Research Projects

SAMAC
Macadamias South Africa NPC

Crop Protection	
Project Name	**Description**
Biology and management of the two-spotted stink bug associated with macadamia orchards in South Africa	The two-spotted stink bug is considered as the most dominant and damaging pest in South African macadamia orchards, where adults are responsible for causing severe yield losses. Understanding the biology of this species is crucial for developing adequate management tools. The overall aim of this project is to study the biology of the two-spotted stink bug and to develop and adapt new/existent management options. For this, i) the genetic diversity of this species will be examined, ii) the alarm pheromone will be characterized and iii) the lethal and physiological effects of insecticides on this species will be evaluated. Results showed that no genetic variation were observed in the country. The alarm pheromone is characterised by three main compounds. Insecticides have various acute lethal effects, and future studies will determine their physiological effects. The results of this project will contribute to improve the pest management program against this species in the South African macadamia orchards.
Characterisation of chemosensation genes and the sex pheromone in the macadamia nut borer	A survey conducted from 2017 to 2019 throughout the three main growing provinces in South Africa identified macadamia nut borer (MNB) as the most dominant moth pest of macadamia, representing over 95% of the larvae collected from nuts. Therefore, the development of effective control measures for MNB needs to be prioritised. With the global movement towards greener farming, pheromone products are becoming an increasingly attractive control tactic. In this project the aim is to characterise the sex pheromone of MNB and identify a repertoire of scents the moths respond to, thereby facilitating the development of various control products compatible with an IPM programme. To achieve this, we will employ both a traditional chemical ecology approach, using chromatography and various bioassays, as well as a 'reverse' chemical ecology approach, where we will identify the genes involved in scent perception.
The non-insecticidal pest management options for stink bugs (Hemiptera: Pentatomidae) in South Africa's macadamia orchards	Stink bugs (Hemiptera: Pentatomidae) are currently the greatest threat to South Africa's macadamia industry. As stink bug numbers are primarily controlled using insecticides there is a growing need for the development of alternative control methods. The main objectives will be to determine the plant DNA content found in the gut and to develop an assay to screen for the efficacy of micronutrient fertilizers to remove the bacterial symbionts of stink bugs that are essential for development and survival of the insect. The alternative plant hosts identified in this study can be used as trap crops and will provide further understanding on which plant hosts potentially serve as alternative breeding hosts in the surrounding environment. This study will also determine if micronutrient fertilizers can be used to successfully surface sterilize stink bug egg capsules. Results obtained in this study will contribute to integrated pest management of stink bugs.
Diversity, agroecology and management of thrips (Thysanoptera) in the Levubu region of Limpopo province, South Africa	Thrips are tiny insects that can lead to losses in the production and value of avocados and macadamias, reducing the capacity to generate wealth and support the communities where these crops are grown. Accurate identification of thrips is a necessary step for establishing the species that may damage avocados and macadamias. Also needed is knowledge of where, when and why thrips are present. Our project is identifying drivers of thrips damage and ways it can be prevented in the Levubu region of Limpopo province, South Africa. By doing so, we will provide advice on the avocado and macadamia varieties and stages of development susceptible to thrips damage, and whether fertilizer application regimes can improve levels of resistance. Maps of thrips 'hotspots' in the Levubu region will be generated, and conditions that promote high thrips abundance will be identified, which can be used to target areas needing control interventions.
Evaluation of different integrated pest management strategies for the management of thrips in macadamia orchards in South Africa	In this study we aim to understand the thrips that cause damage in macadamia orchards and the phenological stages that are susceptible to thrips damage. We aim to develop a scouting method for the industry coupled with an economic threshold relative to damage. It is furthermore one of the major objectives to develop (by statistical experimentation) an effective control method that can be implemented in an integrated pest management (IPM) program. The trials are executed on four different cultivars ('816', '695', '814' and 'A4') to determine cultivar susceptibility and the control program is tested in three different Köppen-Geiger climate zones ('Cwa', 'Cwb' and 'BSh'). This project will give the industry a proven scouting method, coupled with an economic threshold and an effective integrated pest management strategy for growers who experiences significant thrips damage.
Understanding the thermal biology of the two-spotted stink bug	The results of climate change influences agriculture globally through changes in environmental factors such as temperature, which have significant impacts on crop and pest phenologies. The thermal biology of the two-spotted stink bug has not been studied in detail to date. This project aims to quantify the response of two-spotted stink bug life stages to different temperatures. These temperature responses include the critical thermal limits where the ability to function is lost, rapid hardening, and acclimation which enables the pest to adjust to changes in temperature. The results show that the first instar is the most sensitive life stage while hardening and acclimation significantly improved the thermal tolerance of the second instar. Adult two-spotted stink bugs were tolerant to extreme temperatures. Thermal biology parameters form the basis of insect phenology models and population abundance, and hence damage in macadamia orchards.
Macadamia felted coccid biological control using parasitoid	A laboratory colony of the macadamia felted coccid will be established at the FABI Biological Control Centre in anticipation of the import of Metaphycus macadamiae, the parasitoid wasp of Australian origin deployed as a biological control agent against the felted coccid in Hawaii. Once lab-reared populations of both the felted coccid and its parasitoid have been reared, the specificity of the parasitoid will be assessed to confirm that it does not pose a threat to other endemic scale insects, and its effectivity to parasitize the felted coccid determined.
Understanding the basic thermal biology of the macadamia nut borer	The thermal biology and population dynamics of this important pest has not been studied in detail. The goal of this work is to investigate the role of temperature on macadamia nut borer population dynamics. We specifically aim to understand the developmental rates of each life stage, the upper and lower critical thermal limits, and the ability to cold or heat harden. We aim to evaluate a day-degree model and predict the number of generations this pest can complete per season across landscapes. It is important to understand the linkages between climate and population dynamics. The value of this study would be the ability to explain how temperature shapes the population dynamics of macadamia nut borer. This will help predict phenological events which should be targeted in the integrated pest management strategy.
Fungal symbionts of bark borers	The number of bark borers observed in macadamia orchards is on the increase, and it is not known what species of fungi associated with bark borers are causing tree death in macadamia trees. A survey for beetles will be conducted through the Disease Diagnostic Clinic in conjunction with Cropwatch Africa, and this research project will determine which fungal species are responsible and how disease-causing they are to macadamias.
Molecular diagnostic tools to detect the causative agents of macadamia dry flower disease in South Africa	Dry flower disease of macadamia is of growing concern in South Africa and there is a lack of molecular diagnostic tools for the streamlined identification of the dry flower pathogens. Genetic tools will be used to determine the presence of the dry flower causative agents on macadamia leaves and flowers at different flowering stages. Genomes of fungal species associated with dry flower disease will be used to develop a rapid diagnostic tool which can be performed with ease and without the need for expensive, advanced equipment or experts. The diagnostic tool can be combined with on-site DNA extraction methods, allowing for detection of dry flower pathogens directly in the field. The flowering periods of different cultivars and the conducive climatic conditions associated with dry flower disease will also be determined in field. This knowledge will contribute towards informed disease management practices and the timing of fungicide applications.
Understanding fungal nut diseases of macadamia in South Africa	Husk rot, a fungal disease caused by fungi from *Colletotrichum*, *Diaporthe*, and now *Calonectria* genera, has been known to the industry for a number of years. The diversity of species and biology of pathogens responsible for causing this disease are still not understood fully. This is the area on which this research is focused. Sampling over two seasons revealed a trend in pathogen dominance, *Diaporthe* being dominant early and *Colletotrichum* gaining dominance later in the growing season. Sampling each nut developmental stage revealed a high diversity of *Diaporthe* in young nuts with increasing number of *Colletotrichum* infections in more mature nuts on the same tree. Exploring the effect temperature and relative humidity has on their growth and conidia germination reveals differences in the ranges at which these fungi grow and the relative humidities at which infection of husks will be more likely.

Botryosphaeriaceae in the macadamia canopy in South Africa	*Botryosphaeriaceae* species are common endophytes but have the ability to cause disease under conditions of stress. They are well-known to cause branch die-back and tree decline, but have also been associated with diseases of nuts and leaves in other macadamia producing countries. Little is known regarding the diversity or the impact of Botryosphaeriaceae species on these different macadamia plant tissues in South Africa. The objectives of this study were to i) characterize the *Botryosphaeriaceae* and to determine their role in causing disease on different tissues ii) and to study the effect of drought and flooding on die-back disease expression. Pathogenicity assays revealed that most isolates were pathogenic to macadamia tissues, however, aggressiveness of different species differed between different tissues. This study provides new insights into the diversity and pathogenicity of Botryosphaeriaceae species on macadamia in South Africa and provides a foundation to understand the role of stress on the disease expression of these fungi.
Flower blight causal agent identification and laboratory fungicide screening	Flower blight is a fungal disease affecting macadamia flowers. *Neopestalotiopsis* and *Pestalotiopsis* cause a disease known as dry flower disease, Cladosporium cladosporioides causes green mould of flowers and grey mould is caused by Botrytis cinerea. Little is currently known regarding the prevalence and impact of the different flower blight pathogens in South Africa. Our research is therefore centred around identifying fungi obtained from diseased flowers. During our surveys weather data was documented. Once we know which fungi are present and have confirmed that they are flower blight causal agents, laboratory assays of fungicides to test their efficacy against the pathogens will be performed. Correlation of weather data with the presence of specific pathogens in field in and knowledge regarding fungicide efficacy will provide the industry with advice pertaining to fungicide application time windows. Maximising effectivity of fungicide application will reduce the number of sprays, allowing for a greater cost efficiency.
Optimizing the management of Phytophthora root and stem canker on macadamia using phosphonates and seasonal *Phytophthora* root colonization patterns	Phytophthora root and stem canker, caused by *Phytophthora cinnamomi*, cause significant economic losses in macadamia. Phosphonates are systemic fungicides (translocation up and down in trees) that are known to be effective against Phytophthora diseases. The project firstly aims to evaluate whether phosphonate foliar sprays, bark sprays or soil drenches are effective for managing Phytophthora root rot in macadamia orchards. The second aim will be to determine whether there are certain months of the year where *P. cinnamomi* root quantities peak. This information will be useful for optimising phosphonate applications, i.e. application should be conducted so that high root phosphite (phosphonate breakdown molecule active against *Phytophthora* spp.) concentrations coincide with high pathogen root quantities. The project will contribute towards the registration of the most effective phosphonate application method/s and time of application on macadamia since no fungicides are currently registered for managing Phytophthora on macadamia.
Managing oomycete pathogens in macadamia nurseries	Several oomycete species (*Phytophthora cinnamomi, Phytophthora parvispora, Pythium ultimum* and *Phytopythium vexans*) were recently identified in a SAMAC project as being pathogenic toward macadamia. It is thus important that these pathogens should be absent from macadamia nursery trees to ensure the establishment of healthy orchards. The project aims to improve the laboratory methods used for detecting oomycete pathogens in nurseries and to investigate whether biocontrol agents are effective at excluding the pathogens from nursery tree roots when applied in nurseries. A better understanding of how biocontrol agents function in suppressing oomycete pathogens on macadamia will also be obtained. The project will improve the quality of macadamia nursery trees by reducing the probability of introducing oomycete pathogens with nursery trees into orchards, which can result in a decrease in the profitability of orchards.
Characterization of oomycete species associated with macadamia trees	Oomycete species from the genus *Phytophthora* are known to be harmful to macadamia. In 2007, a survey of oomycetes associated with macadamia nursery trees in South Africa indicated that species within the genus *Phytopythium* may also be damaging to macadamia. The first aim of the study is to conduct a survey of oomycete species associated with macadamia tree roots in nurseries, young orchards and older orchards. The identified species will be evaluated for their ability to cause root rot and stem cankers on Beaumont seedlings. Species that are identified as causing root rot and/or stem canker on macadamia will be used to determine whether rootstocks (Beaumont, H2, A16 and Nelmak2) differ in susceptibility to the pathogens. Knowledge generated in this project will allow us to determine which oomycete species must be regulated in nurseries and which rootstocks are best utilised in regions where oomycete species are known to be problematic.
Characterisation of a novel virus from macadamia in South Africa	Macadamia trees in Mpumalanga suffer from severe chlorosis, which coincides with a significant drop in production. In an attempt to determine whether the chlorosis may be associated with a virus, the genetic content of diseased and healthy trees were 'mined'. Unfortunately, analyses could not link a specific virus to the chlorotic trees, however, a novel virus belonging to the *Orthotospovirus* genus was detected from samples. A detection method for the novel virus was optimised and subsequent surveys linked the virus to ringspot symptoms observed on different macadamia cultivars. The virus has to date been identified from orchards in Mpumalanga, Limpopo and KwaZulu-Natal, since initial detection in 2020. Related viruses are known to cause severe crop losses. It is therefore important that the virus, provisionally named macadamia ringspot-associated virus (MRSV), be further studied to determine whether this virus can lead to yield losses and whether it will be economical to implement control strategies against MRSV.
Effect of Macadamia ringspot virus (MRSV) on yield	Macadamia ringspot virus leads to the development of ringspots on macadamia leaves in all 3 major growing areas. The economic significance of MRSV will be determined by comparing yield in healthy and infected trees, as well as the spread of the virus in infected trees over three years. The industry needs to know the impact and incidence of the virus to determine whether it is economically viable to control the disease.
Timing of infection of macadamia fruit by *Phomopsis* spp. and the role of insect damage and climatic conditions on disease incidence	Husk rot disease has emerged as a major threat to macadamia production in South Africa. Symptoms are characterized by black spots that coalesce to form soft and spongy black lesions clearly visible on green fruit. Affected nuts may drop prematurely. Knowledge of the nut development stage/s which are most susceptible to husk rot infection in South Africa and the link between insect damage and husk rot disease incidence could result in improved disease management. Research conducted on husk rot in this project aimed to determine:(1) the link between physiological stages of nut development and time of infection of nuts by Phomopsis spp. in the field , (2) the prevalence of all stages of nut borer and stink bug on developing nuts and the correlation between husk rot incidence and insect damage and 3) the influence of climatic conditions on husk rot infection and disease development under field conditions.
The epidemiology of dry flower disease on macadamia in South Africa	Dry flower disease potentially poses a high threat to macadamia production in South Africa. Economic losses due to the disease have not been documented in South Africa. No studies have been conducted to show which flower development stages are susceptible and it is unclear how prevailing weather conditions in the field affect infection and subsequent disease development. Understanding the epidemiology of the pathogens is important for the development and implementation of effective disease control strategies. The overall aim of this study is to investigate the epidemiology of Neopestalotiopsis and Pestalotiopsis spp causing dry flower disease in South Africa. The specific objectives are (1) to determine the effect of temperature on colony growth of the dry flower disease pathogens in the laboratory, (2) to determine the time of infection of macadamia flowers by Neopestalotiopsis and Pestalotiopsis spp. and (3) to evaluate the impact of climatic conditions on the relative abundance of conidia under field conditions.
Identification of the causal agent of macadamia die-back in South Africa	Macadamia trees are potentially at risk of being infected by many diseases due to ongoing climate change, particularly those caused by latent pathogens. *Botryosphaeriaceae* species are among the most important latent pathogens, with a widespread distribution across many climatic zones and regions. Recently there have been many reports of die-back on macadamia trees in KwaZulu-Natal and Mpumalanga. This project will examine the affected orchards, attempting to understand and evaluate the disease caused by *Botryosphaeriaceae* on macadamia in South Africa. Objectives of this project are to: (1) determine the cause of die-back, (2) examine the virulence of all the *Botryosphaeriaceae* species found, (3) evaluate the tolerance and susceptibility of different macadamia varieties against the most virulent species of *Botryosphaeriaceae*; (4) evaluate fungicides against the fungal species; and (5) track the method by which *Botryosphaeriaceae* were introduced into the orchards – by investigating the rootstock in the nurseries, mature asymptomatic trees in the orchards, as well as the common woody plants growing in close proximity to the orchards.
An approach towards efficient use of entomopathogenic fungi in macadamia orchards	Entomopathogenic (EP) fungi are important pathogens that use the soil as a reservoir for long-term persistence; they are also antagonistic towards pests and diseases. It is important to understand the persistence of applied EP fungi in the soil of agroecosystems to potentially predict the possible duration of the beneficial effects of EP fungi soil inoculations. An integrated pest management approach has to be implemented for the use of bioinsecticide in macadamia orchards. The objectives of the study include: (1) Pathogenicity potential towards nymphal stages of the two-spotted stink bug (Bathycoelia distincta) using selected fungal isolates under laboratory conditions, (2) Examine the horizontal transmission of conidia between treated and untreated B. distincta adults under laboratory conditions, (3) Determine the compatibility of insecticides at particular doses to entomopathogenic fungi and (5) Monitoring the persistence of entomopathogenic fungi in macadamia orchard.

	Crop Production
Project Name	**Description**
Selection and evaluation of new cultivars for the South African macadamia industry	The South African macadamia industry relies primarily on imported cultivars – of the current commercial cultivars only Nelmac 2 and Nelmac 26 are local selections. With the exception of A203 and A268, all other current cultivars are more than 30 years old in South Africa and much older in their country of origin. To determine whether there are more profitable cultivars for adoption, 14 open source and 5 protected varieties have been imported recently from Australia and are being tested along with 4 standard South African cultivars, A203, A268 and 10 cultivars from the ARC germplasm collection. These trials are being conducted at five locations with different climates and will focus on factors such as yield, kernel recovery, kernel size and style split as well as monitor kernel defects which may reduce marketability. The objective is to release new cultivars which enhance profitability through increased production and/or quality.
Nursery based rootstock trials	During the course of the industry-sponsored cultivar trials currently in progress, a number of trees were lost both in the nursery and after planting in the field. The losses were heavily skewed towards several of the newly-imported cultivars and it was assumed that there may be an incompatibility between these cultivars and the clonal "Beaumont" rootstocks used for the trials. As a result, multiple rootstocks (clonal "Beaumont", seedling "Beaumont" and seedling "Nelmac 2") were grafted during the production of trees for the final industry cultivar trial. These trees are being evaluated in the nursery and will be monitored in the field after planting as well. The objective is to determine whether there is incompatibility between the rootstocks and any of the scions in this trial. If compatibility is not an issue, the trees will be examined to determine if there are further factors requiring investigation.
Macadamia husk compost	Production of macadamia in South Africa has increased over the past decade. However, providing enough nutrient elements to meet macadamia crop requirements is one of the greatest challenges facing macadamia producers. The majority of farmers are currently using macadamia husk compost as an alternative to chemical fertilizers in their orchards for various reasons. Regardless of the good results from the application of macadamia husk compost, there is no consensus on the recommended quantity of macadamia husk compost to apply in order to improve the fertility status of the soil as well as increasing crop yield and quality. In order to fill the above-mentioned gaps, a field experiment is being carried out at the ARC-TSC campus' research farm in the Levubu area to establish the effect of different application rates of macadamia husk compost (4, 8 and 12 t ha−1) on soil quality parameters. The preliminary results of this study has shown a significant increase in macadamia yield, significant improvement in soil qualities except for soil physical properties. The application of macadamia husk compost will add organic matter, increases microbial activity, reduces soil bulk density, and enhances nutrient availability.
A comparison of crop removal figures for different cultivars in the South African and Australian macadamia industries	Crop nutrient replacement values, together with leaf and soil analyses, provide a basis for determining annual fertiliser recommendations, and should prevent both under- and overfertilizing. Current estimates of nutrients removed from macadamia orchards through nut in husk harvesting are based on limited data from Australian studies, and to date, there has been limited focus on macadamia fertiliser requirements in South Africa. The objective of this study is firstly, to determine crop removal figures in both the Nelspruit/Barberton area and the KZN South Coast for the following varieties: Nelmak 2, 695, 788, 814, 816, 842, A4 and A16 - this should aid in future fertiliser recommendations. The second research objective is to compare these varieties' crop removal figures to those of varieties widely planted in Australia. The comparison of internal controls, used in both the South African and Australian legs of this study, will allow for the benchmarking of these results.
A comparison of the nutritional status of chlorotic versus healthy macadamia trees	Macadamia yellowing, or chlorosis, usually starts on single branches and eventually spreads throughout entire canopies, coinciding with a steep decline in production. These yellowing trees occur widely throughout the Nelspruit/Barberton/Witrivier/Hazyview area, while the incidence is much less common in other production areas. Various tests to determine whether abiotic factors, fungal or bacterial pathogens are the causal agents have so far proved inconclusive. Another possible explanation is that high phosphorous levels in these orchards interact with either iron or zinc, thereby inducing deficiencies which could lead to chlorosis. However, consensus regarding this theory is lacking in the industry. This illustrates the need for a survey comparing the nutritional status of chlorotic trees to that of healthy trees. The objective of this study is to provide a baseline assessment of major and minor elements in both soils and leaves to determine any deficiencies, as well as relationships or complexes between certain elements.
Determining the seasonal root growth pattern and carbohydrate allocation in macadamia trees	In macadamia trees, vegetative and reproductive development must be balanced to ensure long-term productivity of trees. Sufficient vegetative growth is needed to provide the framework for future bearing sites, as well as foliage to support the crop requirements, while excessive vegetative growth will be in competition with and reduce the current crop. An understanding of growth patterns, in response to the local environment and farming inputs in the form of irrigation and nutrition, is needed to develop effective management strategies in macadamia trees. Current available phenological information is mostly based on work done in Australia, and it is important to update the calendar for the South African industry. The objective of this study is to update the macadamia phenological calendar with a specific focus on the timing of root flushes and determining fluctuations in trunk and leaf carbohydrate reserves across seasons, in 'A4', '816', '695' and 'Nelmak2'.
Genomic technologies for macadamia tree improvement	The Macadamia Genomics Project aims to develop innovative technologies for accelerated macadamia tree improvement. This project of the Forest Molecular Genetics (FMG) Programme and the Macadamia Protection Programme in FABI will assist the South African macadamia industry to move into the genomics era by using expertise and infrastructure developed by the forestry sector. The first step is to develop DNA fingerprinting technologies that will allow the industry to conduct routine cultivar identification, clonal confirmation and parentage analysis. Next is to develop genetic linkage maps using whole-genome sequencing approaches to identify DNA markers located throughout the genome. The linkage maps together with morphological trait data will allow us to identify genomic regions and DNA markers associated with growth, flowering, nut yield, nut quality and resilience to biotic and abiotic stress. These genomic technologies will be implemented in breeding programmes to ensure the sustainability and competitiveness of the South African macadamia industry.
Genotyping of macadamia kernel to determine pollen parents	Recent advances in molecular markers for macadamia, developed in Australia, has made it possible to determine the pollen parent of individual macadamia kernels. In conjunction with Prof. Stephen Trueman of Griffith University, this project aims to identify the pollen parents of kernels of A4, Beaumont, 814 and 816 kernels on the farms under study. The pollen parent has been shown to have an effect on important characteristics such as kernel size, kernel recovery and the percentage whole kernel. As a secondary objective, the nuts sampled in this study will be examined to determine whether pollen parent affects these characteristics in the four cultivars studied. There will also be an attempt to determine whether the pollen parent of the 'Beaumont' kernels affects the extent of the onion ring disorder.
A site classification for macadamia orchards	A new project was initiated in 2021 through a collaboration between SAMAC, the Institute for Commercial Forestry Research (ICFR) and the Forestry and Agriculture Biotechnology Institute (FABI, UP), focussing on the development of a site classification for macadamia nut production. The site classification will provide a decision support tool to assess the land potential for productive macadamia orchards, evaluate site-specific risk, and support technology transfer. The macadamia site classification will also function as a platform for accessing information on site-specific orchard management best practices, generate maps showing the potential risk of important insect pests and diseases, risk of frost, and other threats that could affect the productivity of macadamia orchards. The macadamia site classification is being developed in a spatial environment and will be made accessible to members via a user-friendly, web-based application.
Best pollination practices and guidelines for macadamias in South Africa	Development of mutually beneficial industry standards and guidelines for pollination, based on well-founded research and experience in pollination practices, is crucial. Growers pay substantial fees for pollination and have the right to ask questions about the quality of hives being brought in for pollination. Likewise, beekeepers insist on protection of their bees from pesticides and reasonable compensation for their services. This study aims to evaluate, through in field testing, current hive recommendations of 2-4 hives/ha and determine the best colony placement strategy for optimal and even foraging patterns. Placement will be based on tree age, cultivar, pruning and planting density, taking into account bees that easily fly 300m along rows of 4-year-old trees but only 200m between rows. Both the macadamia and bee industries will benefit from sustainable beekeeping and pollination practices that are becoming more important in view of the growing macadamia industry and the consequent demand for pollination.

How many bee colonies do I need	The value of cross-pollination has been established and widely reported, but this study aims to address this question more directly by introducing different numbers of hives to macadamias under nets. This will also allow us to determine at which point the introduction of more hives no longer has a positive effect on yield, which will allow for recommendations to growers on the maximum number of hives they require.
Honey bee hive closures for better pesticide management in macadamia orchards	This project focusses on further developing hive closure structures (screened bottoms, vented lids, internal feeding systems and easy closing entrances) tested in the previous pilot project. The project showed than bees can successfully be closed inside their hives for five days if water and honey water is provided in order to protect them against chemicals. Colony strength and health will be assessed before and after spraying and hive closure for a season on a commercial farm.
Cross pollination in macadamia cultivars	This project was commissioned by the R&D Committee in order to determine the cross-pollination potential of 12 cultivars, and their production potential when cross-pollinated with other cultivars. The value of specific cultivars as pollen donors will be determined, i.e. determining which combinations of cultivars has the highest yield, best quality and nut size.
Importance of in-hive pollen transfer in the cross pollination of macadamias	Single cultivar blocks have commercially viable yields, and pollen transfer in hives have been identified as a possible mechanism by which cross-pollination can still occur in the absence of different cultivars in close proximity to one another. This project determines whether cross-pollination can occur through the transfer of pollen collected from different cultivars between bees in hives. This will in turn determine whether mixed blocks should be planted or not, if cross-pollinators should be introduced into existing orchards through grafting, or if sufficient cross-pollination is achieved by pollen "mixing" in hives.
Update to climatically suitable growth areas in South Africa for macadamias under present climatic and projected climate change conditions	During 2020 a project to determine the optimum growth areas for macadamia under current and future climatic conditions throughout South Africa was undertaken using a CMIP3 Global Circulation Model (GCM). This project highlighted those areas that are currently optimal for the growth of macadamias, as well as potential projected climatic changes that may result in current optimal areas becoming sub-optimal, and vice versa. This current project was requested to update these future climate projections using an ensemble of six updated CMIP5 GCMS. The value of this to the industry is that growers and industry experts will be able to determine whether current optimal areas will be viable in future, while also potentially identifying more resilient macadamia crops for those areas that may become less optimal in future. The purpose of this project is to give the industry time to plan for potential changes in climate into the future.
Proposed methodology for the evaluation of spray deposition parameters quantity, quality and uniformity as influenced by spray application practices in macadamia nut trees	This project is focussed on determining how much of an active ingredient (pesticide) makes it to its target, the uniformity of the active ingredient on the target (e.g. distribution on a leaf) and uniformity of the distribution between leaves. A fluorescent dye will be used to mimic the activity of an active ingredient, and its distribution will be compared between three different spray volumes. This will serve as the first step to improve spraying practices in our industry and spray drift later on.
Optimizing irrigation of macadamia orchards: transforming theory into practice	This project was commissioned by the R&D Committee in response to the current project on macadamia water requirements which ends in March 2021. The existing project focussed on how much water macadamias need and when, with the new project focussed on how to deliver the required water most efficiently. The trials will focus on optimizing and comparing drip and micro sprinkler irrigation, and will study the leaf anatomy of different cultivars to quantify possible differences in the water requirements of different cultivars. This will determine if field trials are required to compare the water requirements of different cultivars. Lastly, the water stress trial of the existing project, which focussed on the phenological stage at which macadamias are most sensitive to water stress did not provide conclusive results as the researchers struggled to induce adequate levels of stress in the study sites and yield losses couldn't be determined as a result of the national lockdown. That component will be repeated in another orchard in this new project.
National mapping of commercial macadamia orchards in South Africa	Under a SAMAC initiative, researchers at the University of New England's Applied Agricultural Remote Sensing Centre (AARSC) are building the national map of all commercial macadamia orchards across South Africa. The mapping will deliver an accurate understanding of the extent (distribution and area) of production. This foundational information is essential to inform traceability and forward selling, improve resilience to biosecurity threats and for post-natural disaster response and recovery. Understanding the spatial distribution and area of orchards will support yield forecasting across all scales: at national, regional and farm levels. Within this project AARSC will also determine the planting date of all orchards mapped using historic satellite imagery (from 1986 to present) and determine the accuracy of predicting yield at multiple scales, based on the models already developed in Australia using remote sensing.
Production Benchmark	Growers expressed the need for a way to compare or benchmark themselves with an industry average in terms of parameters such as DIS yield per hectare, kernel recovery percentage, back-on-farm income per hectare and production costs based on variables such as growing region, cultivar and irrigation type. An interactive information platform was developed, with SAMAC receiving averages per variable. As more growers participate in the benchmarking process, the quality, representativity and accuracy of the data will improve.
Carbon footprint benchmarking of the South African industry	The Confronting Climate Change (CCC) Initiative is a carbon footprinting project, developed to support the South African fruit and wine sectors by identifying and responding to the risks and opportunities associated with carbon emissions. The CCC Initiative includes an online carbon-footprinting platform; industry engagement workshops; a range of commodity-specific industry benchmark reports; and relevant energy and emissions-related news and information. The CCC Initiative is currently collaborating with SAMAC and several macadamia producers and is in the process of developing a benchmark for the macadamia industry. The information provided in a carbon footprint report for an individual producer is extremely valuable in identifying the hotspots in their business and indicating to them where they should focus their efforts to reduce not only carbon emissions but to minimize input costs and ensure greater resource efficiency and ultimately long-term sustainability of business activities and operations.
Macadamia nutrient monitoring and rectification using a regenerative agricultural approach supported by a precision agricultural workflow	Over the last three years, Beaumont trees have not performed well on the lower North-Coast of KwaZulu-Natal. Despite flowering appearing promising, yield was up to 60% lower than expected. This study aims to determine whether nutrient deficiencies underly the poor performance through advanced soil health tests and leaf sap and leaf analysis.
The efficacy of the ionic solution, Prosol Agrigrow, against Phytophthora on macadamia	*Phytophthora cinnamomi* infection of macadamia trees are widespread in the industry. To date, no products have been registered for use on macadamias against Phytophthora, although trials on phosphonates have been ongoing and will be finalized in 2022. Prosol Agrigrow has showed promise as a safe and environmentally-friendly product which can control *Phytophthora cinnamomi* in irrigation water. Prosol Agrigrow is an ionic solution which also contains a growth stimulant. The product will be tested in the field as well as in the glasshouse, and its effect on Phytophthora infection, tree health, growth and yield determined. It may especially be valuable in the nursery environment, where the presence of known and new Phytophthora species are currently of great concern. If results are promising, a registration will be pursued.

Future Orchards	
Project Name	**Description**
Industry information to unlock the potential of future orchards	Farm management decisions are largely influenced by the factors that result to sustainable, profitable production. This project aims to provide an industry information knowledge base that is relevant and remains up-to date. It is a farm verification tool, that provides detailed orchards census information. While keeping on-farm records of day-to-day activities in a simple way, a wealth of information is shared with growers. Best practice statistics should provide valuable information to grower participants, which could result in knowledge-based best operating practice formulations, and guide future research. Pest and disease monitoring records coupled with pesticide applications can be shared on an industry-wide platform. These could be coupled with harvest records and forecasts. The integration across disciplines, through grower involvement makes this project unique. Data is gathered with integrity, in a transparent manner, so that growers will benefit through participation.
Mechanical harvesting of macadamia nuts	Harvest season is the most important phenological event in a mature orchard's cycle and requires a large influx of temporary labourers to ensure the crop is harvested and processed. Mechanization has increasingly proven its relevance and financial benefit to improve harvest efficiency and consistency throughout the orchard's life span. The objectives of this project will be to investigate the variety of different mechanical harvesters currently used in the Australian industry. Factors such as capital input, running costs, return on investment, repairs, parts and service availability, orchard suitability, ease of use, efficiency, damage and harvest speed per hectare will be considered amongst others.

Post-harvest	
Project Name	**Description**
Addressing the issue of shell skin marks (skin adherence) on macadamia kernel	Skin adherence (the cause of skin marks on kernel) is one of the factors contributing to loss of premium grade kernel in the South African macadamia industry. This disorder tends to be associated with hybrid cultivars such as 'Beaumont', 'Nelmak 2' and 'A4'. Although the losses due to this disorder are relatively low in general, some combinations of growing region and cultivar can lead to losses of up to 1.5% of kernel on a DIS basis where total unsound kernel varies from 2.5% to 4% on a DIS basis (SAMAC loss factor benchmark report, 2020). In 2020, the industry lost 1.31% on a DIS basis due to stinkbug, placing this disorder on a similar scale to stinkbug damage where it occurs. This project seeks to assess the possible factors such as nutrient deficiency and/or water availability which may contribute towards the development of the disorder and, if possible, to ameliorate it.
Loss factor benchmark	Macadamia loss factors are compiled, measured, and benchmarked annually by Source BI (Pty) Ltd. Each grower member of SAMAC receives an interactive online report that compares losses in the industry on various levels, including production areas, cultivars, and seasons. Once data is received from the participating handlers, each delivery is tracked to its origin so that benchmarking can be done per production region where individuals can compare themselves to the regional benchmark as well as other production regions and to the industry.
Cultivar and environment effect on fatty acid profiles and quality in macadamia kernel	Research funded by SAMAC regarding kernel shelf life has revealed that there is a significant intra-seasonal effect on kernel quality. Specifically, late season kernel appears to have a shorter shelf life. It has been hypothesised that this may be due to fundamental differences between kernel from early and late season cultivars. Since the double bonds in fatty acids determine whether oils oxidise, it is likely that late and early season cultivars have different fatty acid profiles and thus differ in shelf life. One objective of this study is to determine whether different cultivars do indeed have different fatty acid profiles. A second objective is to determine whether these profiles affect shelf life of kernel, while a third is to determine whether profiles and antioxidant levels vary during kernel storage. The resulting information should allow the industry to make allowances for these inherent cultivar differences and market kernel in a way that shelf life is optimised.
Determining the effect of ethephon application on "Beaumont" shelf life	Ethephon has been registered as a nut abscission agent for use on the "Beaumont" macadamia cultivar for some time and is efficacious when used at the correct concentration and with the correct timing. However, ethephon has effects other than abscission, one of these being to promote ripening in a number of fruits. This is seen as development of fruit colour associated with ripening as well as, for example, conversion of starch to sugars. This leads to the question of whether ethephon advances the maturity of treated macadamia kernels, and in so doing reduces their shelf life. The current work examines the quality of "Beaumont" kernels harvested with two ethephon concentrations (750ppm, 1000ppm) at two times in the season (May, July). Peroxide analysis and accelerated oxidation tests will be used to determine whether there is a decline in kernel quality, both at processing as well as one year after processing.