribution, means, correlations), and variance analysis
b. How satisfied are avocado R&D sponsors and researchers in South Africa with different criteria in the domain of R&D inputs, throughputs, outputs, outcomes and strategy?	3.1-3.8	Hypotheses C, D, G, H, K, L, M, N	Primary data, quantitative analysis	Descriptive statistics (frequency distribution, means, correlations), and variance analysis
c. How do perceptions of sponsors and researchers compare with calculations of quantitative objective R&D criteria?	3.4, 3.8	Proposition A	Secondary data, qualitative analysis	Inductive reasoning

Source: Researcher's compilation of this research proposal (Chapter 1-4).

5 Chapter 5: Research results

Abstract

The chapter reported on and interpreted the results of the research in the context of the research problem to provide a method to best measure the effectiveness of avocado industry R&D in South Africa. The survey had a response rate of over 95%. Sponsors and researchers had 12–13 years of experience in the avocado industry. The results of research sub-question A showed that a difference existed in the level of importance of 29 R&D criteria. The *growth rate in the publication of SAAGA R&D activities* was the least important. The *skill level of avocado researchers* had the highest importance score and 15 other criteria were found to be equally important. No difference existed between the importance ratings of sponsors and researchers and no interactive effects were found for the importance scores. A positive linear relationship was found between the importance of and satisfaction with R&D criteria. The results of sub-question B showed a difference in the level of satisfaction between the 29 R&D criteria. The respondents were least satisfied with the *growth rate in the number of avocado researchers*, *having enough avocado R&D facilities*, *active communication between avocado R&D institutions* and *the growth rate in the publication of SAAGA R&D activities*. The highest satisfaction score was assigned to *SAAGA follows the right strategy*. There was no difference between sponsors and researchers and their level of satisfaction with the R&D criteria and no interactive effects for satisfaction scores were found. Results for research sub-problem C revealed that the gross funding of avocado R&D showed no real growth and that research intensity was stagnant between 2000 and 2009. The number of SAAGA researchers and paper outputs declined between 2000 and 2009. The satisfaction scores of respondents corresponded with the actual quantitative objective metrics and the proposition was supported. Qualitative inputs suggested the use of metrics relating to researcher capacity, financial or economic returns of R&D, international collaboration, technology transfer and strategically guided research projects are important to consider. The data indicated that avocado R&D is currently moderately effective.

5.1 Introduction

The research results section is concerned with the analysis, presentation and interpretation of the results of the study. To avoid any possible confusion, where possible other research is not referred to in this section. The aim of this chapter is to provide a focused analysis of the data relevant to the main problem and research question and sub-questions of the study. The chapter starts with a profile of the questionnaire respondents and is followed by the results, arranged according to research sub-question. The results of each sub-question are presented according to hypothesis, following a format that first presents descriptive statistics of each dependent variable related to the assumptions of the statistical analysis. This is followed by an analysis of the research hypotheses and proposition, and concludes with a *post-hoc* analysis (if applicable) and interpretations. Next, the categorisation, interpretation and synthesis of the qualitative inputs of the respondents into an overall portrait are provided. A brief concluding section summarises the results in context of the main research problem, research question and sub-questions.

5.2 Profile of respondents

The profiles of the respondents in terms of the study category, employer, number of respondents and their experience in the avocado industry are summarised in Table 5.1. The surveyed population consisted of 42 individuals, of which 40 responded to the questionnaire, providing a response rate of 95.2%. The two non-responses were from the sponsor category, one being self-employed and one working for a local agribusiness. The survey was considered to be representative of the population based on the high overall response rate as well as the high employer response rates (>87.5%) in the sponsor category (Table 5.1).

A total of 20 sponsors and 20 researchers participated in the survey. All the researchers and many of the sponsors had technically oriented qualifications in the agricultural sciences. From personal observation, their demographic and cultural backgrounds (gender, race, religion, and language) were relatively similar (data not shown). One of the researchers and two of the sponsors did not complete the satisfaction ratings for all of the 29 listed questions. In the comments section of the questionnaire, they noted that they could not provide an accurate estimate of the satisfaction ratings. These three questionnaires were thus excluded from the

analysis. Effectively, the sample used in the study was therefore 37, comprising 18 sponsors and 19 researchers. This did not influence the ability to generalise the results of the study, but indicated that the satisfaction ratings of the research may be biased.

The sponsor group mainly comprised self-employed avocado growers and individuals classified as being employed by 'others'. The 'other' category mainly included SUBTROP employees, but employees of all agribusinesses apart from Westfalia were also included there. The most experienced members of the sponsor category were Westfalia, followed by the University of KwaZulu-Natal, self-employed growers and others. The sponsors were somewhat more experienced than the researchers, with a mean of approximately 13 years' experience compared to 12 years for the researchers (Table 5.1).

The researchers were mainly represented by WTS and the ARC-ITSC. On average, the most experienced researchers were self-employed, but these researchers showed a large variation in experience that ranged from five to 34 years in the avocado industry. The University of KwaZulu-Natal was the least experienced on average, but was only represented by one researcher. The responses of another university employee, who served on the SAAGA board and research committee, were considered as part of the sponsor category.

The mean level of experience of the population was 12.5 years, or fell between 9.5 and 15.5 years with a 95% level of confidence (Table 5.1).

Table 5.1. Profile and response rate of participants in the study to measure the effectiveness of avocado R&D in South Africa

Category	Employer	Respondents (response rate)	Respondents percentage of total sample (n=40)	Years of experience, mean ± 95% C.I. (min – max)
Sponsor	Westfalia	3 (100%)	7.5%	21.7 ± 6.3 (19-24)
	ARC-ITSC	0 (n/a)	0%	n/a
	Self-employed	7 (87.5%)	17.5%	17.4 ± 8.2 (10-30)
	University	1 (100%)	2.5%	21.0 (21-21)
	Other	9 (90.0%)	22.5%	6.6 ± 5.3 (1-21)
Subtotal		**20 (90.9%)**	**50.0%**	**13.4 ± 4.4 (1-30)**
Researcher	WTS	7 (100%)	17.5%	8.4 ± 7.6 (2-26)
	ARC-ITSC	9 (100%)	22.5%	13.1 ± 6.9 (2-30)
	Self-employed	3 (100%)	7.5%	16.3 ± 38.5 (5-34)

	University	1 (100%)	2.5%	7.0 (7-7)
	Other	0 (n/a)	0%	n/a
Subtotal		**20 (100%)**	**50.0%**	**11.7 ± 4.4 (2-34)**
Grand total		**40 (95.2%)**	**100%**	**12.5 ± 3.0 (1-34)**

5.3 Results

The results are presented to address the main problem statement: No method is known to best measure the effectiveness of avocado industry R&D in South Africa, resulting in sub-optimal management of the R&D function. More specifically, the research question was addressed: Which criteria within the entire R&D system are considered by industry role players to be the best in measuring the effectiveness of avocado R&D in South Africa and how satisfied are industry role players with the performance in these criteria?

5.3.1 Sub-question A

Sub-question A asked how important avocado R&D sponsors and researchers in South Africa perceive different criteria to be in the domain of R&D inputs, throughputs, outputs, outcomes and strategy. Hypotheses A, B, E, F, I, J, M, N were generated from this sub-question. For ease of reference they are repeated here before their specific results from the data analysis are presented and interpreted.

Data distribution of the importance ratings

The null hypothesis of data distribution is that the data are not different from a normal distribution; while the alternative hypothesis is that the data are different from a normal distribution. This is a standard and generic statistic principle, so these hypotheses were not listed in the text. The K-S test showed a significant difference ($0.25<d<0.49$; $p<0.05$) for all the importance ratings; therefore the null hypothesis was rejected and the alternative hypothesis was supported. It was concluded that the data were not normally distributed. Visually the data generally had a negatively (left) skewed distribution (data not shown). However, the *F*-test used for the analysis of variance is remarkably robust to deviations from normality and skewness of the distribution usually does not have a sizable effect on the *F*-statistic. Furthermore, deviations from normality do not matter much among larger sample sizes ($n>30$) because of the central limit theorem. It was therefore decided to continue using the

proposed parametric tests and not to transform the data to fit a normal distribution (Lindman, 1974).

Hypothesis A

Ho: There is no difference in the level of importance between R&D criteria (29 levels) to measure the effectiveness of avocado industry R&D in South Africa.

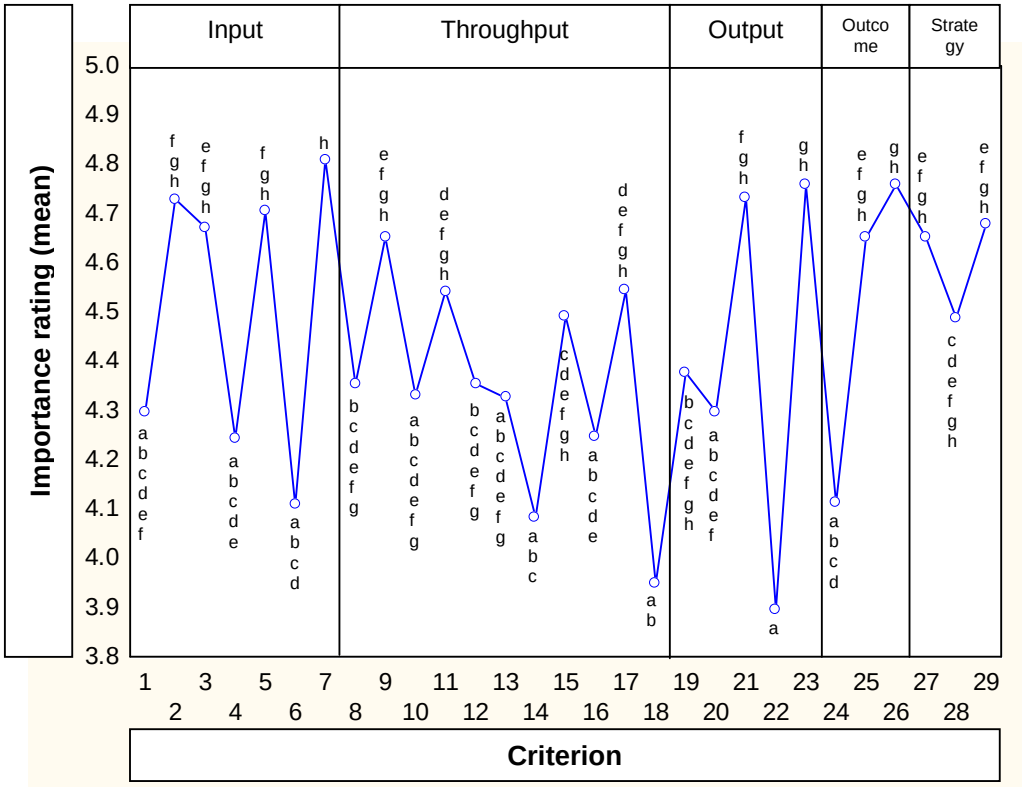
Hypothesis B

Ha: There is a difference in the level of importance between R&D criteria (29 levels) to measure the effectiveness of avocado industry R&D in South Africa.

The multivariate within-subjects repeated measures analysis of variance showed that a significant difference existed between the importance ratings (F = 8.97, df = 28, 8; P=0.002). This was confirmed by univariate analysis (F = 9.03, df = 28, 980; P<0.001). Hypothesis A, the null hypothesis, was therefore rejected and hypothesis b, the alternative hypothesis, supported. It was concluded that there was a difference in the level of importance of 29 R&D criteria to measure the effectiveness of avocado R&D in South Africa. The *post-hoc* Tukey HSD test identified the specific differences between the different criteria (Fig. 5.1). No consistent pattern in significant differences between criteria in the different categories (*viz*. inputs, throughputs, outputs, outcomes and strategy) was observed. The input metrics obtained an average importance score of 4.53, throughput metrics 4.35, output metrics 4.41, outcome metrics 4.50 and strategy 4.61 (data not shown).

Criterion 22, the *growth rate in the publication of SAAGA R&D activities*, had the lowest mean importance score (3.9), which was significantly lower than the score of criteria 2, 3, 5, 7, 8, 9, 11, 12, 15, 17, 19, 21, 23, 25, 26, 27, 28, and 29. The highest mean importance score (4.8) was assigned to criterion 7, *the skill level of avocado researchers*. It had a significantly higher score compared to the scores of criteria 1, 4, 6, 8, 10, 12, 13, 14, 16, 18, 20, 22, and 24. The criteria with importance scores not significantly different to the highest score of criterion 7 were 2, 3, 5, 9, 11, 15, 17, 19, 21, 23, 25, 26, 27, 28, and 29 (Fig. 5.1). The specific criteria linked to the respective numbers are provided in Appendix 2. For ease of reference, the most important criteria identified in Figure 5.1 are listed according to rank in Table 5.2.

Fig. 5.1. The mean importance ratings assigned to 29 different R&D criteria in the avocado industry of South Africa (Criteria 1-7 referred to R&D inputs, 8-18 to throughputs, 19-23 to outputs, 24-26 to outcomes and 27-29 to strategy)



Note: Means with letters in common are not significantly different (p>0.05, Tukey HSD test).

Table 5.2. The most important R&D criteria identified by the South African avocado industry

Rank	Number	Category	Metric
1	7	Input	The skill level of avocado researchers
2	23	Output	Quality of avocado R&D work done for SAAGA
3	26	Outcome	Degree of long-term competitive advantage provided due to the application of SAAGA R&D results
4	21	Output	Usefulness of avocado technology developed for SAAGA, e.g. pest and disease management, quarantine treatments for market access, post harvest practices, etc
5	2	Input	Having enough avocado R&D funding
6	5	Input	The degree of professionalism shown by avocado researchers
7	3	Input	Having enough avocado R&D facilities (institutions and equipment)

8	29	Strategy	The effective implementation/execution of SAAGA R&D strategic objectives
9	27	Strategy	SAAGA follows the right strategy
10	9	Throughput	The appropriateness of avocado R&D priorities selected by SAAGA
11	25	Outcome	Effects of SAAGA R&D on improvement of avocado pre and post harvest management practices (e.g. cost savings and/or quality improvements)
12	17	Throughput	The adequate availability of avocado R&D findings in SAAGA (progress reports, verbal reports, research reports, presentations, etc. by research institutions)
13	11	Throughput	Adaptability of avocado researchers to technology changes (i.e. molecular methods, computers, new equipment etc.)
14	15	Throughput	Collaboration between avocado R&D institutions, producers and marketers
15	28	Strategy	The alignment of avocado strategies at different levels, e.g. the fit between SAAGA strategy and SAAGA R&D strategic objectives
16	19	Output	The success rate in achieving the objectives provided by research institutions in SAAGA R&D proposals.

Hypothesis E

Ho: There is no difference between categories (two levels, sponsor and researcher) in the level of importance of R&D criteria (29 levels) to measure the effectiveness of avocado industry R&D in South Africa.

Hypothesis F

Ha: There is a difference between categories (two levels, sponsor and researcher) in the level of importance of R&D criteria (29 levels) to measure the effectiveness of avocado industry R&D in South Africa.

The multivariate repeated measures analysis of variance showed that no significant difference existed between the sponsors and researchers (F = 0.90, df = 2, 34; P=0.417). Hypothesis E (the null hypothesis) was therefore not rejected, and it was concluded that there was no difference between sponsors and researchers and their perceptions of the importance of 29 R&D criteria to measure the effectiveness of avocado R&D in South Africa. The mean (± 95% C.I.) importance ratings of the sponsors and researchers were 4.52 ± 0.18 and 4.37 ± 0.18, respectively (data not shown).

Hypothesis I

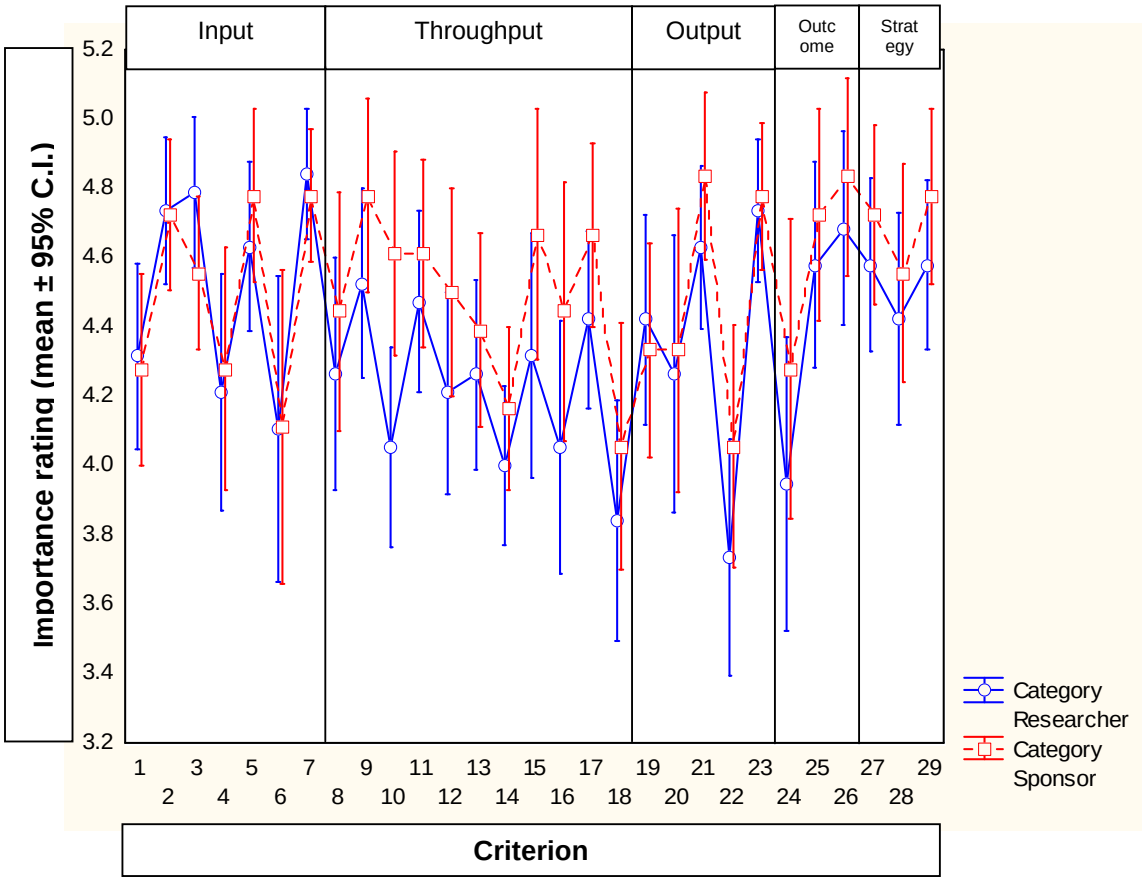
Ho: There is no interactive effect between categories (two levels, sponsor and researcher) and R&D criteria (29 levels) in the level of importance to measure avocado industry R&D effectiveness in South Africa.

Hypothesis J

Ha: There is an interactive effect between categories (two levels, sponsor and researcher) and R&D criteria (29 levels) in the level of importance to measure avocado industry R&D effectiveness in South Africa.

The multivariate within effects of the repeated measures analysis of variance showed that no significant interaction was present between category and criteria for the importance variable (F = 1.48, df = 28, 8; P=0.292). Hypothesis I, the null hypothesis, was therefore not rejected and it was concluded that no significant interaction existed between sponsors and researchers and their perception of the importance of R&D criteria to measure R&D effectiveness in the South African avocado industry. The importance scores of sponsors and researchers for each metric are summarised in Figure 5.2.

Fig. 5.2. The importance ratings (mean ± 95% C.I.) of sponsors and researchers assigned to 29 different R&D criteria in the avocado industry of South Africa (Criteria 1-7 referred to R&D inputs, 8-18 to throughputs, 19-23 to outputs, 24-26 to outcomes and 27-29 to strategy)



Hypothesis M

Ho: There is no relationship between the importance of and satisfaction with R&D criteria (29 levels) in the South African avocado industry.

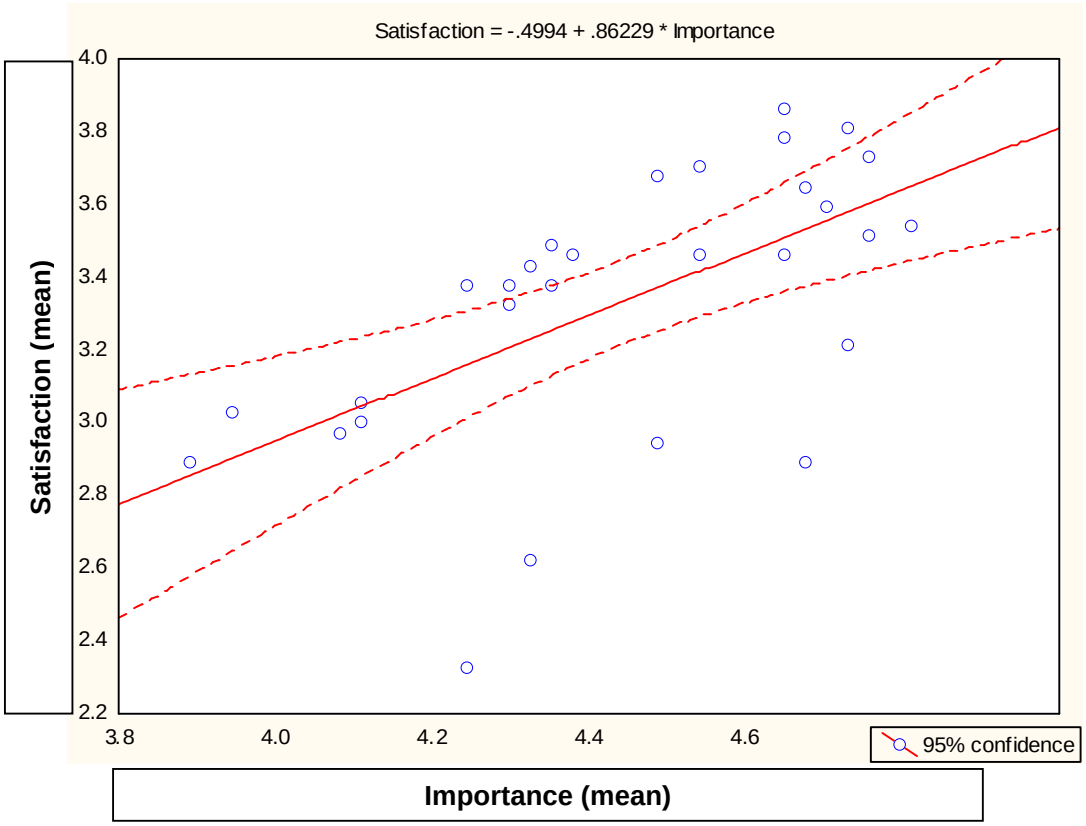
Hypothesis N

Ha: There is a relationship between the importance of and satisfaction with R&D criteria (29 levels) in the South African avocado industry.

The scatterplot of the mean importance and satisfaction ratings per criterion showed support for a linear relationship between the variables. This was confirmed by the Pearson's product moment correlation, which indicated that a significant positive correlation existed between the importance and satisfaction scores (Satisfaction =

0.86.Importance - 0.50, r^2=0.36, p<0.001) (Fig. 5.3). The null hypothesis (hypothesis M) was rejected and the alternative hypothesis (hypothesis N) supported. It was concluded that there was a relationship between importance and satisfaction. As indicated by the r^2 value, the amount of common variation explained by the linear function was relatively low (36%). In other words, although a significant relationship existed, the linear function did not fit the data very well (Diamantopoulos and Schlegelmilch, 2006). The positive relationship between importance and satisfaction scores indicated that respondents were more satisfied with those criteria that were more important in measuring the effectiveness of avocado R&D.

Fig. 5.3. Scatterplot and linear fit function of the mean importance and satisfaction ratings of sponsors and researchers assigned to 29 different R&D criteria in the avocado industry of South Africa



5.3.2 Sub-question B

Sub-question B asked how satisfied avocado R&D sponsors and researchers in South Africa are with different criteria in the domain of R&D inputs, throughputs, outputs, outcomes and strategy. Hypotheses C, D, G, H, K, L, M, and N were generated from this sub-question. For ease of reference they are repeated here before their specific results from the data analysis are presented and interpreted.

Results and interpretation of data for hypotheses M and N were addressed in section 5.3.1 and will not be repeated in this section.

Data distribution of the satisfaction ratings

As mentioned earlier, the null hypothesis of data distribution is that the data are not different from a normal distribution; while the alternative hypothesis is that the data are different from a normal distribution. The K-S test showed a significant difference ($0.186<d<0.457$; $0.150>p>0.001$) for all except two of the satisfaction ratings; therefore the null hypothesis was rejected and the alternative hypothesis was not rejected in 27 out of 29 cases. In two cases the null hypothesis was not rejected. It was concluded that the data were not normally distributed in 27 out of 29 cases and were normally distributed in 2 out of 29 cases. Based on the arguments presented in section 5.3.1, it was decided to continue using the proposed parametric tests and not to transform the data to fit a normal distribution (Lindman, 1974).

Hypothesis C

Ho: There is no difference in the level of satisfaction with R&D criteria (29 levels) in the South African avocado industry.

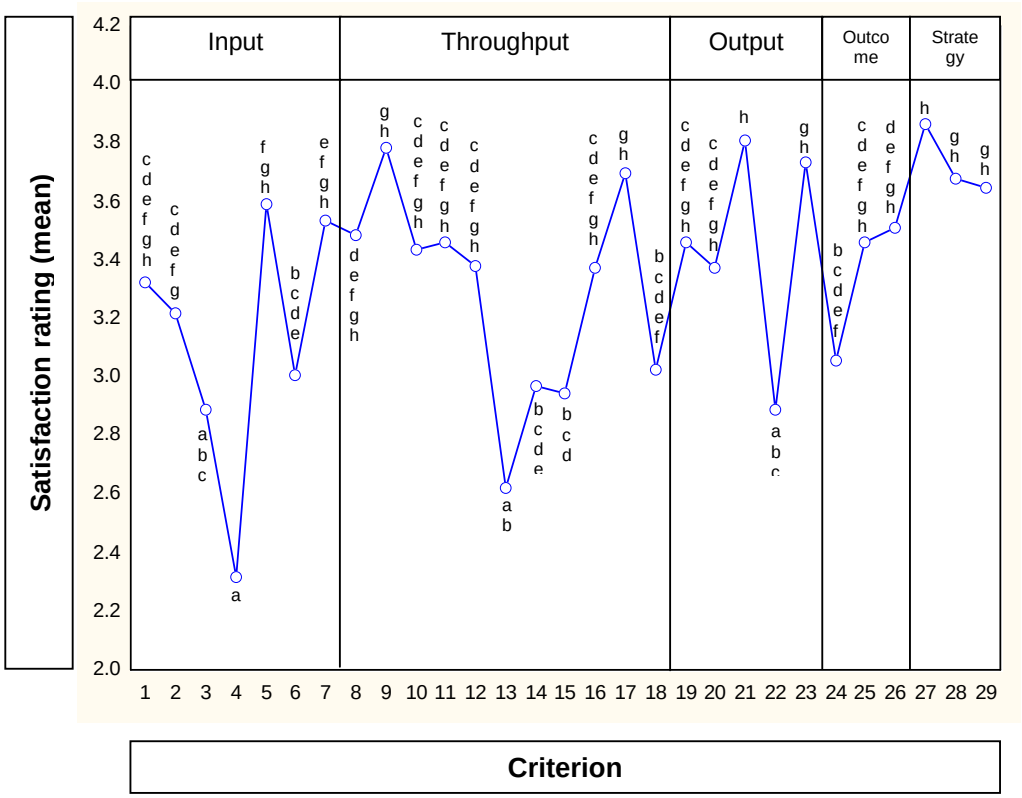
Hypothesis D

Ha: There is a difference in the level of satisfaction with R&D criteria (29 levels) in the South African avocado industry.

The multivariate within-subjects repeated measures analysis of variance showed that a significant difference existed between the satisfaction ratings (F = 3.27, df = 28, 8; P=0.043). This was confirmed by univariate analysis (F = 11.92, df = 28, 980; P<0.001). Hypothesis C was therefore rejected and hypothesis D supported and it was concluded that there was a difference in the level of satisfaction between 29 avocado R&D criteria in South Africa. The *post-hoc* Tukey HSD test identified the specific differences between the different criteria (Fig. 5.4). No consistent pattern in significant differences between criteria in the different categories (*viz*. inputs, throughputs, outputs, outcomes and strategy) was observed, and significantly higher satisfaction ratings were identified in each category. Criterion 4, the *growth rate in the number of avocado researchers*, had the lowest mean satisfaction score (2.3), which was significantly lower than all the other criteria apart from criterion 3, 13 and 22. The

highest mean satisfaction score (3.9) was assigned to criterion 27, *SAAGA follows the right strategy*. It had a significantly higher score compared to the scores of metrics 2, 3, 4, 6, 13, 14, 15, 18, 22, and 24. The specific metrics linked to the respective numbers are provided in Appendix 2. The satisfaction ratings are listed in declining order in Table 5.3.

Fig. 5.4. The mean satisfaction ratings assigned to 29 different R&D criteria in the avocado industry of South Africa (Criteria 1-7 referred to R&D inputs, 8-18 to throughputs, 19-23 to outputs, 24-26 to outcomes and 27-29 to strategy)



Note: Means with letters in common are not significantly different (p>0.05, Tukey HSD test).

Table 5.3. The satisfaction ratings, in declining order, of 29 R&D criteria of the South African avocado industry (The criteria that were found to be most important are underlined)

Rank	Number	Category	Metric
1	27	Strategy	SAAGA follows the right strategy
2	21	Output	Usefulness of avocado technology developed for SAAGA, e.g. pest and disease management, quarantine treatments for market access, post harvest practices, etc

3	9	Throughput	The appropriateness of avocado R&D priorities selected by SAAGA
4	23	Output	Quality of avocado R&D work done for SAAGA
5	17	Throughput	The adequate availability of avocado R&D findings to SAAGA (progress reports, verbal reports, research reports, presentations, etc. by research institutions)
6	28	Strategy	The alignment of avocado strategies at different levels, e.g. the fit between SAAGA strategy and SAAGA R&D strategic objectives
7	29	Strategy	The effective implementation/execution of SAAGA R&D strategic objectives
8	5	Input	The degree of professionalism shown by avocado researchers
9	7	Input	The skill level of avocado researchers
10	26	Outcome	Degree of long-term competitive advantage provided due to the application of SAAGA R&D results
11	8	Throughput	The appropriateness of avocado R&D proposals submitted to SAAGA by research institutions
12	25	Outcome	Effects of SAAGA R&D on improvement of avocado pre and post harvest management practices (e.g. cost savings and/or quality improvements)
13	11	Throughput	Adaptability of avocado researchers to technology changes (i.e. molecular methods, computers, new equipment etc.)
14	19	Output	The success rate in achieving the objectives provided by research institutions in SAAGA R&D proposals
15	10	Throughput	Providing adequate budgeting layouts in R&D proposals
16	12	Throughput	Adequate knowledge of avocado researchers about new technology (i.e. molecular methods, computers, new equipment etc.)
17	20	Output	The degree of usefulness of avocado technology developed outside SAAGA, e.g. rootstocks, cultivars, pesticides, etc. developed privately within South Africa (e.g. Westfalia Technological Services)
18	16	Throughput	Efforts by research institutions to strictly pursue the objectives they provided in SAAGA R&D proposals
19	1	Input	The growth rate of total research and development (R&D) funding by the avocado industry
20	2	Input	Having enough avocado R&D funding
21	24	Outcome	Degree of short-term profit increase due to application of SAAGA R&D results
22	18	Throughput	Efforts to expand SAAGA R&D areas through diversification
23	6	Input	The ratio of avocado researchers to support staff (technicians/administrative personnel) at research institutions
24	14	Throughput	Morale at avocado R&D institutions
25	15	Throughput	Collaboration between avocado R&D institutions, producers and marketers
26	22	Output	The growth rate in the publication of SAAGA R&D activities (e.g. patents, papers, presentations at conferences)

27	3	Input	Having enough avocado R&D facilities (institutions and equipment)
28	13	Throughput	Active communication between avocado R&D institutions
29	4	Input	The growth rate in the number of avocado researchers

Hypothesis G

Ho: There is no difference between categories (two levels, sponsor and researcher) in the level of satisfaction of R&D criteria (29 levels) in the South African avocado industry.

Hypothesis H

Ha: There is a difference between categories (two levels, sponsor and researcher) in the level of satisfaction of R&D criteria (29 levels) in the South African avocado industry.

The multivariate repeated measures analysis of variance showed that no significant difference existed between the satisfaction ratings of sponsors and researchers (F = 0.90, df = 2, 34; P=0.417). Hypothesis G, the null hypothesis, was therefore not rejected, and it was concluded that there was no difference between sponsors and researchers and their level of satisfaction of 29 R&D criteria in the avocado industry of South Africa. The mean (± 95% C.I.) satisfaction ratings of the sponsors and researchers were 3.31 ± 0.22 and 3.35 ± 0.21, respectively (data not shown).

Hypothesis K

Ho: There is no interactive effect between categories (two levels, sponsor and researcher) and R&D criteria (29 levels) in the level of satisfaction of the South African avocado industry.

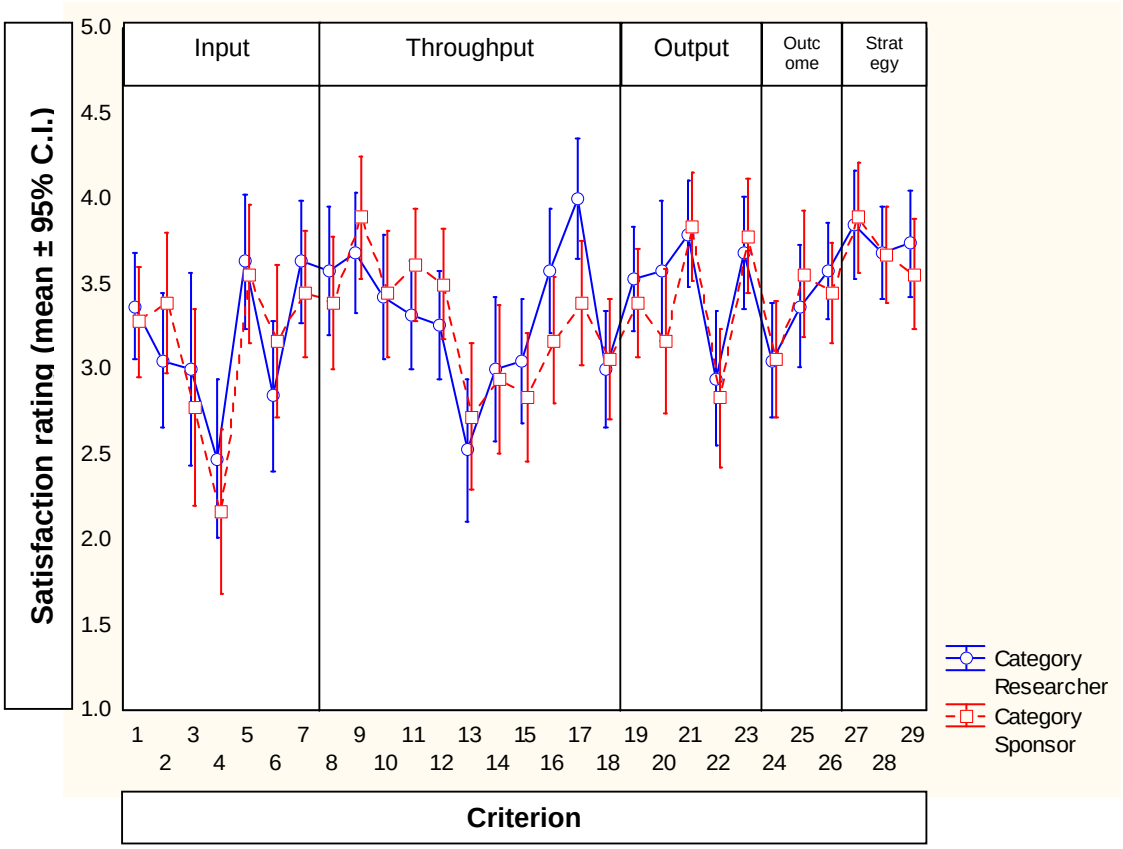
Hypothesis L

Ha: There is an interactive effect between categories (two levels, sponsor and researcher) and R&D criteria (29 levels) in the level of satisfaction of the South African avocado industry.

The within effects of the repeated measures analysis of variance showed that no significant interaction was present between category and criteria for the satisfaction variable (F = 0.73, df = 28, 8; P=0.747). Hypothesis K, the null hypothesis, was

therefore not rejected and it was concluded that no significant interaction existed between sponsors and researchers and their level of satisfaction of R&D criteria in the South African avocado industry. The satisfaction scores of sponsors and researchers for each criterion are summarised in Figure 5.5.

Fig. 5.5. The satisfaction ratings (mean ± 95% C.I.) of sponsors and researchers assigned to 29 different R&D criteria in the avocado industry of South Africa (Criteria 1-7 referred to R&D inputs, 8-18 to throughputs, 19-23 to outputs, 24-26 to outcomes and 27-29 to strategy)



5.3.3 Sub-question C

Sub-question C asked how the perceptions of sponsors and researchers compared with calculations of quantitative objective R&D criteria. The proposition of sub-question C was that actual trends of quantitative objective metrics for selected input and output criteria of the avocado industry generally aligned with the perceptions of the questionnaire respondents. The proposition is repeated here before perceptions and actual figures are presented for the relevant criteria.

Proposition

There is general agreement between the perceptions of the questionnaire respondents with calculated annual trends in real R&D funding, the research intensity (R&D funding/industry revenue), R&D personnel and the number of SAAGA research reports in the avocado industry in South Africa over ten years (2000–2009).

Annual trends in R&D funding

The questionnaire respondents had a mean (± 95% C.I.) satisfaction rating of 3.32 ± 0.22 for the growth rate in avocado R&D funding. The breakdown of the nominal SAAGA R&D funding is provided in Table 5.4. WTS showed relatively strong compounded growth in gross funding and made the largest contribution towards industry R&D funding over the period. However, net avocado R&D investment at WTS increased only marginally from 2000 to 2009 because all royalty income from R&D outputs like avocado plant patents and organic fungicides were channelled back into R&D (personal calculation from unpublished data). Also, the South African tax rate of R&D activities was reduced. Amended taxation legislation relating to research and development took effect in November 2006 (Income Tax Act 1962, Section 11D) to encourage private-sector investment in scientific and technological research and development. Government, through the Department of Science and Technology (DST), now allows a pre-tax deduction of 150% of specific research expenses as well as accelerated depreciation of assets used for research and development. Therefore, considering a local corporate tax rate of 28%, after tax real avocado R&D investment by WTS was approximately 14% less expensive after November 2006.

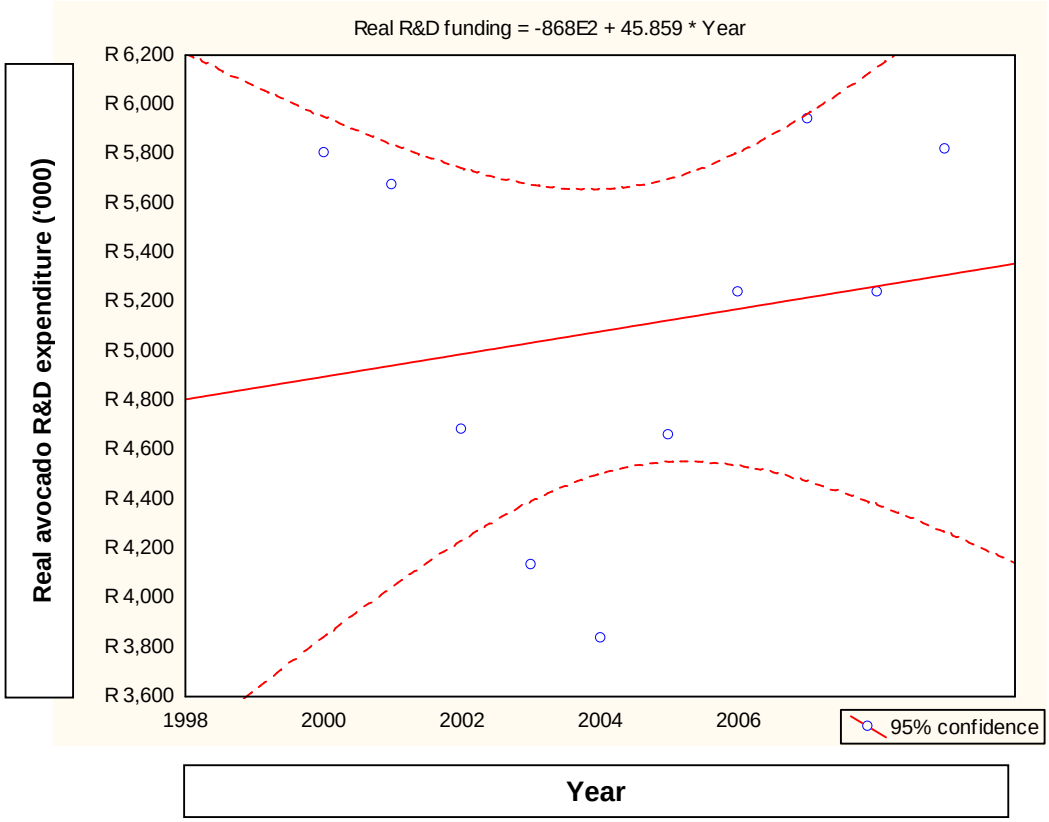
The funding from the ARC-ITSC declined notably after 2000, a direct result of fewer ARC scientists conducting avocado R&D over the period according to data obtained from SAAGA (more details provided in the R&D personnel section). Among the universities, UKZN made the largest contribution towards avocado R&D, but its funding, as well as that of other universities, declined over the period. Funding by SAAGA showed strong compounded growth and in 2009 it was the second largest contributor towards industry research. The real gross R&D funding of the avocado industry from 2000 to 2009 is presented in Figure 5.6.

Table 5.4. The estimated nominal gross R&D funding of the South African avocado industry from 2000 to 2009

Year	Nominal funding by institution ('000)[1]				
	WTS	**ARC-ITSC**	**Universities**	**SAAGA**	**Total**
2000	R572	R1,609	R635 (UKZN)	R625	**R3,441**
2001	R619	R1,413	R642 (UKZN) R240 (TUT)	R628	**R3,542**
2002	R777	R598	R630 (UKZN) R240 (TUT) R25 author est. (UP)	R826	**R3,096**
2003	R1,149	R652	R262 (UKZN) R240 (TUT) R25 author est. (UP)	R652	**R2,980**
2004	R895	R1,036	R316 (UKZN) R70 author est. (UP)	R607	**R2,924**
2005	R1,050	R1,050	R366 (UKZN) R120 author est. (UP)	R1,017	**R3,603**
2006	R1,334	R1,086	R507 (UKZN) R120 author est. (UP)	R1,143	**R4,190**
2007	R1,625	R1,514	R450 (UKZN)	R1,384	**R4,973**
2008	R1,982	R812	R470 (UKZN)	R1,435	**R4,699**
2009	R2,216	R905	R493 (UKZN)	R2,208	**R5,822**
2000-2009	R12,219	R10,675	R5,851	R10,526	**R39,270**

[1] Estimate (excl. VAT) based on official total cost per researcher at ARC-ITSC and personal communication with managers at WTS (Dr Stefan Kohne), UKZN (Prof John Bower), TUT (Prof Ben Botha), and UP (Prof Lise Korsten).

Fig. 5.6. Real avocado gross R&D expenditure (2009 equivalents) from 2000 to 2009



No significant linear relationship between year and real gross avocado industry R&D expenditure was found (Real expenditure = R45,859.Year – R86,821,300 r^2=0.04, p=0.607) (Fig. 5.6). Being insignificant, the straight line equation is immaterial and will not be discussed apart from selected background information. The correlation showed that the linear function fitted the data poorly and captured only 4% of the common variation between the variables. The absolute intercept value at year zero can be ignored when investigating the trend from 2000 to 2009, and would change if the yearly data were inserted as one, two, three… to 10. An annual growth in funding of R45 859 is indicated, but based on the non-significant finding and low r^2 value it is unreliable.

The real funding levels varied between years. The trends in funding showed that it declined sharply in the mid-2000s, increasing again from 2005 onwards. In real terms, funding in 2000 was R5 806 000 compared to R5 822 000 in 2009 (Fig. 5.6). This represented a compounded annual real growth rate of 0.03%. Funding over the entire period was therefore stagnant, but at least compensated for inflationary pressures.

The satisfaction rating of funding growth level was relatively low. In absolute terms it was a more than moderate level of satisfaction, although respondents were not outright satisfied with funding growth. The rating appeared to be a valid perception considering the fact that funding was stagnant in real terms over the period. The proposition was therefore supported in terms of growth in avocado R&D funding in South Africa.

Research intensity

The questionnaire respondents had a mean (± 95% C.I.) satisfaction rating of 3.22 ± 0.28 for having enough avocado R&D funding. To relate sufficient avocado R&D funding to a quantifiable figure, the research intensity was calculated (Table 5.5). The data showed that the research intensity varied annually due to varying nominal funding levels (as discussed in the funding trends section) and varying industry revenue. Industry revenue was mainly influenced by price and volume. A declining trend in the research intensity was observed up to the mid-2000s, which was followed by a recovery period up to 2009. Research intensity peaked in 2001, mainly as a result of relatively low avocado prices and volumes in 2001. From 2000 to 2009 the research intensity was generally constant and averaged at 1.2%. The level was above an arbitrary minimum level of 1%, which is the global public agriculture R&D spending level (Beintema and Stads, 2008). Considering a relatively high demand of R&D in a growing industry like avocado (refer to Chapter 2 for more details), the relatively low satisfaction score in funding levels corresponded with the proposition.

Table 5.5. The estimated research intensity of the South African avocado industry from 2000 to 2009

Year	Nominal funding ('000)[1]	Estimated industry revenue ('000)[2, 3]	Research intensity (R&D funding/revenue)
2000	R3,441	Markets: R181,064 Direct: R96,118 **Subtotal: R277,182**	1.2%
2001	R3,542	Markets: R123,084 Direct: R53,306 **Subtotal: R176,390**	2.0%
2002	R3,096	Markets: R156,567 Direct:R52,141 **Subtotal: R208,708**	1.5%
2003	R2,980	Markets: R195,971 Direct:R43,530 **Subtotal: R239,501**	1.2%

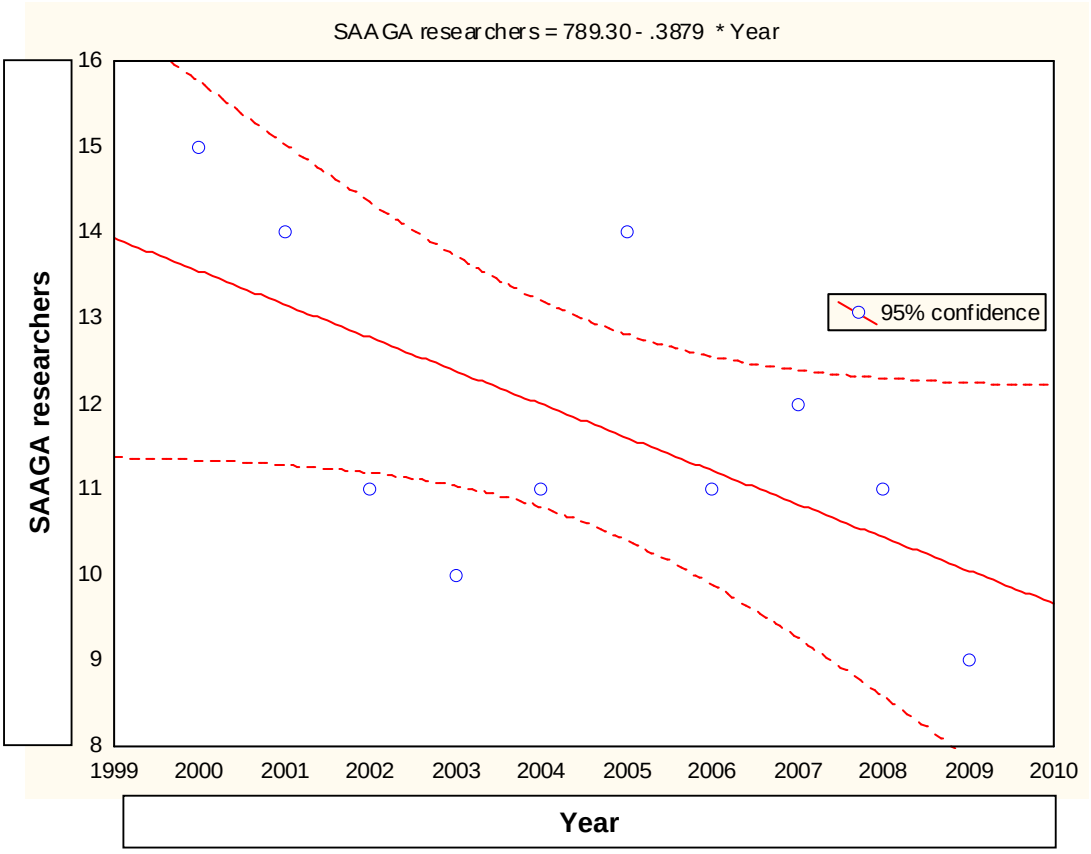
2004	R2,924	Markets: R211,537 Direct: R42,895 **Subtotal: R254,432**	1.1%
2005	R3,603	Markets: R293,030 Direct:R87,415 **Subtotal: R380,446**	0.9%
2006	R4,190	Markets: R248,536 Direct: R89,260 **Subtotal: R337,795**	1.2%
2007	R4,973	Markets: R270,567 Direct:R101,619 **Subtotal: R372,187**	1.3%
2008	R4,699	Markets: R406,451 Direct: R123,212 **Subtotal: R529,664**	0.9%
2009	R5,822	Markets: R330,085 Direct: R132,261 **Subtotal: R462,347**	1.3%
2000-2009	R39,270	Markets: R2,416,893 Direct: R821,758 **Grand total: R3,238,651**	1.2%

[1] Estimate (excl. VAT) based on official total cost per researcher at ARC-ITSC and personal communication with managers at WTS (Dr Stefan Kohne), UKZN (Prof John Bower), TUT (Prof Ben Botha), and UP (Prof Lise Korsten). A breakdown is provided in Table 5.4.
[2] Annual gross sales value of fresh avocado fruit on local markets and free on board value for fresh avocado exports. The average annual local market price (DAFF, 2010) was used for both calculations using unpublished volume estimates from SAAGA (Mr Derek Donkin, personal communication).
[3] Fresh avocado sold to the informal market (at farm-gate) and directly to supermarkets. Volume estimates were obtained from unpublished SAAGA data. The average annual local market price was used in calculations (DAFF, 2010).

R&D personnel

The questionnaire respondents had a mean (± 95% C.I.) satisfaction rating of 2.32 ± 0.33 for the growth rate in the number of avocado researchers. This related to being somewhat to moderately satisfied and was the lowest rated metric of the 29 metrics tested. The data was plotted on a graph to identify the trends in the number of R&D personnel performing SAAGA research between 2000 and 2009 (Fig. 5.7). A linear function was fitted over the data, but it was not significant (SAAGA researchers = -0.39.Year + 789.3, r^2=0.37, p=0.06). The data showed that since the year 2000, the number of active SAAGA researchers declined from 15 to nine. The data had a negative geometric growth rate of 5.5% between 2000 and 2009. Over the period WTS, ARC-ITSC and UKZN performed the bulk of SAAGA R&D. Researchers performing SAAGA projects remained fairly constant at WTS (approximately four) and UKZN (approximately two), declining at the ARC-ITSC (six in 2000, two in 2009) and UP (two in 2005, none in 2009). The relatively low satisfaction ratings therefore corresponded to the notable decline in the number of SAAGA researchers. The proposition was therefore supported in terms of R&D personnel.

Fig. 5.7. The number of R&D personnel conducting avocado R&D for SAAGA from 2000 to 2009



Source: Researcher's calculation from unpublished SAAGA data.

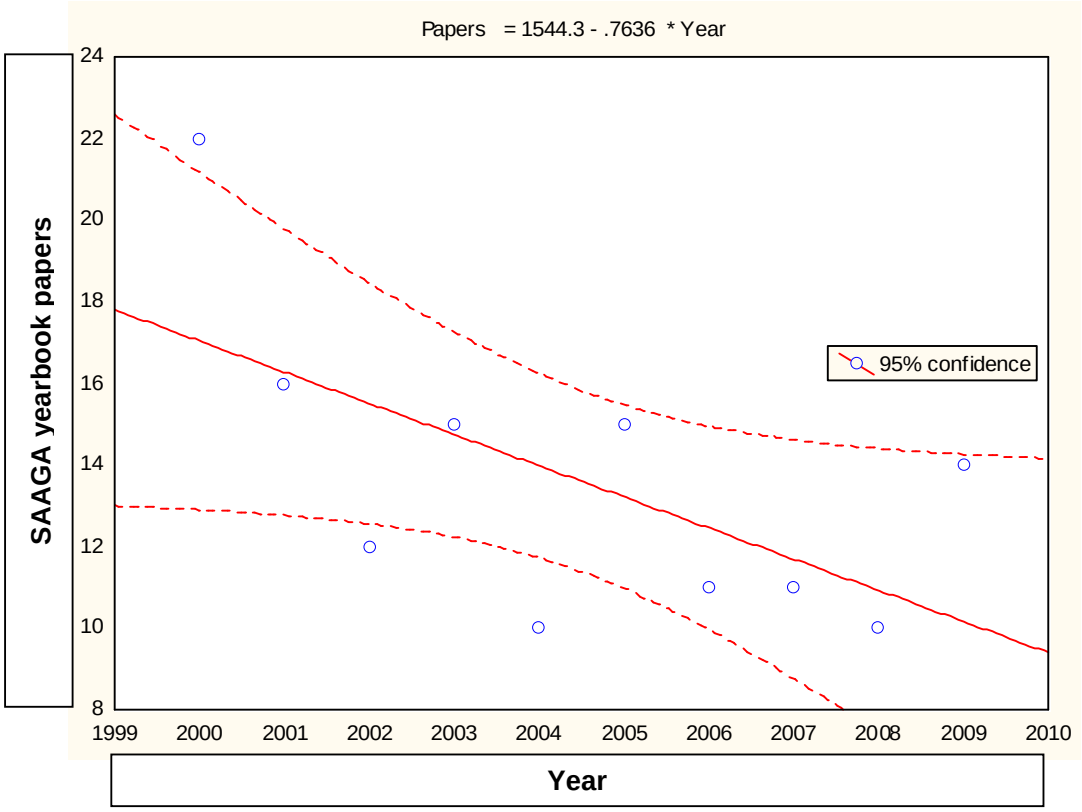
SAAGA research reports

The questionnaire respondents had a mean (± 95% C.I.) satisfaction rating of 2.89 ± 0.28 for the growth rate in the publication of SAAGA R&D activities. This related to being moderately satisfied. Trends in the number of research papers in the SAAGA yearbook were calculated to quantify publication rates. SAAGA yearbook publications between 2000 and 2009 are presented in Figure 5.7. A linear function was fitted over the data, but was not significant (Papers = 1544.3 - 0.76.Year, r^2=0.39, p=0.05). The data showed that since the year 2000, an annual decline of SAAGA research papers occurred until 2009. The data had a negative geometric growth rate of 4.9% between 2000 and 2009. It should be considered that in certain years research conducted outside SAAGA was published in the yearbook (e.g. in 2001 and 2005), the odd SAAGA study was not published and other SAAGA-funded research was published in refereed journals (e.g. De Graaf, 2009) and not in the yearbook. If these factors

are considered then the negative slope is smaller. Nevertheless, the number of SAAGA papers declined over the period.

The relatively low satisfaction ratings of the respondents corresponded to the lack of growth in SAAGA yearbook papers. The proposition was therefore supported in terms of growth rate in the publication of SAAGA R&D activities.

Fig. 5.8. The number of SAAGA research papers published in the SAAGA yearbook from 2000 to 2009



Source: Researcher's calculation from SAAGA yearbook publications (SAAGA, 2000; 2001; 2002; 2003; 2004; 2005; 2006; 2007; 2008 and 2009).

5.3.4 Respondent inputs

The respondents provided inputs and comments on the study. The data presented qualitative inputs by the study participants.

Qualitative inputs

The inputs to section C of the questionnaire are categorised in Table 5.6. The sponsors listed criteria in all of the R&D function categories. The criteria were often very closely related to those listed in the preceding section of questionnaire survey.

The criteria were qualitative or quantitative in nature and in some cases both of these approaches could be used to classify the metrics. The criterion most often identified by the sponsors was a combination metric of both research topic selection and prioritisation, with a total of five sponsors listing metrics of this kind. It was rated as important to very important with levels of satisfaction ranging from being dissatisfied to being satisfied (Table 5.6). This criterion was closely related to criterion 9 of the questionnaire, *the appropriateness of avocado R&D priorities selected by SAAGA*. It shows that research topic selection is perhaps another important component to measure R&D effectiveness. In this regard, apart from obtaining greater inputs from local growers, the suggestion of one sponsor for international research collaboration suggests that a wider global approach is required for R&D topic selection and prioritisation. This may avoid duplication and optimise available resources (Table 5.6).

Return on investment was listed by two sponsors and economic cost-benefit by one sponsor to be important or very important metrics. Satisfaction levels with these criteria were variable, but generally low. Return on investment was related to criterion 24 of the questionnaire, *degree of short-term profit increase due to application of SAAGA R&D results*. It highlighted a need for accurate quantification of financial returns of R&D. Economic cost-benefit analysis of avocado R&D is a wider approach and includes financial, social and environmental elements. It was related to criterion 21 of the questionnaire, *usefulness of avocado technology developed for SAAGA* (Table 5.6).

The remaining sponsor suggested R&D criteria were reported once. Young researcher development was related to criterion 4 of the questionnaire, *the growth rate in the number of avocado researchers*. It provided triangulation support for the low satisfaction finding with this metric identified by the quantitative element of the questionnaire survey and emphasised the concern in the industry with the lack of growth in the number of avocado researchers in South Africa. The generation of intellectual property and number of peer-reviewed papers were deemed to be important with moderate levels of satisfaction. These criteria were related to criterion 22, *the growth rate in the publication of SAAGA R&D activities*. It suggested that refereed papers and other modes of publication (like patents) provide alternative means of value to sponsors (Table 5.6).

Transfer of technology to growers and alleviation of specific production constraints were rated important with moderate satisfaction. It was related to metric

25, *effects of SAAGA R&D on improvement of avocado pre and post harvest management practices (e.g. cost savings and/or quality improvements)* and identified specific R&D outcomes to be achieved. Project strategy alignment with research strategy and implementing the R&D results were perceived as important metrics with relatively low satisfaction rates. These criteria were related to the strategy metrics of the questionnaire (metric 28-29). This indicated that effective avocado R&D may require lower level strategies and more detailed implementation plans (Table 5.6).

The researchers also listed criteria in all of the R&D categories that can be classified as qualitative, quantitative or both types of metrics. International R&D collaboration was most often cited and listed by two researchers. Retention of research capacity, payback time, net present value, grower satisfaction ratings, technology transfer, pro-active research, reactive research and the balance between basic and applied research were each listed once.

At least four listed criteria were common among the researchers and sponsors with relatively similar importance and satisfaction scores. The qualitative inputs suggested that metrics relating to researcher capacity (researcher development or retention), financial or economic returns from R&D (payback, cost-benefit, return on investment, net present value), international collaboration, technology transfer and strategically guided research projects could be criteria to be included for more accurate R&D effectiveness measurement (Table 5.6).

Table 5.6. Criteria listed by different study participants to measure the effectiveness of avocado R&D in South Africa

Respondent	Categorisation	Criteria (respondent citations)	Impor-tance	Satis-faction
Sponsor	Input	- Young researcher development (n=1)	4	3
	Input/output ratio	- Economic cost/benefit (n=1)	5	1
		- Return on investment (n=2)	4	1
			4	4
	Throughput	- International research collaboration (n=1)	5	2
		- Research topic selection and prioritisation (e.g. grower involvement) (n=5)	4	3
			5	1
			5	2
			4	2
			5	4
	Output	- Intellectual property (patents) (n=1)	5	3
		- Number of peer-reviewed papers (n=1)	Not provided	Not provided
	Outcome	- Alleviation of production constraints	5	3

		(e.g. stinkbugs, alternative fungicides) (n=1)		
		- Technology transfer rate (n=1)	5	3
	Strategy	- R&D results implementation (n=1)	5	2
		- Project strategy alignment with research strategy (n=1)	4	3
Researcher	Input	- Retention of research capacity (n=1)	5	2
	Input/output ratio	- Payback time (n=1)	Not provided	Not provided
		- Net present value (n=1)	5	2
	Throughput	- International research collaboration	4	2
		(n=2)	5	3
	Output	- Grower satisfaction ratings (n=1)	5	2
	Outcome	- Technology transfer rate (n=1)	5	2
	Strategy	- Reactive research (n=1)	4	4
		- Pro-active research (n=1)	4	4
		- Appropriate balance between basic and applied research (n=1)	5	2

Note: The names of some criteria were changed from the original descriptions to allow for the grouping of similar metrics. The scores listed were raw individual scores and not averaged.

Comments

Section D of the questionnaire allowed for respondent comments or notes relating to the study. A researcher noted, “I think all of the most important aspects to determine the effectiveness of avo research have been included in the questionnaire”. Another researcher suggested that “R&D on health aspects of avocado consumption and R&D on value adding (author note: the respondent was referring to processing here) in avocado should receive more attention”. One researcher commented that “there should be a do not know, no comment section”. As discussed in section 5.2, this respondent was excluded from the analysis to prevent biases being introduced. Greater use of incentives or rewards to improve paper output quality was suggested by a researcher, suggesting “a reward scheme for scientific publication… it will force researchers to look at producing higher quality work”. “Incentive rewards” was also recommended by one of the sponsors and another sponsor commented that “the quality of research as presented in the yearbooks is generally quite poor… too many researchers present reports at the research symposium with no statistical analysis of results”. Two sponsors raised a concern that they were not informed of operational activities at research institutes and were hesitant to provide satisfaction ratings on

some of the questions. As discussed in section 5.2, these two respondents were also excluded from the analysis.

The comments section suggested that the scope of the research activities may need to be expanded, the standard of SAAGA papers requires improvement and the satisfaction scores of some respondents may have been biased. These interpretations are synthesised in a more complete portrait in the discussion chapter.

5.4 The effectiveness of avocado R&D in South Africa

The research results addressed the research problem of *no method is known to best measure the effectiveness of avocado industry R&D in South Africa, resulting in sub-optimal management of the R&D function*. The results answered the research question in that industry role players validated R&D criteria and expressed their satisfaction with these criteria within the entire R&D system to measure the effectiveness of avocado R&D in South Africa. The results provided answers to the investigative (sub-questions) A, B and C listed in Chapter 1 and also addressed the hypotheses and the proposition linked to the sub-questions. Furthermore, qualitative insight was provided into additional avocado R&D metrics in South Africa.

The research showed that R&D criteria differ in their respective importance and satisfaction ratings. The satisfaction ratings corresponded to the actual quantifications of funding, personnel and SAAGA research reports. The findings relating to the proposition showed the satisfaction ratings (quantitative subjective metrics) provided relatively close estimations of the calculated quantitative objective metrics and these ratings were therefore assumed to be valid. A base-line value for current avocado R&D was calculated by assuming the importance weighted satisfaction scores corresponded to R&D effectiveness (Table 5.7). The weighted level of satisfaction for avocado R&D was 3.34 on the Likert scale (Table 5.7). The corresponding value for the 16 most important criteria was 3.52 (data not shown). Assuming equal scales between satisfaction and effectiveness, a moderate level of avocado R&D effectiveness exists.

The implications and context of the research results, along with a suggested method for using these criteria in a model to measure the effectiveness of avocado R&D in South Africa, is recommended in the next and concluding chapter, Chapter 6.

Table 5.7. The importance-weighted satisfaction levels of R&D criteria in declining order, which cumulatively indicate avocado R&D effectiveness in South Africa

Number	Metric	Importance weighting[1]	Satisfaction	Contribution
21	Usefulness of avocado technology developed for SAAGA, e.g. pest and disease management, quarantine treatments for market access, post harvest practices, etc	3.67%	3.81	0.14
27	SAAGA follows the right strategy	3.61%	3.86	0.14
23	Quality of avocado R&D work done for SAAGA	3.69%	3.73	0.14
9	The appropriateness of avocado R&D priorities selected by SAAGA	3.61%	3.78	0.14
29	The effective implementation/execution of SAAGA R&D strategic objectives	3.63%	3.65	0.13
7	The skill level of avocado researchers	3.74%	3.54	0.13
5	The degree of professionalism shown by avocado researchers	3.65%	3.59	0.13
17	The adequate availability of avocado R&D findings among SAAGA (progress reports, verbal reports, research reports, presentations, etc. by research institutions)	3.53%	3.70	0.13
26	Degree of long-term competitive advantage provided due to the application of SAAGA R&D results	3.69%	3.51	0.13
28	The alignment of avocado strategies at different levels, e.g. the fit between SAAGA strategy and SAAGA R&D strategic objectives	3.48%	3.68	0.13
25	Effects of SAAGA R&D on improvement of avocado pre and post harvest management practices (e.g. cost savings and/or quality improvements)	3.61%	3.46	0.12
11	Adaptability of avocado researchers to technology changes (i.e. molecular methods, computers, new equipment etc.)	3.53%	3.46	0.12
2	Having enough avocado R&D funding	3.67%	3.22	0.12
8	The appropriateness of avocado R&D proposals submitted to SAAGA by research institutions	3.38%	3.49	0.12
19	The success rate in achieving the objectives	3.40%	3.46	0.12

	provided by research institutions in SAAGA R&D proposals			
10	Providing adequate budgeting layouts in R&D proposals	3.36%	3.43	0.12
12	Adequate knowledge of avocado researchers of new technology (i.e. molecular methods, computers, new equipment etc.)	3.38%	3.38	0.11
20	The degree of usefulness of avocado technology developed outside SAAGA, e.g. rootstocks, cultivars, pesticides, etc. developed privately within South Africa (e.g. Westfalia Technological Services)	3.34%	3.38	0.11
16	Efforts by research institutions to strictly pursue the objectives they provided in SAAGA R&D proposals	3.29%	3.38	0.11
1	The growth rate of total research and development (R&D) funding by the avocado industry	3.34%	3.32	0.11
3	Having enough avocado R&D facilities (institutions and equipment)	3.63%	2.89	0.10
15	Collaboration between avocado R&D institutions, producers and marketers	3.48%	2.95	0.10
24	Degree of short-term profit increase due to application of SAAGA R&D results	3.19%	3.05	0.10
6	The ratio of avocado researchers to support staff (technicians/administrative personnel) at research institutions	3.19%	3.00	0.10
14	Morale at avocado R&D institutions	3.17%	2.97	0.09
18	Efforts to expand SAAGA R&D areas through diversification	3.06%	3.03	0.09
13	Active communication between avocado R&D institutions	3.36%	2.62	0.09
22	The growth rate in the publication of SAAGA R&D activities (e.g. patents, papers, presentations at conferences)	3.02%	2.89	0.09
4	The growth rate in the number of avocado researchers	3.29%	2.32	0.08
	Total	**100%**	**n/a**	**3.34**

[1] The weighting calculated by dividing the mean criterion importance score by the aggregate mean score (128.78)

6 Chapter 6: Discussion, conclusions and recommendations

Abstract

The research survey had a high response rate that allowed generalisation to the population, while validity of the instrument was supported by the literature and expert opinion. Limitations of the study were that it was narrowly focused and the satisfaction scores were possibly biased. The goals and objectives of the study were successfully achieved. Certain R&D criteria were considered more important than others. In contrast to some developed countries, a balanced combination of criteria was selected by respondents to measure avocado R&D effectiveness in South Africa. The satisfaction levels with all R&D criteria were relatively low, especially the *growth rate in the number of avocado researchers*. Sponsors and researchers agreed on the importance and satisfaction ratings of all the R&D criteria. The satisfaction ratings were consistent with the selected quantitative objective metrics, suggesting that these ratings were valid. The quantitative and qualitative inputs from respondents indicated that avocado R&D is moderately effective. Specific interventions were recommended to improve avocado R&D effectiveness. A total of 16 R&D criteria across the entire R&D system, using quantitative and qualitative metrics are recommended for a measurement system of avocado R&D effectiveness in South Africa. More research is required into measuring R&D effectiveness in Africa, fruit industries world-wide and the impact of strategy and other contingency factors on R&D effectiveness.

6.1 Introduction

The research discussion section is concerned with the discussion of the research results in the context of the underlying strategic foundation provided in Chapter 2 and the literature review provided in Chapter 3. Following such an approach, the aim of this chapter is to discuss the results relevant to the main problem, research question and sub-questions of the study.

The chapter starts with a discussion on the reliability, generalisability and limitations of the research results. This is followed by a discussion of the results for each research sub-question and the qualitative inputs. A method for measuring the effectiveness of avocado R&D in South Africa is presented next to address the main research problem. This is followed by a conclusion section where the implications of the research were synthesised. Lastly, recommendations for future research are presented.

6.2 Reliability and validity

The study was descriptive in nature, making cause-and-effect conclusions less important than for experimental research. Nevertheless, internal validity was still important in this study to ensure that the conclusions drawn were warranted from the data collected. The exclusion of avocado growers in favour of the SAAGA board and research committee in the target population (for more details refer to section 4.4) increased internal validity by preventing the inclusion of respondents likely to be unacquainted with the criteria being tested. The questionnaire was developed to be relatively short (<20 minutes) to prevent a maturation effect where respondents may modify their answers over time due to boredom, tiredness or other distractions. Although the nature of the study required that three respondents from the target population view the questionnaire before completing it, pre-testing and in-depth discussions were focused on comparable individuals outside the target population to prevent interactions and exchanges with the author that may have influenced study responses (Cooper and Schindler, 2003). Three questionnaires were excluded from the analysis, because the respondents did not complete all the satisfaction ratings. This was done in an attempt to preserve the internal validity of the satisfaction scores in the study. No such problem was reported or identified for the importance ratings.

To improve external validity the study used a real-life setting (not a controlled laboratory experiment), and sampled the entire target population. The study was also compared to previous similar studies to provide 'replication in a different context' (Leedy and Ormrod, 2005). The sample size of 40 (37 after exclusion of three questionnaires) was in excess of the minimum recommended sample of size of 30 and it presented a high response rate of the population (Diamantopoulos and Schlegelmilch, 2006). The research therefore had strong external validity, which meant that the results could be generalised to the population.

Validity and reliability were important to consider, especially because a psychological characteristic (insubstantial phenomena) like R&D effectiveness was studied (Leedy and Ormrod, 2005). Construct validity applied especially in this case, because R&D effectiveness is a construct that cannot be directly observed but was assessed with different predictor variables or criteria (Leedy and Ormrod, 2005). The construct validity of the selected variables in the instrument was considered to be high, because these were selected from the most commonly reported criteria reported in the literature as indicators of R&D success and a very similar questionnaire was used in two other academic studies to specifically measure R&D effectiveness under different conditions (Lee *et al*. 1996; Garcia and Mulero, 2005). Three strategy-related variables were added to the questionnaire, because strategy had been shown to influence the effectiveness of R&D (Roberts, 1995; Garcia and Mulero, 2005). The validity of the instrument was therefore supported by the published literature which made use of expert opinion and statistical tests to confirm the validity of the questionnaire instrument. The small qualitative component of the study made use of a thick description (e.g. quotes) where rich, 'thick' details were provided for the reader to follow the reasoning and interpretations being made. Validity of the instrument was supported by expert opinion in the South African avocado industry and 27 of the 29 criteria were consistently rated as important or very important.

In this study reliability was improved by the researcher presenting a standardised presentation to orientate the respondents, followed by a single standard questionnaire for all participants, while minimising the time between administering the questionnaire to the respondents. A very high response rate (>95%) was achieved in the study, possibly because of this approach where respondents were grouped together and the questionnaire completed by the participants directly after the presentation was given. The reliability of the instrument can be estimated by inter-

rater reliability, internal consistency reliability and test-retest reliability. Inter-rater reliability is the extent to which grouped respondents provide identical judgements. The results showed relatively narrow confidence intervals for responses from the participants and that no difference existed between the ratings of sponsors and researchers, which indicates that the inter-rater reliability of the instrument was high (Leedy and Ormrod, 2005). Internal consistency reliability is the extent to which all items within an instrument yield similar results and test-retest reliability is the extent to which the same instrument yields the same results on two different occasions. These elements were not tested, but a very similar version of the questionnaire was shown to have reliability in both these respects when administered in Korea (Lee *et al*. 1996).

6.3 Limitations and goal achievements

The study was limited by being specific and focused, using a relatively small target population that restricted the conclusions to avocado R&D conducted for SAAGA in South Africa. The design of the study did not include and compare importance and satisfaction ratings of independent, external experts.

The research was descriptive in nature and did not allow for any causal inferences to be made. The survey was a cross-sectional snapshot at a particular moment in time and did not allow for extrapolation far into the future, especially for satisfaction ratings. Furthermore, the study relied on self-report data that may skew results, although this may have been minimised by the option of anonymity being provided to respondents. Collection of the data revealed that three participants felt they did not have sufficient information and insight to assign accurate satisfaction ratings to all the questions. Although these specific questionnaires were excluded from the survey, some respondents may not have noted such concerns while their responses were retained in the dataset used for the analysis. The satisfaction scores may therefore possibly be biased. Another limitation was that the population was relatively homogeneous in terms of background, and greater insight may have been obtained if a more diverse population was studied.

The goals and objectives of the study were successfully achieved. The main goals as defined in the research question were to validate and test the satisfaction in R&D criteria in the avocado industry of South Africa. This was successfully achieved and respondents being representative of the population identified the most important

avocado R&D criteria. Even so, all of the listed criteria apart from two were on average considered to be important or very important and additional criteria were also suggested. Achievement of the objectives of the study allowed the hypotheses, propositions, research sub-questions, the research question and research problem to be addressed. This will be discussed in more detail in this chapter.

6.4 Sub-question A – importance of R&D criteria

In the South African avocado industry, R&D is the cornerstone of competitive advantage and a KSF of the industry. Identifying and validating the most important criteria to measure, track and identify areas for improving avocado R&D effectiveness, allows management to more fully leverage the function as a prime resource and capability.

The results showed that some criteria were statistically more important than others in the measurement of avocado industry (SAAGA) R&D in South Africa. The most important metrics were selected throughout the different components of the R&D system (inputs, throughputs, outputs, outcomes and strategy). This is in contrast to findings for German and US R&D managers (Werner and Souder, 1997b), where a preference for inputs and input/output type criteria was demonstrated, respectively. It appeared as if a more balanced selection of criteria was preferred for avocado R&D in South Africa. The preferred input, output and outcome metrics in this study corresponded closely with Korean findings, although throughput metrics, especially efforts to expand R&D areas through diversification, were considered to be relatively more important in Korea (Lee *et al*. 1996). The *growth rate in the publication of SAAGA R&D activities* had the lowest importance score (rated just below important), while the highest importance score was assigned to *the skill level of avocado researchers* (rated very important). The inclusion of strategy-related criteria proved to be very successful and these were considered to be very important criteria. The results showed that publications had a relatively low level of importance, which is similar to the sentiments expressed by a citrus research manager at CRI (Grout, personal communication) in South Africa. Outcome measurements to track avocado R&D effectiveness (criterion 25), similar to those used by Toerien (1997), were statistically just as important as the skill level of avocado researchers. It should however be considered that outcomes are only indirect measurements, which include

R&D, technology transfer and implementation effectiveness. This is one of the reasons why multiple criteria have higher validity in measuring R&D effectiveness.

The importance ratings of the defined researcher and sponsor groups were similar. The importance ratings of these groups for each criterion (interactive effects) were also similar. This is in general agreement with Lee (*et al*. 1996). The education, demographics and culture of the researcher and sponsor groupings in the present study were relatively similar which may have contributed to the similarity. It may also indicate the strong construct validity of the R&D criteria in the instrument. The study findings can only be generalised to the present population, but not to cases in other countries or other industries. A discrepancy between managers and researchers in their perception of R&D effectiveness may well be present in other cases or where these groups are more heterogeneous (Falkingham and Reeves, 2001). A positive linear relationship between the importance and satisfaction scores of respondents indicated that respondents were more satisfied with those criteria that were considered to be more important to measure the effectiveness of avocado R&D. By extension, assuming that increased levels of satisfaction were related to increased effectiveness, it appeared as if resources were aligned with the importance of R&D criteria listed in the questionnaire.

6.5 Sub-question B – satisfaction with R&D criteria

A measurement system would not be of great value if it did not allow for the identification of areas for improvement and estimates of current effectiveness. The quantitative subjective satisfaction measurements allowed for areas for improvement to be identified and along with the importance ratings could be used to estimate R&D effectiveness.

The satisfaction levels of respondents were different for the 29 R&D criteria. The lowest satisfaction levels, rated just below moderately satisfied, were shown for input-related criteria: the *growth rate in the number of avocado researchers* and *having enough avocado R&D facilities (institutions and equipment)*. The highest satisfaction levels, rated just below satisfied on the Likert scale, were assigned to strategy and outcome criteria: *SAAGA follows the right strategy* and the *usefulness of avocado technology developed for SAAGA*. Although relative differences occurred, the respondents were not satisfied with the performance of any of the R&D criteria.

Similar to the findings for the importance variable, the satisfaction ratings of the defined researcher and sponsor groups were similar. The satisfaction ratings of these groups for each criterion (interactive effects) were also similar. The agreement of ratings between these groups could possibly be assigned to the homogeneity of the groups. This showed that not only was there agreement on the most important R&D criteria, but also on the levels of satisfaction with different R&D criteria. The data therefore provide for a robust system to measure R&D, supported by sponsors and researchers. Before the effectiveness of avocado R&D and a recommended model for effectiveness measurement is discussed, it is important to elaborate on the validity of satisfaction ratings and qualitative inputs from the respondents.

6.6 Sub-question C – validity of perceptions

The validity of the quantitative subjective satisfaction ratings was estimated by comparing these to selected quantitative objective metrics. The approach that was followed considered the absolute and relative satisfaction ratings as well as other intervening variables and trends not considered by the one-dimensional quantitative objective metrics. The inductive evaluation of the relationship between satisfaction ratings and absolute figures also considered several linkage relationships (linear and/or exponential relationships). From these perspectives it is clear that inductive testing of the proposition only confirmed if satisfaction scores and objective metrics corresponded in broad trends, based on in-depth investigation.

Gross avocado industry R&D funding showed no real growth and a stagnant level of research intensity of approximately 1.2% between 2000 and 2009. The relatively low satisfaction ratings with the R&D criteria of growth in funding and having enough R&D funds were considered to be accurate perceptions. Although growth in avocado R&D funding by public R&D institutions appeared to be negative, the overall constant real level of funding corresponded to reports by Liebenberg, Pardey and Khan (2010). Avocado research intensity appeared to be lower than the aggregate level reported for public R&D in South Africa, although both estimates remained constant over the recent past (Liebenberg, Pardey and Khan, 2010). The research intensity of avocado appears to be especially low considering avocado is a growing industry where demand outstrips supply. There are no strict rules about the ideal level of research intensity, but based on the current situation and the

comparable research intensities reported in Chapter 3, a level of 2% appears to be more appropriate for the South African avocado industry at this stage.

The number of research personnel conducting SAAGA research projects declined between 2000 and 2009. The decline was mainly caused by a reduction in the number of avocado researchers conducting avocado R&D at the ARC-ITSC. This trend agrees with a report of an overall decline in the number of full-time equivalent researchers at the ARC (Liebenberg, Pardey and Khan, 2010). The reduction in the number of researchers from 2000 to 2009 justified the very low satisfaction perception of the respondents. The declining number of researchers was also associated with a decline in the number of SAAGA yearbook publications. The latter R&D criterion had a relatively low satisfaction rating, again in line with actual calculations.

The satisfaction ratings were consistent with the calculated quantitative objective metrics, agreeing with the proposition. This suggested that the satisfaction ratings were valid indicators of these respective R&D criteria.

6.7 Qualitative inputs

The qualitative inputs section of the questionnaire allowed for the creation of theory by providing respondents with the opportunity to suggest additional or alternative R&D criteria that can be used to specifically measure avocado R&D effectiveness.

The similarity of sponsors and researchers in terms of their importance and satisfaction perceptions of different R&D criteria were echoed in their qualitative inputs. Researcher development/retention, return on investment indicators (e.g. net present value, cost-benefit ratio), international research collaboration and technology transfer rate were criteria listed by both groups. These criteria, along with other suggestions like measuring research planning or prioritisation and research activity (basic research, applied research, and development) are recommended for inclusion in a R&D measurement tool. However, the literature warns that return on investment calculations should be used with care when applied to measure R&D effectiveness. It has been shown that return on investment metrics place too much emphasis on short-term profitability and underestimate research returns when there is uncertainty about future earnings, thus hurting the long-term profitability and competitive advantage of the organisation (Faulkner, 1996; Mitchell and Hamilton, 2007). It is recommended that a sensitivity analysis of return on investment parameters be

conducted and that only elements under the control of R&D be retained in measurement systems. This will prevent the artificial reduction of R&D effectiveness in situations where poor implementation of R&D results occurred.

Interesting comments received on the study were that greater R&D attention should be paid to avocado processing and the health aspects of avocado. This would represent an expansion of R&D areas, a criterion which had one of the lowest importance ratings, but still rated as being only just below important. Its satisfaction ratings were low in relative and absolute terms. It is well known that almost 15% of avocado fruit production is processed in South Africa, yet virtually no SAAGA research is conducted on processed avocado. One possible reason might be that a limited number of large growers would benefit from such research and that fresh fruit represents higher value than processed avocado due to low recovery rates and food safety risks. However, should processing activities cease, then it would impact greatly on fresh fruit supply and quality, thereby reducing fresh fruit value. Incentive rewards as a motivational tool were suggested by a researcher and a sponsor. Interestingly, performance-based remuneration for researchers was also suggested in Spain (Garcia and Mulero, 2005). One sponsor raised particular concerns over the scientific quality of SAAGA papers.

6.8 The effectiveness of avocado R&D in South Africa

6.8.1 Effectiveness of avocado R&D in South Africa

The findings relating to the proposition showed that the satisfaction ratings (quantitative subjective metrics) provided relatively close estimations of the calculated quantitative objective metrics. This provided support that the satisfaction ratings obtained from the study were valid. The weighting of satisfaction scores by the importance scores of the R&D criteria was assumed to provide an indication of R&D effectiveness. This indicated that SAAGA R&D is moderately effective. Considering that all the satisfaction scores were below four (satisfied), interventions can be recommended to improve R&D effectiveness. However, this research is focused on how R&D effectiveness should be measured and the current level of satisfaction in R&D criteria. It will therefore not delve deeply into suggested interventions and only provide a few guiding comments.

It is suggested that the interventions be rooted in strategic principles and work from the top down. Based on the situation analysis presented in Chapter 2, the strategic R&D objectives of SAAGA should be re-evaluated and re-phrased. An over-arching strategic approach should be adopted, viz. low cost, best cost or differentiation (Thompson *et al*. 2007). The situation analysis indicated that best cost or differentiation through quality and consistency in supply are probably the best fit for the South African industry at present. The R&D strategic objectives should be consistent with the strategy. The current strategic objective "To carry out research and development (R&D), to have R&D carried out and to coordinate such R&D concerning the production and marketing of avocados" should be rephrased to provide greater strategic guidance, for example "Co-ordinate South African avocado R&D in a global arena for communal benefits in the greater avocado trade and to differentiate South African avocado production and marketing in terms of yield, quality, consistency and market reach". More detailed objectives and implementation plans should align accordingly, and special attention should be paid towards specific R&D inputs, throughputs, outputs and outcomes.

Among the R&D inputs, avocado researcher (and student) recruitment, development and retention should receive urgent attention. The number of institutions performing avocado R&D is declining. Attracting more institutions is recommended, especially universities, so that student numbers can improve. Funding levels and funding sources require attention to ensure the South African avocado industry remains competitive in a world-wide growing industry. Incentive rewards should be implemented in researcher remuneration schemes. As R&D throughput criteria, efforts to expand the R&D focus to processed products require attention from a strategic point of view, because a failing processing industry could have a significant impact on fresh avocado markets. Improved communication between R&D institutions and greater collaboration between R&D, producers and marketers is recommended, both nationally and internationally. The number of SAAGA paper outputs and the quality of papers require improvement. The establishment of a rapid review sub-committee (part of the research committee) is recommended to screen SAAGA research proposals and research papers before publication to ensure that a minimum scientific standard is maintained. The outcomes from R&D can be improved by more effective transfer of technology to growers. Where applicable, an illustrative field day could be held after the annual research symposium to demonstrate the application of newly developed processes and technologies. Extension officers

should continue to actively transfer new technologies to growers during grower days, while logistics and marketing companies should be targeted when transferring post-harvest technologies.

6.8.2 Model to measure R&D effectiveness

The main problem statement of the study was that no method is known to best measure the effectiveness of avocado industry R&D in South Africa, resulting in sub-optimal management of the R&D function. The research provided insight into measuring avocado industry R&D in South Africa by selecting criteria from a literature review and validating it with a questionnaire survey completed by prominent industry members.

A total of 27 of the 29 listed criteria were perceived to be important or very important. To reduce the criteria to a more manageable number, the top criteria with statistically similar importance scores (totalling 16) from the quantitative section of the questionnaire are recommended as part of a measurement system for avocado R&D effectiveness in South Africa. In this study, the subjective quantitative metrics of R&D criteria were shown to correspond closely with selected quantitative objective metrics, providing triangulation support for the findings. The research activity of SAAGA can be classified as mainly being applied research and experimental development. Therefore it is important to include objective and subjective quantitative metrics for these criteria to allow accurate measurement. Keeping with the recommended best practice, an approach that also includes qualitative metrics is proposed (Werner and Souder, 1997a). The addition of purely qualitative metrics would allow for even greater triangulation support to be tested in the proposed model.

The 16 most important R&D criteria, validated by industry experts to measure the construct of R&D effectiveness, are presented in Table 6.1. Specific qualitative metrics, quantitative subjective and quantitative objective metrics were recommended for each criterion based on the inputs received from the questionnaire survey. Measurement intervals were arbitrarily set at every second year for qualitative and quantitative subjective surveys and annually for quantitative objective metrics. An independent survey is recommended as one of the qualitative metrics, requiring an independent expert to provide in-depth views on each of the 16 criteria relating to avocado R&D in South Africa. Another recommended qualitative metric is a strategy review (including a situation analysis, scenario analysis and competitive analysis) with a long-term focus to indicate the competitive advantage provided by avocado

R&D activities and the appropriate SAAGA strategy to be followed. A final qualitative metric is investigation into the alignment between projects and R&D strategy, international collaboration activity and the use of new technology in research to measure the implementation of strategic objectives, R&D planning and prioritisation and adaptability of researchers to technology changes. These reports can be conducted within the industry (for example by the chairman of the SAAGA board or research committee).

The industry survey should follow a similar format to the present study, because both the satisfaction and importance levels might change over time. This will provide valuable quantitative subjective metrics. Other quantitative subjective metrics include lagging cost-benefit estimates to determine the usefulness of avocado technology and the effects of R&D on the improvement of management practices. Judging the balance required between basic research, applied research and development activities is aimed at assisting in measuring the ability to execute strategic R&D objectives. An appropriately balanced portfolio of projects will address both long and short-term R&D objectives. It is proposed that the proportions used in other industries be considered: approximately 5% allocated to basic research, 15% to applied research, 60% to development and 20% to services (Bean *et al*. 1998; Bean *et al*. 1999; Bean *et al*. 2000). Leading cost-benefit estimates are recommended to measure project planning and prioritisation. Lastly, discrepancy rates between objectives provided in project proposals and actual deliverables are intended to measure the success rate in achieving objectives.

The quantitative objective metrics include student numbers, researcher numbers, researcher experience, retention rate and succession plans (presence/absence) to assist in measuring the skill levels of avocado researchers. Lagging cost-benefit and return on investment indicators are recommended to indicate the usefulness of avocado R&D and the improvement in management practices. Research intensity, funding trends and benchmarking are suggested to aid in the measurement of avocado R&D funding. The number of institutions involved in avocado R&D aids in the measurement of R&D facilities, while the number of growers and international collaborators participating in prioritisation aids in measuring R&D planning and prioritisation. The number of presentations, papers and grower days provides an indication of the availability of R&D findings.

It is important that the reports of all these metrics include a section on implications, interventions recommended, implementation and tracking plans.

Furthermore, trends should be analysed and downward variances inspected, even if these remain above benchmark or minimum satisfaction levels. Initiatives to build on high performance and core competency areas should also be undertaken. It is recommended that a dedicated R&D sub-committee oversee these surveys and collect the annual quantitative data.

Table 6.1. Model to measure the effectiveness of avocado industry R&D in South Africa

Criteria	Measurement A: Qualitative B: Quantitative subjective C: Quantitative objective	Interval
- The skill level of avocado researchers	A: Independent survey B: Industry survey C: Student numbers, researcher numbers, researcher experience, retention rate, succession plans (presence/absence)	Biannual Biannual Annual
- Quality of avocado R&D work done for SAAGA	A: Independent survey B: Industry survey	Biannual Biannual
- Degree of long-term competitive advantage provided due to the application of SAAGA R&D results	A: Independent survey, strategic scenario analysis, situation analysis (R&D share of core competencies) (long term, >20 years) B: Industry survey	Biannual Biannual
- The degree of professionalism shown by avocado researchers	A: Independent survey B: Industry survey	Biannual Biannual
- Usefulness of avocado technology developed for SAAGA, e.g. pest and disease management, quarantine treatments for market access, post harvest practices, etc	A: Independent survey B: Industry survey, lagging cost-benefit estimates C: Lagging ROI indicators – 5 and 10 year periods	Biannual Biannual Annual
- Having enough avocado R&D funding	A: Independent survey B: Industry survey C: Research intensity, funding trends, benchmarking	Biannual Biannual Annual
- Having enough avocado R&D facilities (institutions and equipment)	A: Independent survey B: Industry survey C: Number of institutions involved in avocado R&D	Biannual Biannual Annual
- The effective implementation or execution of SAAGA R&D strategic objectives	A: Independent survey, project alignment with strategic objectives B: Industry survey, basic research, applied research and development activities	Biannual Biannual
- SAAGA follows the right strategy	A: Strategy review, situational analysis, trends in competitiveness	Continuous
- The appropriateness of avocado R&D priorities selected by SAAGA	A: Independent survey, international collaboration activity B: Industry survey, leading estimates of cost	Biannual Biannual

	benefit C. Number of growers participating in prioritisation, number of international collaborators in R&D.	Annual
- Effects of SAAGA R&D on improvement of avocado pre and post harvest management practices (e.g. cost savings and/or quality improvements)	A: Independent survey B: Industry survey, lagging cost-benefit study of outcomes C. Lagging ROI estimates (5 and 10 year)	Biannual Biannual Annual
- The adequate availability of avocado R&D findings for SAAGA (progress reports, verbal reports, research reports, presentations, etc. by research institutions)	A: Independent survey B: Industry survey C: Number of presentations, papers and grower days (technology transfer)	Biannual Biannual Annual
- Adaptability of avocado researchers to technology changes (i.e. molecular methods, computers, new equipment etc.)	A: Independent survey, use of new technology in R&D projects B: Industry survey	Biannual Biannual
- Collaboration between avocado R&D institutions, producers and marketers	A: Independent survey B: Industry survey	Biannual Biannual
- The alignment of avocado strategies at different levels, e.g. the fit between SAAGA strategy and SAAGA R&D strategic objectives	A: Independent survey B: Industry survey	Biannual Biannual
- The success rate in achieving the objectives provided by research institutions in SAAGA R&D proposals	A: Independent survey B: Industry survey, discrepancy between proposed and actual objectives	Biannual Annual

6.9 Conclusion

The sponsors and researchers agreed that similar R&D criteria and metrics were important to measure avocado R&D effectiveness in South Africa. Both groups also agreed on the levels of satisfaction with these R&D criteria. The responses indicated that avocado R&D in South Africa is moderately effective. The validation of R&D criteria and qualitative inputs by study participants allowed a robust model to be compiled comprising metrics throughout the R&D system to measure the effectiveness of avocado R&D in South Africa.

The model will improve the management of the R&D function, by tracking and measuring the most important R&D metrics to allow front-burner attention to be concentrated in critical areas and initiatives to be undertaken to build on core competencies. The survey results and quantitative objective metrics included in the model allow for competitive benchmarking within the industry over time as well as

between other South African and international fruit industries. The study filled the gap in the literature to validate R&D criteria that can be used to measure the effectiveness of avocado R&D in South Africa at a micro level.

6.10 Recommendations for future research

Foremost, a study calculating the cost-benefit and return on investment of avocado R&D in South Africa is recommended, noting the shortcomings of such outcome metrics as detailed earlier. A benchmarking study between the South African avocado industry and other local fresh fruit industries as well as prominent avocado industries throughout the world is suggested. It is advised that an independent expert survey be conducted on the effectiveness of South African avocado R&D. The avocado industry in South Africa recently joined three other industry bodies as part of a larger umbrella organisation, the SUBTROP. Research into linkage and synergy opportunities for R&D between these industries merits attention. Research investigating linkages and collaborative R&D opportunities between avocado industries world-wide would also add value.

Significantly more research is required into measuring R&D effectiveness in the developing world and in Africa. A gap in the literature also exists for researching R&D effectiveness in the fresh fruit industries worldwide. This gap in the body of knowledge would gain from macro and especially micro-level studies to improve our understanding at both an aggregate and disaggregate level. Studies can adopt a qualitative, quantitative or mixed method design into R&D effectiveness to provide in-depth insight and knowledge that can be generalised to the population. Currently none of the fruit industries in South Africa are formally measuring R&D effectiveness. Industries like fresh mango, largely displaced over the past decade from the European export market by Peru, urgently need to investigate and optimise their R&D effectiveness to support alternative strategies. The impact of the suggested research will therefore be significant. In general, R&D in collaborative settings and the impact of strategy and other contingency factors on R&D effectiveness also warrants further attention.

The undertaking of controlled experimental studies would provide insights into cause-and-effect mechanisms of different R&D measurement tools. No studies were located in the literature following this approach. Where resource constraints prevent an experimental approach, multiple case studies or the combination of research

paradigms are recommended to obtain triangulation support for findings in order to extract maximum value from the research effort.

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8. Appendices

Appendix 1: Questionnaire cover letter

Graduate School of Business Leadership
University of South Africa

August 2010

Dear Business Executive, Grower or Researcher;

The South African Avocado Growers' Association (SAAGA) is appealing to you for help to measure the effectiveness of avocado research and development. All that is required is a few minutes of your valuable time.

Measuring the effectiveness of R&D is important to determine if investments are justified, maximum productivity attained, if researchers are appropriately rewarded and motivated and if avocado R&D in South Africa is internationally competitive. However, various factors relating to R&D activities like uncertainty, time lags and interconnectedness are causing great difficulty in measuring their effectiveness.

The study requires you to voluntarily complete a questionnaire and rate the importance and your satisfaction with different aspects relating to avocado R&D. The study is funded by the SAAGA and undertaken by Dr Johan de Graaf at the University of South Africa as part of his Master of Business Leadership degree under the supervision of Prof Ernst Neuland. Please complete the questionnaire anonymously. The findings of the study will be presented at the annual SAAGA symposium.

Sincerely,
Johan de Graaf
0153090119 or 0721295838; 71806024@mylife.unisa.ac.za

Appendix 2: Questionnaire (modified from Lee et al. *1996)*

Please complete the following questions in section A, B and C. Please use an **X** to indicate your answer. Only mark one option per question. Your participation is voluntary and full anonymity applies.

Section A: Demographics

Demographic	**Measurement**				
Category	Board or research committee member (SAAGA)		Researcher or research manager		
Years of experience in the avocado industry	_____ years				
Current employer	Westfalia/ WTS	Self employed	Govern-ment (e.g. ARC)	University	Other (specify)

Section B: Measuring R&D effectiveness

Please use a scale from 1-5 when evaluating Section B and C. The numbers equate to the following responses (assume equal intervals)

1	2	3	4	5
Unimportant	Somewhat important	Moderately important	Important	Very important
Dissatisfied	Somewhat satisfied	Moderately satisfied	Satisfied	Very satisfied

Please indicate the importance and your current satisfaction with the following variables relating to avocado R&D in South Africa. Please provide your honest opinion based on your knowledge of SAAGA-funded R&D in South Africa. Please consider all research institutes conducting avocado research, i.e. ARC-ITSC, WTS, UKZN and private consultants. In the sections below avocado researchers refer to personnel with at least an MSc or equivalent qualification. This includes PhD students, but excludes MSc and other students.

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Variable	**Measurement**									
Inputs (the 'fuel' for R&D)	Importance					Satisfaction				
1. The growth rate of total research and development (R&D) funding by the avocado industry.	1	2	3	4	5	1	2	3	4	5
2. Having enough avocado R&D funding.	1	2	3	4	5	1	2	3	4	5
3. Having enough avocado R&D facilities (institutions and equipment).	1	2	3	4	5	1	2	3	4	5
4. The growth rate in the number of avocado researchers.	1	2	3	4	5	1	2	3	4	5
5. The degree of professionalism shown by avocado researchers.	1	2	3	4	5	1	2	3	4	5
6. The ratio of avocado researchers to support staff (technicians/administrative personnel) at research institutions.	1	2	3	4	5	1	2	3	4	5
7. The skill level of avocado researchers.	1	2	3	4	5	1	2	3	4	5

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Throughputs (the execution of R&D)	Importance					Satisfaction				
8. The appropriateness of avocado R&D proposals submitted to SAAGA by research institutions.	1	2	3	4	5	1	2	3	4	5
9. The appropriateness of avocado R&D priorities selected by SAAGA.	1	2	3	4	5	1	2	3	4	5
10. Providing adequate budgeting layouts in R&D proposals.	1	2	3	4	5	1	2	3	4	5
11. Adaptability of avocado researchers to technology changes (i.e. molecular methods, computers, new equipment etc.).	1	2	3	4	5	1	2	3	4	5
12. Adequate knowledge of avocado researchers about new technology (i.e. molecular methods, computers, new equipment etc.).	1	2	3	4	5	1	2	3	4	5
13. Active communication between avocado R&D institutions.	1	2	3	4	5	1	2	3	4	5
14. Morale at avocado R&D institutions.	1	2	3	4	5	1	2	3	4	5
15. Collaboration between avocado R&D institutions, producers and marketers.	1	2	3	4	5	1	2	3	4	5
16. Efforts by research institutions to strictly pursue the objectives they provided in SAAGA R&D proposals.	1	2	3	4	5	1	2	3	4	5
17. The adequate availability of avocado R&D findings to SAAGA (progress reports, verbal reports, research reports, presentations, etc. by research institutions).	1	2	3	4	5	1	2	3	4	5
18. Efforts to expand SAAGA R&D areas through diversification.	1	2	3	4	5	1	2	3	4	5

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Outputs (direct output after completing a R&D activity)	Importance					Satisfaction				
19. The success rate in achieving the objectives provided by research institutions in SAAGA R&D proposals.	1	2	3	4	5	1	2	3	4	5
20. The degree of usefulness of avocado technology developed outside SAAGA, e.g. rootstocks, cultivars, pesticides, etc. developed privately within South Africa (e.g. Westfalia Technological Services).	1	2	3	4	5	1	2	3	4	5
21. Usefulness of avocado technology developed for SAAGA, e.g. pest and disease management, quarantine treatments for market access, post harvest practices, etc.	1	2	3	4	5	1	2	3	4	5
22. The growth rate in the publication of SAAGA R&D activities (e.g. patents, papers, presentations at conferences).	1	2	3	4	5	1	2	3	4	5
23. Quality of avocado R&D work done for SAAGA	1	2	3	4	5	1	2	3	4	5
Outcomes (Concerns the outcomes after research outputs were generated, the technology transferred and implemented by the industry)	Importance					Satisfaction				
24. Degree of short-term profit increase due to application of SAAGA R&D results	1	2	3	4	5	1	2	3	4	5
25. Effects of SAAGA R&D on improvement of avocado pre and post harvest management practices (e.g. cost savings and/or quality improvements)	1	2	3	4	5	1	2	3	4	5
26. Degree of long-term competitive advantage provided due to the application of SAAGA R&D results	1	2	3	4	5	1	2	3	4	5

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Strategy (The SAAGA strategy)	Importance					Satisfaction				
27. SAAGA follows the right strategy	1	2	3	4	5	1	2	3	4	5
28. The alignment of avocado strategies at different levels, e.g. the fit between SAAGA strategy and SAAGA R&D strategic objectives	1	2	3	4	5	1	2	3	4	5
29. The effective implementation/execution of SAAGA R&D strategic objectives	1	2	3	4	5	1	2	3	4	5

Section C: Own inputs (optional)

Please list and explain any other measures that you regard as important in determining the effectiveness of avocado research and development. Please indicate the *importance* and your current *satisfaction* with the provided variables. Please extend the table provided should you wish to add more variables.

Variable	Importance					Satisfaction				
1.	1	2	3	4	5	1	2	3	4	5
2.	1	2	3	4	5	1	2	3	4	5
3.	1	2	3	4	5	1	2	3	4	5
4.	1	2	3	4	5	1	2	3	4	5
5.	1	2	3	4	5	1	2	3	4	5

Section D: Comments or notes (optional)

Please provide any comments, notes or concerns relating to this study

_____

_____

_____

_____

- The end, thank you for your contribution -