# Insect Pests of Cultivated and Wild Olives, and Some of Their Natural Enemies, in the Eastern Cape, South Africa

Submitted in fulfilment of the requirements for the degree of

Doctor of Philosophy in Entomology

Rhodes University

by

**NOLWAZI MKIZE**

January 2008

## Abstract

This thesis has two focuses. The first problem facing the olive industry in the Eastern Cape is the growers' perceptions of both what the industry will provide them and what a pest management program might entail. The second focus is the biology of olive pests in the Eastern Cape in terms of understanding their populations and their natural enemies on private farms, with future hopes of understanding how Integrated Pest Management strategies can be developed for this crop.

Eastern Cape private farmers, small-scale farmers and workers from agricultural training institutions were interviewed regarding the history and cultivation of the local olive crop. Only one commercially viable olive grove was identified; other groves were small, experimental pilot ventures. The introduction of olives to small-scale farmers and agricultural training schools was generally a top-down initiative that led to a lack of sense of ownership and the trees being neglected. Other problems included poor human capital; poor financial capital; lack of adequate support; lack of knowledge transfer and stability; lack of communication and evaluation procedures of the project; miscommunication; and finally, olive pests. Apart from hesitancy to plant at a commercial scale, the main problem facing private farmers (Varnam Farm, Hewlands Farm and Springvale Farm) was pests.

Therefore an investigation of pests from private farms was conducted ranging from collection of cultivated and wild olive fruit and flea beetle larvae for parasitism, trapping systems both for fruit flies and olive flea beetle adults.

A survey of olive fruits yielded larval fruit flies of the families Tephritidae (*Bactrocera oleae* (Rossi), *B. biguttula* (Bezzi) and *Ceratitis capitata* (Wiedemann)) and Drosophilidae (*Drosophila melanogaster* (Meigen)) from wild olives (*O. europaea cuspidata* (Wall. ex G. Don) Cif.) but none from cultivated olives (*O. e. europaea* L.). Braconid wasps (Opiinae and Braconinae) were reared only from fruits containing *B. oleae* and *B. biguttula*. This suggests that *B. oleae* is not of economic significance in the Eastern Cape, perhaps because it is controlled to a significant level by natural enemies, but *B. biguttula* may be a potential economic pest. A survey of adult fruit flies using ChamP traps baited with ammonium bicarbonate and spiroketal capsules and Sensus trap baited with methyl eugenol and Questlure confirmed the relative importance of *B. biguttula* over *B. oleae*. ChamP traps were over 50 times better than Sensus traps for mass trapping of *B. biguttula* but both were ineffective for trapping *B. oleae* and *C. capitata*.

Six indigenous flea beetles of the genus *Argopistes* Motschulsky (Chrysomelidae: Alticinae) were found, three described by Bryant in 1922 and 1944 and three new species. Their morphology was investigated by scanning electron microscopy and mutivariate morphometric analysis. The leaf-mining larvae are pests of wild and cultivated olives in South Africa and threaten the local olive industry. At Springvale Farm, *A. oleae* Bryant and *A. sexvittatus* Bryant preferred the upper parts of trees, near new leaves. *Pseudophanomeris inopinatus* (Blkb.) (Braconidae) was reared from 23 *Argopistes* larvae. The beetle larvae might not be controlled to a significant level by natural enemies because the rate of parasitism was low. The olive flea beetles showed no attraction to traps containing various volatile compounds as baits.

The lace bug, *Plerochila australis* Distant (Tingidae), was sometimes a pest. It showed a preference for the underside of leaves on the lower parts of the trees. A moth, *Palpita unionalis* Hübner (Crambidae), was reared in very low numbers and without parasitoids. A twig-boring beetle larva, chalcidoid parasitoids and seed wasps of the families Eurytomidae, Ormyridae and Eupelmidae were also recorded.

## Declaration

I, Nolwazi Mkize, declare that this work is my original research and no part of this work has ever been submitted for examination at any other university or academic institution.

Date

______________________________ ____________________

# Table of Contents

## List of Tables

**Chapter 5**



**Chapter 6**



**Chapter 7**

## List of Figures

**Chapter 7**

without interaction between (%CV 110.19, S.E = 0.003). c, d: Larvae density did not differ significant difference on height but differ significant on side (p < 0.001), without the interaction (%CV 361.20, S.E = 0.002). e, f: adult densities differ significant with height (p < 0.001), but not with with side, without interaction (%CV 164.69, S.E = 0.0032). g, h: . Total olive flea beetle density g and h showed significant difference with height (p < 0.001), and significant difference with side (p = < 0.001) but not interaction (%CV 111,02, S.E = 0.0065).

Figure 4 (a- d): a, b: A total population density of *P. australis* on *O. e. europaea* L. in October in Springvale Farm differ significant height (p <0.001), side (p = 0.003) without iunteraction (%CV = 218.77, S.E. = 0.0048). c, d: In February 2004 no significant difference with height; side, and no interaction between the factors (%CV 2703.93, S.E. = 0.000169).

Figure 5 (a- d): a, b: a total population density of *P. australis* on *O. e. europaea* L. in October and c, d: in Febrauary in Belmont Valley which showed no significant difference with height), side and without interaction. However the pattern of lace bugs densities was similar to the one showed in Springvale Farm (Figure 3 a-d).

## Acknowledgments

My very special thanks to God; to my mom, the late Noluvuyo Mkize; my late grandmother Gladys N. Sonqishe; my husband Jabulani S. Mthombeni; my dad Zola Mkize; siblings Bongo Mkize, Sonwabile Mkize and the rest of my family; to Brenda Obwolo and other friends and colleagues at the Agricultural Research Council; and to my supervisor, Prof Martin H. Villet.

I thank the private olive farmers: Craig Rippon (Springvale Farm), Dave Duncan (Varnam Farm), Ezra Schombee and Johan Stander (Hewlands Farm) and Keith Dankwerts (Carlisle Bridge), and the community olive growers of Peddie, Binfield, Ncera, Enoch Sontonga Rehabilitation Centre and the Ncera Agricultural Development Corporation, and workers from the University of Fort Hare, Fort Cox College and Pandulwazi Boarding School, for allowing access to their olive groves and for their time during interviews; Kim Hoelmer and Alan Kirk (European Biological Control Laboratory, United States Department of Agriculture [EBCL - USDA], Montpellier, France), Abraham S. Chawanji, Charles Willemse and Jabulani S. Mthombeni (Rhodes University [RU], Grahamstown) for helping with interviews, field work and general support; Charles H. Picket (Department of Food and Agriculture [DFA], USA) and Daniel Kriek (Quest Development CC, Brits, South Africa ) for providing traps; Dominique Coutinot (Quarantine Officer, EBCL - USDA, Montpellier, France) for helping to find taxonomist; Mervin W. Mansell (Plant Protection Research Institute, ARC, Pretoria) and Ian M. White (Natural History Museum, London) for identifying fruit flies; Charles H. Pickett (DFA, USA) and Robert A. Wharton (Department of Entomology, Texas A&M University, USA) for identifying fruit fly parasitoids; Simon van Noort (South African Museum, Cape Town) for identifying olive flea beetle parasitoids; Martin Krüger (Transvaal Museum, Pretoria) for identifying moths; Tony Dold (Selmar Schonland Herbarium, RU) for identifying plants; Margie Cochrane (South African Museum, Cape Town), Elizabeth Grobbelaar (National Collection of Insects, Agricultural Research Council [ARC], Pretoria) and Sarah Gess (Albany Museum, Grahamstown) for allowing us to use valuable preserved specimens; Antony Stylianou (Ncera Agricultural Development Corporation) for weather data for Ncera village; John Scrimgeour (South African Olive Industry, Stellenbosch) and Carlo Costa (Infruitec, ARC, Stellenbosch), for photographs; Shirley Pinchuck and Marvin Randall (Electron Microscope Unit, RU), and Angela Simon (Vacutec, Johannesburg) for taking SEM and colour photographs; and Sue Abraham and Bronwyn McLean (Graphics Service Unit, RU) for graphics.

It is with great gratitude and humility that I received financial support for my education from the United States Department of Agriculture, the National Research Foundation, the Andrew Mellon Foundation and the Rhodes University Joint Research Council. Any opinion, findings and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Research Foundation.

# Chapter 1 General Introduction

## 1.1 Olives in South Africa

The cultivated olive, *Olea europaea europaea* L. is a member of the family Oleaceae that produces edible fruit. It originated in southeastern Asia, from where it reached the Mediterranean regions (Costa 1998, Heywood 1998, Copeland *et al.* 2004). The African wild olive, *Olea europaea cuspidata* (Wall. ex G. Don) Cif., is found throughout southern Africa. *Olea capensis* L., *O. exasperata* Jacq. and *O. woodiana* Knobl. are also found in southern Africa (Green 2002). Cultivated olives are a significant crop, because their oil and fruit were fundamental food in early European civilisations and much of their wealth was derived from trade in olive oil. Many cultivars are available worldwide but the most popular are Mission, Kalamata, Manzanilla, Barouni and Frantoio (Costa 1998). Mission is the most popular cultivar in the Western Cape because of its suitability for processing for both table olives and olive oil.

In 1903 an Italian nurseryman, Ferdinando Costa initiated an olive industry in South Africa, at Rosebank and Plumstead, with the Paarl Valley as its centre (Costa 1998). The South African olive industry is now over 80 years old and there are more than 50 commercial olive farmers in the Western Cape, producing approximately 90% of South Africa's total olive production and approximately 430 tons of olive oil and 3500 tons of table olives (Western Cape Investment and Trade Promotion Agency (WESGRO) 1999, 2005/2006). The annual value of the industry is about R150 million, and annual development is worth R25 million, which is very small compared to global plantings in countries such as California, Spain, Italy and Greece. For example, Californian total production in 2005-2006 was estimated to be 110 000 tons (Crop Production Report 2007). Even though South African olive production cannot be compared to other countries, it can still export olives and olive oil to countries such as Switzerland, the United Kingdom and the United States.

An olive-growing industry was initiated in the Eastern Cape (Hattingh 1998, Naki 1998, Zifo 1998, Tamba 2000, Feni 2000), which lies within the natural range of the wild olive, *O. e. cuspidata*. Initially 4000 trees were to be planted at Döhne Agricultural Institute near Stutterheim (Naki 1998), and plans were announced in the local newspapers for establishing a nursery and eventually planting 400 000 trees and creating 20 000 jobs at various sites in the province (Siqoko 1999). Former Eastern Cape Agriculture and Land Affairs Member of the Executive Council (MEC) Max Mamase suggested a transfer of trees to selected areas such as Binfield (between Alice and Hogsback), and six community-based olive growing pilot sites were initiated in the Eastern Cape (Feni 2000). The idea was a joint initiative with an Italian company, Agri Consultants (Hattingh 1998) and aimed to create jobs in the Eastern Cape.

Independently, cultivated olives were also planted a few years later by private farmers at Springvale Farm, Varnam Farm, Hewlands Farm, and Carlisle Bridge Farm.

## 1.2 Olive pest and their control

South African olives growers are fortunate in that there are few pests on local cultivated olives. They include olive fruit fly *Bactrocera oleae* (Gmelin.), which is the most common olive pests in the Mediterranean, Africa and Europe; the olive flea beetles, *Argopistes oleae* (Bryant), *A. capensi*s (Bryant) and *A. sexvittatus* (Bryant); and the olive lace bugs, *Plerochila australis* Distant 1940, *Neoplerochila dispar* Duarte Rodrigues 1982 and *Neoplerochila* sp. (Annecke & Moran 1982, Apenteng & Wallade 2005). Other pests that are not yet considered serious threats are olive psylla, *Euphyllura olivine* (Costa); black scales, *Saissetia oleae* (Olivier); red scale, *Aonidiella aurantii* (Maskell); ross scale, *Lindingaspis rossi* (Maskell); oleander scale, *Aspidiotus hederae* (Vallot) or *A. nerii* (Bouché); olive mites, *Oxyenus maxwelli* (K.); Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann); Natal fruit fly, *Ceratitis rosa* Karsch, seed wasps, *Eurytoma spp*.; unidentified leaf roller moths, unidentified stem borer beetles and several different species of nematodes (Crovetti 1996, Costa 1998). Wild olive trees act as a reservoir for some of these pests.

### *1.2.1* ***Olive fruit fly***

Olive fruit fly, *B. oleae* (Diptera: Tephritidae), is a major pest of cultivated olives and is found in areas such as the Mediterranean, the Canary Islands, Pakistan, the Caucasus, Egypt, Eritrea and South Africa (Annecke & Moran 1982, El-Hakim & El-Sayed 1983, Haniotakis *et al.* 1991, Karamanlidou *et al.* 1991, Crovetti 1996). The larvae feed solely on olive fruits and cause premature fruit drop and yield reduction. It has been reported in Greece that if *B. oleae* is not controlled, crop losses may reach 80% in oil-producing areas and 100% in areas where table varieties are produced

(Broumas 2002), accounting for 20-30% of the total Greek production. *Bactrocera oleae* was detected in California in October 1998 in the Los Angeles area and spread to the rest of southern California in 1999, to the Central Valley in 2000, to Marin, Napa, Sonoma, Solano counties in 2001, and to Shasta, El Dorado and Lake counties in 2002 (Rice *et al.* 2003, van Steenwyk *et al.* 2002, Vossen & Varela 2003).

Spraying registered insecticides is a method for controlling *B. oleae* that has been used world-wide for years and it has been very efficient for ensuring good yields (Haniotakis *et al.* 1991, Manousis & Moore 1987). However, insecticides have been found to pollute the environment, cause human diseases and kill desirable insects such as pests' natural enemies (Neuenschwander 1982, Sharp *et al.* 1986, Desneux et al. 2007), and pesticide residues were detected in olive oil (Montiel-Bueno & Jones 2002), posing a human health risk. It was also reported that *B. oleae* has gained resistance to some insecticides such as organophosphates (Stasinakis *et al.* 2001, Hawkesa 2005 & Skouras *et al*. 2006).

Since then the control methods have moved to mass trapping systems, the use of natural enemies, the sterile insect technique (SIT) and manipulation of pests' genetics (Kapatos 1989) with the aim of eliminating the use of insecticides (Broumas 2002, Dimou *et al.* 2003). Mass trapping systems has been given special consideration due to the availability of potent baits and visual attractants. The mass trapping method includes traps treated with chemosterilants, food or sex attractants (Economopoululos 1979, Raspi 1982, Haniotakis *et al.* 1991, Broumas *et al.* 2002, Montiel-Bueno & Jones 2002). Large numbers of traps are placed in olive groves, and achieve a satisfactory level of control through the capture of large numbers of adult flies (Montiel-Bueno & Jones 2002). Traps show variation in efficiency depending on parameters like trap design, trap density, deployment, attractant type and formulation, insecticide used in toxic traps and method of application, size of the grove, biological factors (pest population density, tree size, variety, fruit size, fruit load), degree of orchard isolation, other cultural practices (irrigation, pruning, fertilization) and number of years the method has been applied in the same orchard (Broumas *et al.* 2002). Raspi (1982) has also shown that some traps can have a negative effect on beneficial insects.

Compared to Mediterranean countries, *B. oleae* is not a major problem in the Western Cape (Annecke & Moran 1982). The reason for this was that the olive fruit fly has a large number of natural enemies, including *Bracon celer* Szépligeti (Braconidae), *Opius africanus* Szépligeti (Braconidae), *O. lounsburyi* Silvestri ((Braconidae), *Achrysocharella formosa* Westwood (Eulophidae), *Cirrospilus* *variegatus* Masi (Eulophidae), *Eupelmus afer* Silvestri (Eupelmidae), *Halticoptera daci* Silvestri (Pteromalidae) and *Psilus silvestrii* Kieffer (Diapriidae). The possible advantage of investigation for natural enemies of *B. oleae* in sub-Saharan Africa has long been appreciated (Silvestri, 1913, 1914, 1916). Fourteen species of parasitic wasps were collected by Silvestri from fruits infested with *B. oleae* in Eritrea in 1914, and ten were taken to Italy, although none of these became established after release (Neuenschwander, 1982; Wharton, 1989). The most well-known parasitoid is a braconid wasp, *Psyttalia concolor* (Szépligeti) (= *Opius concolor*), which was repeatedly introduced into Italy, Greece, France, Spain and Portugal and eventually became established. With the realization that neither native natural enemies nor *P. concolor* was providing satisfactory control in most Mediterranean areas, interest in obtaining new natural enemies was revived in the 1970s. Greathead sought parasitoids in 1975 (Greathead 1976) but no fruiting specimens of *Olea* species were encountered in Kenya and searches in Ethiopia produced insufficient results. Neuenschwander (1982) was much more successful in his search for olive fly parasitoids in South Africa, but unfortunately the material shipped to Europe could not be cultured and thus no species were established.

### *1.2.2* ***Olive flea beetle***

The larvae of olive flea beetles (Coleoptera: Chrysomelidae: Alticinae), namely *Argopistes oleae* (Bryant), *A. capensis* (Bryant) and *A. sexvittatus* (Bryant) (Annecke & Moran 1982), are leaf miners that cause damage to olive leaves and occasionally to fruits (Costa 1998). The adults are 4-5 mm long and are recognized by their yellow colour with dark, longitudinal stripes on the elytra. Adults were described and illustrated by Bryant (1922, 1944), but the descriptions were not particularly comprehensive and the sexes were not distinguished. The descriptions were improved by Taylor (1945) and Myburgh (1952) but in Myburgh's (1952) publication the names of two taxa appear to have been transposed under their photographs. The larvae have not been described and the biology of these beetles is very poorly known (Annecke & Moran 1982).

### *1.2.3* ***Olive lace bug***

The olive lace bug, *Plerochila australis* Distant (= *Teleonemia australis*) (Tingidae: Hemiptera), causes damage to cultivated and wild olives. They damage the leaves by inserting their fine mouthparts to suck out cell contents (Pinhey 1946, Myburgh 1951, Whitehead & Myburgh 1961). *Plerochila australis* is found in the Ethiopian region, Mauritius, Zimbabwe and South Africa (Pinhey 1946, Hill 1983, Stonedahl *et al.* 1992). Heavy infestation leads to complete leaf chlorosis and eventually the leaf abscises. Two other species, *Neoplerochila dispar* and an unidentified *Neoplerochila* species, have also been found on cultivated olives in the Eastern Cape (Apenteng & Wallade 2005)

### *1.2.4* ***Olive pest control***

Various methods were suggested to control either olive flea beetles or olive lace bug in the Western Cape, including winter spraying of overwintering adult beetles with lead arsenate; spraying with a mixture of lead arsenate and fixed nicotine, oil, benzene hexachloride, DDT, Parathion, Malathion, Metasystox and Gusathion; and trapping of the pests (Lounsbury 1918, Mally 1924, Myburgh 1952, Whitehead & Myburgh 1961). Some of the control methods were found to be successful in controlling adult and larval olive flea beetles but others not (Whitehead & Myburgh 1961). Currently some commercial farmers both in the Western Cape and Eastern Cape use the recommended chemical Azinphos-methyl (Costa 1998, Nel *et al.* 2002) against olive flea beetles and demeton-s-methyl and oxydemeton-methyl for olive lace bugs. Some commercial farmers in Olyvenrivier Valley (Western Cape) use Organo-Z by simply spraying regularly followed by a cultural control method i.e. the use of home-made repellents (Eglington 2004) that are claimed to be effective.

Costa (1998) raised concern about insufficient research on these pests in South Africa, and more recent literature indicates a need for urgent attention to ensuring effective protection of olive crops for the benefit of the commercial olive industry and small-scale olive growers in South Africa. This includes the exploration of tools besides pesticides.

## 1.3 Motivation

An olive-growing industry has been initiated in the Eastern Cape, and some sites have potential for producing table olives and olive oil. A number of pests affect the cultivated olives, which presents an opportunity to survey both olive pests and their natural enemies to ensure good quality fruit and oil production in the Eastern

Cape. The area lies within the natural range of the wild olive, which may act as a source of both pests and their parasitoids. This also provides an opportunity to monitor these pests on other host plants during the active olive fruiting season.

## 1.4 Scope

This thesis presents an investigation of olive history, and of olive pests and some of their natural enemies in the Eastern Cape, with future hopes of understanding how Integrated Pest Management strategies can be developed for trees grown for both private and small-scale production in the Eastern Cape.

## 1.5 Aims

In pest control, there is a need to focus on both the farmer and the crop. The application of Integrated Pest Management, i.e. the techniques for control of pests in the field, requires a thorough understanding of the insect pests and their natural enemies, therefore I aimed to:

- investigate olive growers' perceptions of their olive crops, especially those in the olive pilot project
- monitor seasonal trends of insects populations on both cultivated and wild hosts in Springvale Farm throughout the active olive fruiting seasons by identify the species of parasitoids present in these sites at different times and ranking their relative abundance
- compare rates of parasitism at all of the sites where olive fruit was collected
- investigate a better control method for fruit flies by placing a practical number of traps in an olive grove to capture adults
- clarify the species' names and differentiate the sexes of the olive flea beetles
- report on parasitic wasps reared from olive flea beetle larvae collected in the Eastern Cape, with an interest in their biological control potential
- characterize the spatial distribution of olive flea beetle eggs, larvae and adults and of olive lace bug nymphs and adults on olive trees to identify and predict the best trapping positions on a tree
- test the attractiveness of some volatile compounds identified from cultivated olives that may be attractants of adult olive flea beetle under field conditions, with a view to developing practical management tools for adult olive flea beetles.

# Chapter 2 A case study of olive growing in the Eastern Cape: perceptions of provincial development initiatives

## 2.1 Abstract

In 1999 an olive project was initiated in the Eastern Cape that involved small-scale farmers and three agricultural research and training institutions with the hope of alleviating poverty and creating jobs. There were 14 olive-growing sites, many based in the former homelands of Ciskei and Transkei. Five groves were on private farms, six on small-scale farms and four at agricultural training institutions. The status and impact of the olive project was unknown in all the areas, so each grove was investigated by site visits, and by conducting interviews with all of the community members, representatives from the agricultural training schools, and private farmers within the province. Generally, small-scale farms and agricultural training schools applied a top-down approach to implementation that led to the olive trees being neglected. The main problem facing the private farmers was olive pests, while the small scale farmers and the agricultural training institutions reported problems including lack of a sense of ownership; poor human capital (skills, knowledge, and capacity to work); poor financial capital (service); lack of knowledge transfer; lack of stability of support; lack of communication and evaluation of the project; miscommunication of the time-scale of the project; and pests. One privately owned grove is commercially productive.

## 2.2 Introduction

The olive industry in the Western Cape is successful, 51 private farms contributing 90% of South Africa’s total table olive and olive oil productions, with a 10% growth in demand each year for table olives, and 20% annually for oil (Joubert 2002, Anonymous 2004). Such growth enhances the South African economy, which is a national priority for redressing past social inequities.

The Eastern Cape has one of the highest rates of poverty in South Africa and the bulk of the people are unable to secure a livelihood for themselves and their families (Poverty and Inequality Report (PIR) 1998). The poverty is believed to have been brought about by land dispossession during colonial rule and apartheid in South Africa (Kariuki 2004). There is now a crucial need to eradicate poverty and promote sustainable rural livelihoods. The provincial government has responded to this issue by emphasizing and encouraging small-scale and emerging farming projects that were initiated through land reform and reallocation (Sibanda 2001). Land reform is believed to offer an exceptional opportunity to generate socio-political and economic transformation in rural South Africa through the redistribution of land to the landless, tenants and farm labourers, which will ultimately redress the imbalances of land ownership in South Africa (the Eastern Cape Member of the Executive Council [MEC] of the Department of Agriculture and Land Affairs 2000).

It was planned that the provincial government would provide grants to previously-disadvantaged South African citizens to access land specifically for agriculture. Minister Max Mamase, then the MEC of the Department of Agriculture and Land Affairs, believed that such a policy of land reform would offer local people a suite of benefits (Department of Agriculture Strategic Plan for 2004–2007), as follows. Land reform would overcome the legacy of past racial and gender discrimination, and stimulate growth through agriculture. This policy would expand opportunities for promising young people who prefer to remain in rural areas and empower beneficiaries to improve their economic and social well being. Farming would improve nutrition and disposable incomes of the rural poor who wished to farm on any scale. This policy was intended to enable those presently accessing agricultural land in communal areas to make better productive use of their land (Mamase 2000, 2002).

In 1998/1999 the Eastern Cape MEC of the Department of Agriculture and Land Affairs initiated several projects aimed at poverty alleviation in the Eastern Cape, including projects involving goats, chicory, hemp, sugar beet, pineapple and olive-growing (Anonymous 2002a, 2002b). The olive trees were planted on community farms and at agricultural research and training institutions, and were "initially imported from Italy and kept in the Paarl area" (Naki 1998).

Olives are currently grown on 14 sites (Tamba 2000, Feni 2000), mainly in the former homelands of Ciskei and Transkei (Malan & Hattingh 1976). Five are on private farms, six on small-scale farms and three at agricultural training institutions (Fig 1). The small-scale community farmers were in the former 'homelands' of Ciskei (Binfield; Ncera Farm, Ncera Village 6; Peddie (Durban Location) and Enoch Sontonga Rehabilitation Centre) and Transkei (Qunu). The areas were known to have been neglected under the previous government, and these communities are referred to by the current government as under-resourced (Sibanda 2001). Ncera Developmental Trust is a public company that is referred to as an emerging farm and it consists of previously disadvantaged farmers who are aiming to make a change from subsistence to commercial agriculture.

In 2001 the status of the olive tree project on small-scale farms was reported to be good and Tamba (2000) claimed that few problems had been reported. The Daily Dispatch newspaper reported in 2002 that the Eastern Cape olive trees were growing well and that the Deputy Director of Extension, Officer Nariman Khayltash, said that there was consideration of establishing of a nursery (Mdoda 2002). In 2002 an olive production workshop was held at Döhne after the project had started, sponsored by the National Department of Agriculture (Department of Agriculture 2002).

At about this time, several private farmers around Grahamstown planted commercial olive trees to assess their viability. These projects were independent of the provincial government project, and provide a comparison case from a different part of the province. This chapter assesses the status of all of these olive-growing initiatives, investigates the perceptions and attitudes of the various groups of growers, and highlights the challenges faced in the planning and delivery of a significant community olive pilot project.

## 2.3 Materials and Methods

### *2.3.1* ***Growing areas***

A snowballing convenience technique (Kumar 2005), where respondents were asked to suggest other areas and communities that had planted olives in the Eastern Cape, was used to find olive growing areas and to recruit participants. The search for new sites stopped when respondents consistently mentioned only about areas that had already been visited or which were outside the province.

### *2.3.2* ***Status assessment of olive trees***

Each site was visited at least once, and the trees examined and photographed. Any off-colour appearance of leaves was noted and scouting for the presence of pest (which affect the leaves) was done in all the areas. Olive leaves are important organs for nutrient storage and their condition often characterizes the elements that are lacking in a tree (Costa 1998).

Aerial images of many of the groves were obtained from Google Earth (http://www.earth.google.com/).

#### *2.3.3 Stakeholders' perspectives*

**Private farmers**. Unstructured individual interviews were conducted with four private farmers. The fifth private farmer was not interviewed as it was impossible to get in touch with him. The unstructured interviews were used because the private farmers could not be interviewed together as they had busy schedules and because they live far from each other. Most importantly, the unstructured interview gives the interviewee and interviewer freedom in terms of content, wording and structure of the interview (Kumar 2005). Interviews and discussions were audiotaped and/or written up in the field during or immediately after the work. Follow-up questions were usually done by telephone or e-mail.

**Government**: Unstructured interviews were conducted with the relevant agricultural extension officers. Additionally, a telephonic interview was carried out with Mr Max Mamase, the MEC of the Department of Agriculture and Land Affairs who initiated the olive-growing project. The emphasis was to know what criteria were used for choosing the project sites.

**Training institutions**: With the interviewee's permission, unstructured individual interviews (Binns *et al*. 1997) were conducted with the relevant institutional professionals and/or labourers, depending on their availability. Telephonic and e-mail interviews were done with permission where it was necessary to verify written reports about the olive project.

**Small-scale farmers**: Focus group interview methods described by Hope & Timmel (1984) were used to understand the perceptions of small-scale farmers. Interviewees' dignity and privacy were considered by asking for permission from them before conducting the interview (Denzin & Lincoln 1994). This approach to interviewing was used because the people in the communities were illiterate and old, ages ranging from 55-65years, and group meetings were more culturally appropriate than individual interviews. It also allowed respondents to express themselves by discussing issues together, including the group leader (Krueger 1994). The group dynamics stimulated discussions that generated ideas to pursue in greater depth. Field notes were taken and an audiotape was used with respondents' permission to record the discussions to improve the quality of the written notes by replaying, and to minimise loss of data.

Personal attributes such as education, gender, age and employment status of farmers were obtained in the interviews. Formal educational achievement was recorded to gauge the human capital consistency of the respondents; gender was included to understand the gender division of labour; respondents' ages were important to see whether olive farmers were likely to continue serving the olive industry in the anticipated future; and employment status was included to indicate alternative sources of income.

A discussion was held with twenty-two community members in Peddie and with eight community members in Binfield. The community in Ncera Village 6 and the chairman of the Ncera Agricultural Development Corporation (Pty) Ltd were interviewed together as they were based in the same place. The discussions focused on gaining a deeper insight into the ways in which the development initiative and the rural community interacted. The communities provided a preliminary understanding of their perceptions during the first meetings and with the hope that the interviewer will acquire the respondents' honest views. The information was examined and organised by the interviewer, and arranged into, themes that were apparently important to the community (Hope & Timmel 1984), based on the written notes and verbatim transcriptions of the recordings.

Two weeks after the first meeting, problem posing codes (illustrations showing a familiar situation in the community: Figures 2 and 3) were presented to the groups. Freire's method was used to unlock the problem posing codes (Hope & Timmel 1984): the spontaneous feelings of the local community about the situation were gauged from an informal listening survey that compared their narratives to the previously identified themes of concern (Hope & Timmel 1984).

## 2.4 Results

### *2.4.1* ***Private farms***

**Springvale Farm** (33°20'52"S, 26°11'48"E; alt. = 535 m; Figure 3A-C) is 31 km from Grahamstown along the Alicedale road (Figure 1). The average temperatures in winter range from 13°C to 14°C and in summer from 25°C to 32°C. Mean annual rainfall is 580 mm, concentrated in early summer and autumn. Wild olives grow in the river valleys on the farm (Fig. 3A).

In 1820 the farm belonged to the Wilmots and was used to grow mielies. The present owners, the Rippons, bought it in 1915 and farmed merino sheep (for wool), cattle and occasionally goats. The farmers experienced problems with the goats and sheep and got rid of them with the help of many stock thieves.

The current farmer, Mr Craig Rippon, was motivated to start olive farming because of a love of olives, particularly table olives, and the beauty of the healthy wild olive trees on the farm, and because he wanted to farm something that would not be stolen by stock thieves. He was inspired by seeing olive trees while visiting Spain, realising that they could survive the aridity that is a feature of the farm, like the wild olives already growing on the farm. In addition, Mr Rippon believes that women in Africa are the key to unlocking Africa's potential, and olives would draw women into the business of the farm, which was difficult to achieve on a cattle and sheep farm. Finally, Esingeni Bush Camp a tourism potential outlet for olive-related products forms part of the farm, provides tourists with a week-long course that covers subjects like camping skills, fauna and flora, forest conservation, medicinal plants, astronomy and orientation.

In February 2000 Mr Rippon started planting olive trees in what were previously lucerne lands where angora goats bred. The olive groves now cover about 34 hectares. The cultivars planted were Mission, Manzanilla, Coratina, Frantoio and Nocellara del Belice, which are suitable for either table olives or oil production. In 2005 there were 540 Mission cultivar trees in one grove and 100 trees of Manzanilla and other cultivars in other groves. In 2003 the trees were about 2.5 m tall. The farm yielded 300 tons of olive fruit in 2005, 5 tons in 2006 and 110 tons in 2007 (Rippon pers. comm., de Lange 2007). The farmer has sold table olives in the local shops. The only problems reported by the farmer were pests such as olive fruit fly *Bactrocera oleae* olive flea beetles *A. capensi*s (Bryant) and *A. sexvittatus* (Bryant) and olive lace bug, *Plerochila australis*.

**Hewlands Farm** (33°28'38"S, 26°28'39"E; alt. = 247 m; Figure 3D-E) is located near Salem, 19 km from Grahamstown (Figure 1). The average temperatures are 7-9°C in winter and 25-27°C in summer. There are hundreds of indigenous wild olive trees on the farm.

In 1999 commercial olive trees were planted by Mr Harry Tyson, the first person to plant olive trees at an experimental scale. Unfortunately he died soon afterwards, but Mr Tyson's wife said her husband started planting olives because of his love for olives, particularly olive oil. Mr Johan Stander, the owner since 2004, was not particularly interested in olive farming and focused on sheep, cattle and chicken farming.

In 2007 there were about 350 olive trees of unknown mixed cultivars. No fruit was obtained, the trees are neglected, and vegetables such cabbages and potatoes have been planted between the trees. The trees had a variety of pests in small numbers in 2005. The only problems reported by the farmer were pests such as olive fruit fly *Bactrocera oleae* olive flea beetles *A. capensi*s (Bryant) and *A. sexvittatus* (Bryant) and olive lace bug, *Plerochila australis*

**Varnam Farm** (33°19'26"S, 26°38'10"E; alt. = 443m; Figure 3F) is in Belmont Valley, 10.5 km from Grahamstown (Figure 1). The average temperatures and rainfall are similar to those of Grahamstown. Wild olives grow throughout the indigenous vegetation on the farm.

The current farmer, Mr Dave Duncan, inherited the farm from his father, Mr James Duncan, who bought the farm in 1952. The farmer has been growing crops such as spinach, cabbage, broccoli and flowers on the farm. He was personally motivated to start olive farming as an experiment, partly because there were wild olives on the farm.

About 100 Mission and Kalamata olive trees were planted in 1999 and 2000. Thus far no fruit was obtained from the trees. In 2005 there were practically no pests, and the grove was not monitored further. The farmer reported no other problems with the trees until 2007 (Table 3).

**Carlisle Bridge** (33°04'23"S, 26°22'57"E; alt. = 353 m; Figure 3G) is 31 km north of Grahamstown (Figure 1). The climatic conditions are slightly drier and hotter than those of Grahamstown. Wild olives grow on the farm in places along the Great Fish River.

The farm has been in the family of the current farmer, Mr Keith Dankwerts, for at least three generations. Mr Dankwerts farmed vegetable such as spinach, cabbage, broccoli and flowers, and had a small ostrich production system. He wanted to explore other crops, and after talking to Craig Rippon of Springvale, he planted a few dozen olive trees as an experiment which was an olive network neighbourhood influence.

The olive grove was started in 2001 and there were about 150 Mission cultivar trees which were about 2 meters tall in 2005. In 2007 Mr Dankwerts harvested about six 20-litre buckets of olives. According to the farmer, the olive trees did not have olive pests, so no control methods were applied. No pests were found on a visit to the farm in 2005. The cultivated olives were also in close proximity to indigenous wild olive trees, which also bore no traces of pests. In 2007 Mr Dankwerts complained about birds feeding on the crop.

**Farmerfield** (33°30'00"S, 26°32'00"E; alt. = 250 m) is situated in Salem was a Methodist Mission Station on the west bank of the Kariega River. The climatic conditions are similar to Hewlands Farm, and wild olives grow in the area.

The farm was established in 1838 by Reverend William Shaw to encourage the amaXhosa to receive religious instruction and to provide a livelihood. Farmerfield was named after the Rev. Thomas Farmer, a prominent minister in Britain in the early 19th century. In 1850, ownership was transferred to the Wesleyan Missionary Society and later to the Methodist Church of South Africa (Hall 1993, Carlisle 2000).

In about 2000, an estimated 2000-3000 olive trees were planted but were all subsequently cut down which led to no pests problems experienced. This farmer was not interviewed.

### *2.4.2 Agricultural research and training institutions*

Olive trees were planted at agricultural research and training institutions, the main purposes of which were either to conduct agriculture-related research or to train pupils and students in agriculture. These institutions were considered disadvantaged under the previous South African government but had exposure to expertise in agricultural practices in crop and/or animal farming. The selection of these institutions for participation in the olive-growing project was a decision made at a national level.

The only problems reported by either researchers and/or wokers were pests such as the olive flea beetles *A. capensi*s (Bryant) and *A. sexvittatus* (Bryant) and olive lace bug, *Plerochila australis*.

**Döhne Agricultural Development Institute** (32°31’38”S, 27°28’59”E; alt. = 870 m) is located on the north of Stutterheim (Figure 1). It lies in a summer rainfall area in a mist belt receiving 500 mm of rain annually and is characterized by particularly dry winters and wet, humid summers. The area experiences mean maximum temperatures of 23°C and mean minimum temperature of 16°C, and extreme conditions with regular heavy frosts and several snowfalls during winter because of its altitude (Eastern Döhne Central Nucleus 2007, http://dohne.eci.co.za/edcn/). Some wild olive trees grow in the area.

Döhne Agricultural Development Institute is a part of the Eastern Cape Provincial Department of Agriculture (EC-PDA) that renders some technical support such as soil analysis and evaluation of veld quality. Stutterheim is highly populated and surrounded by commercial farms (cattle, fine-woolled sheep and citrus) and smallholdings (Swanepoel 2006).

Although it was reported that the first olive trees in the olive-growing project were to be planted here in 1999 (Naki 1998), it could not ascertained if this actually happened. No pests were reported either.

**Pandulwazi Boarding High School** (32°39'18"S, 26°55'26"E; alt. = 707 m; Figure 3G) is 25 km from Alice towards Hogsback (Figure 1). The climatic conditions are similar to those of Alice and Binfield Farm, which is 4 km away towards Hogsback. There were wild olive trees in the area.

The school is a historically black agricultural training school. The trees were tended by two black staff members who were 45-50 years old in 2005. Their sole income was from the school.

About 300 olive trees of unknown cultivars were planted in 2001 on about one hectare. The application of insecticides was delayed due to the loss of the key to open the chemical store room. Staffs tending the trees were moved to other jobs for several months, and could not cope with the backlog when they returned.

There were serious problems with pests observed in this field which were related to the olive flea beetles *A. capensis* (Bryant) and *A. sexvittatus* (Bryant) and olive lace bug, *Plerochila australis*.

**Fort Cox Agricultural College** (32°47'38"S, 27° 1'18"E; alt. = 445 m) lies about 20 km east of Alice towards Hogback (Figure 1). The climatic conditions are similar to those of Alice. The area had wild olive trees.

This historically black college was established in 1930 near the site of a 19th-century British fort. It has grounds of about 1 354 hectares along a perennial river. The olives were grown by two black staff members aged 40-45 years in 2005, employed and paid only by the college.

In 2000 an unspecified area of olive trees of unknown cultivars was planted. Only two trees survived in 2005 and were 0.5m tall; the rest were either dead or eaten by cows.

**The University of Fort Hare** (32°47'39"S, 26°50'53"E; alt. = 513 m) is in Alice (Figure 1). The climatic conditions include a mean annual rainfall of about 570 mm per annum and mean annual minimum and maximum temperatures of 3°C and 27°C. There were wild olives trees in the area.

This historically black institution played an important role in the advancement of Africa and, more particularly, in the education of the greatest number of present political leaders, including Nelson Mandela (ex-president of South Africa), Seretse Khama (ex-president of Botswana), Yusuf Lule (ex-president of Uganda), Robert Mugabe (president of Zimbabwe), Ntsu Mokhehle (prime minister of Lesotho), Fwanyanga Mulikita (ex-prime minister of Zambia) and Elijah Mudenda (prime minister of Zambia). ANC alumni include Oliver Tambo, Govan Mbeki, Chris Hani and many others. PAC founder Robert Sobukwe and Inkatha Freedom Party (IFP) leader Mangosuthu Buthelezi graduated in the 1950s.

In 1999, 150 olive trees of unknown cultivars were planted on an area of less than one hectare (Brutsch pers comm. 2004, Apenteng pers. comm. 2004-2007).

No olive fruit has been obtained so far, but there have other pest problems such as the olive flea beetles *A. capensi*s (Bryant) and *A. sexvittatus* (Bryant), olive lace bug, *Plerochila australis* and a stem borer. No one was specifically allocated to maintaining the olives but there were black staff members who were occasionally directed to work there. The site was in good condition in 2005 but needed to be sprayed and fertilized, and there were no allocated labour.

### *2.4.3 **Small-scale farms***

**Binfield** (32°40'26"S, 26°53'44"E; alt. = 709 m) is 14 km from Alice towards Hogsback (Figure 1). The climate is like that of Alice. The area experiences very cold temperatures during winter with a mean maximum of 14°C and mean minimum of 6.4°C and occasional snowfalls. Rain falls predominantly in summer. There were wild olive trees in this area.

Binfield is a rural area within the Nkonkobe Municipality in Ward 15 (Nkonkobe Municipality 2004/2005). The population in Nkonkobe Municipality is predominantly rural, with a rural:urban ratio of approximately 4:1 and Binfield is no exception. Generally, rural areas in Nkonkobe Municipality are moderately more densely populated than the urban areas with the population ranging from 745 to 1277 in each village. About 74% of the population is without an income, and their income ranges from R401 to R800; pensioners account for 97.8% in this income range. The average level of education of people in Ward 15 is very low, with only 0.27% of the population having matriculation or post-matric education (Central Statistics Service 2001, Eastern Cape Municipality 2004/2005).

In 2000, 200 olive trees of unknown cultivars were planted at Binfield. An agriculture official based in Alice and colleagues from the Provincial Department of Agriculture in Bisho solved a labour problem at Binfield by allocating 8 or 9 trees per person, but nonetheless some of the trees were neglected. By 2007 no olive fruit has been obtained, although the trees were reported be in good physical shape. An unquantified problem was reported with pests but was considered to be under control. Locusts were also reported to be feeding on the growing points and spraying was recommended to the extension officer responsible in this area by the Department of Agriculture in Alice. The issue of irrigation equipment for the olive trees was also raised.

There were serious problems with pests observed in this field which were related to the olive flea beetles *A. capensi*s (Bryant) and *A. sexvittatus* (Bryant) and olive lace bug, *Plerochila australis*.

**Ncera Developmental Trust Farm** (33°00'24"S, 27°32'54"E; alt. = 357 m; Figure 3H) is situated about 35 km SW of East London towards Port Alfred (Figure 1). The climatic conditions in this area are subtropical, characterised by warm humid to hot dry summers and relatively mild winters with warm days and cool nights. The average temperatures are 7-9°C in winter and 25-27°C in summer. The average annual rainfall is 400-700mm, moderately erratic, and mostly in the form of thundershowers (Stylianou pers. comm. 2005). Wild olives occur naturally here.

Ncera Developmental Trust Farm is in Ward 2 of Buffalo City Municipality. Ncera Developmental Trust is a public company listed with the Provincial Department of Agriculture as the sole shareholder (Buffalo City Municipality 2003/2004). The commitments of this company are to assist small-scale and emerging farmers by providing advice, extension services, training, and other services related to agriculture. The Ncera Development Trust is partially owned by the government. The farm is situated on state-owned land of approximately 3102 hectares. The olive project aimed to promote black commercial farming in an attempt to de-racialise the agricultural sector and also to achieve more widespread development in rural South Africa (Buffalo City Municipality 2003/2004).

In 1999 about 400 olive trees of two different, unknown cultivars, were planted on one hectare at Ncera Development Trust and it was anticipated that planting would be expanded, but in 2007 no expansion had occurred.

So far no fruit has been obtained and no problems were reported either pest such as the olive flea beetles *A. capensi*s (Bryant) & *A. sexvittatus* (Bryant) and olive lace bug, *Plerochila australis* occasionally.

**Ncera Village 6** (33°00'11"S, 27°33'12"E; alt. = 380; Figure 3J-K) is one of twelve villages within 2 km of Ncera Development Trust (Figure 1). It has the same climatic conditions as the Trust. In this area wild olive trees are widely distributed.

Title to this village was transferred to a Tribal Trust under the control of Xhosa Chief Doyle Mpuhle Jongilanga and his indunas (a Zulu word meaning advisor, great leader, ambassador, headman, or commander of a group of warriors) in 1998. The people in this rural area (which falls under Ward 2) are unemployed, faced with poverty and considered by the municipality to have a low quality of life. The population in this area numbers about 17 009 and approximately 80.2% of it is employed, mainly on pineapple farms and in some factories situated in the western side of the ward. Of Buffalo City's population, 26% are children (0-14 yrs), 38% are youths (15-34 yrs) and 8% are 60 years and older (Census 2001). People are involved in very small scale community projects such as piggeries, poultry and sewing, but the largest source of employment is a broiler chicken project serving all twelve villages under Jongilanga. The income of people working in these projects is R4 801–R9 600 annually. Only 0.5% of people are educated due to inadequate education facilities (Buffalo City Municipality 2003/2004, Central Statistics Service 2001).

In 1998, 200 olive trees of unknown cultivars were planted at Ncera Village 6. Most trees died in 1999, apparently because of soil-related problems, and thus far no fruit was obtained.

No pest problems were observed due to the fact that all of the olive trees died.

**Durban Location** (**Peddie**) (33°12'17"S, 27°08'01"E; alt. = 321 m; Figure 3L) is about 10 km from the N2 national road between Kingwilliamstown and Grahamstown (Figure 1). This village is bounded by the Fish River to the south and the Kieskamma River to the north. The climate is characterised by variable moderateto-low rainfall with an annual average 400 mm at Tyefu; 60% of rainfall occurs in summer, peaking in October and February. No wild olive trees were seen in this area.

Durban Location is situated in Ward 11 in the Ngqushwa Municipality (formerly known as Peddie district). The estimated population distribution is fairly evenly spread in all of the wards. Ward 11 houses 5 086 people (1 347 households) with an average household size of 3.8 persons per household. About 95% of the population live in rural areas, with a shortage of basic essential services such as water, sewerage, electricity and community facilities (Central Statistics Service 2001; Ngqushwa Municipality 2005, 2006, 2007). Some 65% of the population are youths (15-34 years old) and the rest are older persons. The people's income sources in this area comes from primary activities (13%) which are farming and mining, secondary sector (18%) which is manufacturing, construction and utilities and tertiary sector (69%).

This location is where the former Minister of Agriculture Max Mamase was born and possibly the olive trees were planted because the MEC Max Mamase wanted to give something back to his community.

In 2001 it was reported that the grove was covered by weeds and the area was extremely wet, resulting to the death of the olive trees (Tamba 2000). However the trees were later replanted. The 141 olive trees occupied two hectares in 2005. No olive fruit was obtained so far from this area. The community also did not involve themselves in taking care of the trees and therefore the Döhne Agricultural Development Institute staff took over. It was later concluded by the National Department of Agriculture that the community must be encouraged. The fence surrounding the olive grove was stolen. It was reported that MEC Max Mamase was "Tired of the ongoing theft in the province", and that he said that, "the voltage of the electric wire protecting the Binfield olive tree pilot project near here would be increased" (Feni 2000). In 2005 no fence was in place.

Other than the fence being removed, the problems observed were related to the olive flea beetles *A. capensi*s (Bryant) and *A. sexvittatus* (Bryant) and olive lace bug, *Plerochila australis.*

**Enoch Sontonga Rehabilitation Centre** (32°56'17"S, 27°28'12"E; alt. = 323 m; Figure 3M-N) in Qongqotha village, 10 km from King Williamstown (Figure 1). The area is characterised by mild winters with temperatures of about 14°C and dry, hot summers of about 30°C. There were no wild olive trees in the area.

Qongqotha village falls under Ward 40. This Rehabilitation Centre was formally known as Nontsapho Rehabilitation Centre, named after President Lennox Sebe's wife, Nontsapho during the Sebe government period in Ciskei. Olive trees were planted on about one hectare of the 12 ha Enoch Sontonga school grounds. On this farm, the Qongqotha villagers grow vegetables that they harvest and sell to earn a living (Mxotwa 2000). This project was called Gwebindlala, which means ‘eradicator of hunger’, because it provided villagers with vegetables and the Eastern Cape Anti-Poverty Foundation staff with an income (Anonymous 2003).

The MEC Mr Max Mamase chose this site to plant cultivated olive to provide disposable incomes for the rural poor (Mamase 2000). In 2001 unknown olive tree cultivars were planted at Enoch Sontonga. The olive trees died, possibly because they were waterlogged and had pest problems, although examination of an aerial photograph (Figure 3M) suggests damage from a grass fire too.

Pest problems were related the olive flea beetles *A. capensis* (Bryant) and *A. sexvittatus* (Bryant) and olive lace bug, *Plerochila australis*.

**Qunu Farm** (31°48'35"S, 28°36'24"E; alt. = 751m; Figure 3O-P) on the premises of ex-president Nelson Mandela, is 32 km south-west of Mthatha on the road between Butterworth and Mthatha (Figure 1) (Smith 1999). Qunu village is assumed to have a climate similar to Mthatha, which is characterised by mean temperatures of 4,5°C in July and 21,7°C in February with average daily maximum range of 12,5°C to 21,7°C, and minimum of 4,2°C to 16,3°C. An annual average of 650 mm of rain falls from October to March, with the peak in February (South African Weather Bureau, 1997). Qunu is situated in a narrow, grassland valley, overlooked by green hills and there are no wild olives or any other trees.

Qunu Farm supports the surrounding community with seeds and fresh vegetables such as maize, sorghum, beans and pumpkins for survival. The local people were in the 40-80 year old age group. The community consist of a few hundred people who live in huts with mud walls and a wooden pole in the centre holding up a peaked grass roof. These rondavels are generally grouped together in homesteads some distance from the fields.

In 2000, 250 olive trees of 200 unknown cultivars (Dickson 2000) were planted at this site. They were reported to be in good condition (Anonymous 2001) but had pest problems. The leaves were completely yellow, showing no sign of good health and there were weeds between the trees (Carlo Costa and John Scrimgeour pers. comm. 2004). Carlo Costa's recommendations were to spray insecticides and apply fertilizer. Thus far no olive fruit have been obtained.

The pest problems observed which believed to have been caused by the olive flea beetles *A. capensis* (Bryant) and *A. sexvittatus* (Bryant) and olive lace bug, *Plerochila australis.*

### *2.4.4 Farmers' profiles*

Most respondents from Ncera Village 6, Binfield and Peddie were old enough to draw pensions (Table 1). The private farmers and the training institution employees were middle aged (Table 1).

A high proportion of respondents in Ncera Village 6, Binfield, Durban Location, Fort Hare Farm, and Phandulwazi High School never attended school (Table 1). The private farmers all had more than 10 years of formal education, and were self-employed, relying on their farms for income. The small-scale farmers depended solely on government old-age pensions, and the employees in the training institutions were paid by their employers.

### *2.4.5 Stakeholders' perceptions*

**Private farmers**. All of the private farmers had positive perceptions of the olive trees. Most viewed the crop as experimental and had not planted enough trees to be commercially viable. Three of the private farmers reported that their biggest problem was pests like olive flea beetles, lace bugs and, where there were commercial olive fruits, olive fruit fly. They did not seem particularly concerned about a lack of governmental support or training, and appeared to rely on their experience of other crops, common sense, and advice from Mr Craig Rippon (a commercial farmer in Springvale Farm) in some cases.

**Government officials**. During a telephonic conversation, MEC Mr Max Mamase said, "A climatological book was used which showed that the areas were suitable for olive growth".

The local government officials reported perceiving their involvement in the olive growing project as an opportunity to create jobs for the local people in terms of empowerment and business access to comprehensive olive oil markets. By 2007, some officials associated with the project had died, and others were promoted or had moved to new posts. An official from Durban Location (Peddie) said that the introduction of the olive project was top-down and politically directed. In 2007 he said, "Nothing is happening with olives. They have been neglected and for the past two years, 2006 and 2007, no one has been on the site to check them".

**Agricultural training institutions**. The rationale, aims, and objectives of the olive pilot project in agricultural training institutions was seen by the institution staff as an opportunity for pupils and/or students to learn about olive farming at an early age using a hands-on approach. However, a variety of problems were described, including a lack of sense of ownership, lack of resources, lack of capacity, and inconsistency of effort.

*Ownership*: The lack of a sense of ownership became evident when all of the trees at Fort Cox Agricultural College died. The trees had not been watered since they were planted, had not been maintained by being sprayed for pest and diseases, and not protected from local cows, which ate them.

*Resources*: There was a lack of financial capital or support to buy some of the equipment required for this project. The worker in Phandulwazi High School said "We do not have the fertilizer to apply on the olive trees".

*Capacity*: Workers stated that they did not have the knowledge to prune the trees. Interviewee A from Fort Hare reported, "There is no one who knows how to manage the olive trees and we have been promised training but so far we have been waiting for six months and we still lack knowledge".

*Discontinuity*: There was discontinuity in management. For example, the workers at Phandulwazi were moved to other tasks for two or three months and by the time they returned the weeds and grass was too long to maintain. At Fort Hare the olive trees did not have any permanent staff member responsible for them.

**Small-scale farmers**. The introduction of the olive tree pilot project was seen by the community as a positive idea and they had high expectations for the long-term success of the project to the extent that the Binfield and Peddie small-scale farmers were passionate and excited about the project. In the Binfield and Peddie communities there was 100% participation, particularly in attending meetings held prior to and soon after project initiation. The community viewed the introduction of the olive trees as providing opportunities for them, potentially including employment opportunities, stipends from the government (for maintaining the trees) and hunger eradication.

Farmers reported that several factors affected the implementation of the project, including a lack of ownership that interacted with a lack of knowledge transfer and a lack of stability of personnel; lack of adequate support such as poor financial capital; poor human capital (skills, knowledge, and capacity among aged to work); lack of communication with officials and evaluation procedures; and miscommunication of time-scales of the project. Because of these above factors the small-scale farmers became disillusioned.

*Ownership*: In Peddie a lack of sense of ownership was created by officials of the Provincial Government Department of Agriculture. At the beginning of the project when the trees were to be planted, the provincial government paid eight people to plant the olive trees on behalf of the people in Durban Location. This gave the people the perception that they were not involved in a project that was supposed to uplift and employ them, and led to the theft of the fence. After the trees were planted not even one community member was involved in the maintenance of the olive trees, and the Provincial Department of Agriculture and the municipality rescued the project by transferring employees from other divisions to look after the trees, perpetuating the alienation.

However, at Binfield and Ncera Village 6 community members showed ownership of the project by being involved in clearing the area where olive trees were to be planted.

*Support*: The farmers at Binfield felt they owned the project but they felt there was lack of adequate support from the Department of Agriculture such as supervision and training, evaluation of how the crop was performing, and provision of fertilizers. The Binfield farmers asked to be supplied with irrigation systems and fertilizers, and for the size of the local dam to be increased so they can be able to maintain the olive trees.

*Capacity*: There was a lack of human capacity such as skills and knowledge about the olive project. Interviewee B in Binfield said “We do not know how to prune the olive trees and the provincial government promised to send someone to teach us. We have been waiting and now are faced with disillusionment because the trees were falling on top of the gardens that were in between the trees”. Some basic training about the olive cultivation including pest and pest control was done by the Department of Agriculture but the training was inadequate.

The training in Peddie for example comprised two staff of the Department of Agriculture, not the community. There was no knowledge transfer to the communities because the two people trained were moved to other Departments before they could teach the people in the community.

However, the Ncera Village 6 farmers felt that the government supported them but the olive trees failed because they did not take good care of them. Interviewee C said, “We never visited the place as often as we should because we were so busy with other things but we do want the olive project”.

*Communication*: The people in Binfield were frustrated by a lack of communication with the government. “The government told us to write all of our needs concerning the project and we have done so, so many times. In return there is no response whether they have received our complaints or not and/or what they are going to do about them? For example, small-scale farmers in Binfield asked for an increasing of the dam close to the olive trees. At the moment the Binfield community doesn’t know whether the government is working on the problems or not” (Interviewee A). Interviewee B said, “We are tired of being asked by Mr G. [the extension officer in the area] to write down our needs and any other complaints about the olive project so that he can report them to the Department of Agriculture in Alice Town, because nothing comes after we have written. Up to now we are waiting for feedback”. The people said the olive pilot project led to disillusionment, with distrust of government officials.

*Discontinuity*: Staff of the Department of Agriculture trained but then were moved to other Departments. The person who attended a training course in Ncera Village 6 left in 2004 for another company, but in 2007 he returned to the olive project. Other officials died or were promoted to administration posts, and not replaced.

*Miscommunication*: When there was communication from the govenrment officials, the information was miscommunicated. All of the interviewees in Binfield pointed out that “someone” from the provincial government said that there had been a mistake, that the trees that were planted were all females and they needed to plant males next to the females. This has created mistrust because all the people now said the government was not reliable. The Binfield community raised a question: who is going to take care of the new “male trees” if the ones planted do not even produce fruit?

*Time-scale*: Many people complained that the delivery time of the product, which is approximately 4-5 years was unrealistically long for them. Interviewee D of Binfield stood up and said, “Four or five years is a long time to wait when you are hungry”. Interviewee E said, “We are used to crops such as cabbages and have maize or potatoes, which tend to be ready in a month to three months' time and we are assured that we will eat. These trees have not produced fruit even during the expected period".

*Disappointments*: Farmers were told that there would be fruit on the trees in five years but when the time came and there was no fruit and no one was available to inform them about what was happening. Disillusion led Interviewee D to say, "We have been struggling with the maintenance and management of this olive project and we are old and going to die without benefiting. Our children lack the interest because they have seen us struggle and they cannot take over".

*Immediate needs such as food*: This was a major concern in all the communities. Binfield farmers were told to plant crops in between the olive trees so that they could get food whilst they are working on the olive trees. For a short time they did this, but then stopped. Their reasons for stopping were that the roots of the trees were competing with their crops, and because the crops needed air and they did not get it between the trees, so they did not produce. Therefore the farmers' immediate needs were not met. At Binfield and Durban Location people complained that the basic needs for survival were not met and at Binfield they felt that they have been working for five years for "mahala" (meaning nothing).

*Employment*: At least eight people were employed and paid by the government in the process of planting the olive trees in Peddie, which encouraged some people in Durban Location because their sons were employed, but the payment stopped after the job, leading people to complain that now they are no longer involved on the olive project. Interviewee F said that there was no motivation for them to work because they did not get anything, while people who are taking care of the trees at Fort Hare Farm, Phandulwazi, Fort Cox Agricultural College and Enoch Sontonga Rehabilitation Center were employed and paid by their institutions. Olive tree project disseminated community divisions.

When farmers stopped tending their trees in Peddie and Binfield, government officials solved the problem by dividing the trees amongst the farmers. This brought community division and that affected olive tree management because some farmers sprayed while others did not. Interviewee C asked, "Why would I spray and waste my energy if my neighbour is making a home for the pests?"

*Accusation*: While farmers recognised some of the negative aspects of the project's implementation, Interviewee D said, "People here in Binfield are also very lazy". However, Interviewee E intervened and said, "The olive trees do not have value to us because we have been working on these olive trees and haven't gained anything. Why should anyone continue?"

## 2.5 Discussion

### *2.5.1* ***Status of olive groves in the Eastern Cape***

MEC Max Mamase indicated the project site selection process was based on climatic suitability and temperatures at the study sites were generally within recommended climatic conditions. Obvious factors that were either observed during site visits or raised in interviews include temperature, rainfall, humidity, irrigation, altitude, wind and solar radiation. For olive production, mean monthly temperatures should never drop below -3°C and summer should be dry and hot with mean monthly temperature between 22°C and 30°C (Costa 1998). Costa (1998) and du Preez (2005) state that the days of traditional growing of olive trees under dry conditions are vanished, and advise that to optimize production and quality of any fruit type, physical soil analysis needs to be done to know its water holding capacity. This apparently did not happen at Durban Location and Enoch Sontonga Rehabilitation Centre, where soil conditions were blamed for the death of trees. The Binfield farmers complained about not having water for the olive trees, although the original plan was to grow about half of the trees without irrigation (Hattingh 1998). In South Africa olive trees grown above 300 m altitude and all the sites were at altitudes above 300 m, except for Hewlands Farm which was at 247 m.

Windbreaks may be essential to support newly planted trees and make sure fungus diseases are checked (Costa 1998). The groves at Durban Location, Enoch Sontonga Rehabilitation Centre and Qunu are in grasslands that are very exposed to wind (Figures 3L, M, O), which may have hampered their establishment. Planting distances, row orientation, pruning and training systems affect light interception and distribution, and the olive trees at most sites were evenly spaced except for trees that had died. The trees at the University of Fort Hare were a bit clustered and the rows were orientated unusually which may create difficulties for orchard management (Figure 3A-P).

The olive growing project on small-scale farms was reported to be in good condition two years after its inception, and few problems were noted by 2001 (Tamba 2000). Subsequently it became evident that the olive pilot project was more of a success in some areas than in others, and a range of problems was raised by respondents in 2005 (Table 2). In 2005 the leaves at several sites often appeared yellow, which might be related to diseases, pests, and inadequate moisture or nutrients. In this case it was reported to be lack of nutrients, specifically, a nitrogen deficiency (Tamba 2000). This also showed a lack of resources and knowledge of the crop. In other areas the project seems to have failed for logistical reasons.

Of the five private olive sites, only one site was commercially successful: Springvale Farm produced 300 tons of olive fruit from 34 hectares in 2005, 5 tons in 2006 and 110 tons in 2007 (de Lange 2007). The other private olive groves were either still experimental and produced only little or no fruit, or no longer pursued olive production at all.

### *2.5.2* ***Farmers' profiles***

The respondents from Ncera Village 6, Binfield and Peddie were too old to maintain the olive orchard (Table 1). One of the interviewees in Binfield said "We are worried that we are too old and going to die without benefiting from these olives". The private farmers and the training institution employees were mostly middle aged (Table 1) and have a good chance of benefiting from their projects. The younger farmers also had more time to benefit from their experience and to hand it on subsequent generations, which was far less certain in the case of the small-scale farmers.

The respondents in Ncera Village 6, Binfield, Durban Location, Fort Hare Farm, and Phandulwazi High School were not educated and many were illiterate, while the private farmers were generally educated to tertiary level. Some respondents therefore had better access to and understanding of information than others. Educational level was important in this study as it is likely to guide the farmers' interpretation of educational pamphlets, books and instructions on containers.

The employment status of the respondents varied considerably between the groups was a key difference to the success of olive groves (Table 1). The private farmers were self-employed, and regard farming as a job, and relied on their farms for their living, while small-scale farmers depended solely on government pensions and the employees of training institutions were being paid by their employers. The differences on the source of income might have a huge effect on the input that each respondent was prepared to make on their olive trees.

### *2.5.3 Agricultural research and training institutions*

Basing an olive pilot project at agricultural research and training institutions was an excellent idea, especially given the expertise of staff and energy of students. At a school level, school gardens have a role in nurturing a realistic understanding of agriculture, nutrition and living skills in children. However, the implementation of the idea hindered its goals. Many of the problems faced at the agricultural institutions were similar to those experienced by small-scale farmers. Generally the institutional staff showed little sense of ownership of the project, lacked academic and financial capital and resources, and was not able to give consistent and continuous attention to project management, leading to neglect of the trees. The lack of ownership showed when the trees at Fort Cox Agricultural College all died because there was no irrigation or spraying programme or protection from cows. The staff consistently did not value their 'ownership' of the olive pilot project. This problem seemed to span the entire management hierarchy, because the reallocation of workers at Phandulwazi for two to three months was not a low-level decision. At Fort Hare the olive trees did not have any permanent staff member responsible for them. These results suggest that a top-down approach to project implementation that probably originated at the provincial agricultural offices that did not consider the needs and capacity of the institutions.

*Resources*: There was a lack of financial and technical support. The worker in Phandulwazi said that they lacked fertilizer for the olive trees. There was a lack of academic capacity, because workers felt that they could not prune the trees because they did not know how. Empowerment was incomplete because workers were promised training that never materialised. This suggests inadequate planning of the project. Adequate planning of any project is necessary for an excellent outcome (Robinson 1981).

### *2.5.4 Small-scale community farms*

The primary problem faced by the olive growing project was alienation of the beneficiaries. Except at Binfield, communities were not interested in the trees, which were either ignored or maintained by staff employed by the implementing agency. The top-down approach also characterised a small-scale irrigation project aimed at sustainable rural development 30 km west of Peddie (Sishuta 2005). Many papers have shown that the failure of development projects is commonly due to the lack of involvement of local people in the decision-making process, or a failure to recognize their greatest needs (Schuftan 1996, Younis 1997, Bollens 2000, Perez 2002, Simpson *et al.* 2003). A bottom-up approach is best because it builds local empowerment and promotes community participation, leadership and ownership of problems and solutions (Mannion 1996, de Beer and Marias 2005). Simpson *et al.* (2003) stated that the Queensland government had their own agenda for the Remote Town Internet Cafe Project and that made the individuals in the community feel left out from decisions and ownership of the project. Younis (1997) reported a strong sense of ownership and management of forests in Scotland with bottom-up initiatives.

A current lack of sustained governmental support also compromised the actualization of the project's specific goals. Possibly without being aware of it, the government created dependency in the recipients. The farmers felt that, besides the trees, they should get supervision, feedback, and more resources from the government. There was a lack of financial support to buy equipment required for this project, the equipment that was donated did not go far enough to assure success.

There was also a lack of technical capacity. Some basic training in olive cultivation and pest control was offered through the Department of Agriculture at Döhne, but the training was apparently ineffective, particularly in terms of its audience. Government staff were trained instead of the farmers themselves. Many small-scale farmers were old, and perhaps unlikely to pass on the expertise they were earning by persisting with farming unassisted. Had they been trained directly, the project would have been jump-started. Instead, unfulfilled promises of training led to disillusionment. For projects to be successful and sustainable there is an essential need for developers to impart genuine skills directly. Perez (2002) stated that lack of resources and training make food management plans doubtful. Community capacity is defined as sharing skills and resources to achieve outcomes that are not possible without assistance. Labonte (1999) also listed the dimensions of community capacity which were skills and knowledge, leadership, efficacy, norms of trust and reciprocity, social networks, and a culture of openness and learning. Due to the abovementioned issues, the small-scale farmers were faced with disillusioned and also demotivated to continue with the project.

MEC Max Mamase was reported as saying, "A pruning company would be established and its members sent for a three-month training period to the Western Cape where similar projects were already up and running. Mamase said the trainees would also learn harvesting and processing techniques as well as managerial skills" (Feni 2000). Although it promised job creation, this solution perpetuated alienation of, and failed to impart knowledge to, the growers. It also created another promise that risked not being kept.

When there was communication between farmers and local government, the information sometimes did not produce feedback or issues were miscommunicated. To advise that the trees were all females and that male plants needed to be procured was not true because olives are monoecious, having both perfect and imperfect flowers (Martin *et al.* 1994, Costa 1998). When this error was uncovered, it created mistrust because all of the people now said that the government was not reliable. Simpson *et al.* 2003 stated that such failures of project can create cracks that go beyond the borders of a project, and have a negative effect on the self-worth and future potential of the community.

The National Department of Agriculture acknowledged that there were problems surrounding the issue of knowledge and expertise, but emphasised the lack of collaboration with, or involvement of, horticulturists, entomologists and other scientists in the province (Tamba 2000). For example, the omission of horticulturists led to the loss of knowledge of the olive cultivars planted at all of the sites (Tamba 2000). It was later concluded that the project was simply not research-based (Tamba 2000).

This lack of research was illustrated in the choice of crop for poverty alleviation. From the government's point of view the anticipated time for the olive project to reach maturity was five years. This was rather unrealistic for poor farmers who were mostly pensioners working on an unfamiliar crop that is known to yield erratically (Neuenschwander 1982). This shows a lack of research or poor advice prior to the initiation of the project and inadequate preparation of the project. Planners need to be practical about timeframes required to achieve effective community engagement on projects. However Lee (2003) says there is no short term solution to key poverty.

Perret *et al.* (2000) and Odeyemi *et al.* (2006) have shown that rural farmers in the Eastern Cape cultivate crops for home consumption, not for income. At least the extension officers offered an immediate solution to the problem by suggesting that farmers should plant vegetables between the olive trees as an interim crop while waiting for the trees to reach production. An article in the Daily Dispatch reported that, "To make maximum use of the land, Mamase said vegetables could be planted in between the olive trees" in Binfield (Feni 2000). However, an orchard and vegetable garden system does not yield staple foods and if poor farmers cannot afford to buy the missing staples, the system cannot be considered a sustainable self-consumption subsistence strategy (Perez 2002). This is because the orchard's potential to become an income-generating source is at risk from so many factors, including frost and hail; a high potential for substantial loss of harvest due to post-harvest problems such as lack of storage facilities; poor resources for, and training in, preservation of the product; inadequate road and rail network support for marketing; no money for distributing the product; no targeted market; and the problem of accumulated debt which means that farmers who make money in a particular season will spend it instantly and will not ensure food or financial security for subsequent months. The small-scale farmers and some of the training institutions such as Binfield and Durban Location had exactly the same experience, since they had no infrastructure to support successful orcharding and lacked logistical and intellectual resources and training to solve the problems.

Some of the people's children were employed in Peddie at the beginning of the project and that created a sense of expectation of sustained and further jobs. The drop in the number of people interested in the project was clearly linked to expectation of jobs. In the Daily Dispatch newspaper, MEC Max Mamase announced that, "his department will plant over 400 000 olive trees in the next two years, which will create more than 20 000 jobs" (Siqoko 1999). In the Daily Dispatch in 1998 Mr Mamase anticipated, "about 300 workers could be employed in pruning, harvesting, and maintaining orchards which could result in more than 4000 jobs" (Siqoko 1999). He later told "about 30 potential olive farmers that a shift from dagga growing to hemp production must also be expected". Local Economic Development (LED) projects that were conducted in the Free State from 1999 to 2001, which were required to recognise plans to ensure job creation and poverty alleviation, showed a similar problem (Marais & Botes 2006). Not even one out of more than 400 jobs created during the LED project lasted long; however the job holders were all depending on the available social grants. Government officials need to be aware of the impact that these kinds of promises have on target communities when they are not met, leading to negative attitudes and raising barriers between them and the community for future projects.

Some small-scale farmers recognised the community's part in the unfruitfulness of the olive project because Interviewee D in Binfield said, "People here in Binfield are very lazy". The response that this comment drew foreshadowed a possible division in this community. It is vital to be practical about impediments encountered in community development such as splitting and conflict in communities (Gilchrist 2003). Putnam (1993) also warns that government activities that neglect or undermine community cohesion can create a strain on previously sound community groups and worsten conflicts that may already exist.

One thing that was fairly clear was that insect pests were a minor problem for the olive growing project, especially since the trees were not bearing fruit.

### *2.5.5 **Private farms***

The main problem of private farmers in the Eastern Cape was olive pests such as olive flea beetles (*Argopistes* spp.) and olive lace bugs (*Plerochila australis*) that affect the olive leaves (Table 2). A simlar report was mentioned for both wild and cultivated olives in the Western Cape (Myburgh 1952, Whitehead & Myburgh 1961, Annecke & Moran 1982, Swain & Prinsloo 1986, Costa 1998, Ellington 2004). One farmer from Springvale Farm also mentioned olive fruit fly (*Bactrocera* spp.), but other subsistence nor commercial farmers had no experience of this pest because their trees have not borne substantial amounts of fruit. Similar results has been reported in many other Africa countries (Lesotho, South Africa, Namibia, Kenya, Eritrea), and other places such as the Mediterranean region (Egypt, North Africa, southern Europe, Canary Islands), the southern Palearctic and Eurasia (Turkey, the Middle East, Caucasus, Pakistan) (Christenson & Foote 1960, El-Hakim & El-Sayed 1983, Crovetti 1996, Copeland *et al*. 2004, and California (Rice 2000, Collier & van Steenwyk, 2003).

## 2.6 Conclusion

This survey of the literature and farmers' perceptions contributed to the understanding of the status of the olive crop in the Eastern Cape, It has shown that a top-down approach to community development and poverty reduction is not successful. It has also been demonstrated that a genuine participation in a particular project requires that unique consideration in involving all citizen groups in the local community, including poor people, in strategic planning and decision making to be considered. Exclusion of the full involvement of community memebers participation will otherwise remain basically an objective rather than an achievement. In general, studies on community development-based projects investigated by various authors have shown to not work for poverty alleviation (Simpson *et al*. 2003, Marias & Botes 2006 and Harvey & Reed 2006, Bowen 2007). The fact that projects do not work is not necessarily due to lack of good ideas but to a certain extent with lack of emphasis on principles, which later hinder the feasibility of the projects. Having examined the social issues and general requirements of olive management illustrated by the olive pilot project in the Eastern Cape, this thesis progresses to entomological research focused on Springvale Farm, where the full spectrum of pests could be found**.**

## 2.7 Acknowledgements

We thank Craig Rippon (Springvale Farm), Dave Duncan (Varnam Farm), Harry Tyson (Hewlands Farm), Keith Dankwerts (Carlisle Bridge), Antony Stylianou (Chairman, Ncera Agricultural Development Corporation (Pty) Ltd.), and the Eastern Cape community and agricultural training institution olive growers for their time during interviews; Charles Willemse and Jabulani S. Mthombeni (Rhodes University) for helping with interviews; John Scrimgeour (South African Olive Industry Association) and Carlo Costa (Agricultural Research Council Infruitec-Nietvoorbij) for taking photographs; Nikiwe Apenteng (Döhne Agricultural Development Institute napenteng2000@yahoo.com.) and Marco Brutsh (University of Fort Hare, Department of Agriculture, Alice) for more information on olives in the Eastern Cape; Bronwyn McLean (Graphics Service Unit, Rhodes University) for graphics; Marli Vlok for translating literature written in Afrikaans; and the United States Department of Agriculture, the National Research Foundation, the Andrew Mellon Foundation and the Rhodes University Joint Research Council for financial support. Any opinion, findings and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Research Foundation.

Table 1: The profiles of small-scale farmers in the Ncera Village 6, Binfield and Durban Location communities, private farmers and workers from agricultural training institutions in the Eastern Cape. n = sample size.

| | Gender | | Average/actual age of respondents (years) | Median no. of years at school (and range) | % of respondents in relation to their source of income. |
|---|---|---|---|---|---|
| | Men | Women | | | |
| Private farmers [a] | | | | | |
| Springvale Farm (n =1) | 100% | | 44 | (0-18) | 0[b] |
| Belmont Valley (n =1) | 100% | | 46 | (0-15) | 0[b] |
| Varnam Farm (n =1) | 100% | | 50 | (0-12) | 0[b] |
| Small-scale farmers | | | | | |
| Ncera Village 6 (n = 5) | 80% | 20% | 65.2 | 0 | 100[c] |
| Binfield (n = 8) | 37% | 63% | 55.8 | 0 | 100 [c] |
| Peddie (n = 22) | 36% | 64% | 63.7 | 0 | 100 [c] |

| | Gender | | Average/actual age of respondents (years) | Median no. of years at school (and range) | % of respondents in relation to their source of income. |
|---|---|---|---|---|---|
| | Men | Women | | | |
| Agricultural training institution[b] | | | | | |
| Fort Hare University (n =1) | 100% | | 49 | 0 | 0[a] |
| Fort Cox Agricultural College (n =1) | | 100% | 39 | 0 | 0[a] |
| Pandulwazi High School (n =1) | | 100% | 55 | 0 | 0[a] |

a: respondents were self-employed and relied on farming income

b: respondents were not employees relied on state old age pension fund.

c: respondents were institution employees relied on wages

Table 2: An overview of the issues affecting the olive pilot project on each olive grower in the Eastern Cape.

| Private farmers | Agricultural research and training institutions | Emergent farmers |
|---|---|---|
| Have ownership | Lack ownership | Lack ownership |
| Have capacity | Lack capacity | Lack capacity |
| Have knowledge of both crop and pests | Lack knowledge of both crop and pests | Lack knowledge on both crop and pests |
| Resourced | Resourced | Under-resourced |
| Communication | Lack of communication | Lack of communication |
| Consistency | Inconsistency | Inconsistency |
| Financially independent | Financially dependent | Financially dependent |
| Have no expectations | Have no expectations | Have expectations |
| Pest problems | Pest problems | Pest problems |
| One farm that has beared fruit out of three | No fruit was beared | No fruit was beared |

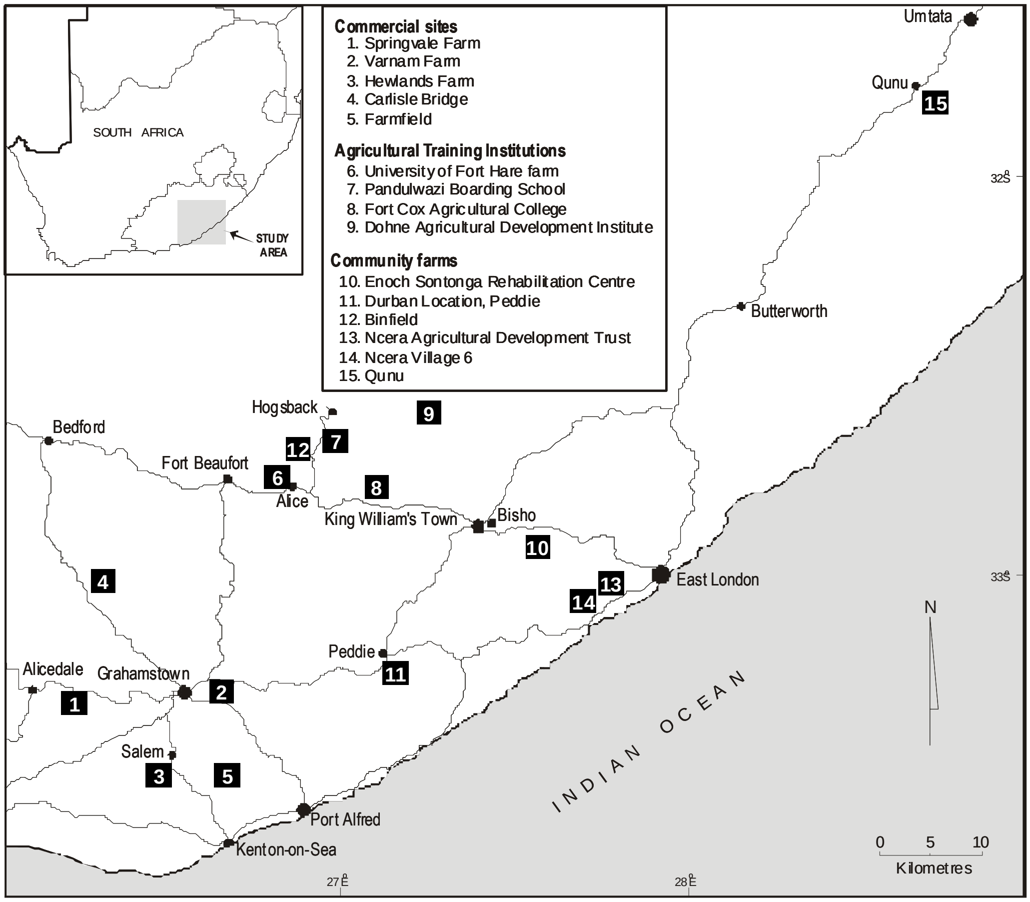


Figure 1: Map showing commercial, agricultural research and training institutions, and community olive farms in the Eastern Cape, South Africa.

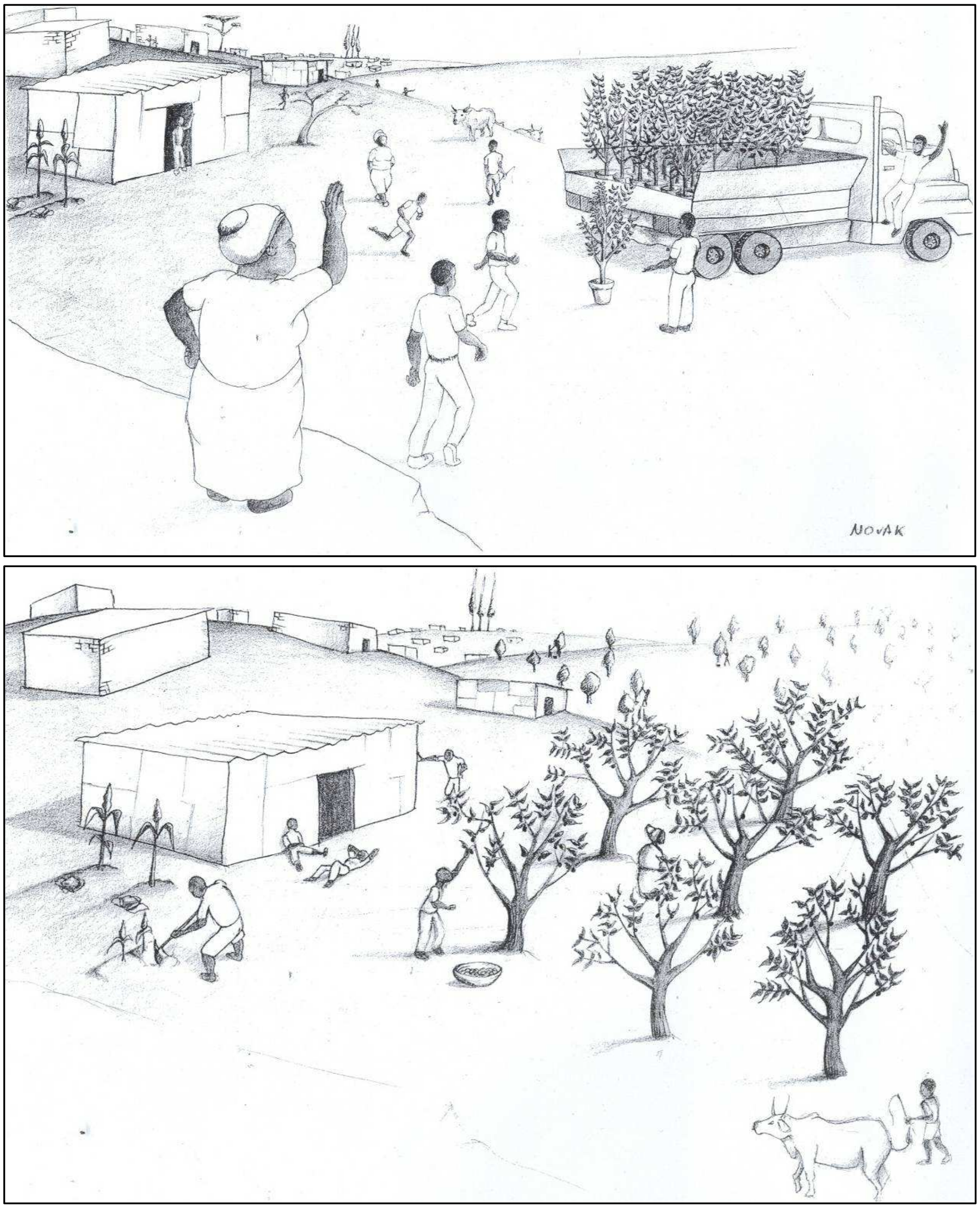


Figure 2: Problem posing code drawings demonstrating (A) how the olive growing project was possibly introduced to the community in the Eastern Cape and (B) the outcome of the olive growing project.

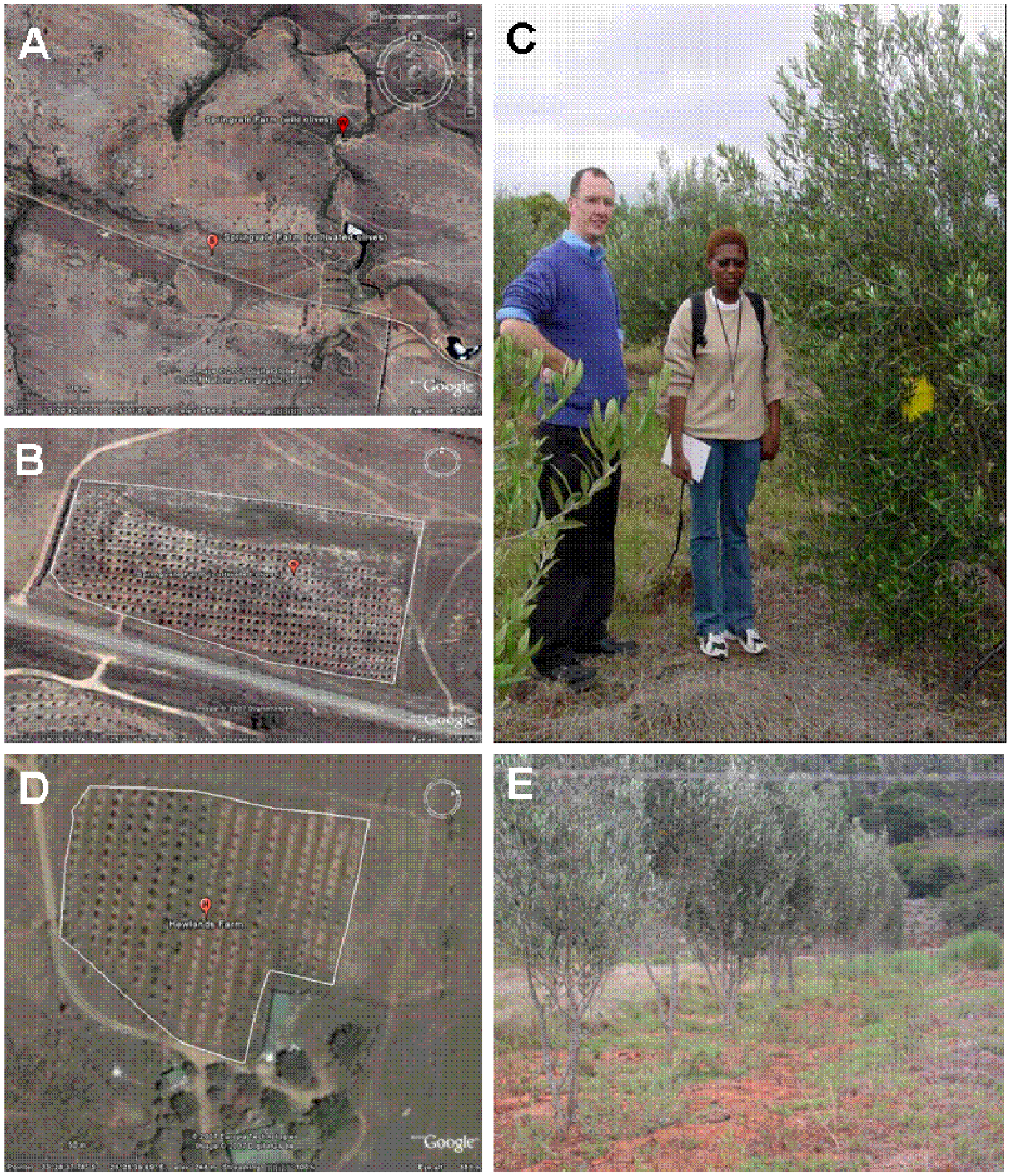


Figure 3 A-C: Springvale Farm. A. Aerial photograph of commercial groves and wild olive site. B. Aerial photograph of the grove where most work was focused. C. Martin Villet, Nolwazi Mkize and Kalamata cultivar olive trees about 2.5m tall. (Picture taken by Carlo Costa, 2005); D-E Hewlands Farm. D. Aerial photograph showing plantings of different ages. E. Unknown cultivar olive trees about 1.5m tall. (Aerial photographs were from Google Earth, Pictures taken by Martin Villet, 2004).

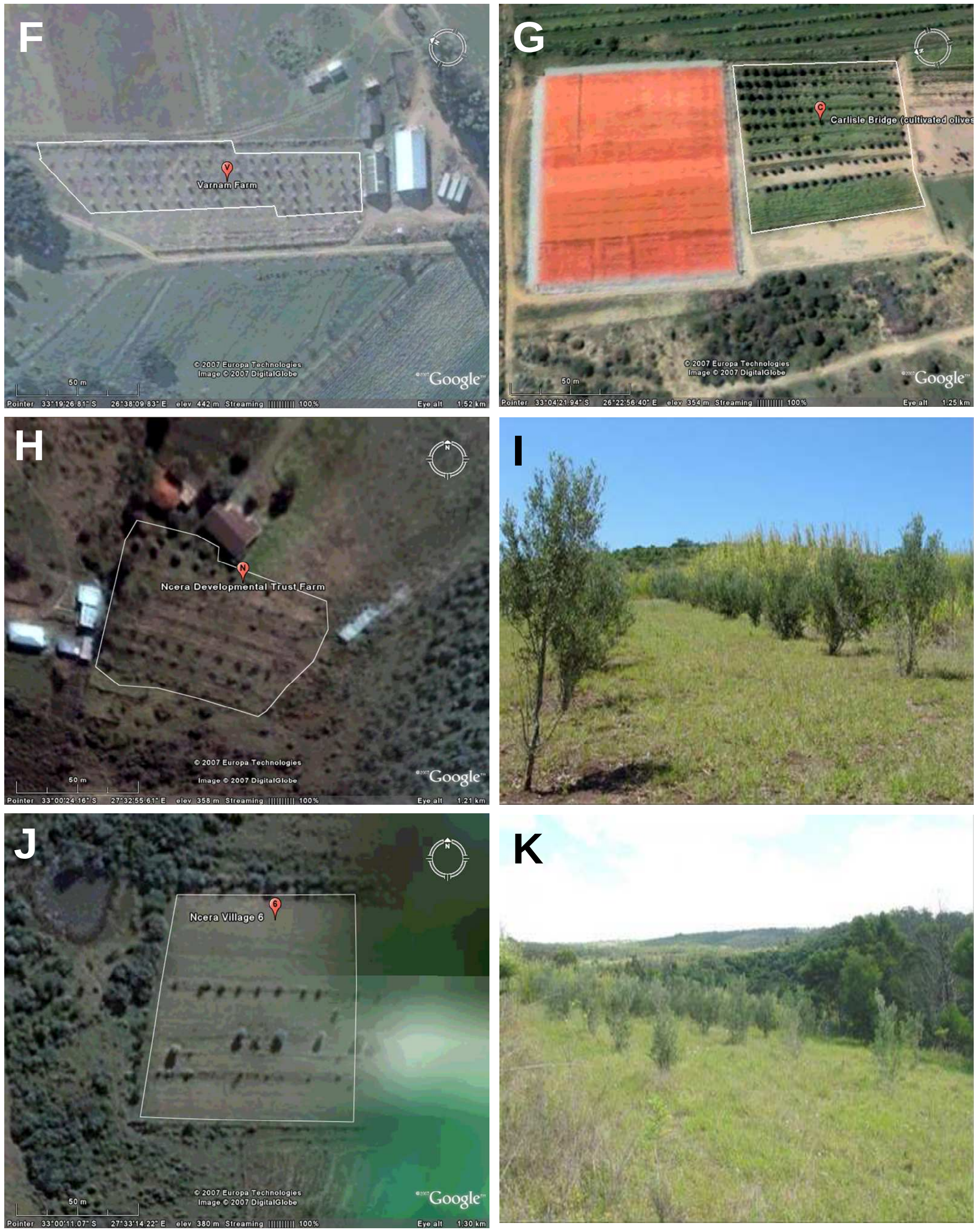


Figure 3 (continued). F. Aerial photograph of Varnam Farm, Mission cultivar olive trees 2m tall. G. Aerial photograph of Carlisle Bridge Farm, unknown cultivar olive trees 2m tall; H-I. Ncera Developmental Trust Farm. H. Aerial photograph. I. Unknown cultivar olive trees about 1.5m tall; J-K. Ncera Village 6. J. Composite aerial/satellite photograph. K. Unknown cultivar olive trees about 1m tall. (Aerial photographs were from Google Earth, Pictures taken by John Scrimgeour, 2005);

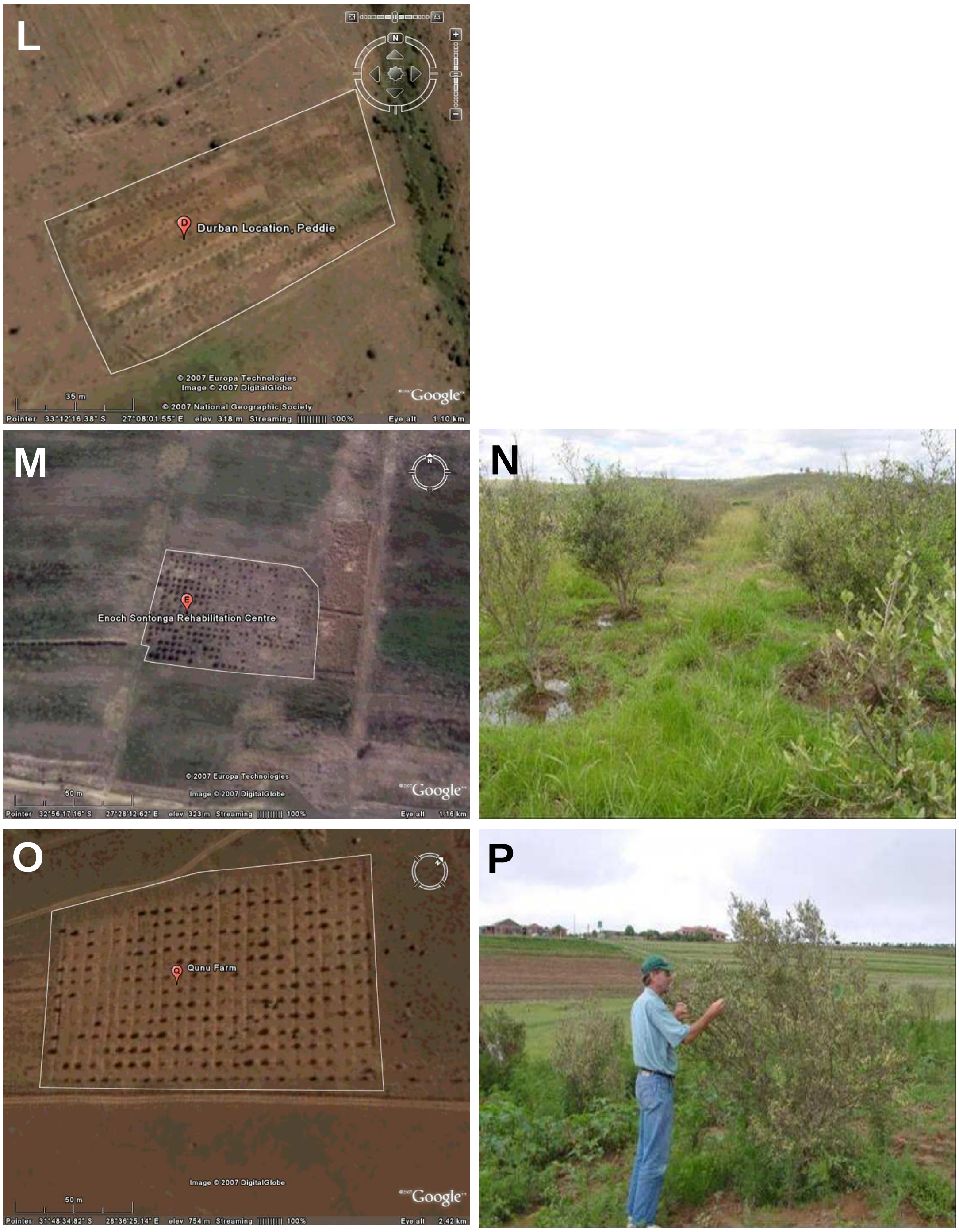


Figure 3 (continued): L. Aerial photograph of Durban Location, Peddie, unknown cultivar olive trees. M-N. Enoch Sontonga Rehabilitation Centre. M. Aerial photograph. N. Unknown cultivar olive trees about 1m tall. (Aerial photographs were from Google Earth. Pictures taken by John Scrimgeour, 2005).

# Chapter 3 A survey of fruit-feeding insects and their parasitoids occurring on wild olives, *Olea europaea* subsp. *cuspidata*, in the Eastern Cape of South Africa.

## 3.1 Abstract

Fruits of wild olives, *Olea europaea* subsp. *cuspidata* (Wall. ex G. Don) Cif., were collected in the Eastern Cape, South Africa, during 2003-2005 to quantify levels of fruit-infesting pests and their parasitoids. Two species of Tephritidae, *Bactrocera oleae* (Rossi) and *B. biguttula* (Bezzi), were the most abundant insects recovered and were reared from most samples. Fruit infestation rates by the *Bactrocera* spp. were generally below 8% and over half of the infestations were under 1%. When parasitism occurred in samples with flies, levels ranged from 7 to 83%. Several species of opiine braconid wasps, *Psyttalia concolor* (Szépligeti), *Psyttalia lounsburyi* (Silvestri), and *Utetes africanus* (Szépligeti) and one braconine wasp, *Bracon celer* Szépligeti, were reared from fruits containing *B. oleae* and/or *B. biguttula*. Chalcidoid parasitoids and seed wasps included seven species of Eurytomidae (*Eurytoma oleae, Eurytoma* sp., and *Sycophila* sp.), Ormyridae (*Ormyrus* sp.), Torymidae (*Megastigmus* sp.), and Eupelmidae (*Eupelmus afer* and *E. spermophilus*). One species of moth, *Palpita unionalis* (Hübner) (Crambidae), was recovered in very low numbers and without parasitoids. The survey results indicate that fruit flies might not become economic pests of the developing commercial olive industry in the Eastern Cape, and the small numbers present may be controlled to a considerable level by natural enemies.

## 3.2 Introduction

Cultivated olives, *Olea europaea* ssp. *europaea* L., have a variety of pests, one of the most serious of which is the olive fruit fly, *Bactrocera oleae* (Rossi) (White & Elson-Harris 1992; Tzanakakis 2003). This fly occurs in sub-Saharan Africa (Lesotho, South Africa, Namibia, Kenya, Eritrea), the Mediterranean region (Egypt, North Africa, southern Europe, Canary Islands), the southern Palearctic and Eurasia (Turkey, the Middle East, Caucasus, Pakistan) (Christenson & Foote 1960; El-Hakim & El-Sayed 1983; Hancock 1989; White & Elson-Harris 1992; Crovetti 1996; Tzanakakis 2003; Copeland et al. 2004), and in 1998 it was found in California, where its rapid spread has threatened the state's olive industry (Rice 2000; Collier & van Steenwyk 2003). The fly causes significant damage to olives produced in Mediterranean countries (Fimiani 1989, Crovetti 1996). For example, reports of crop loss in Greece from uncontrolled populations of *B. oleae* range from 20-30% (Dimou & Koutsikopoulos et al. 2003) to as high as 80% in oil-producing areas and 100% in areas where table varieties are produced (Broumas 2002). Improved control measures are therefore a priority for the international olive industry. It has been proposed that *B. oleae* is not native to southern Europe but rather Africa or Asia (Silvestri 1915; Nardi et al. 2005). Although the fruit fly can reach damaging levels in commercial olives in South Africa, it appears to be a less serious pest there than in the Mediterranean region, and it has been suggested that natural enemies may be responsible for this difference (Annecke & Moran 1982; Costa 1998).

Hoping to find natural enemies of this pest, Silvestri (1913; 1914; 1916) searched for parasitoids of *B. oleae* in sub-Saharan Africa and recovered fourteen species of parasitoid wasps from fruit collected in Eritrea. He returned to Italy with ten species but was unable to rear them in Europe, and although small numbers were released, none of them established (Neuenschwander 1982). The North African braconid, *Psyttalia concolor* (Szépligeti), was repeatedly introduced from North Africa but it did not establish widely in Europe, which was attributed to unsuitable climatic conditions (Raspi & Loni 1994). Neuenschwander (1982) searched in South Africa, where wild olive trees, *O. europaea cuspidata* (Wall. ex G. Don) Cif. (formerly *O. e. africana* (Mill.) P.S. Green (Green 2002)), are widely distributed (Figure 1) and serve as reservoirs for *B. oleae*. His survey of natural enemies in the south-western Cape was productive but he could not establish a culture with the specimens of *Bracon celer* Szépligeti that he shipped to Europe. Exploration conducted in Ethiopia and Kenya in 1975 was unproductive (Greathead 1976). More recently, Copeland et al. (2004) carried out a widespread survey of insects associated with fruits of Oleaceae in Kenya and found *B. oleae* only in fruits of *O. e. cuspidata*. Since the establishment of *B. oleae* in California several years ago new explorations for its natural enemies have been made in South Africa (Western Cape, Eastern Cape, Gauteng, Northwest, and Mpumalanga provinces), Namibia, Kenya, North Africa, Reunion Island, northwestern Pakistan, India and southwestern China (KAH, unpublished information) for possible introduction into California. In South Africa the olive fruit fly and its parasitoids were found in greater abundant in the Western Cape surveys than in the Eastern Cape, but in both provinces a more diverse group of parasitoids was found than in Kenya and Asia. This suggested that more extensive surveys in South Africa were worthwhile, especially since the climate in parts of South Africa is very similar to that of California, so that any new parasitoids would be climatically well adapted if imported.

Although there is a mature olive-growing industry in West Cape, olive culture was only recently initiated in the Eastern Cape (Hattingh 1998; Zifo 1998; Tamba 2000), which is also within the natural range of the wild olive, *O. e. cuspidata*. This provided an incentive to monitor the insects on olives in the East Cape throughout the olive fruiting seasons, which has not previously been done in this region (Figure 1). Sampling was concentrated on wild olives because most of the commercial plantings in East Cape were not yet producing fruit.

## 3.3 Materials and methods

Ten sites with wild olives were located in East Cape for periodic inspection from August 2003 through June 2005; fruit was collected whenever it was present. Nine of the collection sites were situated inland, within 50 km of Grahamstown (Figure 2), between the subtropical and Mediterranean climatic regions. The average temperature of this region is 12.5 - 15°C in winter (May to July) and 20 - 25°C in summer (December to February), and the annual total of 250 - 750 mm of rain falls year-round. In contrast, Ncera Village 6 is close to the coast (Figure 2) and experiences warm humid to hot dry summers and relatively mild winters with warm days and cool nights (Weather SA [=South Africa]). The average temperature is 7 - 9°C in winter and 25 - 27°C in summer, and the annual 400 - 700mm of rain is moderately erratic and mostly in the form of thundershowers (A. Stylianou, pers. comm 2005). Wild olives were also collected on one date at Goudini Spa (Worcester) in the Western Cape. The Worcester site, which was located about 850 - 950 km to the west of the Eastern Cape sites, has a Mediterranean climate and commercial olives have been grown in the vicinity for many decades. This site also differed by being located in a region with substantially more wild and cultivated olives than the Eastern Cape locations.

In close proximity to naturally occurring wild olives, cultivated olives were in production at one site (Springvale Farm) in the Eastern Cape. Commercial olives had also been recently planted at several other Eastern Cape sites (Hewlands farm, Varnam farm, and around Ncera) but at the latter sites trees were young and had not yet borne fruit. Cultivated olives were sampled at Springvale Farm to provide a comparison with wild olives; sampling was timed to occur before applications of insecticide against olive flea beetles (*Argopistes* spp.).

Green (unripe), partially ripened and fully ripe fruits were collected together directly into plastic bags from trees at random, along with some that had recently fallen, and kept in cooler boxes while in the field. They were promptly taken to the laboratory (25°C; 16 L: 8 D photoperiod) where green fruit was separated from ripe and ripening fruit to provide more resolution to the assessments of insect populations. The fruits were transferred to sieves with holes large enough to retain them but allow fruit fly larvae exiting the fruit and parasitoids to pass through. The sieves were placed in screened emergence boxes (for ventilation) that had a 2-3 cm deep layer of dry sand at the bottom that absorbed liquid dripping from rotting fruits and served as a pupation site for mature fly and parasitoid larvae. Every two or three days fly larvae and pupae were retrieved, counted and transferred to well-ventilated Petri dishes maintained at the same environment, and reared until pupation concluded and emergence occurred. The flies and parasitoids that emerged were counted and identified. Flies, their parasitoids, and seed wasps that emerged directly from the fruit were also retrieved and identified.

Percentage infestation was based on the number of *Bactrocera* adults reared and the number of olives collected, using a conservative assumption of one fly per olive. Percentage parasitism was based on the number of adult parasitoids reared and the number of adult flies reared, also assuming that adult parasitoids occurred one per fly. Whenever fly parasitoids were reared, their numbers were included with the counts of flies to obtain estimates of total infestation by the flies. Voucher specimens have been deposited in the Albany Museum, Grahamstown and the South African Museum, Cape Town.

## 3.4 Results and Discussion

Over 62,000 wild olive fruits were collected in 22 samples from 11 sites beginning August 2003 and continuing through June 2005. Two thirds of the fruit sampled was green (mean weight of 0.237 g per fruit) and one third ripe (0.246 g per fruit mean weight). Collections sometimes consisted of entirely green or ripe fruit, while others included both types that were subsequently sorted and divided into green and ripe lots in the laboratory. Flies were reared from 16 collections at eight sites and parasitoids were obtained from eight collections at four of these sites (Tables 1-3). Fruiting of wild olive trees in East Cape Province was highly variable and in 2004 they bore few or no fruit throughout most of the province. The following year there was a substantially larger crop, but the fruiting season began several weeks earlier. For example, fruit was available at Hewlands Farm in August 2003 and February 2005, but none in March 2004. However, in both 2004 and 2005 large fruit crops were obtained from wild olive trees at one exceptional site, Springvale Farm, where the fruiting season ran from April to August in 2004 and from March to June in 2005. Many trees on this farm were located adjacent to a stream, and these trees produced heavier crops than trees located further away from the stream. Four species of parasitoids were reared at Springvale in 2004, but in 2005 only one species was recovered. In contrast to the wild olive samples, no flies or parasitoids were recovered in 2004 or 2005 from samples of nearly 8,000 cultivated olive fruits from Springvale Farm collected on six different dates in May, June, July and August 2004 and May and June 2005. The residual effects of applications of insecticides against flea beetles in the orchards may have prevented attack or successful development of flies. Thus, all olive rearing results discussed hereafter pertain to wild olive samples.

In addition to wild olive samples, one collection of fruit was taken from *Jasminum multipartitum* (Hochst.) at Ncera Village 6 that was growing next to wild olive trees; this species is also a member of the family Oleaceae, and its fruit closely resembles that of *O. e. cuspidata*.

### *3.4.1* ***Fruit flies***

Two *Bactrocera* species, *B. oleae* and *B. biguttula* (Bezzi), were collected. In the East Cape samples, *B. biguttula* was three times as abundant as *B. oleae* (421 vs. 142 adults reared). Only *B. oleae* was reared from the single sample from Worcester (n=49). *Bactrocera oleae* was reared from 13 collections at 6 sites; *B. biguttula* from 14 collections at 7 sites (Table 1). *Bactrocera oleae* was the only fly obtained from 7 of the samples/subsamples, *B. biguttula* was the only fly in 9, and both species were reared from 10 samples/subsamples. Apart from several exceptional infestations of 14% (Hewlands, 'green' wild olives on 20 Aug 2003) and 22% (Grahamstown 1820 Monument, 'ripe' wild olives on 31 May 2005), less than 8% of wild olive fruits in any sample were infested by flies, whether green or ripe fruit, and more than half of the infestation rates were below 1%. Mean sample infestation rates were 2.6 and 1.8% for *B. oleae* and *B. biguttula*, respectively. It is possible that rearing was not 100% efficient and that some flies and parasitoids died without emerging, so rearing results may have underestimated true infestation levels. Three sites with olives obtained only in early season (consisting of green fruits collected in February 2005) yielded no flies at all. Sample dates from which flies were obtained ranged from 29 March to 20 August; this range was the same for both *Bactrocera* species. The Worcester sample from West Cape, collected on 12 January, 2005, was an exception. When numbers of flies were combined across years, rearings of *B. biguttula* exhibited a peak between 120-150 Julian days, which was about one month earlier than the peak for *B. oleae*. However, only *B. oleae* was reared from the Springvale site in 2004, which was the only site with flies that year. Although our data suggest that *B. biguttula* may be prevalent slightly earlier in the season than *B. oleae*, data from additional years are needed to confirm this possibility.

Even though twice as many green fruits were collected as ripe ones, sorted collections consisting of ripe fruits tended to yield more flies than green fruits, probably because they had been available longer for infestation. More than three times as many *B. oleae* were reared from ripe fruit than from green; this difference was even more pronounced for *B. biguttula*, with seven times as many reared from ripe fruit. Both flies showed similar ranges of infestation levels in collections of green fruit (means of 1.1 and 1.3% for *B. oleae* and *B. biguttula*, respectively) but *B. oleae* had a slightly higher mean infestation rate in ripe fruits than *B. biguttula* (4.1 vs. 2.3%).

Munro (1924) reported that *B. biguttula* pupates inside fruit of other wild *Olea* species when these were held in the laboratory, but noted that in the field larvae drop into the soil. It is not clear to what extent pupation in smaller *O. e. cuspidata* fruit might occur in the field. In contrast, *B. oleae* larvae typically leave the fruit to pupate in laboratory and in the field. There is evidence of intense predation of soil-pupating insects like *C. capitata* and certain moths by ants and spiders in citrus orchards in the Grahamstown area (Bownes 2002), and fruit fly larvae such as *B. tryoni* (Frogatt), *B. dorsalis* (Hendel) and *Anastrepha ludens* (Loew) are attacked by ants, rove beetles and spiders (Newell & Haramoto 1968; Thomas 1995) when they leave their fruits, particularly in summer. If *B. biguttula* pupae are differentially protected within fruits in the field, it seems possible that the difference in numbers of *B. biguttula* and *B. oleae* at the same sites in the Eastern Cape could be partly due to differential predation on pupae.

Known only from southern and eastern Africa, *B. biguttula* has previously been reported from fruit of *Olea woodiana* ssp. *woodiana* Knobl., *O. capensis* ssp. *capensis* L. and *Chionanthus foveolatus* L. in South Africa (Munro 1984) and *O. woodiana* ssp. *disjuncta* P.S. Green in Kenya (Copeland et al. 2004). In 2005, however, Copeland (pers. comm) reared two *B. biguttula* from 22 fruits of *O. e. cuspidata* from collections in Kenya. In our study *B. biguttula* was reared in large numbers from *O. e. cuspidata*, and one specimen was reared from a single collection of 131 *J. multipartitum* fruits, the latter a new host record. Evidence of fruit fly attacks on *J. multipartitum* fruits was also seen on preserved specimens in the Selmar Schonland Herbarium (Rhodes University, Grahamstown) when the plants were identified.

A single female Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann), was reared from one sample of green fruit. Medfly has been reported to attack but not develop in cultivated olives in West Cape (Costa 1998). Several overripe samples also produced a few *Drosophila melanogaster* (Meigen).

### *3.4.2* ***Fruit fly parasitoids: Braconidae***

Four species of fly parasitoids (Hymenoptera: Braconidae, n = 83) were reared from wild olive samples (Table 2). Braconids were obtained from both green and ripe fruit. Because of the possibility of fruit infestation by either species of *Bactrocera* it was not possible to be certain which species hosted the parasitoids. However, most of the braconids (n = 66) were reared from samples from which only *B. oleae* adults were obtained, while only five individuals emerged from samples that produced only *B. biguttula*. Twelve were reared from samples that produced both fly species. All the samples that produced only *B. oleae* adults also produced braconids, whereas they were reared from just one of the samples that produced only *B. biguttula*. Since three times as many *B. biguttula* were reared from our samples as *B. oleae*, this suggests that the braconids may be more closely associated with *B. oleae* than with *B. biguttula.*

The opiine braconid *Utetes africanus* (Szépligeti) was the most commonly reared species (n=69; 39 female, 30 male). It was obtained from seven samples and parasitised 7-83% of the fly pupae with a mean rate of 32% (samples with no observed parasitism not included in calculation). Fifty eight individuals were reared from samples that produced only *B. oleae* adults, six were from one sample that yielded adults of both flies, and five came from one sample that produced only *B. biguttula*. A few individuals of the opiine braconids *Psyttalia concolor* (Szépligeti) and *P. lounsburyi* (Silvestri) were also obtained. Two female *P. concolor* and one female *P. lounsburyi* were reared from three samples that produced only *B. oleae*. The fourth species, *Bracon celer* Szépligeti (subfamily Braconinae) was recovered from two samples at one site (n=11, five females and six males, parasitism rates of 19 and 38%) that produced *B. oleae* only from one sample and both *Bactrocera* species from the other.

Only half of the samples containing flies produced braconids. In these samples the total parasitism by all braconids ranged from 7-83%, and the mean number of flies per sample was 40.5. The overall mean rate of parasitized samples was 26%. Braconids were obtained from only three of the seven East Cape sites where flies occurred. Furthermore, a majority of these were obtained from just one of the Eastern Cape sites, Springvale (n= 55, 83% of the total reared from East Cape sites). All four species of braconids were reared from Springvale in 2004, but in 2005 only *B. celer* was recovered, on just one sample date. The diversity present at Springvale may have been due to the consistent availability of fruit at this site or the relative paucity of fruit samples from most of the other sites; longer term surveys are needed to clarify this point. There is insufficient information to account for the relative lack of recovered parasitoids during 2005 when olives were readily available at many of the sites in contrast to 2004..

Although *U. africanus* was the most common parasitoid in our samples in East Cape, it was relatively uncommon in wild olives sampled in Kenya (Copeland et al. 2004). Whereas *P. lounsburyi* was rare in our samples, in Kenya it was dominant wherever parasitoids were reared (Copeland et al. 2004). Neuenschwander (1982) reared only 25 specimens from the Western Cape and Transvaal. *Psyttalia concolor* appears to be rare generally in the Eastern Cape. Similarly, only ten specimens were recovered from wild olives in Kenya (Copeland et al. 2004). The relative rarity of *B. celer* in East Cape is comparable to Kenya (Copeland et al. 2004) but contrasts with the results of Neuenschwander (1982), who reared about 350 specimens of *B. celer* from cultivated olive samples in the Western Cape and Transvaal; it was the most abundant parasitoid species reared in his study (the numbers of olives were not recorded). Possible differences in seasonality or climate at the time of collection, differences in types of olives collected, rearing methods and conditions, etc. make it difficult to draw further conclusions from these comparisons among studies without more detailed information.

### *3.4.3* ***Other Hymenoptera***

Seven species in four families of chalcidoid wasps that are phytophagous on the olive seed, parasitoids of seed wasps, or in a few cases, parasitoids of olive flies (Copeland et al. 2004; Neuenschwander 1982), were reared from wild olives (Table 3). *Eurytoma oleae* Silvestri was the most widespread and abundant chalcidoid reared in East Cape, followed by an unidentified *Ormyrus* species (Ormyridae) and two species of *Eupelmus* (Eupelmidae). Eurytomids were reared from all but three sites, usually in very low numbers. With very few exceptions, their rates of occurrence were less than 1%. *Eurytoma oleae* was found at six of the nine sites. Its peak infestation rate was 6%, but its median infestation was only 0.4%. Another eurytomid, *Sycophila* sp., was recovered from collections at two sites, once each in the Eastern and Western Cape, at a rate of less than 0.6% of either sample. *Eurytoma oleae* and *Sycophila aethiopica* (Silvestri) were reported from cultivated olives in South Africa by Neuenschwander (1982). *Eurytoma oleae* is phytophagous and develops on the seeds of olives (Silvestri 1915, Neuenschwander 1982). *Sycophila* spp. are typically parasitic (Noyes 2003) and the *Sycophila* sp. may be a parasitoid of seed-infesting chalcidoids, as postulated for *S. aethiopica* (Wharton 2007).

Some of the other chalcidoids reared may have been either primary or hyperparasitoids of olive fly parasitoids or seed wasps or both, but these details could not be confirmed based on rearings. *Ormyrus* sp. occurred at four sites in the Eastern Cape at infestation rates below 0.5%. *Eupelmus afer* Silvestri and *E. spermophilus* Silvestri were obtained at low rates of infestation, the former in 3 samples from one site, and the latter in six samples from five sites. *Eupelmus afer* has been recorded as a primary parasitoid of *B. oleae* (Neuenschwander 1982). An unidentified chalcidoid was found at very low rates in two samples from Springvale, and a single specimen of an unidentified *Eurytoma* species was reared from the same site. Most of these chalcidoid species were obtained from both green and ripe fruits, although two thirds of individuals reared were from green olive collections and the overall emergence rate was 0.04 % from green fruit vs. 0.02% from ripe fruit. Aside from the single unidentified *Eurytoma* species, both sexes were obtained of each species.

From the single collection of wild olives at Worcester (West Cape), five females of *Megastigmus* sp. (Torymidae) were reared in addition to specimens of *E. oleae*, *Sycophila* sp., *Ormyrus* sp. and *E. spermophilus*. The rates of infestation of most of these species were marginally higher than in wild olives in the Eastern Cape and that of *E. spermophilus* was notably higher with a rate of infestation of 13.29%.

Copeland et al. (2004) reared a diverse assemblage of chalcidoids from wild olives collected in highland forests of Kenya. In contrast, Neuenschwander (1982) recorded them from only one of seven wild olive collection sites in West Cape, but reported significant levels of attack by seed wasps (*Eurytoma* spp.) in commercial olives. Costa (1998) reported that seed wasps were common in wild olives but infrequent in olive orchards, where they cause serious damage only occasionally. Given the low rates of infestation we found in the Eastern Cape, seed wasps are of questionable concern as potential olive pests in the region.

### *3.4.4* ***Other insects***

The jasmine moth, Palpita unionalis (Hübner) (Crambidae: Spilomelinae) was reared from green and ripe fruits in very low numbers at three sites. Seven individuals were obtained from a total of 1,120 fruits at these sites, giving apparent infestation rates of 0.09 to 0.80%. Most died as larvae or pupae, and no parasitoids were obtained from moth larvae or cocoons.

*Palpita unionalis* has been reported to attack wild olives in Southern Africa (Kroon 1999; Vári et al. 2002) and was also reared from *Jasminum fluminense* Vell. in Kenya (Copeland et al. 2004). The population densities of *P. unionalis* found on wild olive fruit in our study were relatively low, but Mazomenos et al. (2002) reported that *P. unionalis* is considered to be in high numbers if it attacks the fruit because it is known to be a serious pest that feeds on young leaves and shoots of *Jasminum* sp., *Ligustrum* sp. and *O. e. europaea*. Considering the low numbers that were obtained in this study, *P. unionalis* seems to be of negligible potential economic importance to olives in the Eastern Cape.

## 3.5 Conclusions

The irregularity of fruiting of *O. e. cuspidata* during our survey period, with corresponding variability in numbers of insects reared among samples, suggests that more extensive surveys over longer periods of time are needed to better comprehend the dynamics of fly and natural enemy populations in wild olives. Neuenschwander (1982) also noted the irregular fruiting of wild olives in South Africa. Greathead (1976) was unable to find any wild olive fruits during two months of searching in Kenya in 1975. *Olea e. cuspidata* also had irregular fruiting periods in Kenya (Copeland et al. 2004). The unpredictable occurrence of *B. oleae* in wild olives at any given site could be related to either non-fruiting years or the unpredictable fruiting period of wild olive trees (Copeland *et al*. 2004). Although olive trees can generally survive in dry conditions, the general occurrence of fruits only on trees nearer to the stream at Springvale Farm supports the suggestion that fruiting requires more water (Costa 1998). Certain other species of *Olea* have a highly variable fruit production known as "mast fruiting", whereby a majority of a species develop mature fruits only in 'mast' years, thought to be a strategy for surviving seed predation (Kelly 1994). A better understanding of fruiting patterns of *Olea* would assist further survey work, and refine our understanding of the phenology of olive-associated insects. Given the unpredictability of fruiting, supplementing field observations with laboratory studies will help determine the relationship between fly preference, fly development and fruit ripeness.

Detailed information about the population ecology of olive fruit pests and associated natural enemies has thus far been available only from studies in southern European olive groves (e.g., Corfu, Greece , Fletcher et al. 1978). Therefore, a great deal of research remains to be done so that South Africa and other countries can improve the management of these pests. The data presented in this study give a preliminary view of olive flies and their parasitoids associated with wild olives in East Cape. Though the sampling period was limited, the results provide a foundation for additional research which is still needed on the correlation between olive fruit pests and their natural enemies in different South African environments. Neuenschwander

(1982) reported considerably higher levels of wild olive fruit infestation in samples from West Cape Province, with lesser levels in commercial olives, and attributed high levels of parasitism in orchards to the regular availability of cultivated fruit. Given the relatively low infestation levels of wild olives in the Eastern Cape, it is possible that flies might not become economic pests of commercial olives in the Eastern Cape, and the small numbers present may be controlled to a considerable level by natural enemies present in wild olives during a large part of the year

## 3.6 Acknowledgements

I thank the many Eastern Cape olive growers that were involved for allowing access to their farms; A. Stylianou (Chairman, Ncera Agricultural Development Corporation) for weather data; Alan Kirk, Kim Hoelmer, Charles Willemse, and Jabulani S. Mthombeni for helping with fruit collection and sample processing; Ian M. White (Department of Entomology, The Natural History Museum, London) for identifying fruit flies; Charles H. Pickett (California Department of Food and Agriculture-Biological Control Program) and Robert A. Wharton (Department of Entomology, Texas A&M University) for identifying parasitoids; Martin Krüger (Transvaal Museum, Pretoria) for identifying moths; Tony Dold (Selmar Schonland Herbarium, Rhodes University, Grahamstown) for identifying plants; Bronwyn McLean (Graphics Service Unit, Rhodes University) for graphics; and the US Department of Agriculture Agricultural Research Service, South Africa's National Research Foundation, the Andrew Mellon Foundation and the Rhodes University Joint Research Council for financial support.

Table 1: *Bactrocera* species reared from samples of wild olive, *Olea europaea* subsp. *cuspidata*, fruit collected at seven sites in the Eastern Cape and one collection from the Western Cape, 2003-2005.

| Site | Sample date(s) | No. of fruit | Fruit maturity | Fly sp. reared | no. reared | Apparent infestation rate (%) |
|---|---|---|---|---|---|---|
| Hewlands Farm | | | | | | |
| | 20/08/03 | 49 | green | *B. oleae* | 4 | 8.16 |
| | | | | *B. biguttula* | 3 | 6.12 |
| Springvale Farm | | | | | | |
| | 15/05/04 | 5042 | green | *B. oleae* | 5 | 0.18 |
| | 09/06/04 | 7112 | green | *B. oleae* | 3 | 0.18 |
| | | 841 | ripe | *B. oleae* | 19 | 3.80 |
| | 12/07/04 | 6725 | green | *B. oleae* | 4 | 0.16 |
| | | 2858 | ripe | *B. oleae* | 5 | 0.59 |
| | 12/08/04 | 677 | ripe | *B. oleae* | 11 | 2.07 |
| | 29/03/05 | 2800 | ripe | *B. biguttula* | 36 | 1.29 |
| | 27/04/05 | 1496 | green | *B. biguttula* | 10 | 0.67 |
| | | 1957 | ripe | *B. biguttula* | 110 | 5.62 |
| | 31/05/05 | 4629 | green | *B. biguttula* | 5 | 0.11 |
| | | 3216 | ripe | *B. oleae* | 2 | 0.06 |
| | | | | *B. biguttula* | 89 | 2.77 |
| | 22/06/05 | 1520 | green | *B. oleae* | 6 | 0.39 |

| | | | | | |
|---|---|---|---|---|---|
| | | | *B. biguttula* | 3 | 0.20 |
| | 1353 | ripe | *B. oleae* | 4 | 0.74 |
| | | | *B. biguttula* | 21 | 1.55 |
| Grahamstown (1820 Monument) | | | | | |
| 29/03/05 | 918 | ripe | *B. biguttula* | 34 | 3.70 |
| 27/04/05 | 772 | green | *B. oleae* | 1 | 0.13 |
| | | | *B. biguttula* | 20 | 2.59 |
| | 1073 | ripe | *B. oleae* | 2 | 0.19 |
| | | | *B. biguttula* | 27 | 2.52 |
| 31/05/05 | 917 | green | *B. oleae* | 4 | 0.44 |
| | | | *B. biguttula* | 4 | 0.44 |
| | 341 | ripe | *B. oleae* | 68 | 21.41 |
| | | | *B. biguttula* | 1 | 0.29 |
| Ncera Village 6 | | | | | |
| 25/04/05 | 626 | green | *B. biguttula* | 1 | 0.96 |
| 05/05/05 | 502 | green | *B. biguttula* | 4 | 0.80 |
| | 1638 | ripe | *B. biguttula* | 39 | 2.38 |
| Brentwood Farm | | | | | |
| 29/04/05 | 1099 | green | *B. oleae* | 3 | 0.27 |
| | | | *B. biguttula* | 7 | 0.64 |
| Southwell | | | | | |
| 29/03/05 | 1597 | ripe | *B. biguttula* | 5 | 0.31 |
| Grahamstown, 33km N | | | | | |
| 05/04/05 | 681 | green | *B. oleae* | 1 | 0.15 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | *B. biguttula* | 2 | 0.29 |
| Worcester (West Cape) | | | | | | |
| | 12/01/05 | 1512 | mixed | *B. oleae* | 49 | 4.37 |

Table 2: Braconidae reared from *Bactrocera* spp. in samples of wild olive, *Olea europaea* subsp. *cuspidata*, collected at three sites in the Eastern Cape and one site in Western Cape, 2004-2005.

| Site | Sample date | No. fruit collected | Fly spp. in sample | Braconid spp. reared | No. parasitoids emerged | apparent parasitism rate (%) |
|---|---|---|---|---|---|---|
| Springvale Farm | | | | | | |
| | 15/05/04 | 5042 | *B. oleae* | *P. concolor* | 1 | 11.1 |
| | | | | *P. lounsburyi* | 1 | 11.1 |
| | | | | *U. africanus* | 2 | 22.2 |
| | 09/06/04 | 7953 | *B. oleae* | *B. celer* | 5 | 38.5 |
| | | | | *U. africanus* | 18 | 45.0 |
| | 12/07/04 | 9583 | *B. oleae* | *U. africanus* | 19 | 67.9 |
| | 12/08/04 | 677 | *B. oleae* | *U. africanus* | 2 | 14.3 |
| | | | | *P. concolor* | 1 | 7.1 |
| | 22/06/05 | 1353 | *B. oleae*, *B. biguttula* | *B. celer* | 6 | 19.4 |
| Grahamstown (1820 Monument) | | | | | | |
| | 31/05/05 | 1258 | *B. oleae*, *B. biguttula* | *U. africanus* | 6 | 7.8 |
| Ncera Village 6 | | | | | | |
| | 25/04/05 | 626 | *B. biguttula* | *U. africanus* | 5 | 83.3 |
| Worcester (West Cape) | | | | | | |
| | 12/01/05 | 1512 | *B. oleae* | *U. africanus* | 17 | 25.8 |

Table 3: Chalcidoid wasps reared from samples of *Olea europaea* subsp. *cuspidata* collected at six sites in the Eastern Cape, South Africa and one site in the Western Cape, South Africa. No chalcidoids were reared from collections at other sites.

| Site | sample date(s) | No. of fruits collected | No. of Species reared | total no. | highest apparent parasitism rate (%) |
|---|---|---|---|---|---|
| Hewlands Farm | 2 | 49 | *Eurytoma oleae* | 3 | 6.12 |
| Springvale Farm | 8 | 44560 | *E. oleae* | 101 | 1.38 |
| | | | *Eurytoma sp.* | 1 | 0.02 |
| | | | *Eupelmus afer* | 23 | 0.31 |
| | | | *Eupelmus spermophilus* | 9 | 0.43 |
| | | | *Ormyrus sp.* | 12 | 0.20 |
| | | | unidentified chalcidoid | 5 | 0.07 |
| Grahamstown (1820 Monument) | 3 | 7241 | *E. oleae* | 23 | 5.57 |
| | | | *Eupelmus spermophilus* | 1 | 0.29 |
| | | | *Ormyrus sp.* | 2 | 0.59 |
| Ncera Village 6 | 2 | 4325 | *E. oleae* | 19 | 3.04 |
| | | | *Eupelmus spermophilus* | 2 | 0.16 |
| | | | *Ormyrus sp.* | 2 | 0.32 |
| Brentwood Farm | 2 | 1278 | *E. oleae* | 7 | 0.64 |
| 33 km N of Grahamstown | 2 | 1068 | *Eupelmus spermophilus* | 1 | 0.15 |
| | | | *Ormyrus sp.* | 1 | 0.15 |
| | | | *Sycophila* sp. | 4 | 0.59 |
| Worcester | 1 | 1512 | *E. oleae* | 31 | 2.05 |
| | | | *Eupelmus spermophilus* | 201 | 13.29 |
| | | | *Ormyrus sp.* | 17 | 1.12 |
| | | | *Sycophila* sp. | 8 | 0.53 |
| | | | *Megastigmus* sp. | 5 | 0.33 |

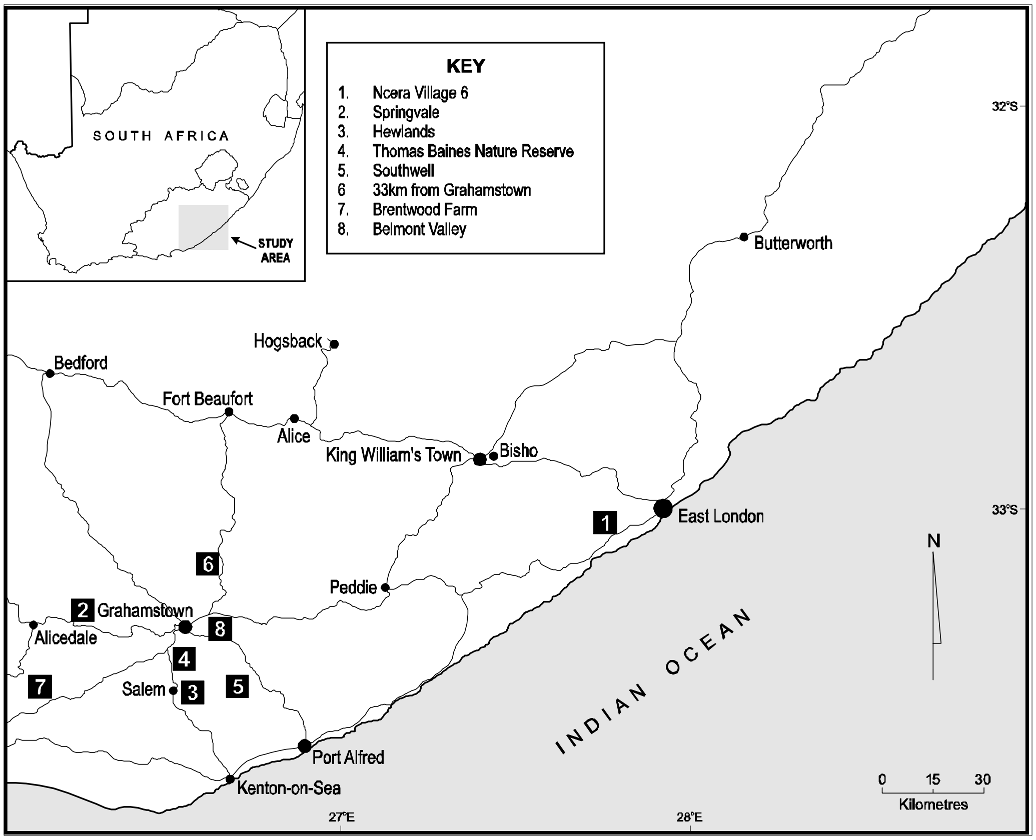


Figure 2: Locations of olive fruit collections in the Eastern Cape, South Africa

# Chapter 4 Monitoring of adult fruit flies from cultivated and wild olives

## 4.1 Abstract

Female and male fruit fly populations were monitored on wild olives and cultivated olives growing at Springvale Farm near Alicedale, using Sensus traps baited with methyl eugenol and quest lure and yellow sticky "ChamP" traps baited with ammonium bicarbonate and spiroketal capsule in 2004-2005. Three species of tephritid fruit flies, *Bactrocera oleae*, *B. biguttula* and *Ceratitis capitata*, were caught; the most abundant species was *B. biguttula*, which is reported from traps for the first time. The ChamP trap caught more flies than the Sensus trap. Most of the fruit flies caught were females. These studies imply that *B. biguttula* is a potential pest for olive crops in the Eastern Cape, and that *B. oleae* and *C. capitata* are thus far not economic pests in this area. ChamP traps offer better potential for mass trapping of these pests.

## 4.2 Introduction

Olive fruit fly, *Bactrocera oleae* (Rossi), is a most important pest of cultivated olives, *Olea europaea* ssp. *europaea* L. (White & Elson-Harris 1994) particularly in the Mediterranean region. The common method for controlling *B. oleae* has been the use of toxic chemicals which created many environmental problems such as negative effects on beneficial species (Karamanlidou *et al.* 1991). Research has shown that some insecticide residues were detected in olive oil (Rastrelli *et al.* 2002) and *B. oleae* has gained resistance to some insecticides such as organophosphates (Stasinakis *et al.* 2001). As a result, effective resources for its control are a major concern for the international olive industry.

In Mediterranean countries, such as Portugal, Spain, Italy, Cyprus, Turkey, Jordan and Tunisia, control methods such as mass trapping systems were developed with the aim of eliminating the use of insecticides (Broumas *et al*. 2002, Dimou *et al*.

2003). The mass trapping methods consist of McPhail traps treated with chemosterilants (Broumas *et al.* 2002), color (visual) traps (Economopoulos, 1979, Raspi 1982, Haniotakis *et al.* 1983, Broumas *et al.* 1985, Montiel-Bueno & Jones 2002), baited with food and/or sex attractants (Haniotakis *et al*., 1983), have been used for the development of effective pest management of fruit flies. It has been shown that combinations of either color trap with food attractants and combination of sex attractants with color and food attractants are effective (Delrio, 1981, Broumas *et al*., 1983) .Even though traps are used, they have been reported to be harmful to beneficial insects that also respond to the lures (Broumas *et al*., 1983; Kapatos and Fletcher, 1983).

Although a great deal is known regarding the olive fruit fly in Europe, particularly in Greece (Broumas & Haniotakis 1987, Broumas *et al.* 2002, Katsoyannos & Kouloussis 2003.), such as different colour trapping and identifying pheromones for olive fruit fly, studies on other continents such as Africa are in a relatively early stage. An olive-growing industry has been recently initiated in the Eastern Cape; South Africa (Hattingh 1998, Zifo 1998, Tamba 2000) and Springvale Farm is one of the successful areas (Chapter 2). It therefore provides the opportunity to carry out the survey of olive fruit fly. Springvale Farm is also in a region which is within the natural range of the wild olive, *O. e.* ssp. *cuspidata*, which may act as a source of olive fruit fly.  There are also dipteran olive fruit pests which are not yet considered serious pests such as *Bactrocera biguttula* (Bezzi) Munro (1924). Currently there is insufficient information about the control of these pests as a result this issue needs to be addressed. These studies will contribute to the development needed of an integrated pest management control program of fruit flies which has not been thoroughly explored in South Africa.

## 4.3 Material and Methods

### *4.3.1* ***Sampling site***

Because olives are a recently developed crop in the Eastern Cape (Chapter 2), Springvale Farm was the only site in the province where both wild and cultivated trees bore fruit. It is situated about 100 km SE of Grahamstown. In 2004, in autumn (March-May) the average minimum and maximum temperatures were 18°C and 26°C, respectively, and the mean relative humidity was 92%. In 2005 the average minimum and maximum temperatures were 18°C and 26°C, respectively, and the relative humidity was 97%. The annual 250-750 mm of rain falls year-round (Weather SA). The temperature and humidity were measured using a thermohygrometer.

The cultivated olive trees were six years old, about 4.5 m tall, and consist of four cultivars (Mission, Manzanilla, Coratina, Frantoio and Nocellara del Belice) that were mixed in some groves and not in others, occupying a total of 34 hectares. The groves were regularly irrigated and sprayed with insecticides for olive flea beetles irregularly. The wild olive trees were growing naturally, about 700 m from the cultivated groves, and separated from them by a ridge of hills (Figure 2.3A). They were up to 10-15 m tall and fruited best nearer to the adjascet stream during the two years of the survey. The insecticides applied to the cultivated olive trees were very unlikely to reach the wild olive trees because of the intervening distance and hills and the prevailing wind direction.

### *4.3.2 **Trapping***

Two types of traps were used: 10.2 x 10.2 cm yellow-panel "ChamP" sticky traps (California Department of Food and Agriculture [CDFA]) and Sensus traps (Quest Development, Brits, South Africa). "ChamP" traps were baited with spiroketal capsules (1.7-Dioxaspiro [5.5] undecane) (Vioryl S.A.; Chemical & Agricultural Industry Research, Athens, Greece), which act as a long-range male sex pheromone, and ammonium bicarbonate (AGRISENSE-BCS, Pontypridd, U.K.), a powerful food attractant for both sexes. The Sensus fruit fly trap is a dry trap for monitoring the presence of male and/or female fruit flies. The traps were baited with Questlure fruit fly attractant capsules (active ingredient, protein hydrolysate; Quest Developments, Brits, South Africa) which is a food attractant for both sexes, and methyl eugenol, which acts as a long-range male sex pheromone.

Ten Sensus traps and ten yellow sticky traps were hung on the south side of cultivated olives trees, inside the canopy, in particular on the trees that were bearing most fruit. The grove contained a mixture of Mission (95%) and Manzanilla (5%) cultivars. Ten Sensus traps were placed on wild olive trees. Grease was applied on the suspending wire of the traps to prevent ants from entering and feeding on trapped insects. Traps were checked every week, cleaned and replaced when necessary. The numbers of each sex of each species were noted each week for 18 weeks (end of March: autumn – beginning of August: winter) in 2004, and for 18 weeks (beginning of February: summer – last week of May: autumn) in 2005. Note that the trapping dates are different each year because of the inconsistency of fruiting or non-fruiting of olive trees in this region in particularly the wild olive, *O. e. cuspidata*.

### *4.3.3 **Statistical analysis***

Data were analysed using chi-squared tests (Snedecor & Cochran 1980) using GenStat software (Payne, 2003).

## 4.4 Results

### *4.4.1 **Trap and attractant efficancy***

There were no seasonal changes of fruit fly on trap catches in 2004 as only *B. oleae* was caught on ChamP trap which was on *O. e. cuspidata* in Springvale Farm. In 2005 three species of fruit fly were caught *B. oleae* (Rossi), *B. biguttula* (Bezzi) and *C. capitata* (Wiedemann) (Figure 1, Table 1). There were significant differences between the two ChamP traps baited with 1.7-Dioxaspiro [5.5] undecane and spiroketal pheromone and Sensus traps baited with questlure and methyl eugenol. ChamP traps has a better potential for mass trapping of *B. biguttula* as it collected a total number of 604 of which 540 fruit flies was from *O. e. cuspidata* and 64 were from *O. e. europaea* (D.F. = 1, $\chi^2 = 577.529$; D.F. = 1; p > 0, 05) (Table 1, Table 2, Figure 2a). ChamP trap also caught only 5 *B. oleae* and 5 *C. capitata*, which could not be analysed since their numbers were insignificant; as a result this analysis was based on *B. biguttula*. Sensus traps were ineffectiveness as they caught a total number of 9 *B. biguttula* only 2 *B. oleae* and 7 *C. capitata* and only on *O. e. cuspidata* (Figure 2b). There were no significant differences with sex ratio and trap type but generally *B. biguttula* showed a female to a male ratio of 1:1 with ChamP trap in spite of the plant subspecies and with Sensus traps showed a 3:1 ratio and on *O. e. europaea* (Table 3).

### *4.4.2* ***Fruit fly ecology***

The annual number of generations of *B. biguttula* is unknown and if trap catches show true population trends then possibly two generations of *B. biguttula* have been demonstrated in this study. In week 2 there was a high peak of *B. biguttula* population, but in week 6 there was a sharp decrease for 5 weeks (Figure 2a). There was also another second peak in week 11 for *B. biguttula* until week 15 and in week 16 there was another peak until the end of the season. Figure 3 showed that temperatures and relative humidity favoured *B. biguttula* as the population increased when temperatures and humidity were fairly stable, particularly on *O. e. cusipidata*.

### *4.4.3* ***Temporal variation***

There was temporal variation in fruiting patterns during the first season in 2004 and second season and in 2005 in Springvale Farm (Chapter 3). The fruit were available for 18 weeks from March to August in 2004 and in February to May in 2005. The increase of fruit flies on trap catches was not consistent with the phenology of the host plants. At least one female *B. oleae* was caught only at the end of the season in 2004 and it was caught from one ChamP trap and none in the Sensus traps. In 2005 three species of tephritid, *B. oleae*, *B. biguttula*, and *C. capitata* were caught on both wild and cultivated trees and *B. biguttula* was the most dominant species ($\chi^2$ = 383.728; D.F. = 1; p > 0, 05; table $\chi^2_{0.05}$ = 3.841) (Table 4). The trap catches of *B. biguttula* in 2005 occurred from May to June. The population of *B. biguttula* on ChamP trap in 2005 (week 2-5) gradually increased on both *O. e. cuspidata* and *O. e. europaea* (Figure 3). In week 6 fruit fly populations decreased on both plant species to a point where there were no fruit fly on *O. e europaea*. A second increase after week 6 was seen on both *O. e. cuspidata* and *O. e. europaea* but after week 9 no fruit flies were caught on *O. e. europaea* and the fruit fly population peaked up on week 12. However the fruit fly population on *O. e. cuspidata* fluctuated until the end of the season. A third peak was also shown on *O. e. cuspidata* during week 8 to week 10. Finally a fourth peak was observed from week 10 to week 13. However on Sensus trap the *B. biguttula* was only caught only from week 7 to week 13 and only on *O. e. cuspidata*.

## 4.5 Discussion

### *4.5.1 **Trap and attractant efficancy***

ChamP traps baited with 1.7-Dioxaspiro [5.5] undecane and spiroketal pheromone offered better potential for mass trapping of *B. biguttula* as it collected 540 fruit flies on *O. e. cuspidata* in 2005. Yellow traps baited with ammonium carbonate and sex pheromone showed satisfactory results in Italy, especially if the olive harvest was good and the olive fly population was low (Montiel-Bueno & Jones 2002). The results obtained from this study were not expected according to Rice *et al* (2003) findings using the similar ChamP trap baited with ammonium bicarbonate lures and spiroketal pheromone for attracting *B. oleae*. In our studies female and male ratios showed 1:1 ratio of females and males and Rice *et al* (2003) reported that the sex ratio of *B. oleae* was 3:1 when using ChamP traps. However mass trapping cannot represent the actual sex ratio; therefore only rearing of flies from pupae should also be considered. In Chapter 2 a similar sex ratio of 1:1 was found when rearing *B. biguttula* and *B. oleae* from olive fruit in the same area Springvale Farm. A normal sex ratio would be 1:1 (Moore 1962).

Sensus traps baited with Questlure and methyl eugenol were ineffective as they collected a total number of 18 flies, and only on *O. e. cuspidata* in 2004. This may possibly for the reason that Questlure is only known as an attractant of female *C. capitata*, *C. cosyra* and *C. rosa* (Ware 2002). However methyl eugenol is known to attract males of many species of *Bactrocera* and *Ceratitis* (*Pardalaspis*) (White and Elson-Haris 1992) and also to attract both sexes of the fruit flies *Ceratitis rosa* and *C. capitata* (Booysen *et al.* 2003, White 2004) but no *Bactrocera* were caught in the traps.

### *4.5.2 **Fruit fly ecology***

In general, the seasonal activity of adult *B. oleae* in Springvale Farm indicated relatively low population levels in spite of the plant subspecies. Low populations of *B. oleae* were also demonstrated when adults were reared on olive fruit collected in the same locality (Chapter 2 of the thesis). Neuenschwander (1982) also reported the erractic occurrence of *B. oleae* on wild olives in the Western Cape and there were suggestion that natural enemies may be responsible for its lesser pest status in South

Africa (Annecke and Moran 1982, Costa 1998). There are also high possibilities that the ovarian development of *B. oleae* was inhibited to a greater extent during summer conditions (Fletcher *et al.* 1978) which possibly will cause a low fruit fly response to trap lures (Rice *et al.* 2003).

Relative humidity was high all throughout the study reaching 100% and for this reason it could not have had a negative influence on fruit fly development (Figure 3). Tsitsipis & Abatzis (1980) reported that *B. oleae* eggs hatched well at 100% and 95% relative humidity with temperature at 20°C. Duyck *et al.* (2006) also stated that atmospheric humidity strongly influences the survival of fruit fly pupae and demonstrated that all species i.e. *Ceratitis rosa* (Karsch), *C. catoirii* (Guérin-Mèneville) and *B. zonata* (Saunders) survived well at 100% RH.

*Bactrocera biguttula* is known to occur in South Africa on fruits of three plant species, all Oleaceae: *Olea woodiana* Knobl. ssp *woodiana*, *Olea capensis* L. ssp. c*apensis* and *Chionanthus foveolatus*, and in Kenya on *O. woodiana* ssp. *disjuncta*, the only *Olea* or *Chionanthus* found in coastal lowland habitats (Munro 1924, Copeland *et al.* 2004, White 2004). This is first report on *B. biguttula* being recorded from traps hung on *O. e. europaea*. The *B. biguttula* numbers trapped at this site possibly indicate that it is a potential pest for *O. e. europaea* in Springvale Farm. The biology of *B. biguttula* is unclear and unknown in Kenya and South Africa and is thought to be similar to that of *B. oleae*. If trap catches of *B. biguttula* particular using "ChamP" traps, indicate the real population trends then there would be three possible generations in 2005 (Figure 2a & 3): the first peak from week 2 to week 6 marks the end of the first generation; the second peak from week 6 to week 10, the second generation; and the third generation peaking after week 10. After week 9 the *B. biguttula* population on *O. e. europaea* was very low and is possibly affected by spraying the field with insecticides for olive flea beetles. There was a peak of *B. biguttula* observed on week 12 which is a possible sign that there either a movement of flies from other host plants. However it has been reported that in California *B. oleae* can complete one generation in about 30-35 days at temperatures between 20-30ºC and in a year it can have three to seven generations depending on environment and fruit availability (Rice *et al.* 2003, Vossen *et al.* 2005). The number of possible generations for *B. oleae* and *C. capitata* were not shown in this study.

The fruit fly activities in relation to *O. e. cuspidata* were different from the reports of olive fly phenology from California and in the Mediterranean areas

(Economopoulos *et al*. 1982, Longo and Benfatto 1982, Ramos *et al.* 1982, Kapatos and Fletcher 1984, Haniotakis 1986, Montiel-Bueno 1986, Rice *et al.* 2003). In Springvale Farm the data showed relatively high adult fly activity at the end of summer to winter. In California the olive fly adults are present and active throughout the year (Rice *et al* 2003). Tzanakakis (2003) also pointed out that olive fruit fly is adapted to develop best in autumn, when its larval food is at its best condition for larval growth.

### *4.5.3* ***Temporal Variation***

The trapping data from commercial and wild olive groves showed the inconsistent pattern of *B. biguttula* phenology over two years as shown in Table 2, given the fact that there were no fruit flies caught in 2004. Munro (1984) also pointed out that infestation of *B. biguttula* occurred from May to September and by October all the flies had emerged. A similar pattern was found in this study with infestation rates where the infestation started in March up to June in 2005 (Table 1, Chapter 3). During this study also trap catches generally occurred from March to June. Temporal variation of *B. biguttula* was probably due to inconsistency of fruiting pattern of olive trees in this region, especially the wild olive, *O. e. cuspidata*. It has been observed that the fruiting season lasted from the end of March (autumn) to the beginning of August (winter) in 2004 which is expected (Venter & Venter 1996). However it was from the beginning of February (summer) to the last week of May (autumn) in 2005.

Newell and Haramoto (1968) have shown that fruit fly population succession generally follow cycles of host fruit production. However in this study this may possibly not be true since *B. biguttula* was not caught in the traps nor reared on fruit collected in the same area in 2004. It is conceivable that *B. biguttula* in 2004 reproduced in unknown host plant as it is polyphagous (Munro 1984, Copeland *et al.* 2004, White 2004) and also because in 2004 wild olives bore little or no fruit throughout most of the province. Munro (1984) also states that *O. woodiana* was a preferred host plant followed by *Chionanthus foveolatus* early in the season during the study that was carried out in East London. The fruiting patterns on *O. e. europaea* (mission cultivar) were fairly similar to *O. e. cuspidata* as it was from end of March to July and showed two fruit fly generations till week 12. No fruit flies were caught on

*O. e. europaea* on week 9 till week 12 possibly affected by spraying for olive flea beetles.

As far as temporal variation and ecology is concerned these are preliminary studies and to a large extent further research is needed to gain knowledge and management of olive fruit flies in South Africa. However these studies provides the basis for continued investigation on the fly behaviour; phenology and a better understanding of when and how to apply various integrated pest management (IPM) strategies such as trapping.

## 4.6 Acknowledgements

We thank Craig Rippon (Springvale Farm) for allowing us to use his groves; Charles Willemse and Jabulani S. Mthombeni (Rhodes University) for helping with counting of fruit flies; Ian M. White (Department of Entomology, The Natural History Museum, London) and for identifying fruit flies; Charles H. Picket (Department of Food and Agriculture-Biological Control Program, Carlifonia) and Daniel Kriek (Quest Development CC, Brits, South Africa ) for providing traps; Tony Dold (Selmar Schonland Herbarium, Rhodes University) for identifying plants; Bronwyn McLean (Graphics Service Unit, Rhodes University) for graphics; Marie Smith (Agricultural Research Council-Biometry Unit) for statistics, and the United States Department of Agriculture, the National Research Foundation, the Andrew Mellon Foundation and the Rhodes University Joint Research Council for financial support.

Table 1: Actual numbers of fruit flies, classified by sex, trap type and plant species, collected from Springvale Farm in 2005.

| Trap type | Species | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | *B. biguttula* | | | *B. oleae* | | | *C. capitata* | | |
| | Female | Male | Total | Female | Male | Total | Female | Male | Total |
| Sensus | | | | | | | | | |
| *O. e. cuspidata* | 7 | 2 | 9 | 1 | 1 | 2 | 5 | 2 | 7 |
| *O. e. europaea* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 7 | 2 | 9 | 1 | 1 | 2 | 5 | 2 | 7 |
| | | | | | | | | | |
| ChamP | | | | | | | | | |
| *O. e. cuspidata* | 309 | 231 | 540 | 1 | 0 | 1 | 1 | 0 | 1 |
| *O. e. europaea* | 32 | 32 | 64 | 4 | 0 | 4 | 4 | 0 | 4 |
| Total | 341 | 263 | 604 | 5 | 0 | 5 | 5 | 0 | 5 |

Table 2: One sample chi-squared test comparing trap type versus one fruit fly species. Number of comparisons = 2, D.F. = 1, table $\chi^2 = 3.841$; $\chi^2 = 577.529$; D.F. = 1; $p > 0,05$.

| OBSERVED FREQUENCIES | | | |
|---|---|---|---|
| Fruitfly species | Sensus | ChamP | Total |
| ***Bactrocera biguttula*** | 9 | 604 | 613 |
| Total | 9 | 604 | 613 |

Table 3: Chi-squared test for *Bactrocera biguttula* testing gender versus trap type: $\chi^2 = 1.643$; D.F. = 1, $p > 0, 05$; table $\chi^2 = 3.841$. The frequencies were not significantly different.

| OBSERVED FREQUENCIES | | | |
|---|---|---|---|
| | Female | Male | Total |
| Sensus | 7 | 2 | 9 |
| ChamP | 341 | 263 | 604 |
| Total | 348 | 265 | 613 |

Table 4: Chi-squared test of *B. biguttula* versus plant species. $\chi^2 = 383.728$; D.F. = 1; $p > 0,05$; table $\chi^2 = 3.841$. The frequencies are significantly different.

| OBSERVED FREQUENCIES | | |
|---|---|---|
| | ***O. e. cuspidata*** | ***O. e. europaea*** |
| Observed | 549 | 64 |
| Expected | 306.5 | 306.5 |

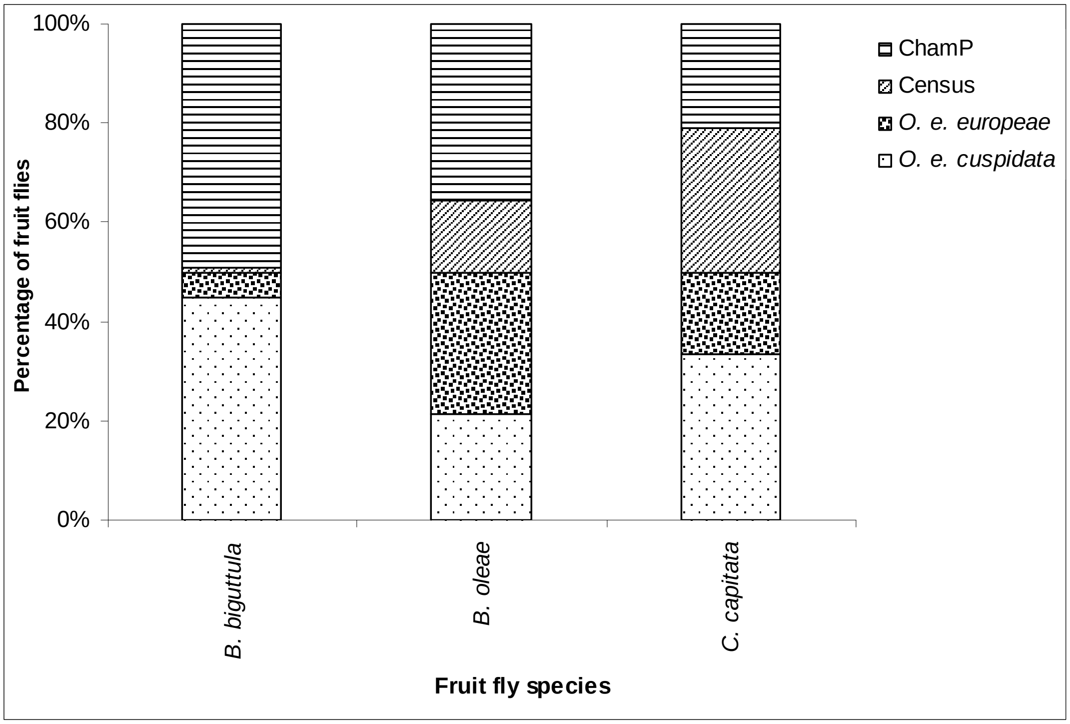


Figure 1: Total number of fruit fly per species versus olive tree subspecies, collected using ChamP and Sensus traps in Springvale Farm in 2005. The most dominant species was *B. biguttula* and these flies were caught on ChamP traps.

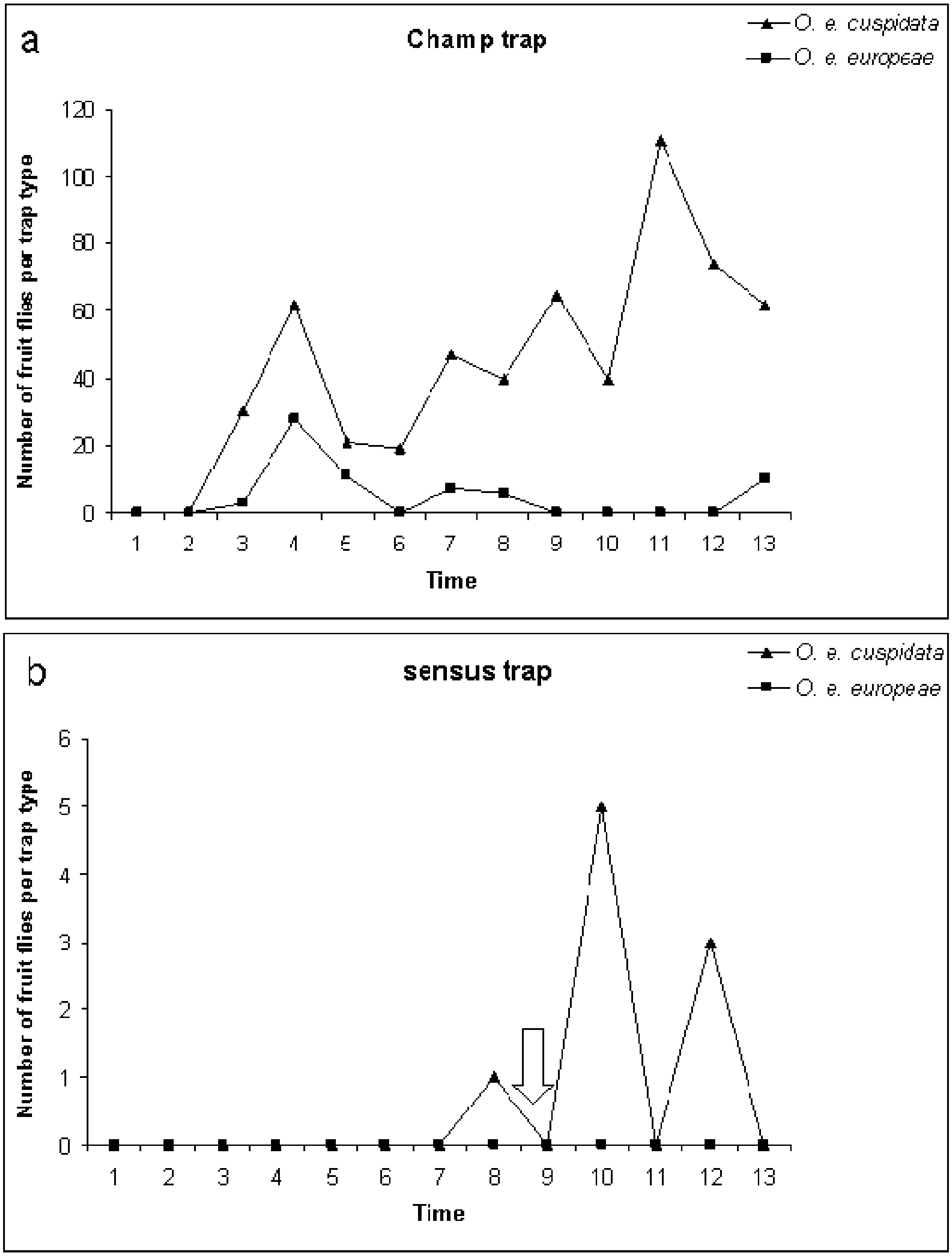


Figure 2: Total number of *B. biguttula* collected from (a) ChamP and (b) Sensus traps on two different subspecies of *O. europaea* on Springvale Farm in 2005 (from beginning of February to the last week of May). The *O. e. europaea* L. was sprayed in week 9, indicated by an arrow with Azinphos-methyl for olive flea beetle larvae.

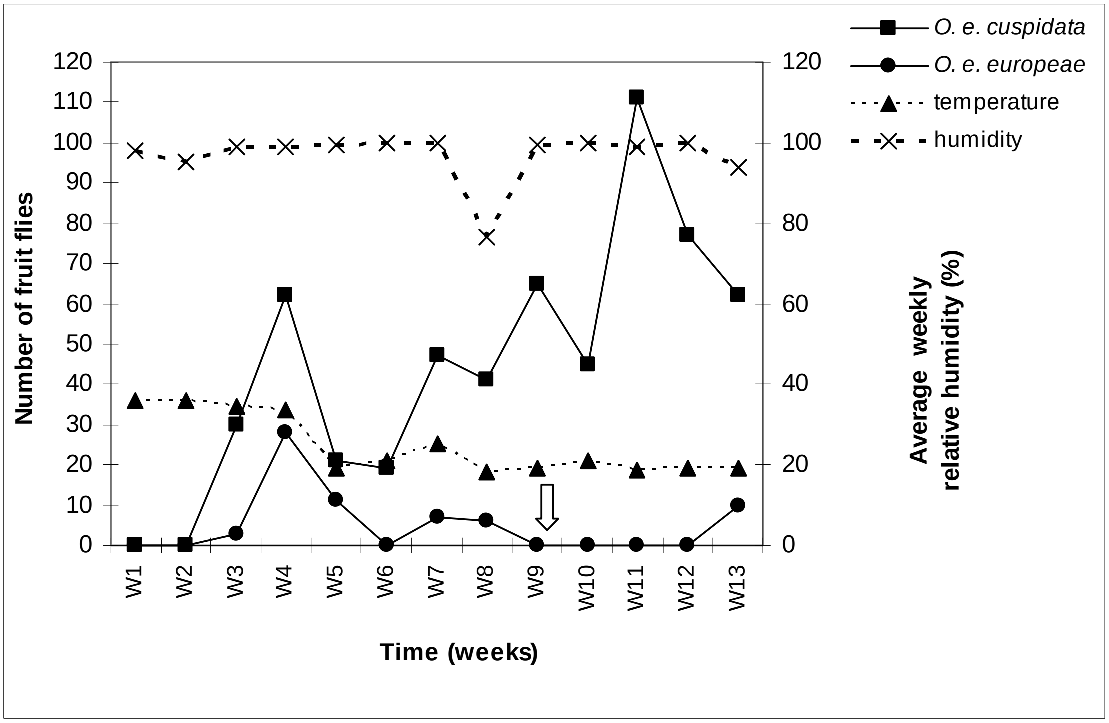


Figure 3: Total number of *B. biguttula* collected from two different subspecies of *O. e. europaea* and the average weekly temperature and relative humidity measurements for Springvale Farm (from March to June 2005). The arrow indicates spraying activity in week 9 which was Azinphos-methyl for olive flea beetle larvae.

.

# Chapter 5 The flea beetle genus *Argopistes* (Coleoptera: Chrysomelidae: Alticinae) in South Africa

## 5.1 Abstract

In South Africa, at least five species of flea beetles (genus *Argopistes* Bryant 1922) are found on wild and/or commercial olives. These can be serious crop pests. Bryant (1922, 1944) described three of these species, but their identity has been confused in subsequent literature, making identification problematic. To resolve this problem, the morphology of all five species was studied by SEM, principal component analysis and discriminant function analysis. We present photographs of the sternites of both sexes, and the aedeagus and spermathecae of all species, redescriptions of Bryant's species and descriptions of the other two, and a key to all five species. An additional *Argopistes* species collected from a light trap is presented. The body length, elytra length, body width and antennae length and pronotum length were the most important variables used to discriminate between species. Male and females were morphometrically distinguishable mainly using their pronotum length. Males had a longer pronotum than females. The classification function using discriminant function analysis provided the correct identification for some species and not for other species. However colour and pattern of the elytra and SEM photographs clarified the incorrect classification.

## 5.2 Introduction

Wild and cultivated olives, *Olea europea cuspidata* (Wall. ex G. Don) and *O. e. europaea* L (Palgrave 2002), are host to at least five species of flea beetles of the alticine genus *Argopistes* Bryant in South Africa. These flea beetles feed on the leaves (Myburgh 1952, Whitehead & Myburgh 1961, Annecke & Moran 1982, Swain &

Prinsloo 1986) and sometimes the fruit (Costa 1998), and some species can become pests (Costa 1998, Eglington 2004). Adults are the shape of ladybirds (Coleoptera: Coccinellidae) but have stripes rather than spots, and enlarged hind femora that allow them to jump strongly when disturbed (Costa 1998, Biondi & D'Alessandro 2003).

Bryant (1922) described and illustrated adults of *A. oleae* Bryant 1922 and *A. sexvittatus* Bryant 1922, but the descriptions were not particularly detailed, and the sexes were not differentiated. A drawing of the male of *A. sexvittatus* was included (Bryant 1922: Figure 4a). Bryant (1944) later described *A. capensi*s Bryant 1944. In this description, some morphological features were not clarified, possibly because the species was described in isolation. Taylor (1945) and Myburgh (1952) revised the descriptions and Myburgh published photographs of the adults of *A. oleae* and *A. sexvittatus*, but appears to have transposed the names of these taxa. He did not provide identification for a third species that he illustrated. In the process of resolving the identity of these species, it was discovered that two forms of *A. sexvittatus* described by Bryant (1922) appear to represent two distinct species, one of which is otherwise undescribed.

This paper clarifies the species' names and differentiates the sexes of these beetles using characters of the sternites and internal genitalia. Three more species from South Africa are also described for the first time.

## 5.3 Material and Methods

Distribution of wild and cultivated olive trees where adult flea beetles are found in the Eastern Cape Province, South Africa (Figures 1 & 2). Pinned material was examined from the South African Museum, Cape Town (SAMC) the South African National Collection of Insects, Pretoria (SANC) and the Albany Museum, Grahamstown (AMNH). The SAMC and SANC material includes specimens determined by G.E. Bryant.

Adult flea beetles were dissected under a stereomicroscope, covered by a few drops of insect saline solution. The aedeagus or spermathecae of several specimens of each species were macerated in 10% potassium hydroxide for 4 hours or more, depending on how delicate the specimens were, and then rinsed twice in slightly acidic water. The specimens were later placed in 96% alcohol for about 5 minutes and then air-dried and fixed with adhesive to scanning electron microscope (SEM) specimen stubs and coated with a thin film of metal layer of gold in an Edwards 306 vacuum coating unit. The specimens were examined with a JEOL JSM U3 scanning electron microscope. The aedeagus and spermathecae was measured using the analySIS Software Imaging System programme (www.softimaging.net).

The width of the body (measured at base of elytra), the length of the body (from the base of antennae to the apex of the elytra), length of elytra (from base to apex), pronotum (along the midlines), and antennae length (from base of antennae to the apex of the flagellum) were measured using a Wild MS stereomicroscope and Olympus micrometer. Various dimensions of the aedeagus were measured from SEM photographs. The log–transformed measurements were analysed using Principal Component Analysis (PCA) and Discriminant Function Analysis (DFA).

## 5.4 Results

Family: Chrysomelidae

Subfamily: Alticinae

### *5.4.1 **Genus: Argopistes Bryant 1922***

Nine named species of *Argopistes* occur in the Afrotropical region: *A. sexvittatus* (Bryant), *A. oleae* (Bryant), *A. capensis* (Bryant), *A. nigra* (Bryant, 1940) - Uganda, *A. hargreavesi* (Bryant, 1926) - Uganda, *A. 6-guttatus* (Weise 1895) - Madagascar, *A. brunneus* (Weise 1895) - Madagascar, *A. vosseleri* (Weise 1919) - Eritrea, and *A silvestrii* (Weise 1914) - Nefasit, Eritrea. Bryant (1922) noted that *A. sexvittatus* have been kept in the British Museum collection since 1867 under the manuscript name *Pseudococcinella sexvittata* (Chevr). Taylor (1945) and later Myburgh (1952) misinterpreted this to mean that these beetles were formerly classified under the genus *Pseudococcinella.*

In general the presence of these beetles in South Africa has been reported in many areas of the Western Cape, such as the Tsitsikamma mountains (Bryant 1951), Somerset West, Stellenbosch, Fransch Hoek, Groot Drakenstein, Paarl, Wellington, and Olifants River valley (Myburgh 1952), and most recently on the Mission cultivar in Olyvenrivier Valley, outside Ladismith in the Klein Karoo (Eglington 2004) and in the Eastern Cape.

Principal Component Analysis of the external dimensions indicated six morphometric groups, and in particular that two of the flea beetles with black elytra which was previously assigned to *A. sexvittatus* were morphometrically distinct from the striped form of *A. sexvittatus*. This can be seen by drawing convex hulls on a plot of the first two principal components (Figure 9), which collectively captured 92.1% of the variance. Most of the coefficients in the Eigenvector of the first component (Table 1) are very similar magnitude and sign, so that the axis can be interpreted as a general indication of size. Thus, *A. lilliputianus* sp. nov. was smaller than all of the other species, while *A. melanus* sp. nov. was slightly larger than the others. The sizes of *A. sexvittatus*, *A. oleae* and *A. capensis* were not clearly different. The Eigenvector of the second component (Table 1) emphasised the length of the pronotum, which is longer in *A. capensis* and rather variable in *A. sexvittatus,* A. *oleae* and *A. lilliputianus* (Figure 9).

Principal Component Analysis suggested that *A. melanus* sp. nov. males were bigger than females (Figure 9) but this was not shown for all species. Generally in all six species it has been demonstrated that females have proportionally shorter pronotums than males. When the aedeagal dimensions were added to the analysis, the groups became even more distinct, but these results are not shown because new specimens can be adequately differentiated in component space on their external dimensions alone. When the aedeagal dimensions alone were subjected to PCA, the convex hull around A. *melanus* sp. nov. was still distinct.

In the *a posteriori* assessment of the morphometric distinctness of the species using Discriminant Function Analysis, the first two functions showed that 79% of the specimens were classified correctly (Table 2), which is sufficient for the analysis. Only two specimens of *A. melanus* were incorrectly classified using DFA (Table 2) and 83% of the specimens were classified correctly. *Argopistes lilliputianus* was always correctly classified using the external dimensions both in PCA and DFA (Figure 9, Table 2). The misclassified specimens were two *A. sexvittatus*, and one each of *A. capensis* and *A. oleae*; these species are easily identified by their colour patterns, which were not included in the PCA or the DFA. *Argopistes epomistus* sp. nov. was not easy to identify using external dimensions, as two specimens were misclasified as *A. sexvittatus* or *A. oleae* (Figure 9, Table 2). However 50% of the specimens were correctly identified.

These analyses lead to the conclusion that there are at least six species of *Argopistes* in our sample, and that they can be distinguished using their external dimensions (Figure 9), the structure of their aedeagi (Figures 10-33), and their colouration (Figures 3-8). Three of these taxa (*A. lilliputianus* sp. nov., *A. melanus* sp. nov. and *A. epomistus* sp. nov.) are previously unrecognised.

### *5.4.2* ***A. sexvitattus Bryant, 1922***

*Argopistes sexvitattus* Bryant, 1922: 475, Figure 4

*Argopistes oleae* Myburgh, 1952: 1, Figure 2 [error]

**Adult** (Figure 3)**:**

*Male*: 3.50-4.50 mm long, oval, convex (Figure 3). *Head*: brownish-yellow, eyes close together; *antennae*: 1.4-2.0 mm long, inserted close together, first six segments yellow and the next five dark brown, first segement very long and almost equal to the next three combined, last seven joints slightly broader and brown. *Pronotum* 0.72-1.28 mm wide, brownish, "finely and closely punctured" (Bryant 1922), strongly oblique, wider at base, sides slightly obliquely converging, posterior margin convex. *Scutellum*: "black, triangular" (Bryant 1922). *Elytra* 2.95-3.54 mm wide (Figure 3), "more finely punctured than pronotum" (Bryant 1922), variable in colour: either (if pronotum is fuscous) flavous with "sutural margin black, lateral margins broadly testaceous with inner margins narrowly black from base of suture to apex, a narrow black vitta down middle of each elytron" (Bryant 1922). *Legs*: front and intermediate pairs either entirely yellow sometimes moderately brownish; hind legs with femora strongly thickened, black and brownish at bottom, tibiae brownish broadly dilated, deep grooves, with toothlike projections at the edges, terminated by two spurs. *Sternites* (Figure 10): brown to dark brown "second to fourth sternite much contracted in middle" (Bryant 1922), fifth bigger than other four, strongly incised and deflexed, posterior margin with narrow paramedian incisures. *Aedeagus* (Figures 16-18): thin, elongated (1.68-1.7 mm); ventral surface with apex slender, prolonged, triangular; lateral compressions form deeply indented surfaces distal to apex; more pronounced protruding structures proximal to basal opening resemble earlobes; lateral surface gradually thinned towards the apex, slightly curved, protruding structures at base similar to ears; dorsal view with protruding structures on sides similar to ears.

*Female* (Figure 3)**:** 3.8-4.1 mm long, general size, colouration and shape as in male. *Abdomen* (Figure 34): curved, sternite equally spaced, last sternite longer than other four. *Spermatheca* (Figure 35): short (0.8-0.9 mm), dark brown, apex of pump pointed, triangular; proximally to base of pump, pump slightly curved, forming a V; receptacle shortened and distally curved towards distal part of pump; spermeathecal duct thick and shortened.

**Diagnosis:** The male and female fifth sternite of *A. sexvittatus* is physically similar to *A. melanus* sp. nov. but the latter is obviously bigger than *A. sexvittatus* (Figure 7) and can be distinguished by the colour and pattern of the scutellum and elytra; the scutellum for *A. melanus* is flavous with black margins, while *A. sexvittatus* has yellow elytra with six black stripes and *A melanus* has black elytra with no stripes. The melanic variety of *A. sexvittatus* has its elytra and prothorax blue-black with a broad testaceous border (Bryant 1922) therefore *A. melanus* sp. nov. cannot be regarded as a variety of *A. sexvittatus* since it has black elytra and a brown pronotum.

**Material examined:** Holotype: 1 male, Bathurst, 25 May 1949, Ac. PE 295 [SANC]. Allotype: 1 female, Bathurst, 25 May 1949, Ac. PE 295 [SANC]; Paratypes: SOUTH AFRICA: LIMPOPO: 1 male, 1 female, Chuniespoort (24°11’59”S 29°29’36”E), 6 November 1965, P. Paliatseas [SANC]; 1 female, GAUTENG: Pta Monument (Pretoria) (25°39’44”S 28°09’55”E), 30 October 1967, M.W. Algers [SANC]; 4 males, 2 females, Zebediela (24°17’45.74”S 29°13’14.64”E), 1 February 1929, H.B. O'Dogherty Ac. P 4054 [SANC]; 1 male, 1 female, Vanderbijlpark (26°41’23.76”S 27°49’33.84”E), 4 October 1965, J. Olckers, Ac. Col 87 [SANC]; FREE STATE: 1 male, Orange Free State, Ficksburg (28°52’19.13”S 27°52’37.84”) 11 November 1966, A.L. Capener [SANC]; 7 males, 9 females Bloemfontein (30°19’00”S 26°48’00”E), 6 November 1916, Ac. P 2588, determined by G.E. Bryant [SANC]; 2 females, Orange Free State, Bloemfontein (30°19’00”S 26°48’00”E), 6 November 1916, J.C. Faure, A 056755, Ag Dp S. Afr [SAMC]; Orange Free State, 1 female, Glen College of Agriculture (28°58’S 26°30’E), 16 May 1920, A 056757, *Pseudococcinella sexvittata* Chevr., determined by G.E. Bryant [SAMC];

MPUMALANGA PROVINCE: 26 uncertain, Transvaal, Loskop Dam (25°25’00”S 29°23’00”E), 25 January 1993, E. Grobbelaar [SANC]; EASTERN CAPE: 4 males, 1 female, Bathurst (33°29’00”S 26°50’00”), 25 May 1949, Ac. PE 295 [SANC]; 1 female, Steytlerville (33°19’58”S 24°20’41”E), 25 October 1964, A.L. Capener [SANC]; 1male, 4 uncertain, Alice, Fort Hare Farm (32°47’39”S 26°50’53”E), 510m, 11 October 2004, S. Waladde [SANC]; 1 male, 7 females, Middleburg (31°30’S 25°00’E), 9 November 1987, M. de Jager, Ac. P 8979 [SANC]; WESTERN CAPE: 1 uncertain, Cape Town (33°55’00”S 18°25’00”E), March? 1917?, Ac. P 2483 [SANC]; 1 female, Cape Town (33°55’00”S 18°25’00”E), 1 December 1919, Ac. P 2483 [SANC]; 1 male, 1 female, Paarl (33°43’40.59”S 18°57’48.07”E), 20 October 1917, C.W. Mally, Ac. P 2483 Ag Dp S Afr [SANC]; 1 female, Paarl (33°43’40.59”S 18°57’48.07”E), 26 June 1917, C.W. Mally Ac. P 2483 Ag Dp S Afr [SANC]; 1 female, Paarl (33°43’40.59”S 18°57’48.07”E), 26 June 1917, C.W. Mally, Ac. P 2483, Ag Dp S Afr [SANC]; 2 females, Malmesbury (33°27’47.61”S 18°43’57.28”E), 31 March, 1916, P.J.v.d. Westhuisen, Ac. C 2483/Ac. P 1073, Ag Dp S Afr [SANC]; 1 female, Sir Lowry's Pass (34°08’38.88”S 18°55’38.85”E), 26 October 1964, A.L. Capener [SANC]; 3 females, Stellenbosch (33°55’55.72”S 18°51’30.80”E), 20 January 1981, C. Hochse, Ac. P 1956 [SANC]; 1 male, Malmesbury (33°27’47.61”S 18°43’57.28”E), 29 January 1916, G.G.v.d. Westhuizen, A 056752, Ac C 2483, *Pseudococcinella sexvittata* Chevr., determined by G.A.K. Marshall [SAMC]; 1 male and 2 females, Malmesbury (33°27’47.61”S 18°43’57.28”E), 29 January 1916, G.G.v.d. Westhuizen, A 056752, Ac C 2483, determined by G.E. Bryant [SAMC]; 1 male, 2 females, Malmesbury (33°27’47.61”S 18°43’57.28”E), 22 March 1939, A 056751, detemined by G.E. Bryant [SAMC]; 1 female, Stellenbosch (33°55’55.72”S 18°51’30.80”E), 3 September 1923, C.J. Joubert, A 056754 [SAMC]; 1 female, Stellenbosch (33°55’55.72”S 18°51’30.80”E), 2 March 1930, A 056753, Ac US [SAMC]; NAMIBIA: 1 male, 2 females, N Grootfontein (33°00’00.13”S 18°11’00.08”E), 1 October 1948, A.H. de Vries, Ac. P. 4903 [SANC]; 1 uncertain, South West Africa/Namibia (4 km N Grootfontein) (19°32’00”S 18°07’00”E), 13 March 1987, R. Oberprieler [SANC]; 1 male, 2 females, 1 uncertain, Namibia, Windhoek (22°34’12”S 17°05’01”E), 1919, Purch, A 056756, determined by G.E. Bryant [SAMC].

**Distribution** (Figure 45a): South Africa (Limpopo, Gauteng, Free State, Eastern Cape, Western Cape provinces) and Namibia.

**Host plant:** Found on both cultivated and wild olive trees.

### *5.4.3* ***A. melanus sp. nov.***

**Adult** (Figure 4):

*Male*: 4.0-5.0 mm long, round and convex. *Head***:** flavous, testaceous**,** eyes close together; *antennae*: 1.49-1.81 mm long, inserted close together, first four segments yellowish and last seven segments dark-brown; first segment very long, almost as long as the three following together, which are the same size, last seven segments slightly bigger, *Pronotum*: 0.55-0.87 mm wide, brown, wider at base; sides obliquely converging, slightly rounded from base to apex, posterior margin black, slightly sinuate. *Scutellum*: triangular, flavous, margins black. *Elytra*: 3.84-4.34 mm long (Figure 4), glossy black; slightly punctured, lateral borders brownish, no vitta on elytra. *Legs*: front and intermediate pairs entirely yellowish, sometimes with spots at bottom, hind legs with femora swelling and black, tibiae broadly dilated, deep furrows, edged with toothlike projections, terminated by two spurs. *Sternites* (Figure 11): second to fourth sternite much contracted in middle; fifth bigger than others, strongly incised, deflexed, posterior margin with narrow paramedian incisures. *Aedeagus* (Figures 19-21): 1.6-1.7 mm long, extensive, shortened; ventral surface with apex broad, shortened, triangular, bent forward; lateral compressions form deeply indented lateral surfaces distal to apex; less pronounced protruding structures proximal to basal opening resemble earlobes; lateral surface gradually thinned towards apex, slightly curved, base with protruding structures similar to ears; dorsal view with slightly protruding structures on sides similar to ears.

*Female* (Figure 4): 4.1-4.2 mm long, smaller than males, general colouration and shape as in male. Abdomen (Figure 36): slightly V-shaped, margins on sternite equal spaced, last sternite bigger than other four. *Spermatheca* (Figure 37): shortened, 0.8-0.9 mm long, dark brown; apex of pump slightly pointed; proximally to base of pump, pump slightly curved; receptacle shortened, distally curved towards distal part of pump; spermeathecal duct thick, shortened.

**Etymology:** From the Greek word *melas*, meaning black.

**Diagnosis:** This taxon is not a variety of *A. sexvittatus* because *A. sexvittatus* variety has its elytra and prothorax blue-black with a broad testaceous border (Bryant 1922), while *A. melanus* **sp. nov.** has black elytra and a brown pronotum**.** *A melanus* **sp. nov.** is similar to *A. sexvittatus* (Bryant 1922) but it can be distinguished externally by the size, colour and pattern of the scutellum and the elytra. *A. melanus* is slightly bigger than *A. sexvittatus* (Figure 7); colour of the scutellum for *A. melanus* is flavous with black margins and *A. sexvittatus* has yellow elytra with six stripes and *A. melanus* has black elytra with no stripes.

**Material examined:** Holotype: 1 male, Enoch Sontonga, 9 November 2004, N. Mkize [SANC]. Allotype: 1 female, Enoch Sontonga, 9 November 2004, N. Mkize [SANC]; Paratypes: SOUTH AFRICA: EASTERN CAPE: 1 male, 1 female, Enoch Sontonga (32°56’17”S 27°28’11”E), 9 November 2004, N. Mkize [SANC]; WESTERN CAPE: 4 females, Stellenbosch (33°55’55.72”S 18°51’00”E), 6 January 1988, K. Bothma, Ac. F.R. 2011/2012, E.G. Riley 1989 [SANC]; 1 uncertain, Malmesbury (33°27’47.61”S 18°43’57.28”E), 29 January 1916, G.G.v.d. Westhuizen, Ac c 2484 Ag Dp S. Afr, A 056758 [SAMC]; 1 female, Stellenbosch (33°55’55.72”S 18°51’30.80”E), 20 January 1981, C. Hochse, Ac. F.R. 1954 [SAMC]; 1 uncertain, Stellenbosch (33°55’55.72”S 18°51’30.80”E), [no other data], A 056759 [SAMC]; 2 males, 2 females, Stellenbosch (33°55’55.72”S 18°51’30.80”) [no other data], A 056759 [SAMC].

**Distribution** (Figure 45b): South Africa (Eastern Cape and Western Cape provinces).

**Host plant:** Found on wild and cultivated olive trees

### *5.4.4* ***A. epomistus sp. nov.***

**Adult** (Figure 5):

*Male*: 4.2-4.5 mm long, round, convex. *Head***:** flavous or testaceous**,** eyes close together; antennae 1.3-2.2mm long, inserted close together, first segment very long, almost as the three following together, which are the same size, first three segments brownish and last seven segments yellowish, last three segments slightly bigger than latter. *Pronotum*: 0.75-0.85 mm wide, flavous, strongly transverse, widest at base; sides obliquely converging, slightly rounded from base to apex, deflexed; posterior margin black, slightly sinuate. *Scutellum*: triangular, yellow, margins dark brown. *Elytra*: 3.6-4.0mm long, glossy black with small yellowish vittae near sutural margin, lateral margins broadly testaceous, flavous, base bending evidently. *Legs*: front and intermediate pairs entirely yellow with dark-brow markings, hind legs with femora strongly incrassate, black; tibiae broadly dilated, deeply sulcate, dentate, terminated by two spurs. *Sternites* (Figure 18): second to fourth sternite much contracted in middle; fifth bigger than other four, strongly incised, deflexed, posterior margin with narrow paramedian incisures. *Aedeagus* (Figure 22-24): 1.6-1.7 mm long, extensive, shortened; ventral surface with apex broad, shortened, triangular, bent forward; lateral compressions form deeply indented surfaces distal to apex; less pronounced protruding structures proximal to basal opening resemble earlobes; lateral surface gradually thinned towards apex, slightly curved, with protruding structures at base similar to ears; dorsal view with slightly protruding structures on sides similar to ears.

*Female*: 4.2-4.5 mm long; general size, colouration and shape as in male. *Abdomen* (Figure 38): slightly V-shaped, margins on sternite equal spaced, last sternite bigger than other four. *Spermatheca* (Figure 39): 0.8-0.9 mm long, shortened, dark brown; apex of pump slightly pointed; pump slightly curved proximal to its base; receptacle shortened, distally curved towards distal part of pump; spermeathecal duct thick, shortened.

**Etymology:** From the Greek word *επομισ*, a shoulder plate, related to the French word *epaulette*, a shoulder badge worn by military and naval officers.

**Diagnosis:** This taxon could not be regarded as a variety of *A. sexvittatus* because *A. sexvittatus* variety has elytra and prothorax blue-black with a broad testaceous border Bryant (1922), while *A. epomistus* **sp. nov.** has black elytra and a fulvous pronotum**.** *Argopistes epomistus* **sp. nov.** is similar to *A. melanus* sp. nov. but it can be distinguished externally by the small vittae on the elytra. The elytra for *A. melanus* are black with no stripes, while *A. epomistus* has stripes (Figures 4 & 5).

**Material examined:** Holotype: WESTERN CAPE: 1 male, 1 female, Stellenbosch (33°55’55.72”S 18° 51’00”E), 6 January 1988, K. Bothma Ac. F.R. 2011/2012, determined by B. Grobbelaar 1991 [SANC], [SANC]. Allotype: EASTERN CAPE: 1 female, Enoch Sontonga Rehabilitation Centre (32°56’17”S 27°28’11”E), 9 November 2004, N. Mkize [SANC]; Paratypes: SOUTH AFRICA: EASTERN CAPE: 1 male, 1 female, Enoch Sontonga Rehabilitation Centre (32°56’17”S 27°28’11”E), 9 November 2004, N. Mkize [SANC]; WESTERN CAPE: 1 uncertain, Stellenbosch (33°55’55.72”S 18°51’00”E), [no other data], A 056759 [SAMC].

**Distribution** (Figure 45c)**:** South Africa (Eastern Cape and Western Cape provinces).

**Host plant:** Found on wild and cultivated olive trees

### *5.4.5 **A. capensis Bryant, 1944***

*Argopistes capensis* Bryant, 1944: 817, Figure 2

Small green beetle (Ac. FR. 181) Myburgh 1952: 1

**Adult** (Figure 6):

*Male*: 3.9-4.4 mm long, round, convex. *Head*: flavous, “almost hidden in the prothorax, impunctate, eyes close together” (Bryant 1944); *antennae*: 1.92-2.21 mm long, “extending almost to middle of elytra, flavous, first segment very long, almost as three following together” (Bryant 1944), the next three same size, last seven segments short than previous and broader. *Pronotum*: 0.87-1.82 mm long, olive green, “strongly transverse, widest at base; sides obliquely converging, slightly rounded from base to apex, deflexed; posterior margin slightly sinuate” (Bryant 1944). *Scutellum*: olive green “small, triangular” (Bryant 1944). *Elytra*: 3.24-3.51 mm long;

deep punctures arranged in striae; interspaces more or less broad; olive green (brownish in preserved specimens), sutural border darker than lateral margins, each elytron with three longitudinal darker olive vittae (brown in preserved specimens), vitta in middle of elytron starts from pronotum and does not reach end of elytra, other two vittae start at center of elytra do not reach end of elytra. *Legs*: “front and intermediate pairs entirely olive green; hind femora very strongly incrassate” (Bryant 1944) compared to other *Argopistes* species, olive green and black at bottom, “tibiae broadly dilated, deeply sulcate, dentate, terminated by two spurs” (Bryant 1944). *Sternites* (Figure 13): yellowish, second to fourth sternites much contracted in middle; fifth sternite bigger than other four sternites, posterior margin with V-shaped paramedian notch. *Aedeagus* (Figure 25-27): 1.5-1.6 mm long, substantial, shortened; ventral surface with arrow-shaped apex, protrusions at base of apex, deeply indented surfaces distal to apex forming cup-like structures; slightly protruding structures proximally to basal opening resemble earlobes; extreme apex reflexed in lateral view, distally slightly curved; dorsal surface with outside anterior opening and further raised forming parallel lines at base, deep creases distally.

*Female* (Figure 6): 3.9-4.4 mm long, general form and colour as in male. *Abdomen* (Figure 40): V-shaped, margins on sternite equally spaced, last sternite bigger than other four, more wrinkled on sides. *Spermatheca* (Figure 41): 0.9-1.0 mm long, shortened, dark brown; apex of pump pointed, slightly rounded; pump slightly curved distal to its base; receptacle shortened, distally curved towards distal part of pump, spermathecal duct thick, shortened.

**Diagnosis:** The elytron of *A. capensis* is similar to *A. sexvittatus* Bryant (1922) but smaller, not so convex, paler and vittae not so conspicuous**.** The fifth sternite of this *A. capensis* (Bryant 1944) is similar to that of *A. oleae* (Bryant 1922) and *A. lilliputianus*, which makes the three species to fall in the same group, but they can be clearly distinguished externally by colour and pattern of the elytra, pronotum, head and the scutellum and internally feature the aedeagus.

**Material examined**: SOUTH AFRICA: SOUTH AFRICA: Holotype: 1 male, Bathurst, 25 May 1949, Ac. PE 295 [SANC]. Allotype: 1 female, Nutwood Farm, SE Grahamstown (31°18’42.25”S 26°31’54.64”E), 12 December 1984, Mrs Stock [SANC]; Paratypes: WESTERN CAPE: 1 female, Stellenbosch (33°55’55.72”S

18°51’30.80”E), 27 November 1926, R. I. Nel [SAMC]; 1 female, Stellenbosch (33°55’55.72”S 18°51’30.80”E), 31 March 1927 [SAMC]; 1 female, Stellenbosch (33°55’55.72”S 18°51’30.80”E), 6 June 1943 [SAMC]; 1 female, Stellenbosch (33°55’55.72”S 18°51’30.80”E), 14 October 1943, H.P.v. Heerden [SAMC]; 4 females, Stellenbosch (33°56’11.0”S 18°52’21.0”E) [SAMC]; 1 uncertain, Brandwag, 18 km N Mosselbaai (34°10’55.59”S 22°08’03.20”E), 3 December 1988, E. Grobbelaar [SANC]; 1 male, Knysna (34°02’25.67”S 23°04’18.84”E), 1924, Ac. P. 3315, COM INST ENT COLL. NO 11186, determined by G.E. Bryant [SANC].

**Distribution** (Figure 45d): South Africa (Eastern Cape and Western Cape provinces).

**Host plant:** Found on wild olive trees only.

### *5.4.6 **A. oleae Bryant, 1922***

*Argopistes oleae* Bryant, 1922: 474, Figure 3

*Argopistes sexvittatus* Myburgh, 1952: 1, Figure 1 [error]

**Adult** (Figure 7):

*Male*: 3.4-3.8 mm long, round, convex. *Head*: “nearly hidden in prothorax, base to between eyes black, finely punctured, front and clypeus flavous” (Bryant 1922); *antennae*: 1.72-2.00 mm long, inserted close together, first seven segments yellow and last four dark brown; first segment very long, nearly equal to three latter segments, last seven dark and slightly broader than the previous three segments. *Pronotum*: 0.60-0.81 mm long; black, yellow-brownish at edges; “finely punctured, strongly transverse, about three times as broad as long; sides obliquely converging, slightly rounded from base to apex, deflexed; anterior angles obtuse, fulvous; posterior margin sinuate” (Bryant 1922). *Scutellum*: “black, triangular” (Bryant 1922). *Elytra* 2.70-3.45 mm long, glossy and “yellow with black sutural borders, lateral margins black” (Bryant 1922) and on each elytra a vitta at the centre that reaches anterior end of elytron but not bottom. *Legs*: “front and intermediate pairs entirely flavous; hind femora strongly incrassate, flavesent, margin black, tibiae broadly dilated, deeply sulcate, dentate, terminated by two spurs" (Bryant 1922). *Sternites* (Figure 14): light brown to dark brown, second to fourth sternites contracted in middle; fifth sternite bigger than other four segments, posterior margin with V-shaped paramedian incisures. *Aedeagus* (Figure 28-30): 1.48 mm long, thick, shortened, with a well-developed denticle; ventral surface with compressions forming slightly indented surfaces distal to apex, further leading to membranous window; extreme apex reflexed in lateral view, distally curved and further curved at base; dorsal surface with deep creases on both sides.

*Female* (Figure 7): 3.7-4.1 mm long, general form and colour as in male. *Abdomen* (Figure 42): curved, lines on sternite equally spaced, last sternite bigger than other four. *Spermatheca* (Figure 43): 1.0-1.1 mm long, elongated, light brown; apex of pump pointed, slightly round; far from pump curved; receptacle elongated, distally curved towards apex of pump; spermeathecal duct thin, elongated.

**Diagnosis:** *Argopistes oleae* (Bryant 1922) is similar to *A. sexvittatus* but can be distinguished by the colour and pattern of its elytra, pronotum, head and scutellum, and by the shape of the aedeagus. *Argopistes oleae* is also similar to *A. capensis*, as indicated by the shape of the posterior margin of the fifth sternite, but they can be distinguished by their general size, the colour and pattern of the elytra, pronotum, head and scutellum, and by the shape of the aedeagus.

**Material examined**: SOUTH AFRICA: Holotype: 1 male, Bathurst, 25 May 1949, Ac. PE 295 [SANC]. Allotype: 1 female, Nutwood Farm, SE Grahamstown (31°18'42.25"S 26°31'54.64"E), 12 December 1984, Mrs Stock [SANC]; Paratypes: EASTERN PROVINCE: 4 females, Sterkstroom (31°34'00"S 26°33'00"E). 12 August 1958, G. C. Morgan, Ac. PC 2993 [SANC]; 8 males, 6 females, Nutwood Farm, SE Grahamstown (31°18'42.25"S 26°31'54.64"E), 12 December 1984, Mrs Stock [SANC]; 1 male, 1 uncertain, Bathurst (33°29'00"S 26°50'00"E), 25 May 1949, Ac. PE 295 [SANC]; 1 uncertain, East London Coast Reserve, Umtiza (33°02'25.38"S 27°49'15.86"E), 25 November 1988, determined by B. Grobbelaar [SANC]; WESTERN CAPE: 2 males, 5 females, 1 uncertain, Knysna (34°02'25.67"S 23°04'18.84"E), 26 November 1983, R. Oberprieler [SANC]; 1 uncertain, Cape Town (33°55'00"S 18°25'00"E), 1 March 1918, C.W. Mally [SANC]; 1 female, Constantia (29°58'59.79"S 21°40'00.06"E), 9 March 1918, Ac. P. 2589, determined by G.E.

Bryant [SANC]; 1 female, Bloubergstrand (33°46’00”S 18°30’00”E), 12 December 1982, H. Geertsema Ac. PE 295 [AMNH]: 1 uncertain, Cape Town (33°55’00”S 18°25’00”E), November 1814, A 056749, determined by G.E. Bryant [SAMC]; 1 female, Cape Town (33°55’00”S 18°25’00”E), December 1884, A 056750 [SAMC]; 1 female, Cape Town (33°55’00”S 18°25’00”E), November 1884, A 056750, determined by G.E. Bryant [SAMC]; 1 female, 2 uncertain, Cape Town (33°55’00”S 18°25’00”E), 15 March 1947, Alfi oleae Veruncosa, A 058314 determined by G. E. Bryant [SAMC]; 1 uncertain, Cape Town (33°55’00”S 18°25’00”E), 5 April 1947, Oleae veruncosa, A 058315 [SAMC]; 1 female, 1 uncertain, Cape Town (33°55’00”S 18°25’00”E), 5 April 1948, A 058314 [SAMC]; 1 uncertain, Cape Town (33°55’00”S 18°25’00”E), 26 March 1950, Bevils Paris, Aunt oleae veruncosa, A0568316 [SAMC].

**Distribution** (Figure 45e): South Africa (Eastern Cape and Western Cape province).

**Host plant**: Found on cultivated and wild olive trees.

### *5.4.7 **A. lilliputianus sp. nov.***

**Adult (**Figure 6):

*Male*: 2.3-2.4 mm long, round, convex. *Head*: flavous, almost hidden in the prothorax, eyes close together; antennae 0.9-1.0 mm long, set close together, flavous, first five segments brown, broad, last six yellow, narrower than previous segements. *Pronotum*: 0.35-0.42 mm wide, flavous, slightly transverse, widest at base; sides obliquely converging, slightly rounded from base to apex, slightly deflexed; posterior margin brown, slightly sinuate. *Scutellum*: small, flavous, margins brown, triangular. *Elytra*: 1.99-2.05 mm long, broad at base, flavous, sometimes with brown spots apically and at base, sutural margins brown, black, deep punctured forming a triangular-shape marking apically, adjacent to sutural margins strongly punctured, brown lateral margins. *Legs*: front and intermediate pairs flavous; hind femora very enlarged, flavous with brown margins, armed at apex with a solid blunt spur, tibiae slightly dilated, sulcate, terminated by two small spurs. *Abdomen* (Figure 15): margins on first 4 sternites equal spaced; fifth sternite bigger than other four, posterior margin with indistinct V-shaped paramedian incisures. *Aedeagus* (Figure 31-33): 0.8-1.0 mm long, light brown, thick, shortened, with a well-developed denticle, narrowing distally, very large membranous window; ventral surface distal to apex smooth, forming slightly indented surfaces, further leading to membranous window; apex reflexed in lateral view; dorsal surface with deep creases on both sides.

*Female*: 2.4-2.6 mm long, general form and colour as in male. *Abdomen* (Figure 44): very curved, margins on sternite equally space, last sternite bigger than other four. *Spermatheca***:** not examined.

**Etymology:** This species is named after a characteristic of Lilliput, the mythical land in Jonathan Swift's book, *Gulliver's Travels*, where everything was unusually small.

**Material examined**: Holotype: 1 male, Transval, D' Nyala Nature Reserve, Ellisras District, Limpompo [SANC]. Allotype: 1 female, Transval, D' Nyala Nature Reserve, Ellisras District, Limpompo (23°45'00"S 27°49'00"E) [SANC]; Paratypes: SOUTH AFRICA: LIMPOPO: 4 males, 1 female, Transval, D' Nyala Nature Reserve, Ellisras District (23°45'00"S 27°49'00"E), 850m, 13-14 January 1991, B. Grobbelaar [SANC].

**Diagnosis:** *Argopistes lilliputianus* is similar to *A. hargreavesi* (Bryant 1926). Its head, pronotum and elytra are flavous with brown margins, while *A. hargreavesi* has its head and prothorax black with the basal part castaneous in the middle, and elytra that are castaneous with the apical third black and the outer margins narrowly black. The elytra of *A. lilliputianus* are strongly and regularly punctured at the base and adjacently to the margins, and those of *A. hargreavesi* are very finely and irregularly punctured. The legs of *A. lilliputianus* are brown with the femora dark brown and armed with a blunt, dark brown apical spur, while those of *A. hargreavesi* are castaneous with the hind femora black and armed with a stout, blunt, black apical spur. The fifth sternite of *A. lilliputianus* is similar to *A. oleae* and *A. capensis*, which places them in the same group of species, but it can be distinguished externally by the general size, colour and pattern of its elytra, pronotum, head and scutellum, and by features of the aedeagus.

**Distribution** (Figure 45f): South Africa (Limpopo and Northern provinces (specimens collected by Marizio Biondi).

**Host plant:** Unknown; specimens were collected at light.

### *5.4.8 **Key to adults of the Argopistes species in South Africa***

1. Fifth sternite of male with deep, narrow paramedian incisures (Figures 10, 11, 12). Female curved, sternite equally spaced, last sternite longer than other four. Spermatheca (0.8-0.9 mm), dark brown, apex of pump pointed, triangular; proximally to base of pump, pump slightly curved, forming a V; receptacle shortened and distally curved towards distal part of pump; spermeathecal duct thick and shortened ......................................................... 2

-. Fifth sternite of male with V-shaped paramedian incisures (Figures 13, 14, 15). Female V-shaped, margins on sternite equally spaced, last sternite bigger than other four, more wrinkled on sides. Spermatheca (Figure 41): 0.9-1.0 mm, shortened, dark brown; apex of pump pointed, slightly rounded; pump slightly curved distal to its base; receptacle shortened, distally curved towards distal part of pump, spermathecal duct thick, shortened ................................ 4

2(1). Elytra yellowish with sutural margins black, lateral margins broadly testaceous, with inner margins narrower and black, a narrow brown vitta down center of each elytron that does not reach either end of elytron (Figure 3), finely punctured. Apex of median lobe of aedeagus in ventral view long and broad, but narrower than rest of aedeagus (Figure 16-18) *A. sexvitattus* (Bryant)

-. Elytra glossy black, finely punctured. Top of middle lobe of aedeagus in ventral view long and broad, but narrower than rest of aedeagus .................. 3

3(2). Elytra with no stripes (Figure 4). Head and pronotum brown. .......................... ............................................................................. *A. melanus* sp. nov.

-. Elytra with one brief stripe adjacent to sutural margin of each elytron (Figure 5). Head and pronotum brown to pale black. .................. *A. epomistus* sp. nov.

4(1). Median lobe of aedeagus apex in ventral view substantial and shortened, arrow-shaped apex (Figure 25 & 27), distally to apex, deep dented surfaces forming cup-like structures, proximally to basal opening, slightly protruding structures resembling earlobes. Dorsal view outside anterior opening and further raised forming parallel lines at base, distally deep crease (Figure 25). Spermatheca duct shortened pump slightly curved, pointing towards receptacle (Figure 40 & 41) ........................................................................................ ........................................................................................ *A. capensis* (Bryant)

-. Median lobe of aedeagus apex in ventral view with well-developed denticle . 5

5(4). Small, 1.99-2.6 mm long. Elytra brown, often with dark brown spots, sutual margins dark brown and outer lateral margins brown; no vitta (Figure 8). Median lobe of aedeagus with apex in ventral view with a well-developed denticle but narrowing down distally (Figure 31-33) ... *A. lilliputianus* sp. nov.

-. Larger, 3.4-4.1 mm long. Elytra yellow to almost orange with outer sutual margins black and lateral margins brown; a wide vitta runs down the center of each elytron, reach prothorax but not the reach tip of the elytron (Figure 5). Median lobe of aedeagus with apex in ventral view with a well-developed denticle (Figure 28). Spermatheca duct thin, elongated; receptacle elongated, with a very sharp curve pointing towards the pump (Figure 43) ....................... ........................................................................................ *A. oleae* (Bryant)

## 5.5 Discussion

There are several characters that define and strongly suggest a close relationship of the speceis of *Argopistes* in the Afrotropical region. The best-shared character is their tendency to feed on plants of the family Oleaceae, in particular olives (Weise 1895, 1914, 1919, Bryant 1922, 1926, 1940, 1944, Inoue 1991). The distribution of the olive flea beetles, in particular *A. sexvittatus*, is generally similar to the distribution of wild olive, *O. e. cuspidata* (Wall. ex G. Don) in South Africa and Namibia (Figures 2 and 45A). Other characters include the adults' external morphometric, external and internal morphological similarities.

The six species within the genus *Argopistes* can be separated using body width, body length, elytron length, pronotum length, and antenna length, but it was difficult to appreciate this in *Argopistes* using Principal Component Analysis because there was an overlap between *A. sexvittatus*, *A. oleae* and *A. capensis* (Figure 9). However, this simply means that one character cannot be used to discriminate unambiguously between species but species can be separated using all of the important characters, including colour and pattern of the elytra (Figures 3, 6, 7 & 8).

The other external differences were the obvious differences in the coloration and pattern of the elytra in all of the flea beetles. Females' coloration was the same as conspecific males. There were also morphological similarities. The fifth sternites of all of the males and females of these flea beetles have universal features: the abdomen of males was curved, and the fifth sternite of males was bigger than the other four sternites with an M-shaped posterior margin. The shape of the last sternite was either closed or opened. Using this taxonomic feature, these species are clearly separated into two distinct groups. *Argopistes oleae, A. capensis* and *A. lilliputianus* **sp**. **nov**. form a group with the posterior margin of the fifth sternite with V-shaped paramedian incisures, and an aedeagus that showed deeply indented surfaces on the sides in dorsal view (Figures 13, 14, 15, 25, 28,31). *Argopistes sexvitattus*, *A. melanus* **sp**. **nov**. and *A. epomistus* **sp**. **nov**. form another group since the posterior margin of their fifth sternite was strongly incised and the structures of their aedeagi were similar (Figures 10, 11, 12, 16, 19, 22).

The shape of the abdomen in females was either curved or V-shaped and the fifth sternite was bigger than the other four. Morphologically, the females grouped differently from the males. For example, in *A. sexvittatus, A. oleae, A. lilliputianus*, and *A. epomistus* the abdomen was curved and on the sternites the margins were equally spaced except for the last sternite, which was bigger. In contrast, the abdomens of *A. capensis* and *A. melanus* **sp**. **nov.** were V-shaped and the sternite margins were different in that *A. capensis* had margins that were equally spaced and wrinkled on the sides but *A. melanus* **sp. nov.** were slightly contracted in the middle. Only the spermatheca of *A. oleae* was distinctive. The morphological characteristics indicated overlapping similarities for both males and females, which strongly suggest a close relationship of these species. Cytogenetic and phylogenetic study of the whole genus will help to resolve their relationships.

## 5.6 Acknowledgements

I would like to thank the olive growers that were involved in the Eastern Cape for allowing access to their farms; Charles Willemse & Jabulani S. Mthombeni for helping to collect the specimens; Dominique Coutinot (EBCL Quarantine Officer, France) for helping to find taxonomists; Margie Cochrane (South African Museum, Cape Town), Elizabeth Grobbelaar (South African National Collection of Insects, Pretoria), Sarah Gess (Albany Museum, Grahamstown) and Maurizio Biondi (Dipartmento di Scienze Ambientali, Università di L'Aquila, Coppito-L'Aquila, Italy) for identification and allowing us to use valuable preserved specimens; the Electron Microscope Unit (EMU), Rhodes University and Angela Simon (Vacutec, Johannesburg ) for taking SEM and colour photographs; Bronwyn McLean (Graphics Service Unit, Rhodes Universty) for graphics; and the United States Department of Agriculture, the National Research Foundation, the Andrew Mellon Foundation and the Rhodes University Joint Research Council for financial support. Any opinion, findings and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Research Foundation.

Table 1: The first two Eigenvectors of the Principal Component Analysis. These two factors cummulatively summarised about 92.1% of the variation. The most important variables are in bold.

| Variable | Factor 1 | Factor 2 |
|---|---|---|
| Body length | **-0.48352** | 0.195628 |
| Elytra length | **-0.466831** | 0.312422 |
| Pronotum length | -0.345406 | **-0.903823** |
| Body width | **-0.474957** | 0.208707 |
| Antennae length | **-0.451273** | -0.060555 |

Table 2: This is a factor matrix of structure coefficients, which shows the correlations of each variable with each discriminant function. Rows are the observed classifications and columns the predicted classifications. Generally there is a high rating of classification of species and has correctly classified 79% of the species. Of all these six groups of species one was correctly classified and three for *A. melanus*, five for *A. sexvittatus*, one for both *A. capensis* and *A. oleae* and two for *A. epomistus* were misclassified.

| Actual species | % correct | Predicted identity | | | | | |
|---|---|---|---|---|---|---|---|
| | | *A. melanus sp. nov.* p = 0.27907 | *A sexvittatus* p = 0.23404 | *A. capensis* p = 0.12766 | *A. oleae* p = 0.17021 | *A. lilliputianus sp. nov.* p = 0.12766 | *A. epomistus sp. nov.* p = 0.8511 |
| *A. melanus* sp. nov. | 83 | 10 | 1 | 0 | 1 | 0 | 0 |
| *A sexvittatus* | 73 | 2 | 8 | 1 | 0 | 0 | 0 |
| *A. capensis* | 83 | 0 | 1 | 5 | 0 | 0 | 0 |
| *A. oleae* | 75 | 0 | 2 | 0 | 6 | 0 | 0 |
| *A. lilliputianus* sp. nov. | 100 | 0 | 0 | 0 | 0 | 6 | 0 |
| *A. epomistus* sp. nov | 50 | 1 | 1 | 0 | 0 | 0 | 2 |
| Total | 79 | 13 | 13 | 6 | 7 | 6 | 2 |

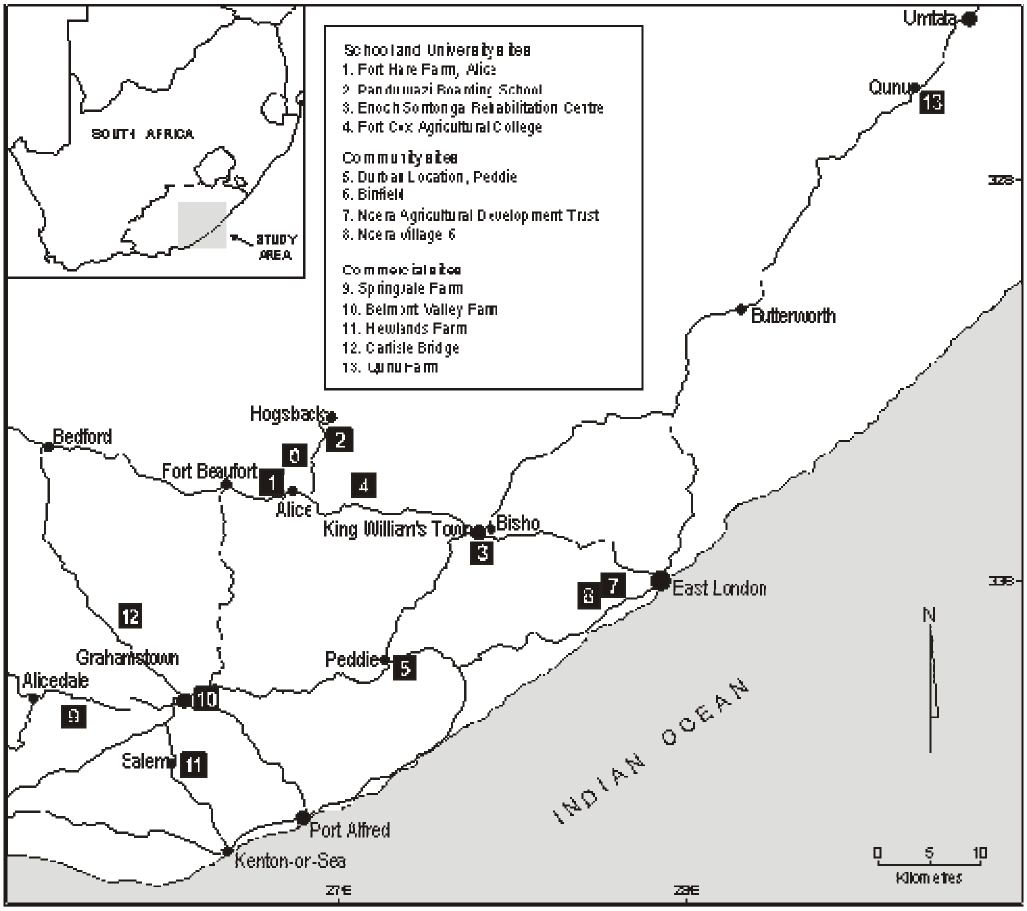


Figure 1: Distribution of cultivated olives, *O. europaea europaea* L. in the Eastern Cape, South Africa.

Figure 2: Distribution of wild olives, *Olea e. cuspidata* (Wall. ex G. Don) in Southern Africa (Palgrave 2002).

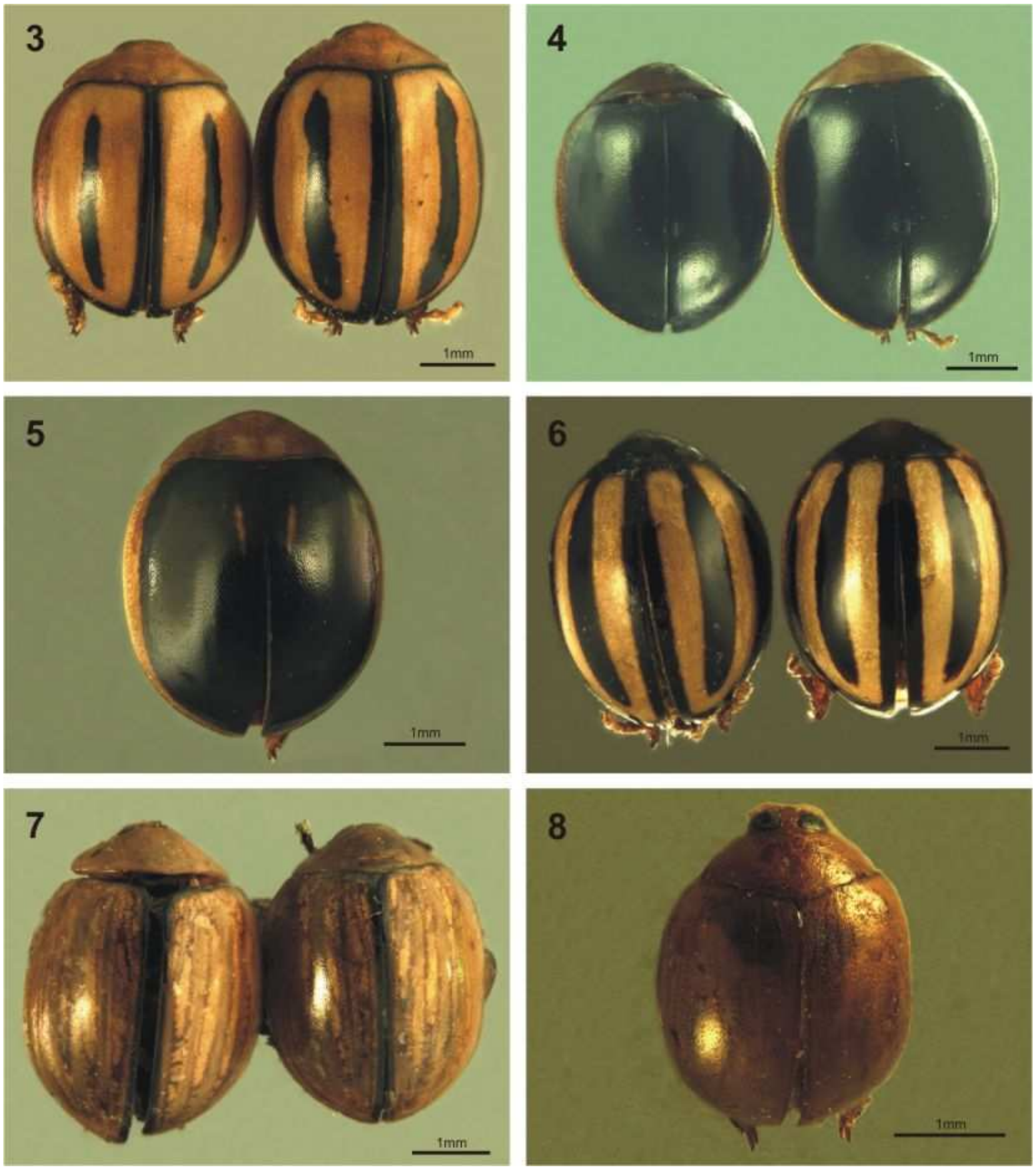


Figure 3-8: Habitus (dorsal view) of *Argopistes* species from South Africa. 3: *A. sexvittatus* (male and female); 4: *A. melanus* sp. nov. (male and female); 5: *A. epomistus* sp. nov. (male); 6: *A. oleae* (male and female); 7: *A. capensis* (male and female); 8: A *lilliputianus* sp. nov. (male).

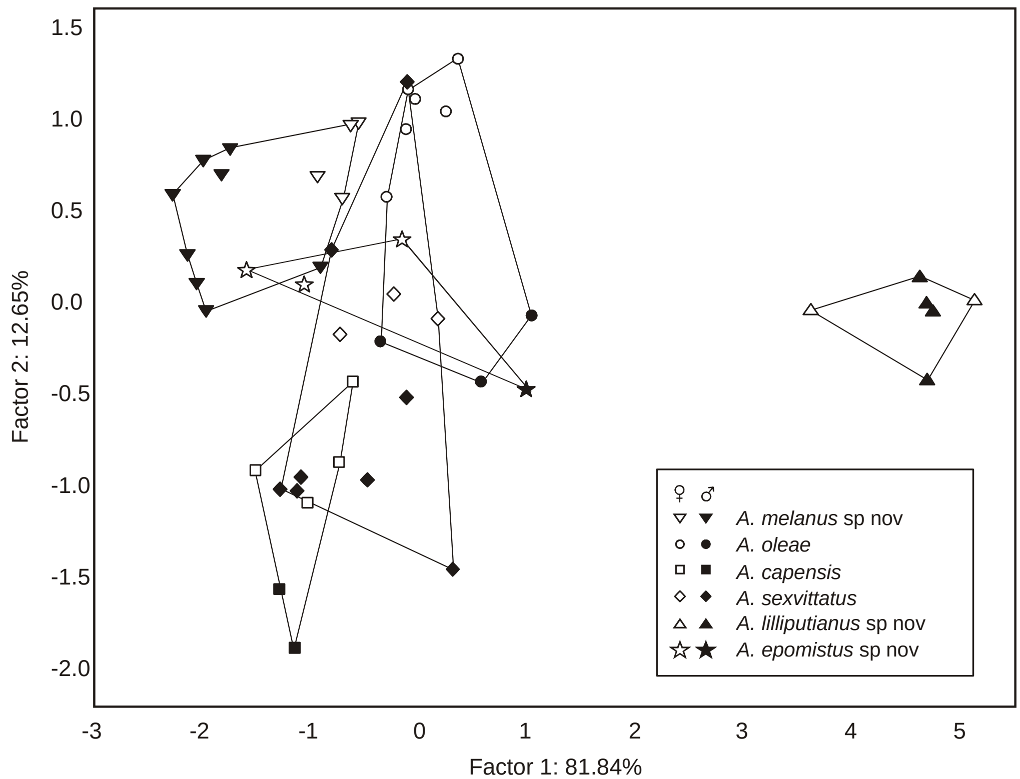


Figure 9: Plot of loadings and scores for the first and second eigenvectors of a Principal Component Analysis carried out on 5 variables and 47 individuals. Each species represented by the convex hull. There was a clear separation of *A. melanus* sp. nov. and *A. lilliputianus* sp. nov. from all the species, *A. melanus* sp. nov. was slightly bigger than all the species and shows sexual dimorphism where males are generally larger than females and *A. lilliputianus* sp. nov. to be the smallest. There was an overlap of convex hull for *A. epomistus* sp. nov. to the nearest species.

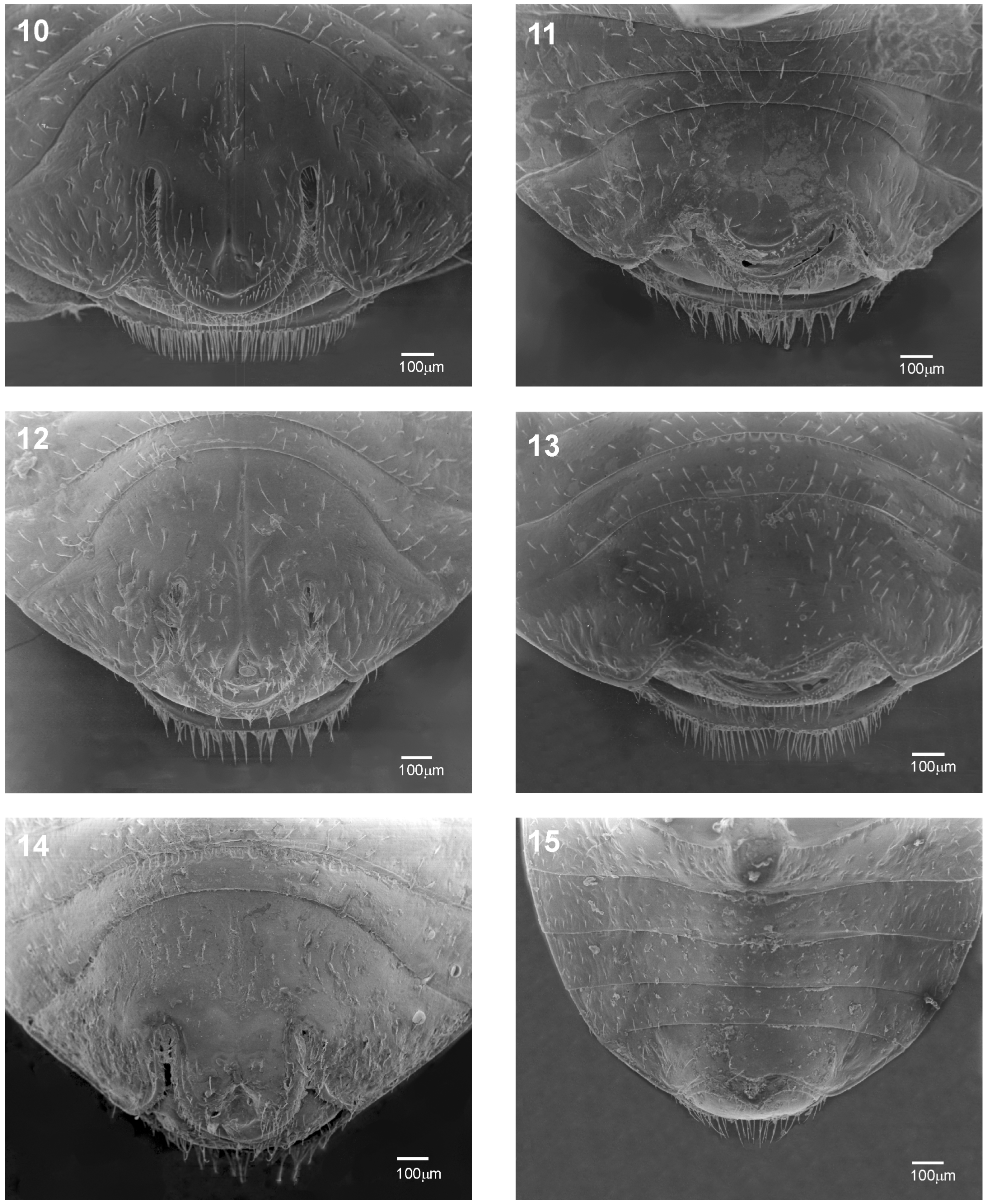


Figure 10-15: SEM photographs of the male abdomen, 10: *A. sexvittatus*, 11: *A. melanus* sp. nov., 12: *A. epomistus* sp. nov., 13: *A. capensis*, 14: *A. oleae* and 15: *A. lilliputianus* sp. nov.

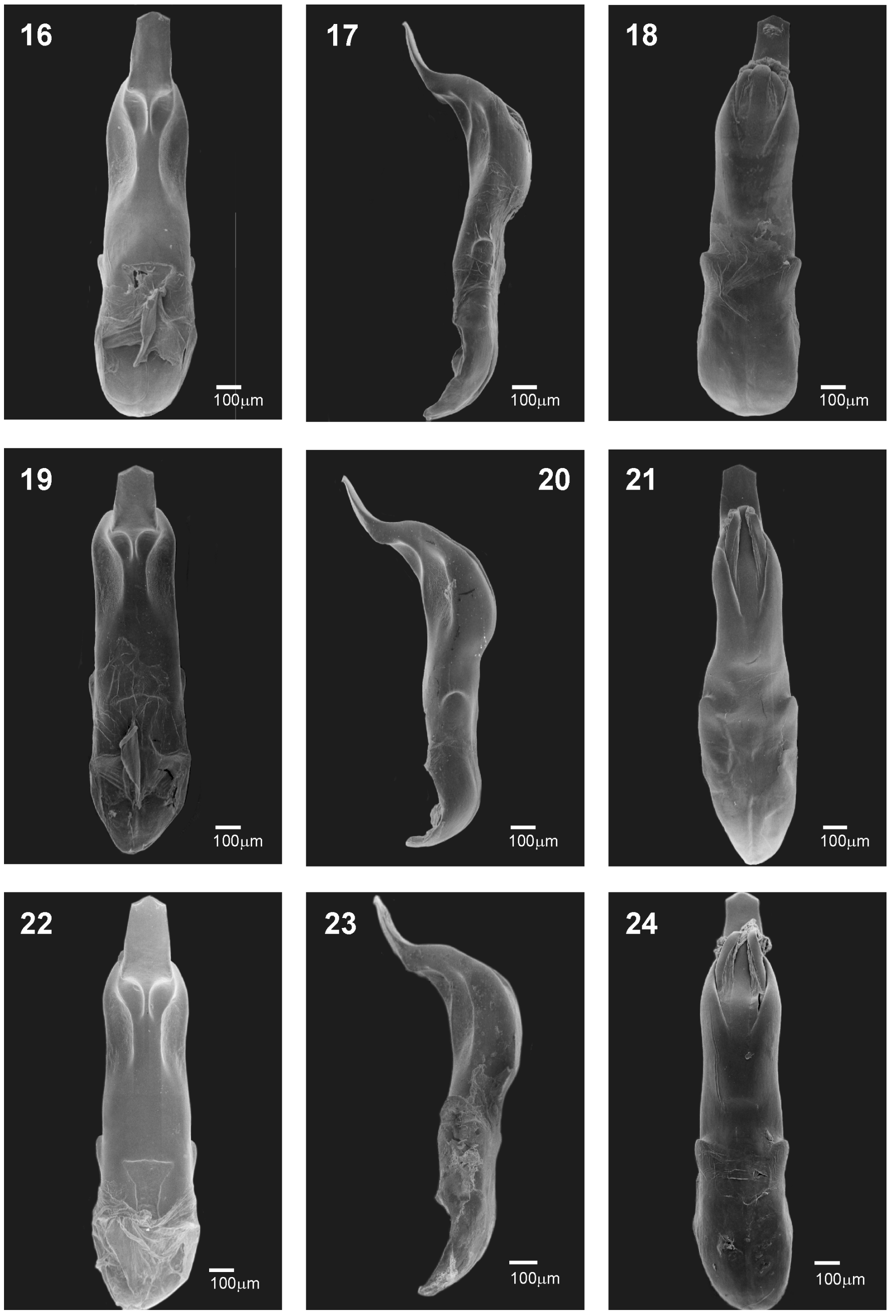


Figure 16-33: SEM photographs of the aedeagus in ventral, lateral and dorsal views, 16-18: *A. sexvittatus*, 19-21: *A. melanus* sp. nov. and 22-24: *A. epomistus* sp. nov.

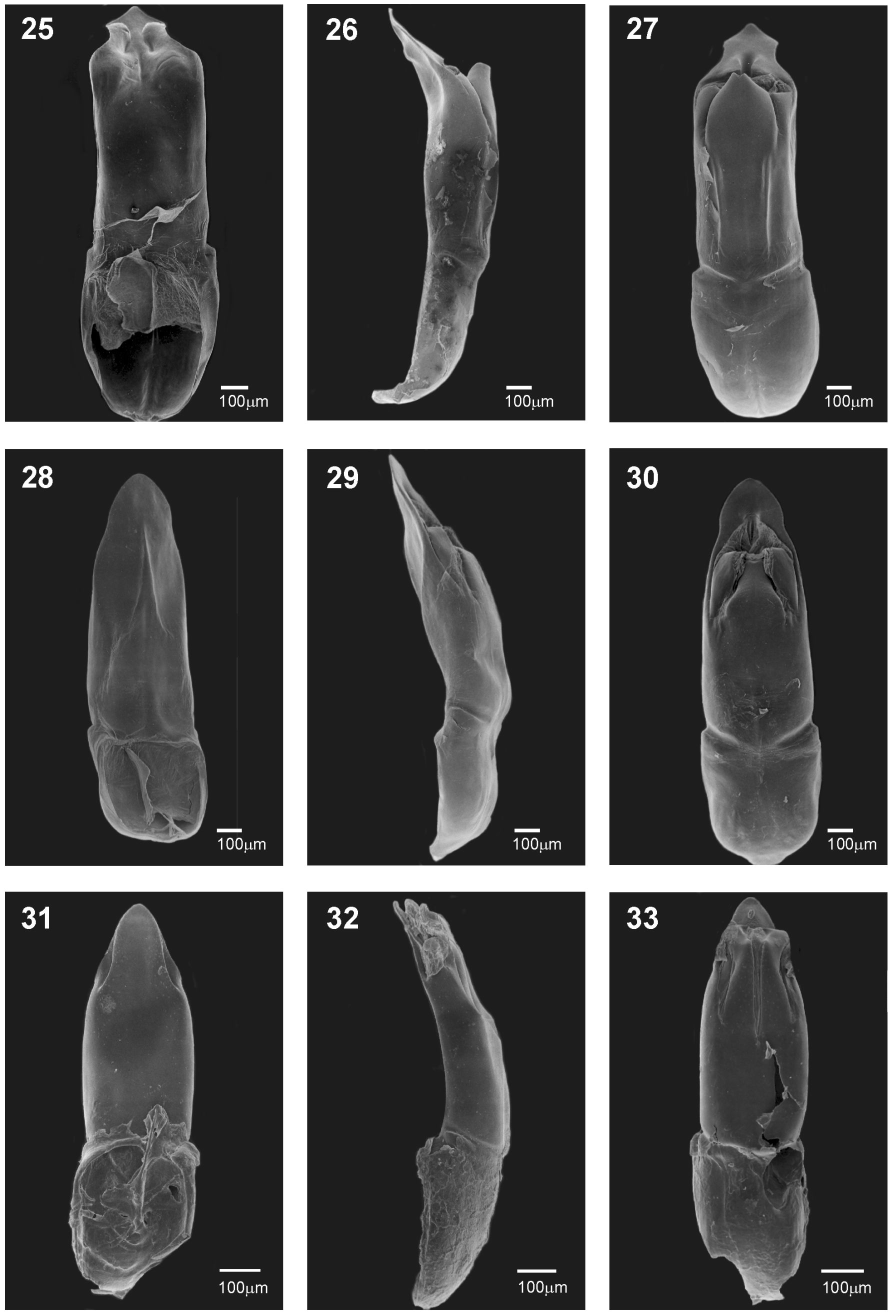


Figure 25-33: SEM photographs of the aedeagus in ventral, lateral and dorsal views, 25-27: *A. capensis,* 28-30: *A. oleae* and 31-33: *A. lilliputianus* sp. nov.

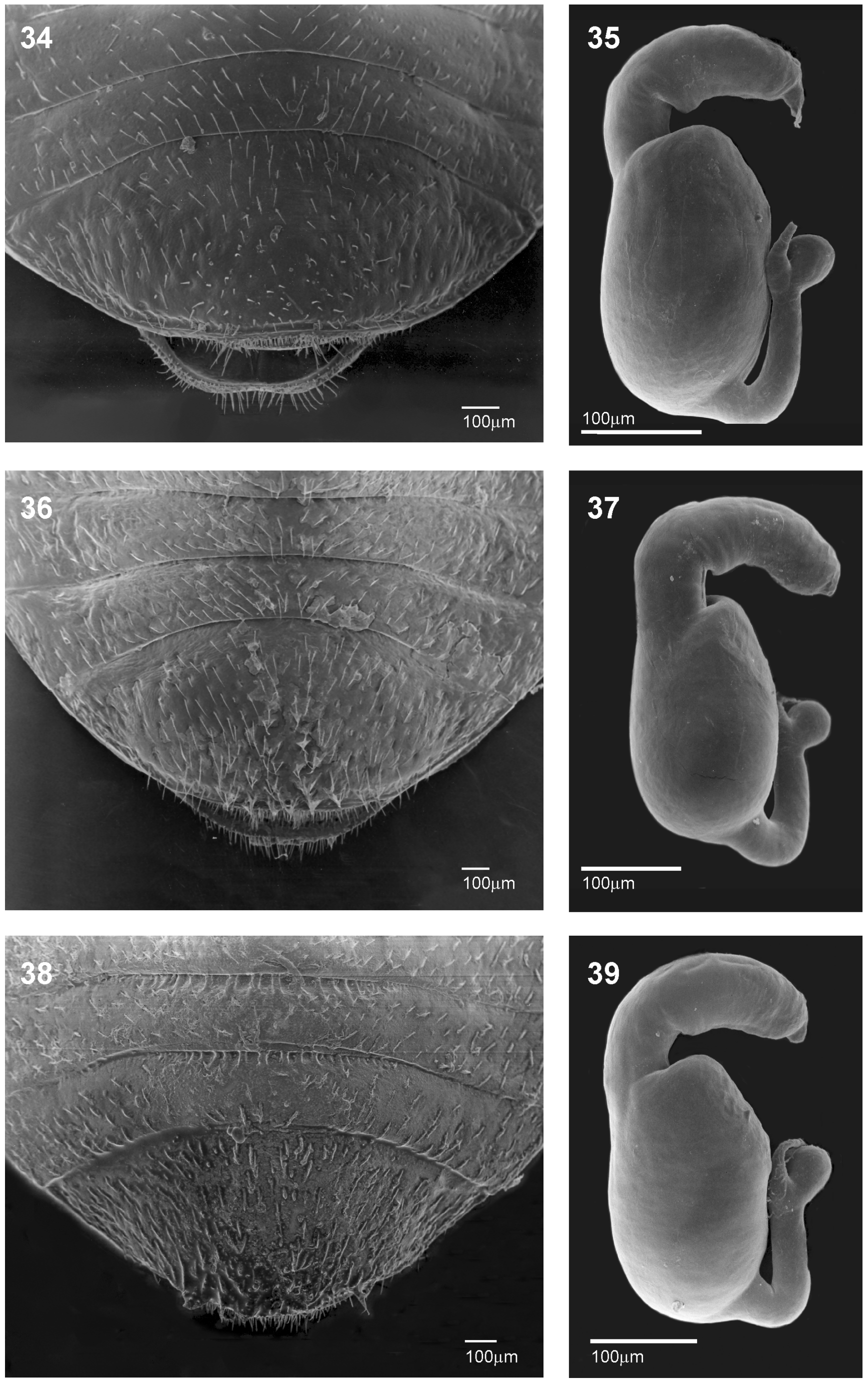


Figure 34-39: SEM photographs of the female abdomen and lateral view of spermathecae. 34-35: *A. sexvittatus*, 36-37: *A. melanus* sp. nov., 38-39: *A. epomistus* sp. nov.

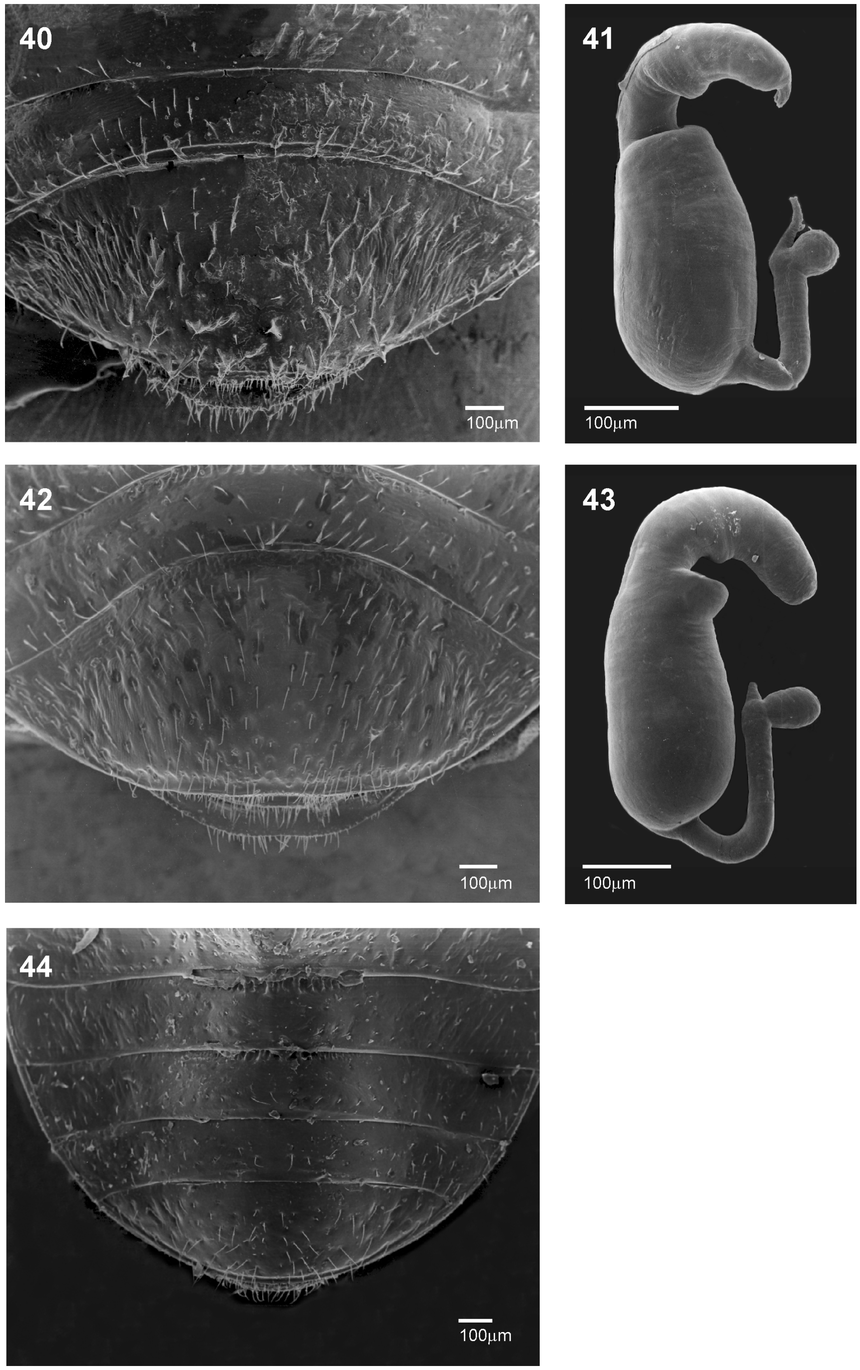


Figure 40-44: SEM photographs of the female abdomen and lateral view of spermathecae. 40-41: *A. capensis*, 42-43: *A. oleae* and 44: *A. lilliputianus* sp. nov. (spermatheca not examined).

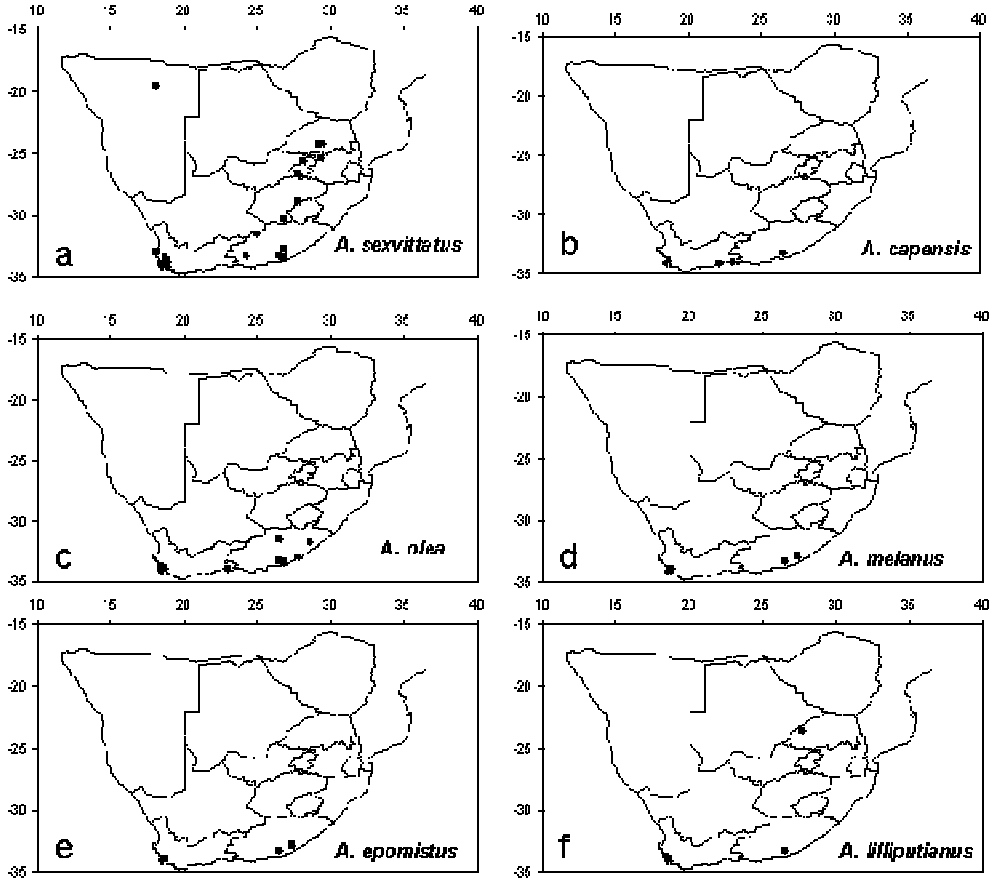


Figure 45 (a-f): The general distribution map of five species of olive flea beetles in South Africa shows a similar trend to that of wild olive trees. a: *A. sexvittatus* from the Limpopo province to Namibia; b: *A. capensis* Eastern Cape and Western Cape provinces; c: *A. oleae* Eastern Cape and Western Cape provinces; d: *A. melanus* Eastern Cape and Western Cape provinces; e: *A. epomistus* Eastern Cape and Western Cape provinces and f: *A. lilliputians* Eastern Cape, Western Cape and Limpopo provinces.

# Chapter 6 Monitoring olive flea beetle larvae and their parasitoids on wild and cultivated olives

## 6.1 Abstract

A survey of natural enemies of larvae of olive-feeding *Argopistes* Bryant flea beetle was conducted on a total of 320 larvae collected from wild and cultivated olives at five sites in the Eastern Cape, South Africa. Only 23 specimens of *Pseudophanomeris inopinatus* (Blkb.) (Hymenoptera: Braconidae) were recovered: 2 females and 4 males from Grahamstown, and 10 females and 7 males from Qunu. Beetle larvae were not found in seven out of 14 surveys, and were often absent when sites were resurveyed, and did not show consistent associations with either wild or cultivated olives. The scarcity of parasitoids may be due to the erratic occurrence of olive flea beetles during the study, and to insecticide spraying of commercial olives.

## 6.2 Introduction

Leaf-mining beetle larvae of the genus *Argopistes* Bryant (Chrysomelidae: Alticinae) are pests of cultivated and wild olives, *Olea europaea europaea* L. and *O. e. cuspidata* (Wall. ex G. Don) Cif., in South Africa. The larvae mine on growing olive leaves (Myburgh 1952, Whitehead & Myburgh 1961, Annecke & Moran 1982, Swain & Prinsloo 1986) and some species are economic pests (Costa 1998, Eglington 2004) that have a high potential to threaten the South African olive industry.

Bryant (1922, 1944) described three olive flea beetle species *Argopistes oleae, A. sexvittatus and A. capensis*. Museum collections show that two species are found on cultivated olives i.e. *A. oleae* and *A. sexvittatus*. These olive flea larval identities were never explored but literature shows that there was more concern of their control methods. Several methods were suggested for controlling *Argopistes* adults in South Africa. Mally (1924) suggested trapping but this was never implemented. Winter spraying of overwintering adult beetles with lead arsenate was reported to be successful (Lounsbury 1918), and lead arsenate and fixed nicotine, benzene hexachloride, and DDT were used concurrently as insecticides in 1942, 1945 and 1948 respectively (Myburgh 1952, Whitehead & Myburgh 1961). It was later discovered that lead arsenate was a human stomach poison, while DDT often resulted in increased populations of scale and related insects when used without the addition of other insecticides (Whitehead & Myburgh 1961). DDT residues were also found in milk and other foods, and in food chains of predatory birds and other animals and plants (Myburgh 1952, Pedigo 2002). Parathion, Malathion, Metasystox and Gusathion were also tried, but showed no practical control, or gave poor control by creating other problems like an increase of olive psylla (Whitehead & Myburgh 1961). Gusathion was found to be more effective than any other insecticide. Currently some private farmers both in the Western Cape and Eastern Cape use the recommended chemical Azinphos-methyl (Costa 1998), which they report to be ineffective. Private farmers in Olyvenrivier Valley (Western Cape) use Organo-Z by simply spraying regularly and using a home-made repellent (Eglington 2004).

As an alternative to chemical control, the search for natural enemies of *Argopistes* larvae was initiated by Taylor (1945) but attempts at rearing *Argopistes* larvae in the laboratory were unsuccessful. Taylor (1945) reported a few unidentified species of chalcid egg parasitoids. A female of the braconid wasp *Pseudophanomeris inopinatus* (Blkb.) was reared from olive beetle larvae collected in 1956 from Stellenbosch, and described by Belokobylskij (2000) in the genus *Colastes* (*Shawiana*) Hal. This species is poorly known in South Africa because the male is unknown and there is no literature considering its agricultural importance. This paper therefore reports parasitic wasps reared on *Argopistes* larvae collected in the Eastern Cape, South Africa, with an interest in motivating their biological control.

## 6.3 Material and methods

Samples of *Argopistes* larvae were collected during summer from cultivated olive trees at Springvale Farm (33°20’52”S 26°11’48”E), Varnam Farm (33°19’26”S 26°38’10”E), and the farm of ex-president Nelson Mandela near Qunu (31°48’35”S 28°36’24”E), and from wild olives at Springvale Farm, Hewlands Farm (33°28’38”S 26°28’39”E) and Grahamstown (33°19’10”S 26°31’04”E). Springvale Farm was the only site with both wild and mature cultivated trees. The cultivated olive grove was regularly irrigated and irregularly (which was Azinphos-methyl for olive flea beetle larvae) with insecticides, but the residues could not reach the wild olive trees. Sampling was done before applications of insecticide whenever possible.

Fifty leaves containing third or fourth instar *Argopistes* larvae, which were about 7 mm long and 3 mm in diameter, were collected if available from ten randomly selected wild and/or cultivated olive trees from each study site. The larvae were collected with their leaves from new shoots when they had almost stopped feeding, and were not removed from their mines. They were transferred from the field (in well-ventilated 2L plastic containers) to a constant environment room kept at about 25°C and a 16L:8D photoperiod. They were regularly supplied with fresh olive leaves and reared to adulthood in well-ventilated Petri dishes. Dead larvae were removed and recorded, and moisture and droppings wiped away to prevent mould and diseases. Any parasitoid species that emerged were identified and recorded. The larvae were not identified as taxonomic studies have not been done.

## 6.4 Results

### *6.4.1* ***Olive flea beetle larvae***

Abandoned leaf mines were found on old leaves at Springvale, Hewlands and Varnam farms. The occurrence of olive beetle larvae was erratic and a total of 320 larvae were collected from different sites (200 from Springvale Farm, 20 from Varnam Farm, 50 from Grahamstown, & 50 from Qunu) (Table 1). Larvae were always present at Springvale on cultivated olives (which were sprayed), but none were found on unsprayed wild olives within 2000m of the grove. At Varnam Farm larvae were found only in small numbers in January 2005. Although no larvae were found at Hewlands Farm, there were old leaf mines on both *O. e. europea* and *O. e. cuspidata*.

### *6.4.2* ***Parasitoids***

Only 23 specimens of *Pseudophanomeris inopinatus* (Hymenoptera: Braconidae) were reared from olive flea beetle that were collected from Grahamstown and Qunu (Table 1), showing rates of parasitism of 12% and 34%, respectively.

## 6.5 Discussion

In previous studies in the Eastern Cape and Western Cape, *Argopistes* larvae were found from September to November (Taylor 1945; Myburgh 1952), with a second generation in the Western Cape in January (Myburgh 1952). However, Taylor (1945) reported no traces of olive flea beetles in the Kat River area (33°45'S 26°36'E) of the Eastern Cape. It seems that the unpredictable occurrence of olive flea beetle is not unusual.

The occurrence of *P. inopinatus* may be affected by the availability of *Argopistes* larvae. Unfortunately, it is not know if the wasp has alternative hosts. The absence of *P. inopinatus* in Springvale was probably due to the spraying of chemicals during the active season (Costa 1998). *Pseudophanomeris inopinatus* is the most first record of the genus *Colastes* Hal. from the Afrotropical region, particularly in the Eastern Cape, South Africa. It is unclear whether the species is indigenous or introduced because most *Pseudophanomeris* species such as *P. unicolor* (Blkb.) (Russian), *P. pilosus* (Blkb.) (Korean) and *P. himalayicus* (Blkb.) are found in the Northern Hemisphere or in tropical and subtropical areas (Belokobylskij 1984, 2000, van Noort pers. comm. 2004). Belokobylskij (2000) suggested that *P. inopinatus* is closely related to the Palaearctic species *P. pilosus.*

## 6.6 Acknowledgements

We thank Craig Rippon, Dave Duncan, Ezra Schombee, Johan Stander and Nelson Mandela for allowing access to their farms; Charles Willemse, Abraham Chawanji and Jabulani S. Mthombeni for helping to collect olive flea beetle larvae; Simon van Noort (South African Museum, Cape Town) for identifying parasitoids; and the United States Department of Agriculture, the National Research Fundation, the Andrew Mellon Foundation and Rhodes University for financial support. Any opinion, findings and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Research Foundation.

Table 1: Seasonal activity of *Argopistes* olive flea beetle larvae and their parasitoids on wild and cultivated olive leaves.

| Site | Host plant | Sampling date | Number of beetle larvae collected | Wasp reared | | Rate of parasitism (%) |
|---|---|---|---|---|---|---|
| | | | | F | M | |
| Springvale Farm | *O. e. europaea* | November 2003 | 50 | 0 | 0 | 0 |
| | | January 2004 | 50 | 0 | 0 | 0 |
| | | November 2004 | 50 | 0 | 0 | 0 |
| | | January 2005 | 50 | 0 | 0 | 0 |
| | *O. e. cuspidata* | November 2003 | 0 | - | - | - |
| | | January 2004 | 0 | - | - | - |
| | | November | 0 | - | - | - |

| Site | Host plant | Sampling date | Number of beetle larvae collected | Wasp reared F | Wasp reared M | Rate of parasitism (%) |
|---|---|---|---|---|---|---|
| | | 2004 | | | | |
| | | January 2005 | 0 | - | - | - |
| Varnam Farm | *O. e. europaea* | November 2004 | 0 | - | - | - |
| | | January 2005 | 20 | 0 | 0 | 0 |
| Hewlands Farm | *O. e. cuspidata* | November 2004 | 0 | - | - | - |
| | | January 2005 | 0 | - | - | - |
| Grahamstown | *O. e. cuspidata* | November 2004 | 50 | 2 | 4 | 12 |
| Qunu | *O. e.* | November | 50 | 10 | 7 | 34 |

| Site | Host plant | Sampling date | Number of beetle larvae collected | Wasp reared | | Rate of parasitism (%) |
|---|---|---|---|---|---|---|
| | | | | F | M | |
| | *europaea* | 2004 | | | | |
| | | Total: | 320 | 12 | 11 | 46 |

# Chapter 7 Preliminary studies of distribution and trapping of olive flea beetles and olive lace bugs on cultivated olives.

## 7.1 Abstract

Some pests can be monitored and even controlled by trapping. This requires a knowledge of where to trap, and is facilitated by baiting. This chapter reports the first steps in developing this technique for the control of olive flea beetles (*Argopistes* spp.) and olive lace bugs (*Plerochila* sp., *Neoplerochila* spp.), which infest both wild and cultivated olives, *O. e. cuspidata* and *O. e. europaea* in South Africa. The spatial distributions of infestations of flea beetles and lace bugs were examined on trees in three cultivated olive groves in the Eastern Cape to aid in the appropriate placement of traps and sprays. Olive flea beetles preferred flushing leaves near the top of the tree, and most adults occurred from about 60 cm from the ground to a height of about 280 cm, but showed no preference for the north or south aspect of trees. No interaction between height and aspect was evident. Olive lace bugs were found lower on the tree, at heights of 20 cm to 60 cm. Using this information, traps placed at 1m on the north aspect of trees were baited with various olive leaf volatiles, including trans-2-hexanal (~98%); hexanal; hexanol; 3-methyl-butanol, 2,4-hydroxyphenyl alcohol and Texas volatile. The volatile compounds were refilled in some traps.

## 7.2 Introduction

Olive flea beetles of the genus *Argopistes* (Chrysomelidae: Alticinae), including *Argopistes oleae* Bryant and *A. sexvittatus* Bryant, *A. capensis* Bryant, and three species of olive lace bug (Tingidae), *Plerochila australis* Distant 1940, *Neoplerochila dispar* Duarte Rodrigues 1982 and an unidentified *Neoplerochila* sp., are pests of wild and/or cultivated olives trees, *Olea europea cuspidata* (Wall. ex G. Don) and *O. e. europaea* L. in South Africa (Bryant 1922, 1940, 1944, Myburgh

1952, Whitehead & Myburgh 1961, Costa 1998, Apenteng & Wallade 2005), but little is known of their biology.

Monitoring systems are needed for all these pests, and monitoring traps would facilitate this. Herbivorous insects often interact with plants by means of volatile semiochemicals, particularly for location of suitable hosts on which to feed or oviposit (Francke 1998, Vet & Dicke 1992, Szauman-Szumski *et al.* 1998, Barata *et. al* 2000). Law and Regnier (1971) defined semiochemicals as substances that carry messages between organisms, both plant and animal. Those emitted by an individual and producing a response in a conspecific individual are referred to as pheromones (Karlson & Luscher 1959), and can be classified by the response they release in the receiver (Shorey 1977, Suckling 2000), e.g. aggregation pheromones, alarm pheromones, recognition pheromones and kairomones. For example *Argopistes coccinelliformis* Csiki has a tendency to make use of food as a cue to the suitability of the location for oviposition (Inoue 1991). Plant odours are possibly the most essential signal directing phytophagous insects to their hosts and the potency of odour stimulant attraction is definitely linked with the level of specialty (host range) of the insect (Visser 1986). Several volatile compounds on cultivated olive tree leaves and fruits have been identified as semiochemicals (Scarpati *et al.* 1993, Barata *et al.* 2000), which can be valuable in integrated control strategies of olive pests.

In contrast to olfactory attractants, visual attractants such as traps for the control of insect pests have been considered (Campbell & Borden 2006). Coloured stimuli significant in host recognition have been used to monitor populations of various insects, particularly phytophagous insects in field crops (Hesler & Sutter 1993, Mensah 1996, 1997, Suckling 2000). Different colors have been used as visual signals to trap insect pests and most insects that have been studied showed preference to some colours more than others (Prokopy & Owens 1983, Prokopy *et al.* 1983). For example, yellow traps have been used to catch *Diabrotica speciosa* Germar (Ventura *et al.* 1996, 2000, 2001). Although Hoback *et al.* (1999) observed no preference for particular trap colours in coleopterans, Dominick (1976) stated that coleopteran families like Chrysomelidae showed preference for yellow traps and for green colour.

Therefore this chapter aims first to characterize the spatial distribution of olive flea beetle egg, larvae, adult habitat and olive lace bug on olive trees to identify and optimise the trap position on trees. The second aim of this work is to test whether some of the identified volatile compounds from the host plant *O. e. europaea* are attractants of adult olive flea beetle under field conditions using two types of trap, with special consideration to the development of practical management tools of adult olive flea beetles.

## 7.3 Material and Methods

The study of spatial distribution was conducted on Springvale Farm (33°20’53”S 26°11’48”E), Varnam Farm (33°19’25”S 26°38’08”E), Hewlands Farm (33°28’53”S 26°11’48”E) and trapping of flea beetles was conducted only at Springvale Farm in the Eastern Cape province, South Africa. Details of the study sites are given in Chapter 2.

### *7.3.1* ***Sampling strategy***

Sampling dates were October 2003 till Febrauary 2004 were based on information (Table 1) from Taylor (1945) and Myburgh (1952). Thirty trees were selected in each olive grove and tagged. The presence or absence of all life stages of olive flea beetles and olive lace bugs were noted in 20 cm bands from ground level to the maximum height of each tree. When there were no beetles physically present at the time, a survey was done by noting the presence of old indicators such as brown excrement which usually covers beetle eggs, the mines between leaf surfaces that are formed by larvae, and shot-hole marks on the leaves from adult feeding (Figure 1A and C). **This was a qualitativ**e **measure of damage, and a more rigorous quantitative study is needed.** When there were no lace bugs, old visual indicators such as chlorotic speckling of leaves from feeding were noted. Four variables were investigated during the study: densities of egg packets, larvae and adult beetles, height and/or side preference, and lace bug densities. The total beetle density was also calculated, which was simply the sum of the number of egg, larvae and adult density.

The relationship between month, aspect, height and width in relation to the densities of the eggs, larvae and adults of the olive flea beetle and the olive lace bug were compared using analysis of variance (F-test) and GenStat software (Payne, 2003).

### *7.3.2* ***Trapping***

The results of the spatial distribution study were used to determine the position of the traps for olive flea beetles and the site(s) where the pests were available. The traps were assembled only at Springvale Farm. Two types of trap were used for trapping olive flea beetle, green and yellow. These colours are typically used in traps to monitor insects. A total of 65 green and 65 yellow traps were hung on randomly selected cultivated olives trees, placed at a height of l m above ground level on the north side.

The volatile compounds used as baits were trans-2-hexanal (~98%); hexanal; hexanol; 3-methyl-butanol, 2,4-hydroxyphenyl alcohol and Texas volatile, which is known as a feeding attractant and stimulant for adult control of noctuid and other lepidopteran species (Lopez *et al.* 1998). Some of these compounds were found on olive leaves (Barata *et al*. 2000). Synthetic compounds were obtained from commercial sources (Aldrich Chemical Co. Ltd; Fluka Chemie AG) and were more than 97% pure. The volatile compounds were transferred to a 1.5ml plastic pipette and the open ends were closed by melting them. Lures were exposed from October 2004 to February 2005 and some traps were refilled monthly. Traps were emptied fortnightly, and any captured insects were counted and tabulated.

## 7.4 Results

### *7.4.1* ***Spatial distribution***

No significant olive flea beetles populations of *A. oleae* and *A. sexvittatus* were observed in Varnam Farm for the duration of this particular assessment. In Hewlands Farm olive flea beetle eggs, excrement, and old larvae mines were observed that were most probably from the previous year (Figure 1a, c). Two species of olive flea beetles, *A. oleae* and *A. sexvittatus*, were found at Springvale Farm. Their eggs were laid at the tips of leaves (Figure 1).

At Springvale Farm, olive flea beetles prefered the higher part of cultivated olive trees at a height of about 50-60 cm (Figure 2a-h, 3a-h). The mean density of eggs for both species were generally low on both north and south sides of the trees, ranging from 0.00111-0.00427 eggs/$cm^2$ on the north side and 0.00051-0.00500 $cm^2$ eggs/$cm^2$ on the south side in October 2003 and from 0.00111-0.004263 eggs/$cm^2$ on the north side and 0.00051-0.00499 eggs/cm² on the south side in February 2004 (Figure 2a, b). Analysis of variance of density of eggs showed a significant difference in height in October 2003 ($P < 0.001$, Figure 2a-h) and February 2004 ($P < 0.001$, Figure 3a-h) implying that more eggs were laid at a height of 50 cm and above. No significant difference was shown between the north and south aspects in either October 2003 or February 2004.

The mean density of larvae of *A. oleae* and *A. sexvittatus* ranged from 0.0008-0.0040 larvae/cm² on the north side and 0.0010-0.032 larvae/cm² on the south side in October 2003 and from 0.00083-0.00404 larvae/cm² on the north side and 0.00036-0.3151 larvae/cm² on the south side in February 2004 (Figure 2c, d). Analysis of variance showed that the density of larvae in October 2003 was significantly different both on height ($P = 0.002$) and side ($P < 0.001$), with no interaction between height and side. In February 2004 there was a significant difference between sides ($P < 0.001$), but no difference between heights and no interaction (Figure 2c, d, 3c, d).

The mean density of adults of *A. oleae* and *A. sexvittatus* ranged from 0.0010-0.0009 adults/cm² on the north aspect and 0.0002-0.0005 adults/cm² on the south aspect in October 2003 and from 0.0011-0.0009 adults/cm² on the north aspect and 0.00018-0.000476 adults/cm² on the south aspect in February 2004 (Figure 1e, f). Analysis of variance of density of adults showed no significant difference between heights in October 2003 but significant differences between aspects ($P = 0.004$). It was vice versa in February 2004, where a significant difference was shown with height ($P < 0.001$) and aspect (Figure 1g and h). There was a significant difference in the total density of beetles, between height ($P < 0.001$), aspect ($P < 0.001$) and month ($P < 0.001$).

The total density of *A. oleae* and *A. sexvittatus* in October 2003 showed significant difference with height and side ($p < 0.001$, $p = 0.001$) and no interaction between the two (Figure 2g, h). In February there were no significant differences between heights or sides, and no interaction between the two (Figure 3g, h).

At Springvale Farm, olive lace bugs on both aspects were more common on the lower part (< 20 cm) of the tree and decreased in density at a height of about 240 cm in October 2003. The mean lace bug density showed a significant difference in October 2003 on both height ($P < 0.001$) and aspect ($P = 0.003$) and no significant difference in February 2004 (Figure 4a, b). However, no interaction was shown between height and aspect, either in October 2003 or February 2004 (Figure 4c, d). At

Springvale Farm in October 2003, lace bug density showed a significant difference in height ($P < 0.001$) and aspect ($P = 0.003$). However, in February 2004 there were significant differences in both height and aspect, but no interaction between the two.

The results of lace bug densities at Varnam Farm and Hewlands Farm could not be analysed, but there was a trend that olive lace bugs preferred the lower parts of the olive tree. The olive lace bugs at Varnam Farm were densest between about 20-60 cm up the olive trees in October 2003 on both north and south aspects (Figure 5a, b). The patterns for the olive lace bug were similar in February 2004 (Figure 5c, d), but in January 2005 olive lace bugs were found more on the lower part of the trees.

### *7.4.2 **Trapping***

The traps caught only one species of olive flea beetle, *A. sexvittatus*, whereas there were two species present at Springvale Farm on commercial olives (Table 2). No olive flea beetles were caught in October, November and December although olive flea beetles were present on the trees. A male and a female *A. sexvittatus* were caught in a trap baited with 3-methyl-butanol in January and February but the number of captured flea beetles was too low to make statistical inferences about treatment effects. A range of volatile compounds (hexenal, 2,4-hydroxyphenyl alcohol, Texas volatile, trans-2-hexanal and hexanol) showed a slight attractiveness to the olive flea beetles (Table 1) but numbers were too low to make coherent analyses.

## 7.5 Discussion

### *7.5.1 **Spatial distribution***

The practical significance of the spatial distribution of pests has been long recognized (Taylor 1984, Basset 1991, Rafoss & Sæthre 2003, Cocu *et al.* 2005). Spatial information of pest is needed for understanding pest movements on host plants (Binns *et al.* 2000, Nansena *et al.* 2004) to strengthen the development of pest control strategies such as spraying programmes and Integrated Pest Management. For example it indicates where traps can be set to catch a large number of pests. The spatial distribution of insects in a given environment may change over time (Nansena *et al.* 2004). Investigating spatial distribution patterns over time and in different areas provides essential information as to how insects react to a changing environment, and this can be useful in the improvement of Integrated Pest Management (IPM) strategies (Korie *et al.* 2000).

The overall results showed that *A. oleae* and *A. sexvittatus* populations were thriving at Springvale Farm and practically absent at other sites such as Hewlands Farm and Varnam Farm. Few beetles were observed in the Kat River area in the Eastern Cape, and Taylor (1945) suggested that there was a factor inhibiting that olive flea beetle population. Inoue and Shinkaji (1989a, b) claim that eggs laid on new leaves of *Olea fragrans* var. *aurantiacus* during the normal oviposition season hatch when there are new leaves but if the leaves are old the eggs did not hatch because the leaves would be too tough for the hatchlings to eat. The farmers from Varnam and Hewlands farms suggested anecdotally that the timing of pruning of commercial olive trees may have affected the olive flea beetle populations, a matter also discussed by Inoue (1998).

Olive flea beetles were found mainly above 60 cm from the ground on commercial olive trees. Fernandez & Hilker (2007) reported that the size of a plant may possibly influence the host choice of chrysomelids, for the reason that if they enter areas with unoccupied host plants, the largest plants have a chance of being the most attractive as they may discharge the largest amount of voltile attractive odours or present the largest visual stimulus. Bolter *et al*. (1997) showed that Colorado potato beetle, *Leptinotarsa decemlineata* Say, was attracted to bigger plants over 60 cm in height.

Significant differences in density of eggs were found between heights at Springvale Farm. *Argopistes oleae* and *A. sexvittatus* laid eggs at a height of 60 cm and above on newly-formed leaves. Similarly, newly-emerged females of *A. coccinelliformis* oviposited on newly-formed rather than old leaves (Inoue 1991). Nahrung & Allen (2003) reported that the paropsine leaf beetle *Chrysophtharta agricola* Chapuis preferred immature foliage for oviposition. Larvae of *Chrysophtharta bimaculata* Olivier were unwilling to feed on leaves of the genus *Eucalyptus* from the previous season (Howlett *et al*. 2001). There was no significant difference in densities of eggs between the north and south sides of the tree, which implies that female flea beetles do not consider warmth when laying eggs. This might be due to the tendency of the adult olive flea beetles to feed on newly-formed leaves (Costa 1998) and adult flea beetles of *A. coccinelliforms* Csiki are know to prefer new to mature leaves regardless of the season (Inoue 1991). Many authors have said that insects usually feed only in certain height levels (Selman & Lowman 1983, Bogacheva 1984, Grossmueller & Lederhouse 1985, Moore *et al.* 1988)

The larvae density of *A. oleae* and *A. sexvittatus* in October 2003 exhibited a significant difference between sides and heights ($p = 0.002$, $p < 0.001$, respectively). However in February 2004 there were significant differences with side only ($p < 0.001$) (Figure 2 c, d). The distribution of larvae in October 2003 suggested that they preferred younger leaves than older for better development. This is possibly a common characteristic with chrysomelids because larvae of *Lamprolina aeneipennis* Boisduval (Coleoptera: Chrysomelidae) fed on young leaves of *Bursaria spinosa* Cav. (Pittosporaceae) (Hawkeswood 1986), and there was a difference in the weight of both larvae and pupae of the water-lily beetle, *Galerucella* (= *Pyrrhalta*) *nymphaeae* (L.) (Coleoptera: Chrysomelidae) feeding on young and old leaves (Kouki 1993). In October 2003 and February 2004, there were significant differences in density of larvae between the north and south side ($p = 0.002$, $p <0.001$) which may possibly mean that the larvae were more on the warm aspect of the tree on the north (Figure 3c, d). Higher temperatures acelerate the growth rate of insects (Tingle and Copland 1988), which is generally an advantage because the insects can breed sooner and are exposed to risks like predation for a shorter period.

Lace bug distributions at all of the sites showed that olive lace bugs preferred the lower part of the tree, but were also found higher on the trees in smaller numbers (Figure 1a-d, 2a-d, 3a-d). Adult lace bugs were found attacking the older leaves in the Western Cape (Costa 1998). Nymphs of *Leptodictya tabida* Herrich-Schaeffer (Hemiptera: Tingidae) remained on the same leaf throughout their development but adults moved up to younger leaves to oviposit, which means that damage begins on old leaves and later appears on new growth (Hall & Sosa 1994). Further survey is needed to understand the ecology of the olive lace bugs in the Eastern Cape.

### *7.5.2* ***Trapping***

The olive flea beetles *A. oleae* and *A. sexvittatus* showed practically no attraction to all of the volatile compounds tested. Therefore conclusions about the effects of olive leaf volatile compounds on *Argopistes* species would be premature.

The chrysomelid leaf beetles are a large and economically significant family whose pheromones, biology and semiochemical attractants are inadequately studied (Soroka *et al.* 2005). The semiochemicals most studied thus far are for *Diabrotica* rootworm beetles (Lampman *et al.* 1987, Hibbard & Bjostad 1988, Lance 1988), *Phyllotreta* spp. (Liblikas *et al.* 2003) and *Phloetribus scarabaeoides* Bernard (Coleoptera: Scolytidae) olive bark beetle (Pivnick *et al.*1992, Szauman-Szumski *et al.* 1998). Continued exploration of the semiochemicals of other leaf beetles is necessary because it will help in understanding host detection by leaf flea beetles, and the use of these attractants could be an alternative to insecticidal control by luring the pests into traps. Insecticides can be placed in the traps to prevent escapes, and in that case they need not affect the environment to any significant degree.

## 7.6 Acknowledgements

I thank the private Eastern Cape olive growers that were involved for allowing access to their farms; Charles Willemse and Abraham Chawanji for helping with data collection and counting; John Scrimgeour (South African Olive Industry, Paarl, Cape Town, john@buffetolives.net; the United States Department of Agriculture-Agricultural Research Service, South Africa's National Research Foundation, the Andrew Mellon Foundation and the Rhodes University Joint Research Council for financial support. Any opinion, findings and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Research Foundation.

Table 1: Reported olive flea beetle (*A. oleae* and *A. sexvittatus*) generations which were used as benchmark for sampling in this study.

| August | September | October | November | December | January | February | March |
|---|---|---|---|---|---|---|---|
| **Taylor (1945) (one generation)** | | | | | | | |
| | Larvae present | | | | | | |
| **Myburgh (1952) (two generation)** | | | | | | | |
| Adults laying eggs on new leaves | | | | | | | |
| | Larvae present till mid November | | | | | | |
| | | | For two weeks no larvae observed | | | | |
| | | | Adults emerge and eggs are deposited | Larvae starts mining | No young stages have been observed | Young adults emerge, feed for some weeks and then over-winter | |

Table 2: Number of olive flea beetle, *A. sexvittatus* caught on traps on different dates.

| Sampling date | Trap type | Lure | Sex |
|---|---|---|---|
| 10/01/05 | Green (control) | - | 1 male |
| | Green | 2,4-hydroxyphenyl alcohol | 1 female |
| | Green (refilled) | 2,4-hydroxyphenyl alcohol | 1 female |
| | Green (refilled) | 3-methyl-butanol | 1 male |
| | Green (refilled) | Trans-2-hexanal | 1 female |
| | | | |
| | Yellow (control) | - | 1 female |
| | Yellow | 3-methyl-butanol | 1 male, |
| 1 female | | | |
| | Yellow | Texas volatile | 1 male |
| | Yellow (refilled) | hexenal | 1 female |
| | Yellow (refilled) | Trans-2-hexanal | 1 female |
| | Yellow (refilled) | Trans-2-hexanal | 1 female |
| | | | |
| 10/02/05 | Yellow | Texas volatile | 1 female |
| | Yellow (refilled) | 3-methyl-butanol | 1 male |
| | Yellow (refilled) | hexanol | 1 male |

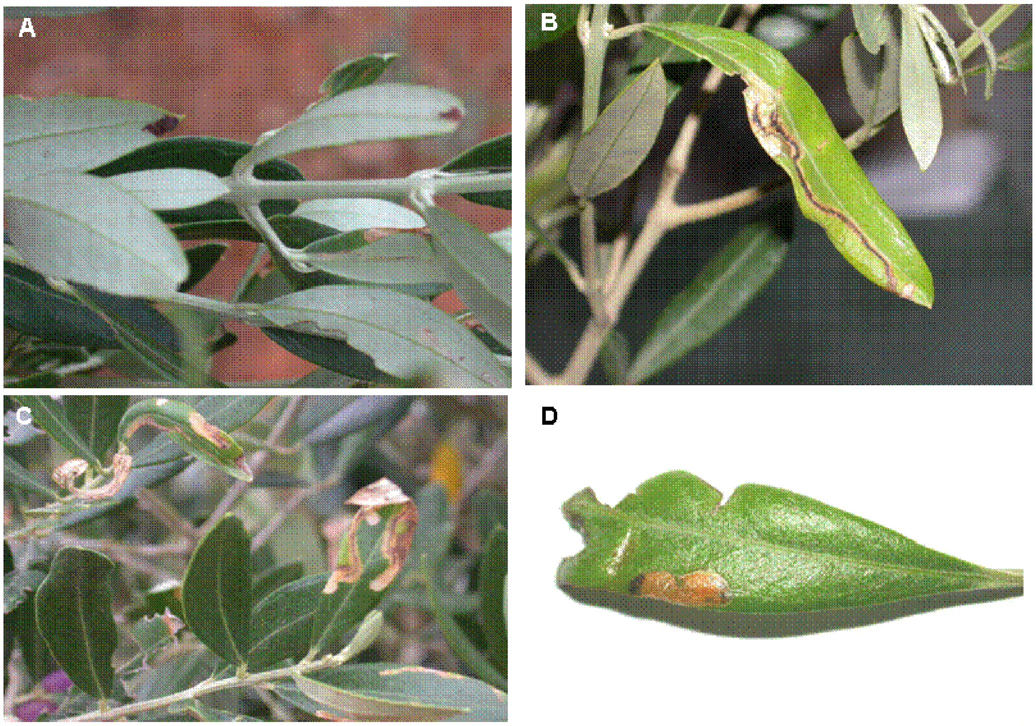


Figure 1: A. Adult flea beetle eggs covered by brown excrement at tip of a leaf of a cultivated olive *Oleae europea europea* L. (Mission cultivar). B-C. Old mines of olive flea beetle larvae. D. Olive flea beetle (orange) mining through a leaf.

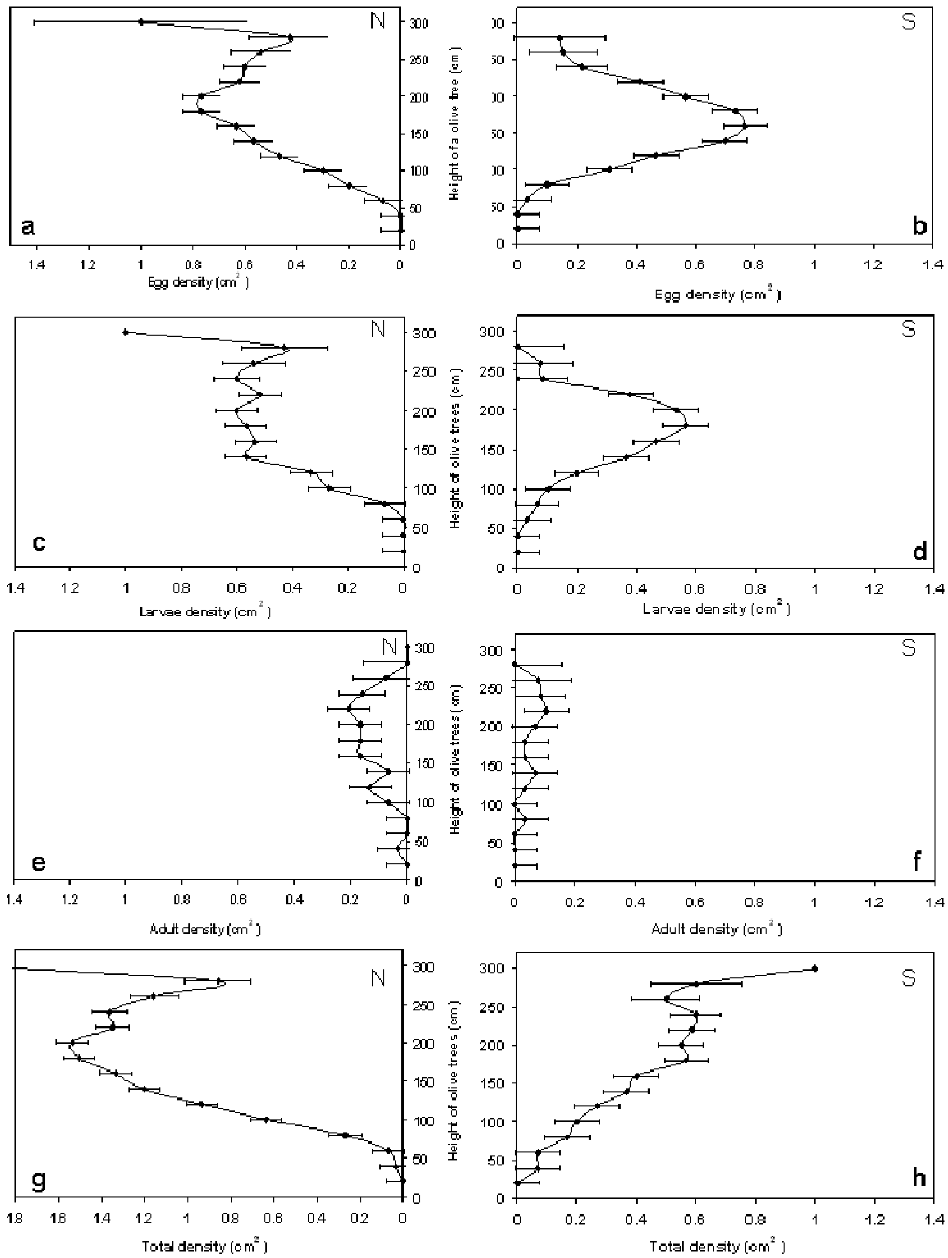


Figure 2a-f: Distribution of *Argopistes oleae* and *A. sexvittatus* on north (N) and south (S) sides on cultivated olives in October 2003 in Springvale Farm. a, b: Egg density differed significantly with height ($p < 0.001$) but not side, without interaction (%CV 123.9, S.E = 0.003). c, d: Larvae density differed significantly with height ($p < 0.001$), and side ($p = 0.002$) only (%CV 154.7, S.E = 0.002). e, f: Adult densities differed significantly with height ($p = 0.004$) only (%CV 426.9, S.E = 0.002). g, h: Total density differed significantly with height only (%CV 121.54, S.E = 0.006).

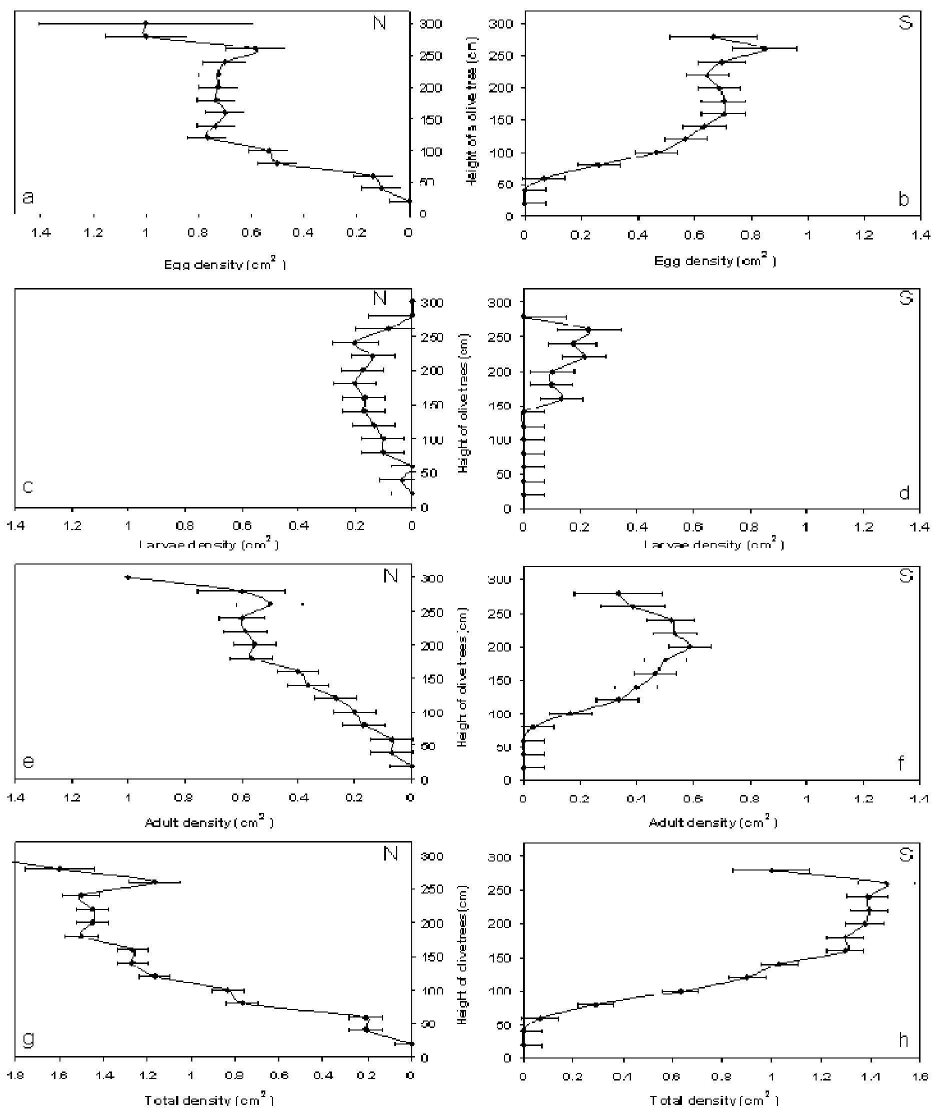


Figure 3a-f: Distribution of *A. oleae* and *A. sexvittatus* on north (N) and south (S) sides on cultivated *O. e. europaea* L. in February 2004 in Springvale Farm. a, b: egg density differed significantly with height ($p < 0.001$), but not side, without interaction (%CV 110.19, S.E = 0.003). c, d: Larvae density did not differ significant difference on height but differed significant on side ($p < 0.001$), without interaction (%CV 361.20, S.E = 0.002). e, f: adult densities differ significant with height ($p < 0.001$), but not with side, without interaction (%CV 164.69, S.E = 0.0032). g, h: Total olive flea beetle density showed significant difference with height ($p < 0.001$), and side ($p = < 0.001$) without interaction (%CV 111,02, S.E = 0.0065).

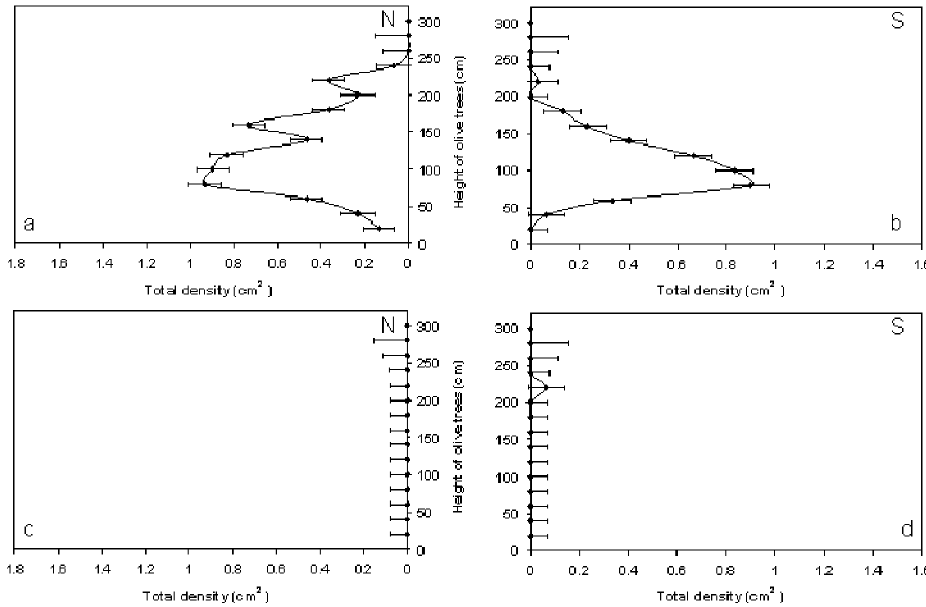


Figure 4a-d: a, b: Total population density of *P. australis* on *O. e. europaea* L. in October in Springvale Farm differed significantly with height ($p < 0.001$) and side ($p = 0.003$) without interaction (%CV = 218.77, S.E. = 0.0048). c, d: In February 2004 no significant difference was found with height; side, or interaction (%CV 2703.93, S.E. = 0.000169).

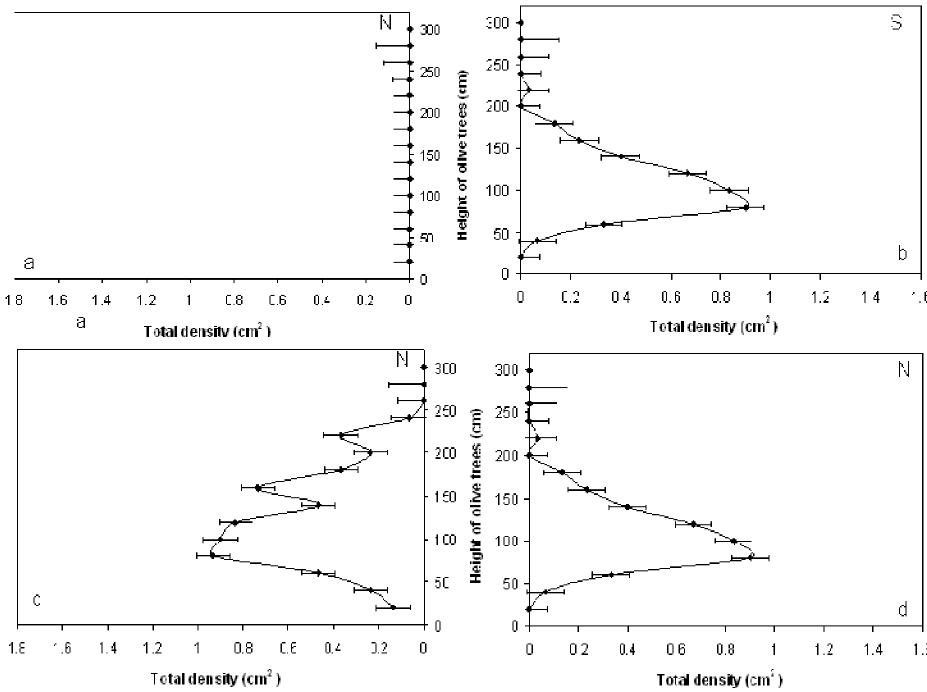


Figure 5a-d: a, b: a total population density of *P. australis* on *O. e. europaea* L. in October and c, d: in Febrauary in Belmont Valley which showed no significant difference with height, side or interaction. However the pattern of lace bugs densities was similar to that shown in Springvale Farm (Figure 3 a-d).

# Chapter 8 Synthesis

This chapter provides a review of the study and conclusions on future actions imperative for the successful integration of small-scale farmers' olive project into the commercial agricultural economy. The study investigated small-scale olive growers, agricultural research and training institutions and private olive growers located in the Eastern Cape. It has also brought more understanding of the biology of olive fruit flies, olive flea beetles, olive lace bugs and their parasitoids on the olive crop in the Eastern Cape.

## 8.1 The context of the olive industry in the Eastern Cape

*Olea e. europeae* L. is a world-wide valuable and economically important crop especial in subtropical areas with a Mediterranean climate as it provides edible olive fruits and olive oil (Copeland *et al*. 2004). Areas with a Mediterranean climate, mainly in southern Europe and the Levant, South Africa and California cultivate extensively commercial olives (Copeland *et al.* 2004). In South Africa olive oil development is approximately 7% of revenue annually, which is higher than the world olive oil growth, which is 2% annually, while growth in local table olives is roughly 5% annually (WESGRO 2005/2006). Private farmers' problems were pests; the agricultural research and training institutions' problems included lack of a sense ownership, lack of resources, lack of capacity, and inconsistency of management; and small-scale farmers' problems were pest and logistical issues that the Provincial Department of Agriculture needs to consider before implementing an agricultural project, including lack of a sense of ownership of the project by the small-scale farmers, lack of adequate support from the Provincial Department of Agriculture, poor human capital (knowledge, skills, and capacity to work), lack of knowledge transfer, poor stability, lack of communication and evaluation procedures, inconsistency of management, miscommunication and unrealistic time-scales. Due to the above factors, all of the olive trees that were not privately owned were neglected, which created a hospitable environment for pests. From a pest management point of view this raises a concern because a collective pest management strategy needs to involve various groups including the agrochemical industry, pesticide dealers, government institutions, NGOs, and/or groups of farmers themselves (Knight & Norton, 1989).

However, pest problems in many countries have been controlled with registered insecticides for many years. In 2003 there was a campaign suggesting a shift to other pest management strategies in South Africa (Maredia 2003). This was due to the expense of pesticides, development of resistance of pests to pesticides, and the harmful effects of pesticides on biodiversity and the environment, food and water quality, and human and animal well-being. The global economy was also moving towards a free market structure, free trade, and firm policy on pesticides residues on imports to the extent that European and North American markets were forced to review pest management approaches if they wanted to remain internationally competitive (Henson & Loader 2000). Agricultural markets were forced to shift from the use of chemicals to ecologically- and biologically-based pest management such as the use of behavioral control, biological control, biopesticides, botanical pesticides, cultural control, host plant resistance, mechanical control, transgenic plants, quarantine and quality regulations (Karim 2003) that were collectively termed Integrated Pest Management (IPM).

The concept of IPM raises questions about whether it would work with the abovementioned farmers if they do not have the essential IPM tools to manage their pests. However Rodríguez & Niemeyer (2005) stated that IPM symbolizes a challenge for farmers in developing countries where the farmers' education level is predicted to be less than in developed countries. The apparent difficulty of implementing IPM is attributed to the economic threshold IPM concept, which has been demonstrated to be too complex for resource-poor farmers to implement (Orr 2003, Morse & Buhler 1997). The idea of IPM has also been developed in the olive growing industry as a means of reducing pesticides use (Walton 1995).

## 8.2 Fruit fly pests of olive crops in the Eastern Cape

This study surveyed natural enemies specifically parasitoids of fruit flies (*Bactrocera oleae, B. biguttula* and *Ceratitis capitata*) and also explored one of the tools of Integrated Pest Management which is a trapping system for olive fruit flies in the Eastern Cape. The results revealed, first, that IPM can efficiently control olive fruit pests in the Eastern Cape for the reason that their natural enemies such as parasitoids were available and in good numbers, and second, that traps are able to catch olive fruit flies to a considerable level.

Tephritidae (*Bactrocera oleae* (Rossi), *B. biguttula* (Bezzi) and *Ceratitis capitata* (Wiedemann)) were obtained only from wild olives fruits, *O. e. cuspidata*. Fruit infestation rates were in general lower than 8% and over half of the infestations were under 1%. In this study, parasitism of fruit flies ranged from 0% - 83% in some areas. In the Western Cape parasitism was 0%-100% (Neuenschwander 1982), while in Kenya it was only 0%- 50% (Copeland *et al.* 2004). In all of these areas, the parasitoids were reared from fruit of from *O. e. cuspidata*. The results obtained in this study suggest that fruit flies are not yet a problem in the Eastern Cape and the small number present can be restricted to a considerable level by parasitoids.

The parasitoid reared in this study were the opiine braconids *Utetes africanus* (Szépligeti), *Psyttalia concolor* (Szépligeti), *Psyttalia lounsburyi* (Silvestri), and *Bracon celer* (Szépligeti) (subfamily Braconinae). Several species of braconid wasps (Opiinae and Braconinae) were reared from fruits containing *B. oleae* or *B. biguttula*. Chalcidoid parasitoids and seed wasps included species of Eurytomidae, Ormyridae and Eupelmidae specifically *E. oleae, E. afer, Ormyrus sp., unidentified sp., E. spermophilus, Eurytoma sp., Sycophila sp., Megastigmus sp.* and *Sycophila sp.* Neuenschwander (1982) and Copeland *et al.* (2004) obtained similar species. In Kenya, no parasitoids were obtained from samples that produced *Bactrocera munroi* White, *B. biguttula* and *Ceratitis capitata* (Copeland *et al.* 2004), but very few individuals of these flies were obtained anyway. More thorough studies of the biology and ecology of the fruit flies and their parasitoids are needed. There are also indications that spraying insecticides for olive flea beetles may check olive fruit fly populations.

All three species of tephritid fruit flies were caught during mass trapping and the most abundant species was *B. biguttula*, which may be a potential pest for cultivated olives in the Eastern Cape because it was caught in traps placed on cultivated olive trees. *Bactrocera biguttula* has been reported in South Africa and on three species of Oleaceae in Kenya (Copeland *et al.* 2004), but this is the first report of *B. biguttula* being caught in traps. It would be interesting to further investigate whether *B. biguttula* can be caught every year. The olive industry needs to establish whether *B. biguttula* is a potential pest as it is currently only known to attack wild olives. ChamP traps baited with 1.7-Dioxaspiro [5.5] undecane and spiroketal pheromone offered better potential for mass trapping of *B. biguttula* than Sensus traps baited with Questlure and methyl eugenol. Montiel-Bueno & Jones (2002) and Rice *et al* (2003) found similar results but the traps had negative effects on untargeted insects. McPhail traps baited with ammonium bicarbonate solution were used to monitor olive fly population levels in orchards and showed a high rate of fly captures (Saour and Makee 2004). The temporal variation and ecology of populations of olive fruit flies on wild and cultivated olives in South Africa needs further research, and this study has provided a starting point for this kind of investigation to provide suitable clarification for these annual and seasonal changes.

The microbial insecticide Tracer [(Spinosad) CB 0.24g] is currently the only registered insecticide against olive fruit flies in South Africa (National Department of Agriculture 2007). Spinosad is a microbial-derived compound that has low toxicity to vertebrates but high toxicity to a number of species of tephritid fruit fly pests (Kollman 2002). Spinosad bait sprays have been used on an experimental basis in Greece and shown to be as effective as organophosphate insecticide-bait sprays. At present it is used in California and is registered under the trade name GF-120 on an emergency exemption (section 18). For Californian table olives, GF-120 is typically applied weekly from pit hardening (mid-June) until harvest (mid- September). The efficacy of GF-120 under Californian environment conditions has not yet been demonstrated (Collier & van Steenwyk 2003).

Other control methods, such the sterile insect technique (SIT) and manipulation of pest genetics (Karamanlidou *et al*. 1991), are being developed with the aim of eliminating insecticide use (Broumas 2002, Dimou *et al*. 2003). An SIT program involves mass-produced males; female embryos are selectively eradicated by heating in genetic sexing strains that have a temperature-sensitive lethal mutation (Franz *et al.* 1996) and the remaining males are sterilized with gamma irradiation and released into the environment to mate with wild females, resulting in infertile eggs. It is also know that such a technique can be applied if there is significant knowledge of the species involved, such as basic genetic, biochemical and molecular information (Zambetaki *et al.* 1991). SIT for prevention, suppression, or eradication of *C. capitata* is used worldwide due to the pests' global distribution, wide range of hosts, fast dispersal, and adaptation to low temperatures (Hendrichs *et al.* 1995, André *et al.* 2007).

## 8.3 Flea beetle pests of olive crops in the Eastern Cape

In South Africa, at least five species of flea beetles (genus *Argopistes* Bryant) are found on wild and/or commercial olives. Some of these flea beetles are serious crop pests, particularly in the Western Cape (Costa 1998), and wild olives serve as reservoirs. The scanning electron microscopic photographs of the sternites of both sexes, and the aedeagus and spermathecae of all species have lead to an understanding of the flea beetle sexes and the relationship of all the species. Bryant's (1922) illustrations of adults of *A. oleae* Bryant 1922 and *A. sexvittatus* Bryant 1922 were not particularly detailed and this has been rectified in this study. A key to all five species has also been presented. The taxonomic studies performed by Weise (1895, 1914, 1919), Silvestri (1914) and Bryant (1922, 1940) on other species of *Argopistes*, namely *A. silvestrii* Weise, *A. sexguttatus* Weise, *A. brunneus* Weise, *A. vosseleri* Weise, *A. nigra* Bryant *and A. hargreavesi* Bryant included no photographs and/or no differentiation of the sexes. It is understandable that systematics was not that developed in those authors' times. The entire genus needs to be reviewed to determine the relationships between the species in all parts of the world. It was also important to investigate the lengths of the body, elytra, antennae and pronotum and the width of the body to discriminate between species. Mota-Sanchez *et al.* (2003) stated that it is important to identify the insect species correctly in order to design any management programs. This study has shown that further taxonomic research, including cytogenetic and phylogenetic studies, need to be undertaken.

In the Eastern Cape these leaf miners were attacked by one species of parasitoid, *Pseudophanomeris inopinatus* (Hymenoptera: Braconidae). The closely related Northern Hemisphere species *P. unicolor* (Blkb.) (in Russia), *P. pilosus* (Blkb.) (in Korea) and *P. himalayicus* (Blkb.) (in India) are not know to parasitise leaf miners. It is not yet known which flea beetle species *P. inopinatus* preferred as the taxonomy of the beetle larvae is unknown, and the taxonomy of the flea beetle larvae is therefore a priority. Lee (1992) described and illustrated the larvae of two Japanese *Argopistes* species, *A. coccinelliformis* (Csiki) and *A. biplagiatus* (Motschulsky), and thus far no parasitism of the larvae has been reported. Further study of *P. inopinatus* parasitism will provide better understanding of the efficacy of this leaf miner parasitoid for biological control.

The populations of *A. oleae* and *A. sexvittatus* were successful in Springvale Farm because there were two generations a year compared to either one or none on the other sites in Hewlands and Varnam farms. Significant differences in egg density in Springvale Farm in terms of height on the tree showed that the eggs were mainly laid on newly formed leaves. Similarly, newly emerged adult females of *A. coccinelliformis* oviposited on newly formed leaves rather than old leaves (Inoue 1991). The non-significance distribution of egg density in relation to aspect showed that female flea beetles do not prefere a particular side of the tree on which to lay eggs. This is due to the tendency of the adult olive flea beetles to feed on newly formed leaves (Costa 1998). Adult flea beetles of *A. coccinelliforms* Csiki are know to prefer new leaves to mature ones regardless of season (Inoue 1991). It appears that overwintered flea beetles laid eggs in October in Hewlands Farm but there were no leaves for the newly emerge larvae to eat, which may have depressed the local population. Taylor (1945) also reported that there were no traces of olive flea beetles in the Kat River area in the Eastern Cape and suggested that there could be some factor inhibiting olive flea beetle larvae there. This "factor" might be the timing of leaf growth relative to beetle oviposition. Inoue and Shinkaji (1989a, b) claim that when eggs were laid on new leaves of *Olea fragrans* var. *aurantiacus* during the normal ovipositional season hatch, the leaves had become too old for hatchling beetles to feed. Inoue (1998) reports that the timing of pruning of Oleaceae can affect populations of olive flea beetle, and this deserves particular attention in future research.

All of the volatile compounds tested towards the olive flea beetles showed little attractiveness. These were preliminary studies on chemicals attractive to olive flea beetles in South Africa and there are other volatile compounds found in olives leaves could be alternatives to classical control, including 3-methyl-1-butanol, branched epoxyalkane, ethyl propionate, (Z)-3-hexen-1-ol, α pinene, (E)- β ocimene, (E)-4,8-dimethyl-nona-1,3,7-triene, and germacrene-D (Scarpati *et al.* 1993, Barata *et al.* 2000).

Jameson (1970) reported that turnip flea beetle, *Phyllotreta* species, could be controlled by benzene hexachloride drilled with the seed, which is similar to the suggestion made by Myburgh (1952) and Whitehead & Myburgh (1961) regarding the olive flea beetles *A. oleae* and *A. sexvittatus*. Currently some private farmers both in the Western and Eastern Cape use the recommended chemical Azinphos-methyl [SC 350g/L and 200g/L, WP 350g/kg] (National Department of Agriculture 2007) which the farmers report to be ineffective (Costa 1998). Other private farmers in Olyvenrivier Valley (Western Cape) spray Organo-Z regularly and use a home-made repellent (Eglington 2004). Kunicki *et al.* (1996) and Kabaluk & Vernon (2000) reported that cultural control for the management of flea beetles that includes crop rotation, delayed planting, and row cover barriers. However tis form of cultural control of olive flea beetles is impractical as the olive trees are planted once and the tree last for a life time.

## 8.4 Lace bug pests of olive crops in the Eastern Cape

Olive lace bug preferred the lower part of the tree, although they were also found higher in the tree in smaller numbers (Table 1a,b,c). Adult lace bugs were found attacking older leaves in the Western Cape (Costa 1998). Hall & Sosa (1994) found that nymphs of *Leptodictya tabida* (Hemiptera: Tingidae) remained on the same leaf throughout their development but adults moved up to younger leaves to lay eggs, which means that damage began on old leaves and later appeared on new growth. A further survey is needed to understand the biology and ecology of the olive lace bug, and how these preferences can be used in imporving the design of spraying and trapping programmes.

One moth species, *Palpita unionalis* (Hübner) (Crambidae), was reared in very low numbers and with no parasitoids, as also found by Copeland *et al.* (2004). A few seed wasps were reared in very small numbers, and appear to be unimportant as pest, as was an unidentified twig-boring beetle larva. Although olive psylla was found on some wild olive trees, it was not recorded on commercial olives, and does not seem to have pest potential.

## 8.5 Conclusion

Olives are a viable crop in the Eastern Cape. Olive fruit flies, olive flea beetles and olive lace bugs are the principle pests of olives in the Eastern Cape, and attention should be given to the taxonomy of the flea beetles. Parasitoids may keep the populations of the olive fruit flies at much lower levels than in other producing countries. However the very low numbers of olive fruit fly and parasitoid reared make any statement about efficient biocontol of olive fruit fly by parasitoids in the Eastern Cape difficult to justify. Trapping techniques show promise for control of some of the pests but not others, and improved pruning techniques might help to control olive flea beetle populations. There is ample scope of futher research in any of these specific directions.

# Chapter 9 References

André, V.; Urbaneja, A.; Sabater-Muñoz B. & Castañera P. 2007. A novel molecular approach to assess mating success of sterile C*eratitis capitata* (Diptera: Tephritidae) males in sterile insect technique programs. Journal of Economic Entomology 100: 1444-1449.

Annecke, D.P. & Moran, V.C. 1982. Insects and mites of cultivated plants in South Africa. Butterworths, Durban. 383pp.

Anonymous, 2001. Olive project doing well. Eastern Cape Herald. Monday March 05, 2001. Reference: 2000. http://www.samedia.uovs.ac.za/cgi-bin/getpdf?year=2001&refno=2000&topic=19

Anonymous, 2002a. How special projects are going. Daily dispatch, Friday, March 08, 2002. http://www.samedia.uovs.ac.za/cgi-bin/getpdf?year=2002&refno=931&topic=19.

Anonymous, 2002b. Pineapple research to resume. Daily dispatch online, Thursday, April 25, 2002. http://www.samedia.uovs.ac.za/cgi-bin/getpdf?year=2002&refno=1701&topic=19.

Anonymous, 2003. Funds available for women's projects. Daily dispatch, Friday, June 6, 2003. http://www.dispatch.co.za/2003/06/06/features/FARM1.HTM

Anonymous, 2004. Doing business: trends and growth. Better than bitter for olives, Proudly South Africa Wednesday, April 28, 2004. http://www.southafrica.info/doing_business/trends/newbusiness/olive-industry.htm.

Apenteng, N.V. & Wallade, S.M. 2005. Olive pests and their natural enemies in the central Eastern Cape Province of South Africa. Proceedings of 15th of Entomological Congress, 10-13 July, Grahamstown.

Athanassiou, C.G.; Kavallieratos N.G. & Mazomenos B.E. 2004. Effect of Trap Type, Trap Color, Trapping Location, and Pheromone Dispenser on Captures of Male *Palpita unionalis* (Lepidoptera: Pyralidae). Journal of Economic Entomology 97: 321-329.

Barata, E.N.; Pickett, J.A.; Wadhams, L.J.; Woodcock, C.M. & Mustaparta, H. 2000. Identification of host and nonhost semiochemicals of eucalyptus woodborer

*Phoracantha semipunctata* by gas chromatography-electro-antennography. Journal of Chemical Ecology 26: 1877-1895.

Basset, Y. 1991. Influence of leaf traits on the spatial distribution of insect herbivores associated with an over storey rainforest tree. Oecologia 87: 388-393.

Belokobylskij, S.A. 1984. On division of the tribe Exothecini s. 1. (Hymenoptera, Braconidae) into two tribes of a new genus and subgenus, Zoologicheskii Zhurnal 63:1019-1026.

Belokobylskij, S.A. 2000. New taxa of the braconid subfamily Exothecinae (Hymenoptera, Braconidae) from the tropics and subtropics of the Old World: II. Entomological Review 80: 64-84. Translated from Entomologicheskoe Obozrenie 79: 180-203.

Binns, M.R.; Nyrop, J.P. & van der Werf, W. 2000. Sampling and monitoring in crop protection: the theoretical basis for developing practical decision guides. CABI, New York.

Binns, T.; Hill, T. & Nel, E. 1997. Learning from the people: participatory rural appraisal, geography and rural development in the 'new' South Africa. Applied Geography 17: 1-9.

Biondi, M. & D' Alessandro P. 2003 Revision of the *Pepila fuscomaculata* species-group and description of four new species from Australia (Coleoptera: Chrysomelidae: Alticinae). Australian Journal of Entomology 42: 313-326.

Bollens, S. 2000. Community development in democratic South Africa. Community Development Journal 35: 167-180.

Bolter, C.J.; Dicke, M.; van Loon, J.J. A.; Visser, J.H. & Posthumus, M.A. 1997. Attraction of Colorado potato beetle to herbivore-damaged plants during herbivory and after its termination. Journal of Chemical Ecology 23: 1003–1023.

Bongacheva, I.A. 1984. Distribution of Phyllophegon insects in the crown of drooping birch on northen boundary of tree vegetation. Soviet J. Ecol 15: 153-159.

Booysen, G.; McLaughlin, J.R.; Sack, C.V.; Czokajlo, D.; Kirsch, P. & Venter, S. 2003. New formulations for *Ceratitis* fruit fly trapping management. Proceedings of the 14th Entomological Congress of the Entomological Society of Southern Africa. 6-9 July 2003. University of Pretoria, Pretoria, South Africa.

Bownes, A. 2002. The structure of ant communities and their impact on soil-pupating pests in citrus orchards in the Grahamstown area of the Eastern Cape. Master of Science thesis, Rhodes University, Grahamstown, Rep. South Africa.

Broumas, T., Liaropoulos, C.M., Katsoyannos, P., Yamvrias, C., Haniotakis, G. & Strong, F. 1983. Control of the olive fruit fly in a pest management trial in olive culture. In: Fruit Flies of Economic Importance. R. Cavalloro (Ed.), pp.584-592. Proceedings of the CEC/IOBC, International Symposium, Athens, Greece, 16-19 November 1982.

Broumas, T.; Haniotakis, G.; Liaropoulos, C. & Yamvrias, C. 1985. Experiments on the control of the olive fruit fly by mass trapping. In: Proc. Int. Joint Meeting, CEC-FAOIOBC, on the Integrated Control in the Olive Groves, April 3–6, 1984, Pisa, Italy. Ed. by Cavalloro, R.; Crovetti, A. Rotterdam, The Netherlands: Balkema, 411–419.

Broumas, T. & Haniotakis, G. 1987. Further studies on the control of the olive fruit fly by Mass-trapping. Proceedings II International Symposium Fruit Flies/Crete Sept. 1986, pp 561-565.

Broumas, T.; Haniotakis G.; Liaropoulos C.; Tomazou T. & Ragoussis N. 2002. The efficacy of an improved of the olive fruit fly, *Bactrocera oleae* (Gmelin) (Dipt. Tephritidae): pilot-scale feasibility studies. Journal of Applied Entomology 126: 217-223.

Bryant, G. E. 1922. Some new injurious Phytophaga from Africa. Bulletin of Entomological Research 10: 473-475.

Bryant, G. E. 1940. New species of African Phytophaga (Col.). Proceedings of the Royal Entomological Society of London 9: 41-48.

Bryant, G. E. 1944. New species of African Chrysomelidae (Halticinae: Coleoptera). The Annals and Magazine of Natural History 84: 817-821.

Bryant, G.E. 1926. New species of African Phytophaga (Col.). Proceedingsdings Royal Entomological Society London 9:41-48.

Bryant, G.E. 1951. Coleoptera: Chrysomelidae I: South African Animal Life 6: 1-510.

Buffalo City Municipality. 2003/2004. Integrated Development Plan (IDP) Review. Report on Amendments to IDP 2002. October 2003 http://www.buffalocity.gov.za/municipality/idp2005.stm.

Campbell, S.A. & Borden, J.H. 2006. Integration of visual and olfactory cues of hosts and non-hosts by three bark beetles (Coleoptera: Scolytidae). Ecological Entomology 31: 437–449.

Carlisle, A. 2000. 56 families stranded as land deal stalls. Daily Dispatch online, Tuesday, June 6, 2000. http://www.dispatch.co.za/2000/06/06/easterncape/CDEAL.HTM.

Christenson, L.D. & Foote, R.H. 1960. Biology of fruit flies. Annual Review of Entomology 5: 171-192.

Clausen, C. P.; Clancy, D. W. & Chock, Q. C. 1965. Biological control of the Oriental fruit fly (*Dacus dorsalis* Hendel) and other fruit flies in Hawaii United States Department of Agriculture Technical Bulletin 1322:1-102.

Cocu, N. Harrington, R.; Hulle, M.´† & Rounsevell, M.D.A. 2005. Spatial autocorrelation as a tool for identifying the geographical patterns of aphid annual abundance. Agricultural and Forest Entomology 7: 31–43.

Collier, T. & van Steenwyk, R. 2003. Prospects for integrated control of olive fruit fly are promising in California. California Agriculture 57:28-31. http://ucce.ucdavis.edu/files/filelibrary.

Copeland, R.S.; White I.M.; Okumu, M.; Machera, P. & Wharton RA. 2004. Insects associated with fruits of the Oleacea (Asteridae, Lamiales) in Kenya with special reference to the Tephritidae (Diptera). Bishop Museum Bulletin in Entomology 12: 135-164.

Costa, C. 1998. Olive production in South Africa. A handbook for olive growers. Agricultural Research Council. 124 pp.

Crop Production Report. 2007. National Agricultural Statistics Service USDA Washington, D.C. Released August 10, by the National Agricultural Statistics Service (NASS), Agricultural Statistics Board, U.S. Department of Agriculture. http://www.usda.gov/nass/PUBS/TODAYRPT/crop0807.txt.

Crovetti, A. 1996. Plant Protection: Development of methodologies and the protection of production and the environment 225-250pp. In: Plaza & Janés Editores, South Africa, Enric Granados. *1996*. World Olive Encyclopaedia. International Olive Oil Council. Barcelona, Spain. 479pp.

CSS Information 2001. Republic of South Africa*:* statistics in brief. Central Statistics Service, Pretoria.

de Beer F. & Marais, M. 2005. Rural communities, the natural environment and development- some challenges, some successes. Community Development Journal 40: 50-61.

de Lange, R. 2007. Olyfbome op Springvale kreun onder 110 ton vrugte. Beeld daily news, 05 July 2005, Reference no: 3919. [In Afrikaans].

http://www.samedia.uovs.ac.za/cgi-bin/getpdf?year=2007&refno=3919&topic=19

Delrio, G. 1981. Esperienze di lotta integrata in olivicoltura in Sargegna. In Etat d'avancement des travaux et echanges d'informations sur les problemes poses par la lutte integree en oleiculture. (Proc. CEC Experts Meeting) pp.73-85. November 1981, Antibes.

Denzin, N. K. & Lincoln, L. 1994. Handbook of Qualitative Research. Sage, London. 643pp.

Department of Agriculture in the Eastern Cape. 2002. Olive Production. A practical orientation to successful live farming at Döhne 16 October 11pages.

Desneux, N.; Decourtye, A. & Delpuech J-M. 2007. The Sublethal Effects of Pesticides on Beneficial Arthropods**. Annual Review of Entomology** 52: 81-106.

Dickson, P. 2000. Oiling the E Cape economy. Mail and Guardian, Friday, April 28, 2000/ Thursday, May 04, 2000. http://www.samedia.uovs.ac.za/cgi-bin/getpdf?year=2000&refno=1478&topic=19.

Dimos, I.; Koutsikopoulos, C.; Economopoulos, A. & Lykakis, J. 2003. The distribution of olive fruit fly captures with McPhail traps within an olive orchard. Phytoparasitica 31:124-131.

Dimou, I. Koutsikopoulos, C. Economopoulos, A. & Lykakis J. 2003. The distribution of olive fruit fly captures with McPhail traps within an olive orchard. Phytoparasitica 31: 124-131.

Dominick, C.B. 1976. Collection of the tobacco flea beetle on coloured panels. Journal Economic Entomology 64: 1575.

du Preez. T. 2005. Orchard planning and soil preparation for quality olive farming, Techno Park, Stellenbosch. 5pages. http://www.saolive.co.za/downloads/FieldDay-Orchardplanningtalk.pdf

Duyck, P.F.; David, P. & Quilici, S. 2006. Climatic niche partitioning following successive invasions by fruit flies in La Reunion. Journal of Animal Ecology 75(2): 518-526.

Eastern Döhne Central Nucleus. 2007. Production Sale 6 Report March. http://dohne.eci.co.za/edcn/ .

Economopoulos, A.P. 1979. Attraction of *Dacus oleae* (Gmelin) (Diptera, Tephritidae) to odor and color traps. Zeitschrift fur Angewandte Entomologie 88: 90–7.

Economopoulos, A.P.; Haniotakis, G.E. & Michelakis, S. 1982. Population studies on the olive fruit fly, *Dacus oleae* (Gmel.) (Dipt., Tephritidae) in Western Crete. Z Ang Ent 93:463–76.

Eglington, L. 2004. Winning the war against the olive beetle. Farmer's Weekly. 6 February. pp 40-41.

El-Hakim, A.M. & El-Sayed, S. 1982-1983. Studies on the infestation of olive fruits with the olive fruit fly, *Dacus olea* Gmel. in Egypt (Tephrytidae: Diptera). Bulletin de la Societe Entomologique d'Egypte 64: 221-226.

Feni, L. 2000. Binfield olive farm to take further anti-theft measures. Daily Dispatch online. Friday, February 11, 2000. http://www.dispatch.co.za/2000/02/11/features/FARM3.HTM.

Fernandez, P. & Hilker, M. 2007. REVIEW: Host plant location by Chrysomelidae. Basic and Applied Ecology 8: 97—116.

Fimiani, P. 1989. Chapter 2.1 - Mediterranean Region. In: Robinson AS, Hooper G, editors. World Crop Pests: Fruit Flies, their biology, natural enemies and control, vol. 3A. Amsterdam: Elsevier Press. p. 39-50.

Fletcher, B.S.; Pappas S. & Kapatos, E. 1978. Changes in the ovaries of olive flies (*Dacus oleae* (Gmelin)) during the summer, and their relationship to temperature, humidity and fruit availability. Ecological Entomology 3: 99-107.

Francke, W. 1988. Identification and synthesis of new pheromones. Agricultural Ecosystems Environment 21: 21-30.

Franz, G.; Genecheva, E. & Kerremans, Ph. 1994. Improved stability of genetic sex-separation strains for the Mediterranean fruit fly, *Ceratitis capitata*. Genome 37: 72-82.

Gilchrist, A. 2003. Community development in the UK – possibilities and paradoxes. Community Development Journal Volume 38: 16-25.

Google Earth. Placeopedia. 2007. Image NASA, Europa Technologies, Tele Atlas, Map data, DMapas/El Mercurio. http://earth.google.com/.

Greathead, D.J. 1976. Report on a survey for natural enemies of olive pests in Kenya and Ethiopia, September-December 1975. Commonwealth Institute of Biological Control, Delémont, Switzerland. 23 pp.

Green, P.S. 2002. A revision of *Olea* L. (Oleaceae). Kew Bulletin 57:91-140.

Grossmveller, D.E. & Lederhouse, R.C. 1985. Oviposition site selection: an aid to rapid growth and development in tiger swallowtail butterfly, *Papilio glaucus* Oecologia 66: 68-73.

Hall, D.G. & Sosa, O. Jr. 1994. Population levels of *Leptodictya tabida* (Hemiptera: Tingidae) in Florida sugarcane. Florida Entomologist 77: 91-99.

Hall, M. 1993. The archaeology of colonial settlement in Southern Africa. Annual Review of Anthropology 22:177-200.

Hancock, D.L. 1989. Chapter 2.2 - Southern Africa. In: Robinson AS, Hooper G, editors. World Crop Pests: Fruit Flies, their biology, natural enemies and control, vol. 3A. Amsterdam: Elsevier Press. p. 51-58.

Haniotakis, G.; Kozyrakis M.; Fitsakis T. & Antonidaki A. 1991. An effective mass trapping for the control of *Dacus oleae* (Diptera: Tephritidae). Journal of Economic Entomology 84: 564-569.

Hattingh, M. 1998. Olive project gets under way. Daily Dispatch online, Tuesday, 24 November, 1998. http://www.dispatch.co.za/1998/11/24/easterncape/OLIVE.HTM

Hawkesa, N.J.; Janesb, R.W. Hemingwaya, J. & John Vontasa, J. 2005. Detection of resistance-associated point mutations of organophosphate-insensitive acetylcholinesterase in the olive fruit fly, Bactrocera oleae (Gmelin). Pesticide Biochemistry and Physiology 81: 154-163.

Hawkeswood, T.J. 1986. New food plants for adults of three species of the Australian genus *Lamprolina* (Coleoptera: Chrysomelidae). The Coleopterists Bulletin 40: 104.

Hegazi, E.; Herz, A.; Hassan, S.A.; Khafagi, W.E.; Agamy, E.; Zaitun, A.; El-Aziz, G. A.; Showeil, S.; El-Said, S. & Khamis, N. 2007. Field efficiency of indigenous egg parasitoids (Hymenoptera, Trichogrammatidae) to control the olive moth (*Prays oleae*, Lepidoptera, Yponomeutidae) and the jasmine moth (*Palpita unionalis*, Lepidoptera, Pyralidae) in an olive plantation in Egypt. Biological Control 43: 171-187.

Hendrichs, J.; Franz, G. & Rendón, P. 1995. Increased effectiveness and applicability of the sterile insect technique through male-only releases for control of Mediterranean fruit-flies during fruiting seasons. Journal of Applied Entomology 119: 371-377.

Henson, S. & Loader, R. 2000. "Barriers to agricultural exports from developing countries", World Development 1: 85-102.

Hesler, L. & Sutter, G.R. 1993. Effect of trap color, volatile attractants, and type of toxic bait dispenser on captures of adult corn rootworm beetles (Coleoptera: Chrysomelidae). Environmental Entomology 22:743-750.

Heywood, V.H. 1998. Flowering plants of the world. B.T. Batsford, Ltd., London. 336 pp.

Hibbard, B.E. & Bjostad, L.B. 1988. Behavioral responses of western corn rootworm larvae to volatile semiochemicals from corn seedlings. Journal of Chemical Ecology 14: 1523-1539.

Hill, D.S. 1983. Agricultural Insect Pests of the Trpoics and their control. 2nd edition Cambridge University Press, Cambridge, U.K 746pp.

Hoback, W.W.; Svatos, T.M.; Spomer, S.M. & Higley, L.G. 1999. Trap colour and placement affects estimates of insect family-level abundance and diversity in a Nebraska salt marsh. Entomologia Experimentalis et Applicata 91: 393-402.

Hope, A. & Timmel, S. 1984. Training for Transformation Book 1. A handbook for community workers. Mambo Press. Gweru, Zimbabwe.

Howlett, B.G.; Clarke, A.R. & Madden, J.L. 2001. The influence of leaf age on the oviposition preference of *Chrysophtharta bimaculata* (Olivier) and an establishment of neonates. Agricultural and Forest Entomology 3: 121-127.

Howlett, B.G.; Clarke, A.R. & Madden, J.L. 2001. The influence of leaf age on the oviposition preference of *Chrysophtharta bimaculata* (Olivier) and an establishment of neonates. Agricultural and Forest Entomology 3: 121-127.

Inoue, T. & Shinkaji, N. 1989a. Studies on the Life History of the fleabeetle, *Argopistes coccinelliforms* Csiki (Coleoptera: Chrysomelidae). I. Feeding habits and seasonal development on various trees of Oleceae. Journal of Applied Zoology and Entomology 33: 217-222.

Inoue, T. & Shinkaji, N. 1989b. Studies on the Life History of the fleabeetle, *Argopistes coccinelliforms* Csiki (Coleoptera: Chrysomelidae). II. Developmental ability on various host trees. Journal of Applied Zoology and Entomology 33: 223-230.

Inoue, T. 1991. Host plant preference of fleabeetle, *Argopistes biplagiatus* Motshulsky adults (Coleoptera: Chrysomelidae). Journal of Applied Zoology and Entomology 26 (3): 403-406.

Inoue, T. 1991. Studies on the life history of the flea beetle *Argopistes coccinelliforms* Csiki (Coleoptera: Chrysomelidae). V. Effects of food condition on oviposition. Journal of Applied Entomology and Zoology 35: 213-220.

Inoue, T. 1998. Life history of the flea beetle, *Argopistes coccinelliformis* Csiki (Coleoptera: Chrysomelidae). VI. Overwintering and oviposition abilities of adults which emerged late in the season. Applied Entomology and Zoology 33: 21–27.

Jameson, H.R. 1970. Control of Turnip Flea Beetle by Benzene Hexachloride drilled with the Seed. Nature 165: page 980.

Jewison, R. 2003. Community development practice in South Africa receives a presidential mandate. Oxford University Press and Community Development Journal 38: 367-369.

Joubert, S. 2002. SA's olive industry blossoms. Business Day. Monday, April 2002. http://www.samedia.uovs.ac.za/cgi-bin/getpdf?year=2002&refno=1257&topic=19.

Kabaluk, J.T. & Vernon, R.S. 2000. Effect of crop rotation on populations of *Epitrix tuberis* (Coleoptera: Chrysomelidae) in Potato. Journal of Economic Entomology 93: 315-322.

Kapatos, E.T. & Fletcher, B.S. 1983. Development of a pest management system of *Dacus oleae* in Corfu by utilizing ecological criteria. In: Fruit Flies of Economic Importance. R. Cavalloro (ed). Proceedings of the CEC/IOBC, International Symposium Athens Greece, 16-19 Nov. 1982, pp 593-602.

Kapatos, E.T. & Fletcher, B.S. 1984. The phenology of olive fly, *Dacus oleae* Gmel. (Diptera, Tephritidae), in Corfu. Zeitschrift fur Angewandte Entomologie 97:360–70.

Kapatos, E.T. 1989. Integrated pest management systems of *Dacus oleae*, pp. 391–398 in Fruit Flies: Their Biology, Natural Enemies and Control, Vol. 3B, edited by A.S. Rombinson & G.H.S. Hooper. Elsevier, Amsterdam.

Karamanlidou, G.; Lambropoulos, A.F.; Koliais, S.I.; Manousis, T.; Ellar D.J. & Kastritsis, C. 1991. Toxicity of Bacillus thuringiensis to laboratory populations of the olive fruit fly (Dacus oleae), Applied and Environmental Microbiology 57: 2227–2282.

Karim, M. 2003. Integrated Pest Management in the Global Arena editors: K.M. Maredia, D. Dakouo & D. Mota-Sanchez. CABI publishing. 544pages.

Kariuki, S.M. 2004. Failing to learn from failed Programmes? South Africa's Communal Land Rights Act (CLRA 2004), ASC Working Paper ** /2004 School of Social Sciences, Department of Sociology, University of The Witwatersrand, South Africa. http://www.ascleiden.nl/pdf/paper118317626.pdf

Karlson, P. & Luscher, M. 1959. 'Pheromones' a new term for a class of biologically active substances. Nature 183: 55-56.

Katsoyannos, B.I. & Kouloussis, N.A. 2003. Captures of the olive fruit fly *Bactrocera oleae* on spheres of different colours. Entomologia Experimentalis et Applicata 100: 165 – 172.

Kelly, D. 1994. The evolutionary ecology of mast seeding. Trends in Ecology and Evolution 9:465-470.

Knight, A.L. & Norton, G.W. 1989. "Economics of Agricultural Pesticide Resistance in Arthropods". Annual Review of Entomology 34: 293-313.

Kollman, W.S. 2002. Environmental fate of spinosad. Department of Pesticide Regulation. Environmental Monitoring Branch P.O. Box 4015 Sacramento, California. http://www.cdpr.ca.gov/docs/emon/pubs/fatememo/spinosad_fate.pdf.

Korie, S.; Perry, J.N.; Mugglestone, M.A.; Clark, S.J.; Thomas, C.F.G.; Roff, M.N. 2000. Spatio-temporal associations in beetle and virus count data. Journal of Agricultural, Biological, and Environmental Statistics 5, 214–239.

Kouki, J. 1993. Female's preference for oviposition site and larval performance in the water-lily beetle, *Galerucella nymphaeae* (Coleoptera: Chrysomelidae). Oecologia 93: 42-47.

Kroon, D.M. 1999. Lepidoptera of Southern Africa - Host-plants and Other Associations. A catalogue. Lepidopterists' Society of Africa, Sasolburg, South Africa: Sasolburg Litho.

Krueger, R.A. 1994. Focus groups: A practical guide for applied research. Sage Publications.

Kumar, R 2005. Research Methodology. A step by step guide for beginners. 2nd edition. Sage Publications. Thousands Oaks, California page 332.

Kunicki, E.; Cebula, S.; Libik, A. & Siwek, P. 1996. The influence of row cover on the development and yield of broccoli in spring production. Acta Horticulture 407: 377-383.

Labonte R. 1999. Social capital and community development: Practitioner emptor. Australia and New Zealand Journal of Public Health 23: 430-433.

Lampman, R.L. Metcalf, R.L. & Andersen, J.F. 1987. Semiochemical attractants of *Diabrotica undecimpunctata howardi* Barber, southern corn rootworm, and *Diabrotica virgifera virgifera* Leconte, the western corn rootworm (Coleoptera: Chrysomelidae). Journal of Chemical Ecology 13: 959-975.

Lance, D.R. 1988. Responses of northern and western corn rootworms to semiochemical attractants in corn fields. Journal of Chemical Ecology 14:1177-1185 .

Law, J.H. & Regnier, F.E. 1971. Pheromones. Annual Review of Biochemistry 40: 533-548.

Lee, A. 2003. Community development in Ireland. Community Development Journal 38: 48-58.

Lee, J.E. 1992. Larval description of four alticine species of genera Altica and Argopistes from Japan (Chrysomelidae, Coleoptera). Korean Journal of Entomology 22: 287-295.

Li, L. 1994. Worldwide use of Trichogramma for biological control on different crops: a survey, pp. 37Ð53. In E. Wajnberg and S. A. Hassan (eds.), Biological control with egg parasitoids. CAB International, Berkshire, United Kingdom.

Liblikas, L.; Mõttus E.; Borg-Karlson, A.K.; Kuusik, S.; Ojarand, A.; Kännaste, A. & Tanilsoo, J. 2003. Flea beetle (Chrysomelidae: Coleoptera) response to alkyl thiocyanates and alkyl isothiocyanates. Agronomy Research 1: 175-184.

Longo, S. & Benfatto, D. 1982. Observation on olive fly (*Dacus oleae* (Gmel.)) – Population. dynamics in Sicily. Proc CEC/IOBC Int Symp, Fruit Flies of Economic Importance. Athens, Greece. Rotterdam: AA Balkema. p 612–615.

Lopez, J.D., Shaver, T.N., Beerwinkle, K.R. & Lingren, P.D. 1998. Feeding attractant and stimulant for adult control of noctuid and/or other lepidopteran species. Patent number 166655, United States of America, 5 October 1998.

Lopez-Villalta, M.C. 1999. Olive pest and disease management. International Olive Oil Council, Principe de Vergara, 154-28002, Madrid, 206p.

Lounsbury, C.P. 1918. Report with appendices for the year ended 31st March 1918. Department of Agriculture. Union of South Africa: Blue Book. UG 37-39. Cape Times Limited. Government Printers, Cape Town.

Malan, T. & Hattingh P.S. 1976. Black Homelands in South Africa. South African Homelands 25th Anniversary 1952-1977. Africa Institute of South Africa. 255 pp.

Mally, C.W. 1924. A means of catching the fruit nibbler (*Odontionopa serica* Gyll.) Journal of the Department of Agriculture for United of South Africa. IX, No. 4, Pretoria.

Mamase, M. 2000. Speech: Keynote address by the honourable MEC of Agriculture and Land Affairs in the Eastern Cape, Mr Max Mamase, on the provincial perspective on land redistribution and state land disposal at the information day on land redistribution, Whiteney Farm, Victoria East, 27 October.

Mamase, M. 2002: Speech: Strategic partnership workshop, Eastern Cape. Eastern Cape Provincial Government Speech (13/12/2002) http://www.ecprov.gov.za

Mannion, J. 2003. Partnership, participation and capacity building: rural development based on local bottom-up strategies. Leader Magazine 12 (10), pp. 6–10. http://ec.europa.eu/comm/archives/leader2/rural-en/biblio/defis/art02.htm.

Manousis, T. & Moore, N.F. 1987. Mini-review. Control of *Dacus oleae* a major olive pest of olives. Insect Science and its Application *8(1)*, 1-9.

Maredia, K.M. 2003. Chapter 1: Introduction and overview. In: Integrated Pest Management in the Global Arena editors: K.M. Maredia, D. Dakouo & D. Mota-Sanchez. CABI publishing. 544pages.

Martin, G.C.; Ferguson, L. & Polito, V. S. 1994. Flowering, pollination, fruiting, alternate bearing, and abscission. In Olive Production Manual, pp. 19–21 (Eds

L. Ferguson, G. S. Sibbett and G. C. Martin). Publication 3353, University of California, Davis, CA, USA.

Mavragani-Tsipidou, P. 2002. Genetic and cytogenetic analysis of the olive fruit fly *Bactrocera oleae* (Diptera: Tephritidae). Genetica 116: 45-27.

Mazomenos, B.E.; Konstantopoulou, M.; Stefanou, D.; Skareas, S. & Tzeiranakis, L.C. 2002. Female calling behaviour and male response to the synthetic sex pheromone components of *Palpita unionalis* (Lepidoptera: Pyralidae) - Use of pheromones and other semiochemicals in integrated production. International Organization of Biological Control, Western Palearctic Regional Section Bulletin 25:203-212.

Mdoda, W. 2002. EC olive trees growing well. Daily Dispatch online, Friday, January 11, 2002. http://www.dispatch.co.za/2002/01/11/features/FARM1.HTM.

Mensah, R.K 1996. Evaluation of coloured sticky traps for monitoring populations of *Austroasca viridigrisea* (Paoli) (Hemiptera: Cicadellidae) on cotton farms. Australian Journal of Entomology, 35: 349-353.

Mensah, R.K. 1997. Yellow traps can be used to monitor populations of *Coccinella transversalis* (F.) and *Adalia bipunctata* (L.) (Coleoptera: Coccinellidae) in cotton crops. Australian Journal of Entomology 36: 377-381.

Mensah, R.K. 1997. Yellow traps can be used to monitor populations of *Coccinella transversalis* (F.) and *Adalia bipunctata* (L.) (Coleoptera: Coccinellidae) in cotton crops. Australian Journal of Entomology 36: 377-381.

Montiel-Bueno, A. & Jones, O. 2002. Alternative methods for controlling the olive fly, *Bactrocera oleae,* involving semiochemical. Use of pheromones and other semiochemicals in integrated production. International Organization for Biological and Integrated Control–West Palearctic Regional Section (IOBC/WPRS) Bulletin 25: 147-156.

Montiel-Bueno, A. & Jones, O. 2002. Use of pheromones and other semiochemicals in integrated production. International Organization for Biological Control Bulletin 25.

Montiel-Bueno, A. 1986. The use of sex pheromone for monitoring and control of olive fruit fly. In: Proc Second Int Symp Fruit Flies. Crete, Greece. Amsterdam: Elsevier Science. p 483–95.

Moore, I. 1962. Further investigations of the artificial breeding of the olive fly *Dacus oleae* (Gmel.) under aseptic conditions. Entomophaga VII:53–7.

Moore, L.V.; Myers, J.H. & Eng, R. 1988. Western tent caterpillars prefer the sunny side of the tree, but why? Oikos 51: 321-326.

Morse, S. & Buhler, W. 1997. IPM in developing countries: the danger of an ideal. Integrated Pest Management Reviews 2: 175–185.

Mota-Sanchez, D.; Alvarado-Rodriguez, B.; Diaz-Gomez, O.; Mojica, H.B. Martinez, G. S. & Bujanos, R. 2003. Chapter 21: Integrated Pest Management in Mexico. In: Integrated Pest Management in the Global Arena editors: K.M. Maredia, D. Dakouo & D. Mota-Sanchez. CABI publishing. 544pages.

Munro, H.K. 1924. Fruit flies of wild olives - Notes on the bionomics of fruit flies (Trypaneidae: Diptera) infesting the fruits of wild olives (*Olea* spp.) in South Africa. Entomological Memoirs, Department of Agriculture, Union of South Africa 2:5-17.

Munro, H.K. 1984. A taxonomic treatise on the Dacidae (Tephritidae: Diptera) of Africa. Entomological Memoirs, Department of Agriculture and Water Supply, Republic of South Africa 61:1-313.

Mxotwa, M. 2000. 'Three musketeers' make their mark in fight in rural areas. Daily Dispatch online, Monday, February 28, 2000. http://www.dispatch.co.za/2000/02/28/features/LP1.HTM.

Myburgh, A.C. 1952. Olive beetle in the Western Cape Province. Farming in South Africa (April). Western province Fruit Station, Stellenbosch Popular Series No. 115 (Reprint No. 17). The Government Printer, Pretoria. pp 1-4.

Nahrung, H.F., & Allen, G.R. 2003. Intra-plant host selection, oviposition preference and larval survival of *Chrysophtharta agricola* (Chapius) (Coleoptera: Chrysomelidae, Paropsini) between foliage types of a heterophyllous host. Agricultural and Forest Entomology 5: 155–162.

Naki, E. 1998. Italians extended olive branch for Eastern Cape venture. Daily Dispatch online, Wednesday, 9 September 1998. http:/www.dispatch.co.za/1998/09/09/easterncape/AVENTURE.HTM.

Nansena, C.; Subramanyamb B.; Roesli, R. 2004. Characterizing spatial distribution of trap captures of beetles in retail pet stores using SADIE® software. Journal of Stored Products Research 40: 472483.

Nardi, F.; Carapelli A.; Dallai, R.; Roderick G.K.; Frati F. 2005. Population structure and colonization history of the olive fly, *Bactrocera oleae* (Diptera, Tephritidae). Molecular Ecology 14:2729-2738.

Nasr, F. N.; Abou-Elkhair, S. S.; Stefanos, S. S.; Youssef, A. A.; Shehata, W. A. 2002. New record of some biological control agents of *Palpita unionalis* Hübn. (Lepidoptera: Pyralidae) and *Prays oleae* Bern. (Lepidoptera: Yponomeutidae) in olive groves in Egypt. Egyptian Journal of Biological Pest Control 12:129 Rodrı´guez, L.C. & Niemeyer, H.M. 2005. Integrated pest management, semiochemicals and microbial pest-control agents in Latin American agriculture. Crop Protection 24: 615–623.

National Department of Agriculture, 2007. A guide for the control of plant pests, 40th edition. Directorate: Agricultural Productions Inputs. National Department of Agriculture, Republic of South Africa. Pretoria.

Nel, A.; Krause, M. & Khelawanlall, N. 2002. A guide for the control of plant pests (39th ed.). Directorate: Agricultural Productions Inputs. National Department of Agriculture, Republic of South Africa, Pretoria.

Neuenschwander, P. (1982) Beneficial insects caught by yellow traps used in mass trapping of the olive fly, *Dacus oleae*. Entomology experimental. & Applied. 32: 286-296.

Neuenschwander, P. 1982. Searching parasitoids of *Dacus oleae* (Gmel.) (Dipt., Tephritidae) in South Africa. Zeitschrift für Angewandte Entomologie 94: 509-522.

Newell, I.M & Haramoto, F.H. 1968. Biotic factors influencing populations of *Dacus dorsalis* in Hawaii. Proceedings. Hawaiian Entomological Society. 20: 81-139.

Ngqushwa Municipality. 2005/2006/2007. Integrated Development Plan (IDP), 2005/2006/2007 http://www.ngqushwamun.gov.za/content.php?i=IDP

Nkonkobe Municipality. 2004/2005. Integrated Development Plan (IDP). Final Draft.

Noyes, J. 2003. Universal Chalcidoidea Database. Available online at http://www.nhm.ac.uk/jdsml/research-curation/projects/chalcidoids/hosts.dsml?index=Hosts&searchPageURL=indexHosts.dsml&VALGENUS=sycophila&VALSPECIES=%25.

Orr, A. 2003. Integrated pest management for resource-poor African farmers: is the emperor naked? World Dev. 31: 831–845.

Palgrave, M.C. 2002. Trees of the Southern Africa. 3rd edition. Struik Publishers. South Africa. pp 1-1071.

Payne, R.W. 2003. GenStat® for Windows® (7th Edition), Oxford, UK.VSN International.

Pedigo, L.P. 2002. Entomology and Pest Management. 4th ed. Prentice Hall, Upper River, New Jersey 741 pp.

Perez, N. 2002. Achieving sustainable livelihoods – a case study of a Mexican rural community. Community Development Journal 37: 178-187.

Pierce, A.M.; Pierce H.D.; Borden J.H. and Oehlschlager, A.C. Fungal volatiles: 1991. Semiochemicals for stored-product beetles (Coleoptera: Cucujidae). Journal of Chemical Ecology 17: 81-597.

Pinhey, E.C.G. 1946. The olive lace bug. Rhodesia Agriculture Journal 43:8-10.

Pivnick, K.A.; Lamb, R.J. & Reed, D.1992. Response of flea beetles, *Phyllotreta* spp., to mustard oils and nitriles in field trapping experiments. Journal of Chemical Ecology 18: 863-873.

Poverty and Inequality Report, 1998. Poverty and Inequality in South Africa, Praxis Publishing, Durban.

Prokopy, R.J. & Owens, E.D. 1983. Visual detection of plants by herbivorous insects. Annual Review of Entomology 28: 337–364.

Prokopy, R.J.; Collier, R.H. & Finch, S. 1983. Leaf color used by cabbage root flies to distinguish among host plants. Science 221: 190 – 192.

Province of the Eastern Cape. 2004. Department of Agriculture. Strategic Plan. 2004-2007. Provincial Department of Agriculture. pp. 93.

Putnam, R.D. 1993. The prosperous community social capital and public life. The American Prospect Inc. http://www.prospect.org/archives/24/24putn.html.

Rafoss, T. & Sæthre, M.G. 2003. Spatial and temporal distribution bioclimatic potentialfor the codling moth and Colorado potato beetle in Norway: model predictions versus climate and field data from the 1990s. Agriculture and Forest Entomology 5: 75-85.

Ramos, P.; Jones, O.T. & Howse, P.E. 1982. The present status of the olive fruit fly (*Dacus oleae* (Gmel.)) in Granada, Spain, and techniques for monitoring its populations. In: Proc CEC/IOBC Int Symposium, Fruit Flies of Economic Importance. Athens, Greece. Rotterdam: AA Balkema. p 38–40.

Rapsi, A. 1982. Preliminary considerations on the capture of useful entomofauna during the use of chemiochromotrophic traps in the olive-grove. Frustula Entomologia 4: 103-109.

Raspi, A. & Loni, A. 1994. Alcune note sull'Allevamento di *Opius concolor* (Szépl.) (Hymenoptera Braconidae) e su recenti tentativi d'introduzione della specie in Toscana en in Liguria. Frustula Entomologica 17:135-145.

Rastrelli, L., Totaro, K. & De Simone, F. 2002. Determination of organophosphorus pesticide residues in Cilento (Campania, Italy) virgin olive oil by capillary gas chromatography. Food Chemistry 79: 303-305.

Rice, R.E. 2000. Bionomics of the olive fruit fly *Bactrocera* (*Dacus*) *oleae*. University of California Plant Protection Quarterly 10 (issue 3), 2-5. Available: http://www.uckac.edu/ppq.

Rodrı´guez, L.C. & Niemeyer, H. M. 2005. Integrated pest management, semiochemicals and microbial pest-control agents in Latin American agriculture. Crop Protection 24: 615–623.

Saour, G. & Makee, H. 2004. A kaolin-based particle film for suppression of the olive fruit fly *Bactrocera oleae* Gmelin (Dip., Tephritidae) in olive groves. Journal of Applied Entomology 128: 28–31.

Scarpati, M.L.; Lo Scalzo, R. & Vita, G. 1993. *Olea europaea* volatiles attractive and repellent to the olive fruit fly. Journal of Chemical Ecology 19: 881-890.

Schuftan, C. 1996. The community development dilemma: what is really empowering. Community Development Journal 31: 260-264.

Selman, B.J & Lowman, M.D. 1983. The biology and herbivory rates of *Novocastria nothofagi* Selman (Coleoptera chrysomelidae), a new genus of species on *Nothofagus moorei* in Australian temperate rainforests. Australian Journal of Zoology 31: 179- 191.

Sharp, D.S ; Eskenazi, B.; Harrison, R; Callas, P & Smith, A.H 1986. Delayed health hazards of pesticide exposure. Annual Review of Public Health 7:441-71.

Shorey, H.H. 1977. Animal Communication by Pheromones. Academic Press, NewYork.

Sibanda, S. 2001. Land Reform and Poverty Alleviation in South Africa. Paper presented at the South African Regional Poverty Network Conference on Land Reform and Poverty Alleviation in Southern Africa held at the Human Sciences Research Council, 4th-fifth June, 2001, Pretoria.

Siegel, S. 1956. Nonparametric Statistics for the Behavioral Sciences. New York: McGraw-Hill.

Silvestre, F. 1913. Viaggio in Africa per cercare parassiti di mosche dei frutti. Bollettino del Laboratorio di Zoology Generale e Agraria della Reale Scuola Superiore d'Agricoltura, Portici 8:1–164.

Silvestre, F. 1916. Prima notizia sulla presenza della mosca delle olive e di un parassita di essa in India. Atti della Reale Accademia dei Lincei 25:424–427.

Silvestri, F. 1914. Viaggio in Eritrea per cercare parassiti di mosche delle olive. Bollettino del Laboratorio di Zoologia Generale e Agraria deli Reale Scuola Superiore d'Agricoltura, Portici 9: 186-226.

Silvestri, F. 1915. Contributo alla conoscenza degli insetti dell'olivo dell'Eritrea e dell' Africa meridionale. Bollettino del Laboratorio di Zoologia Generale e Agraria deli Reale Scuola Superiore d'Agricoltura, Portici 9:240-334.

Simpson, L.; Wood, L. & Daws, L. 2003. Community capacity building: starting with people not projects. Community Development Journal 38: 277-286.

Siqoko, B. 1999. 400000 olive trees; 20000 jobs for EC. Daily Dispatch online, Saturday, May 8, 1999. http://www.dispatch.co.za/1999/05/08/easterncape/

Sishuta, B. 2005. Small-scale irrigation development for sustainable rural development: a case study of the Tyhefu irrigation scheme. African Sociological Review 9: 184-206.

Skouras, P.J.; Margaritopoulos, J.T. Seraphides, N.A. Ioannides, I.M. Kakani, E.G. Mathiopoulos, K.D. and Tsitsipis, J. A. 2006. Organophosphate resistance in olive fruit fly, *Bactrocera oleae*, populations in Greece and Cyprus. Pest Management Science 63: 42-48. http://greek.ari.gov.cy/content/diakratiki/paper.pdf

Smith, A.D. 1999. Mandela praises whites in farewell. The Independent (London) online, Friday, May 21 1999. http://findarticles.com/p/articles/mi_qn4158/is_19990521/ai_n14236814

Snedecor, G.W. & Cochran, W.G. 1980. *Statistical methods* (7th Ed.). Iowa State University Press. Ames, IA, USA.

Soroka, J.J.; Bartelt, R.J.; Zilkowski, B.W. & Cossé, A.A. 2005. Responses of flea beetle *Phyllotreta cruciferae* to synthetic aggregation pheromone components and host plant volatiles in field trials. Journal of Chemical Ecology 31: 1829-1843.

Stasinakis, P.; Katsares, V. & Mavragani-Tsipidou, P. 2001. Organophosphate Resistance and Allelic Frequencies of Esterases in the Olive Fruit Fly

*Bactrocera oleae* (Diptera: Tephritidae). Jouranl Agricultural Urban Entomology 183: 157–168.

Stonedahl, G.M.; Dolling, W.R.; & duHeaume, G.J. 1992. Identification guide to common tingid pests of the world (Heteroptera: Tingidae). Tropical Pest Management 38: 438-449.

Suckling, D.M. 2000. Issues affecting the use of pheromones and other semiochemicals in orchards. Crop Protection 19: 677-683.

Swain, V.M. & Prinsloo G.L. 1986. A list of phytophagous insects and mites on forest trees and shrubs in South Africa. Republic of South Africa. Department of Agriculture and Water Supply. Entomology Memoir 66: 1-91.

Swanepoel, J.W. 2006. A genetic evaluation of the Döhne merino breed in South Africa. M.Sc.Agr. Dissertation, University of the Free State.

Szauman-Szumski, K.J; Pena, A.; Kelly, D.R. & Campos, M. 1998. Identification of chemicals attractive to the bark beetle, *Phloetribus scarabaeoides* in laboratory. Biocontrol 43: 345-355.

Tamba, PN. 2000. Olive Founding Document. MEC: Eastern Cape Department of Agriculture and Land Affairs, South Africa 7 pp.

Taylor, J. S. 1945. Notes on the Olive Beetle (*Argopistes sexvittatus* Bryant). The Journal of the Entomological Society of Southern Africa 8:49-52.

Taylor, L.R., 1984. Assessing and interpreting the spatial distributions of insect populations. Annual Review of Entomology 29, 321–357.

Thomas, D.B. 1995. Predation on the soil inhabiting stages of the Mexican fruit fly. Southwestern Entomologist 20:61-71.

Tingle, C.C.D. & Copland, M.J.W. 1988. Predicting development of the mealybug parasitoids *Anagyrus pseudococci*, *Leptomastix dactylopii,* and *Leptomastidea abnormis* under glasshouse conditions. Entomological Exp. Applied. 46: 19–28.

Tsitsipis, J.A. & Abatzis C. 1980. Relative humidity effects, at 20°, on eggs of the olive fruit fly, Dacus oleae (Diptera: Tephritidae), reared on artificial diet. Entomologia Experimentalis et Applicata 28: 92-99.

Tzanakakis, M.E. 2003. Seasonal development and dormancy of insects and mites feeding on olive: a review. Netherlands Journal of Zoology 52:87-224.

Van Steenwyk, R.A.; Ferguson, L. & Zalom, F.G. 2002. Olive fruit fly. University of California Pest Management Guidelines. http://www.ipm.ucdavis.edu/PMG/r583301311.html (6 June 2003).

Vári, L.; Kroon, D.M. & Krüger, M. 2002. Classification and checklist of the species of Lepidoptera recorded in Southern Africa. Chatswood, Australia: Simple Solutions Australia.

Venter, F. & Venter, J.A. 1996. Making the Most of Indigenous Trees. Revised Edition. Briza Publications. Pretoria. 320p.

Ventura, M.U.; Ito, M.; Montalvan, R. 1996. An attractive trap to capture *Diabrotica speciosa* (Ger.) and *Cerotoma arcuata tingomariana* Bechyné. Neotropical Entomology 25: 529-535.

Ventura, M.U.; Martins, M.C.; Pasini, A. 2000. Responses of *Diabrotica speciosa* and *Cerotoma arcuata tingomariana* (Coleoptera: Chrysomelidade) to volatile attractants. Florida Entomologist 83: 403-410.

Ventura, M.U.; Mello, E.P.; Oliveira, A.R.M.; Simonelli, F.; Marques, F.A.; Zarbin, P.H.G. 2001. Males are attracted by female traps: a new perspective for management of *Diabrotica speciosa* (Germar) (Coleoptera: Chrysomelidae) using sexual pheromone. Neotropical Entomology 30: 361-364.

Vet, L.E.M. & Dicke, M. 1992. Ecology of infochemicals used by natural enemies in a tritrophic context. Annual Review of Entomology 37:141–172.

Visser, J.H. 1986. Host odor perception in phytophagous insects. Annual Review of Entomology 31: 121–144.

Vossen, P. & Varela, L. 2003. Olive fruit fly. University of California Cooperative Extension - Sonoma County. http://cesonoma.ucdavis.edu/HORTIC/olive_fly/olive_fruit_fly.pdf (6 June 2003).

Vossen, P.; Varela L. & Devarenne, A. 2005. Olive Fruit Fly. University of California Cooperative Extension Sonoma County. June 4 pp.

Walton, M.P. 1995. Chapter 9: Integrated Pest Management in olives. pages 222-238. In: Integrated Pest Management: Dent, D. Contributor N. C. Elliott, J. a Farrell, A.P. Gutierrez, J.C. Van Lenteren, M. P. Walton, S.D. Wratten. Springer. 372 pages.

Ware, A.B. 2002. A comparison of fruit fly attractants used in Southern Africa. SA Vrugte Joernaal: 1(2): 45-51 AUG/SEPT.

Weise, von J. 1895. Neve Chrysomeliden nebst synonymischen Bemerkungen. Deutsche Entomologische Zeitschrift 2: 327-352.

Weise, von J. 1914. Chrysomeliden and Coccinelliden aus Erythraea. Bollettino del Laboratorio generale e agraria della Reale Scuola superiore d'Agricultura in Portici 9: 227-233.

Weise, von J. 1919. Bemerkungen zu einigen ostfrikanischen Chrysomelinen and Beschreibung einer Halticine. Deutsche Entomologische Zeitschrift 182-184.

Western Cape Investment and Trade Promotion Agency (WESGRO). 1999. Cape Sector fact sheet. Business sector information updates from South Africa’s Western Cape. Cape Town. http://www.wesgro.org.za/.

Western Cape Investment and Trade Promotion Agency (WESGRO). 2005/2006. Natural Products Sector Brief. http://www.wesgro.org.za/assetlibrary/assets/255108448.pdf.

Wharton, R. 2007. Parasitoids of Fruit-Infesting Tephritidae. Available on-line at **http://hymenoptera.tamu.edu/paroffit/**. Accessed June 2008.

Wharton, R.A. 1989. Classical biological control of fruit-infesting Tephritidae. In: A.S. Robinson and G. Hooper (eds), World Crop Pests, Vol. 3A. Elsevier, Amsterdam, the Netherlands. pp. 303–313.

White, I.M. & Elson-Harris, M.M. 1992. Fruit Flies of Economic Significance: their Identification and Bionomics. Commonwealth Agricultural Bureau International & Australia Center for International Agricultural Research, Wallingford, UK.

White, I.M. 2004. Taxonomy of the Dacina (Diptera: Tephritidae) of Africa and the Middle East. African Entomology Memoir No. 2.

Whitehead, V.B & Myburgh, A.C. 1961. Olive beetles and lace bugs. “The Decidous Fruit Grower” (September). Western Province Fruit Station, Stellenbosch). National Commercial Printers, Elsies River. pp 1-4.

Younis, T. 1997. Bottom-up implementation after Rio: rural community participation in Scottish forestry. Community Development Journal 32: 299-311.

Youssef, A.A.; Nasr, F.N.; Stefanos, S.S.; Abou Elkhair, S.S.; Shehata, W.A.; Agamy, E.; Herz, A.; & Hassan, S.A. 2004. The side effects of plant protection products used in olive cultivation on the hymenopterous egg parasitoid *Trichogramma cacoeciae* Marchal. Journal of Applied Entomology 128: 593–599.

Zambetaki, A.; Zacharopoulou, A.; Scouras, Z.G. & Mavragani-Tsipidou, P. 1991. The genome of the olive fruit fly *Bactrocera oleae*: localization of molecular markers by in situ hybridisation to the salivary gland polytene chromosomes. Genome 42: 744-751.

Zifo, M. 1998. Olive tree project off to promising start. Daily Dispatch, Thursday, 26 November. http://www.dispatch.co.za/1998/11/26/easterncape/PROJECT.HTM.